COLORADO WATER CONSERVATION BOARD

WATER SUPPLY RESERVE ACCOUNT
2007-2008 GRANT APPLICATION FORM

Demonstration of Membrane Zero Liquid Discharge Process for Drinking Water Systems	Arkansas, Metro, S. Platte, Basins
Name of Water Activity/Project	**River Basin Location**

$100,000 from selected Basin Accounts* $700,000 from State Account	[X] Basin Account [X] Statewide Account	[X] Yes [ ] No
Amount of Funds Requested	Please Check Applicable Box	Approval Letter Signed By Roundtable Chair and Description of Results of Evaluation and Approval Process

* See Table 1 of application for detailed funding request

*** For the Basin Account, the Application Deadline is 60 Days Prior to the Bimonthly CWCB meeting. The CWCB meetings are posted at www.cwcb.state.co.us and are generally the third week of the month.**

*** For the Statewide Account, the Application Deadline is 60 Days Prior to the March and September CWCB Board Meetings.**

* In completing the application you may attach additional sheets if the form does not provide adequate space. If additional sheets are attached please be sure to reference the section number of the application that you are addressing (i.e., A.1. etc.).

Instructions: This application form must be submitted in electronic format (Microsoft Word or Original PDF are preferred). The application can be emailed or a disc can be mailed to the address at the end of the application form. The Water Supply Reserve Account Criteria and Guidelines can be found at http://cwcb.state.co.us/IWMD/. **The criteria and guidelines should be reviewed and followed when completing this application**. You may attach additional sheets as necessary to fully answer any question, or to provide additional information that you feel would be helpful in evaluating this application. Include with your application a cover letter summarizing your request for a grant. If you have difficulty with any part of the application, contact Rick Brown of the Intrastate Water Management and Development (Colorado Water Conservation Board) for assistance, at (303) 866-3514 or email Rick at rick.brown@state.co.us. Generally, the applicant is also the prospective owner and sponsor of the proposed water activity. If this is not the case, contact the Rick Brown before completing this application.

Water Supply Reserve Account – Grant Application Form
Form Revised May 2007

Part A. - Description of the Applicant (Project Sponsor or Owner);

1. Applicant Name(s): Colorado Department of Public Health & Environment - Water Quality Control Division

Mailing address: 4300 Cherry Creek Drive South
Denver, CO 80246-1530

Taxpayer ID#: Email address: daakers@smtpgate.dphe.state.c

Phone Numbers: Business: 303 692-3500
Home:
Fax:

2. Person to contact regarding this application if different

Name: Dave Akers

Position/Title Clean Water Facilities Program Manager

3. Provide a brief description of your organization below: see "Description of Applicant" in Part 2 of Criteria and Guidance for required information.

The Water Quality Control Division is statutorily created at C.R.S. 25-8-301(2) and its duties include:
(a) Carrying out the enforcement provisions of the Water Quality Control Act (WQCA) and the state Drinking Water Statutes;
(b) Administer the permit system as provided in Part 5 of the WQCA;
(c) Monitor waste discharges and the state waters as provided in Section 25-8-303;
(d) Submit an annual report to the commission as provided in Section 25-8-305;
(e) Review and certify, conditionally certify, or deny requests for certifications under the provisions of Section 401 of the federal Clean Water Act and this article, known as "401 certificates." ;
(f) Perform such other duties as may lawfully be assigned to it.

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4. If the Contracting Entity is different than the Applicant (Project Sponsor or Owner) please describe the Contracting Entity here.

MTW ZLD Application – Submitted

Not applicable

Part B. - Description of the Water Activity – Please Refer to Criteria and Guidance Document for Eligibly Requirements

1. Name of water activity/project:

Demonstration of Membrane Zero Liquid Discharge Process for Drinking Water Systems

What is the purpose of this grant application?

[ ] Environmental compliance and feasibility study

[X] Technical Assistance regarding permitting, feasibility studies, and environmental compliance

[ ] Studies or analysis of structural, nonstructural, consumptive, nonconsumptive water needs, projects

Study or Analysis of:

- [ ] Structural project or activity
- [ ] Nonstructural project or activity
- [ ] Consumptive project or activity
- [ ] Nonconsumptive project or activity

[ ] Structural and/ or nonstructural water project or activity

2. Describe how the water activity meets these **Threshold Criteria.**

1. The water activity meets the eligibility requirements outlined in Part 2 of the Criteria and

Guidelines.

The project will provide information and assistance to drinking water suppliers desiring to use membrane treatment in situations where a permit for discharge of the concentrate cannot be obtained because such discharge would cause water quality standards adopted by the Water Quality Control Commission (WQCC) to be exceeded. Zero liquid discharge (ZLD) of membrane treatment concentrate (e.g. treating all of the raw water for drinking such that a dry solid remains) has been identified as the only available technology for environmental compliance at most locations where membrane treatment systems are expected to be located in Colorado. The project will be implemented at two public drinking water utilities, managed by the American Water Works Association Research Foundation, the preeminent drinking water research organization in the United States, with assistance from the Membrane Treatment Workgroup (MTW) and oversight by the Colorado Department of Public Health and Environment. The MTW was established as a workgroup under the Water Quality Forum at the direction of the WQCC. The MTW was tasked with:

- Taking a leadership role in assuring that membrane treatment technologies remain a viable option for drinking water and other uses within Colorado;
- Developing recommendations for resource recovery and disposal for membrane treatment concentrate that are cost effective and address environmental impacts.

The Scope of Work provides additional detail on the proposed scheme for funding and managing the project.

2. The water activity is consistent with Section 37-75-102 Colorado Revised Statutes. The requirements/language from the statute is provided in Part 3 of the Criteria and Guidelines.

   The project will pilot technology for relatively small water flows at two locations in Colorado. This project will not restrict the ability of the holder of a water right to use or dispose of that water right in any matter permitted by Colorado law and is consistent with Section 37-75-102.

3. The water activity underwent an evaluation and approval process and was approved by the Basin Roundtable (BRT) and the application includes a description of the results of the BRTs evaluation and approval of the activity. At a minimum, the description must include the level of agreement reached by the roundtable, including any minority opinion(s) if there was not general agreement for the activity. The description must also include reasons why general agreement was not reached (if it was not), including who opposed the activity and why they opposed it. Note- If this information is included in the letter from the roundtable chair simply reference that letter.

   Table 1 summarizes funding requests/approvals from BRTs. The letters of commitment are attached.

Table 1 Basin Funding Requests

Basin	Amount	Approval Date	Comment
Arkansas	$25,000	June 11, 2008	Funding contingent upon obtaining $75,000 from other basins.
Metro	$50,000	June 12, 2008	
S. Platte	$25,000	July 8, 2008	

In addition to the financial commitments from the above Roundtables, the Colorado Basin Roundtable will provided a letter of political support for the project.

4. The water activity meets the provisions of Section 37-75-104(2), Colorado Revised Statutes. The requirements/language from the statute is provided in Part 3 of the Criteria and Guidelines.

Membrane treatment for municipal drinking water supply is the best technology for producing potable water from lower quality/impacted sources that will meet, and often exceed, regulatory requirements adopted pursuant to the federal Safe Drinking Water Act (SDWA) and/or consumer requirements. Currently, many sources of water in the Arkansas and South Platte River Basins exceed the regulatory maximum contaminant level under the SDWA for one or more parameters and/or have high levels of total dissolved solids that are unacceptable to consumers.

The zero liquid discharge process technology this project will pilot is the solution that will enable public water systems to use this technology for existing sources while meeting regulatory requirements and would also allow development of new lower quality sources for municipal use. For example, the implementation of ZLD technology would allow the Cities of La Junta and Brighton to remove less water from the respective river system than withdrawals that occur with their current membrane treatment systems while meeting the conditions of their discharge permits that require reduction in the concentration of one or more contaminants. This process would make the water supply for both of these communities sustainable as the combined membrane treatment/ZLD technology would meet all current and anticipated future SDWA/discharge permitting requirements. Membrane treatment/ZLD technology would likely allow new sources, principally saline groundwater, to be used for municipal water supply.

Thus, implementation of this technology would allow municipal water supplies to become more sustainable and could meet a portion of the consumptive water needs in basins throughout Colorado.

3. For Applications that include a request for funds from the Statewide Account, describe how the water activity meets the **Evaluation Criteria**. See Part 3 of Criteria and Guidelines.

The following is a description of how this project will meet the Evaluation Criteria for CWCB allocation of funds:

Promoting Collaboration and Cooperation

a. *Addresses Multiple Needs*
The project addresses issues related to making additional poorer quality water supplies available for municipal water supply and is applicable to multiple water supply interests in all basins.

The lack of viable options for disposal of concentrate disposal from membrane treatment processes has restricted the use of this highly effective treatment technology for drinking water production. Membrane technology is essential in treating water of lower quality to drinking water standards. This technology also improves the efficiency of the treatment process, permitting a greater percentage of the water treated to be available for consumption. The ability to treat lower quality water will assist in meeting future municipal water supply needs.

b. *Promote Cooperation and Collaboration*
A wide variety of entities are represented in this application and are working together through a process of cooperation and collaboration to develop the necessary information contemplated by this pilot project.

Concentrate disposal is a pressing statewide issue currently being addressed by the MTW (current e-mail list contains 73 participants), a collaborative group established under the auspices of the Water Quality Forum. The MTW has brought together a broad spectrum of interests who are cooperatively working together to develop solutions to the problem of environmentally acceptable disposal of membrane treatment concentrate. The pilot testing of ZLD technologies was identified by the MTW as a critical step in solving the problem of concentrate disposal in Colorado.

The collaborative nature of this project is illustrated by the broad range of project proponents included in Table 2. These proponents have agreed to support the project either through direct financial contribution, in-kind services or participation in project planning.

Table 2. Project Proponents			
Organization	Role		
	Financial Contribution	In-kind Services	Planning Participant
City of La Junta	$25,000	X	X
City of Brighton	$10,000	$50,000	X
East Cherry Creek Valley Water and Sanitation District	$5,000		X
Metropolitan Wastewater Reclamation District	$30,000		X
South Adams County Water and Sanitation District	$5,000		X
City of Aurora	$15,000	$15,000	X
City of Thornton		X	X
Arapahoe County Water and Sanitation District	Under review		X
Northern Water Conservancy District	Under review		X
Denver Water			X
United Water and Sanitation District	$5,000		X
Water Quality Control Division (CDPHE)	$15,000	X	X
America Water Works Research Foundation (AwwaRF)	$150,000	X	X

Key: TBD = To be determined, X = Value has yet to be estimated

Facilitating Water Activity Implementation

c. *Reduce Uncertainty of Implementation*
Funding from the Account will reduce the uncertainty that membrane treatment projects will be implemented by improving cost and performance estimates for ZLD technologies at La Junta, Brighton and other locations throughout the state. The cost of the pilot project proposed in this application are significant and the applicant is not aware of other sources of funding that could support implementation of a meaningful pilot project. Furthermore, the most impacted entities in Colorado, communities like Brighton and La Junta, do not have the resources to implement such a project.

This application has been developed by the MTW, under the guidelines of the Colorado Water Quality Forum. The MTW has solicited input from a wide variety of stakeholders, culminating in a consensus report to the Water Quality Control Commission recommending demonstration of ZLD technologies. The final report prepared by this group is attached.

Funding of this project from this account will reduce uncertainty regarding the suitability of ZLD to applications throughout Colorado. Determination of the feasibility of ZLD is a pressing need for participating utilities including:
- City of La Junta
- City of Brighton
- East Cherry Creek Valley Water and Sanitation District

Pilot testing at the Brighton and La Junta water treatment plants will assist these and other Colorado communities in:

- Developing new sources needed to meet municipal water supply demands;
- Protecting the quality of existing water bodies through the elimination of current or future discharges.

d. *Urgency*

Existing communities such as Brighton and La Junta have compliance schedules in their discharge permits that require alternative means of concentrate disposal. As previously stated, ZLD is the only technology that will meet the requirements for these and many other communities that are currently contemplating use of membrane treatment for their municipal water supply. In addition, one community, the City of Thornton, applied for a permit for discharge of membrane treatment concentrate from a proposed water treatment facility. Their application was denied by the Water Quality Control Division due to the fact that the discharge would have caused water quality standards to be exceeded.

e. *Timeliness of Application*

The MTW has developed a schedule for completion of the project by the end of 2009 which will provide information for Colorado communities to move forward with membrane treatment water supply projects. Given the complexity of the project, the proposed schedule will result in a final report in short amount of time.

f. *Availability of Expertise to Implement Activity*

The Applicant has selected the Colorado-based AwwaRF to manage this project. AwwaRF has managed hundreds of projects of this scope and magnitude and is recognized as the premier research organization for drinking water issues.

Funding provided by this grant will be used to select the most technically qualified contractor to execute the project. The project will be managed through AwwaRF, a non-profit research institution capable of providing technical peer review of the project. AwwaRF participation will assure work performed by this project will be of the highest technical standards.

g. *Receiving Matching Funding*

A significant amount of matching funds and in-kind services have been secured by the MTW for this project. AwwaRF has indicated that it will match utility and/or state funding on a one for one basis up to $150,000. In addition, matching funding in the $100,000 to $150,000 range has been committed by the project proponents. Several members of the MTW have pledged in kind services including laboratory testing, and covering utility costs for the pilot project, as well as technical expertise as part of an anticipated Project Advisory Committee to AwwaRF. In addition, AwwaRF will provide its project management services at no cost as an in-kind contribution.

h. *Nonavailability of Alternative Funding*
The MTW has investigated a number of alternative funding sources none of which can provide sufficient funding or funding in a timely manner. The MTW has therefore coordinated with many interested parties to solicit a large amount of matching and in-kind funding to leverage Colorado Water Conservation Board (CWCB) funding of the project.

Meeting Water Management Goals and Objectives and Identified Water Needs

i. *Assists in Completing Needs Assessment*
Technical data and equipment operations experience gained from this project will assist in meeting the needs assessment by providing information regarding the practicality of the treatment of poor water quality sources by membranes through a better understanding of the cost and feasibility of ZLD systems.

j. *Meets SWSI Objectives*
The proposed project addresses several SWSI objectives including: sustainability in meeting municipal demands, optimizing existing and future water supplies, providing for environmental enhancements, providing operational flexibility and complying with regulations.

As outlined in the October 2007 Report of the Membrane Treatment Workgroup to the Water Quality Control Commission, ZLD technologies are the only viable long-term approach for disposal of concentrate of membrane processes used for meeting Safe Drinking Water Act and Clean Water Act requirements while making maximum use of existing resources.

The ability of this project to meet SWSI objectives is summarized in the conclusion of this report, which has been endorsed by the Water Quality Control Commission:

> *To assure an adequate and sustainable supply of high-quality water for municipal and industrial uses, the State of Colorado should take a leadership role in demonstrating cost effective and energy-efficient ZLD technologies to manage RO/NF residuals with minimal environmental impact. This role should include active support and financial assistance, in cooperation with private interests, for the development and operation of ZLD pilot testing programs.*

k. *Promotes Conservation and Efficiency*
The results of this project will promote water conservation and efficiency. High pressure membrane systems without ZLD typically operate at 75 to 80 percent efficiency, with 20 to 25

percent of the water treated by the membrane not being available for consumption. Through the use of ZLD technology, efficiency of membrane treatment is increased to the point where practically the entire volume of source water entering a treatment plant is available for consumption. By implementing ZLD technology, membrane treatment systems could meet demands while withdrawing less water from surface or groundwater sources.

l. *Existing Water Conservation Plan*
Not applicable

m. *Makes New Water Available for Use*
By assisting in solving the membrane concentrate disposal dilemma, many lower quality and saline water sources currently not considered suitable for drinking water sources could be brought into production.

n. *Reoperation of Facilities*
Not applicable

The Water Activity Addresses Issues of Statewide Value

o. *Meets Environmental Needs*
The discharge of membrane concentrate to surface water bodies is frequently constrained by in-stream standard established under the Clean Water Act. Even when the discharge is permitted, membrane concentrate adds additional contaminant burdens to those water bodies. ZLD systems provide environmental benefits by reducing contaminants loads in water bodies that would otherwise receive discharge and removing these contaminants from the water cycle.

p. *Administration of Compact-entitled Waters*
Not applicable

q. *Recovery of Threatened Species*
Not applicable

r. *Provides a High Level of Benefit to Colorado*
Through the use of matching funds and in-kind services, the MTW is proposing a program that highly leverages the use of state funds. Disposal of membrane concentrate is a statewide issue. Membrane treatment is in use or under consideration in all Basins in Colorado. The program will not only benefit the pilot utilities of Brighton and La Junta, but provides statewide benefits to any utility using or considering membrane treatment.

s. *Relationship to Other CWCB Programs*
A planned test of ZLD technologies by East Cherry Creek Valley Water and Sanitation District (ECCV) has been funded by the CWCB. The project proposed by the MTW in this application builds on information gathered by the ECCV pilot. While the ECCV pilot is a valuable start, the objectives of that pilot test are focused on the immediate needs of ECCV. The test is limited to testing proprietary technologies while still leaving a number of key questions unanswered.

The objectives and conduct of the pilot project proposed by this application differs from the ECCV pilot in several ways:

- The project addressed statewide objectives that were identified through consensus building process by the stakeholders participating in the MTW. The result of this consensus process assures the testing performed during the proposed pilot project provides relevant information to stakeholders and the state at large;
- The project includes testing in two basins providing a better statewide assessment of the feasibility of ZLD;
- The pilot tests involves separate water quality issues not addressed by the ECCV pilot, including selenium;
- The pilot program will test additional non-proprietary technologies, not tested by ECCV;
- The project leverages additional sources of funding;
- Management by AwwaRF taps into the most recent research in the area, assuring the pilot test is relevant and consistent with current research in this field.

The MTW realizes that ZLD technologies are inherently energy intensive and alternative energy sources may be a cost-effective way of supplying power to ZLD systems. In a parallel effort, the MTW is developing the project "Feasibility Investigation and Preliminary Design of Renewable Energy Systems for Zero Liquid Discharge Concentrate Management." Funding for this energy-related project is NOT the subject of this grant request; rather other funding sources are being developed to finance it. When funded, the Energy System Project will run concurrently with the proposed pilot project. The Energy System Project will use data developed by this pilot project to provide potential users of ZLD with an assessment of alternative energy options which may lower the operating cost of ZLD while improving environmental stewardship.

t. *Supports Colorado's Economic Vitality*
Reliable, safe and affordable municipal water is fundamental to the state's economic vitality. This project will assist in using poorer water quality sources for municipal supply, reducing demands on agricultural supplies and assuring membrane treatment remains a viable technology in Colorado. Experience gained by the project will establish Colorado as a leader in this area with potential economic benefits to the statewide participants in the project.

4. Please provide an overview of the water project or activity to be funded including – type of activity, statement of what the activity is intended to accomplish, the need for the activity, the problems and opportunities to be addressed, expectations of the participants, why the activity is important, the service area or geographic location, and any relevant issues etc. Please include any relevant TABOR issues that may affect the Contracting Entity. Please refer to Part 2 of Criteria and Guidance document for additional detail on information to include.

As indicated above, this project has been developed by the MTW to implement its recommendation that ZLD treatment technologies be pilot tested in Colorado. The Workgroup has assembled a team of project proponents from across the state. The MTW has identified two geographically separate locations in different basins for testing. This approach illustrates the statewide applicability of the

test results.

In order to assure the highest scientific standards for the project, as well as to draw upon the experience of national experts in the field, the project will be managed under the direction of AwwaRF. AwwaRF involvement will result in a project executed to the highest technical standards.

The specific objectives of the project are:

- Comparing the performance of alternative ZLD technologies;
- Developing capital and operating and maintenance costs for ZLD technologies;
- Completing a detailed analysis of energy consumption;
- Determining the quantity and quality of the water recovered from the ZLD process;
- Characterizing the quantity and composition of solid created by the process;
- Determining the handling, transportation and disposal requirements for solids created by the process;
- Identifying potential marketable residuals from the ZLD process and summarizing applicable case studies;
- Assessing the different requirements of two distinct source waters representing different water quality conditions for the State of Colorado.

5. Please summarize the proposed scope of work. Please refer to Part 2 of the Criteria and Guidance document for detailed requirements.

Scope of Work

Objectives of Pilot Study

At present, drinking water utilities have been reluctant to undertake reverse osmosis (RO) or nanofiltration (NF) membrane projects due to the uncertainty surrounding the availability of feasible disposal options for the concentrate. Zero liquid discharge (ZLD) is a sustainable disposal option that represents a long-term solution to concentrate disposal for utilities that need membrane treatment to produce safe drinking water. The primary barrier to implementing ZLD is the lack of cost and performance data developed for drinking water systems under conditions unique to Colorado. A pilot test demonstrating ZLD will help resolve the technical and financial uncertainties which currently hinder its implementation.

Objectives of the proposed pilot testing will include:

- Comparing the performance of alternative ZLD technologies;
- Developing capital, operating and maintenance costs for ZLD technologies;
- Completing a detailed analysis of energy consumption;
- Determining the quantity and quality of the water recovered from the ZLD process;
- Characterizing the quantity and composition of solid created by the process;
- Determining the handling, transportation and disposal requirements for solids created by the process;

- Identifying potential marketable residuals from the ZLD process and summarizing applicable case studies;
- Assessing the different requirements of two distinct source waters representing different water quality conditions for the State of Colorado.

Pilot Study Project Management

Management of the pilot project will be supervised by the American Water Works Research Foundation (AwwaRF) through a Project Advisory Committee (PAC) that will include members of the MTW and a representative of the Colorado Department of Public Health and Environment (CDPHE), the applicant for this grant request. This oversight will provide a high level of assurance that any funds provided by the State of Colorado will be used to produce high-quality information that can be used by Colorado drinking water utilities and other interested parties. CDPHE, as the grantee and a member of the PAC, will assure that payment requests from AwwaRF are complete and meet the requirements of the CWCB process. An outline of the project structure is presented in Figure 1.

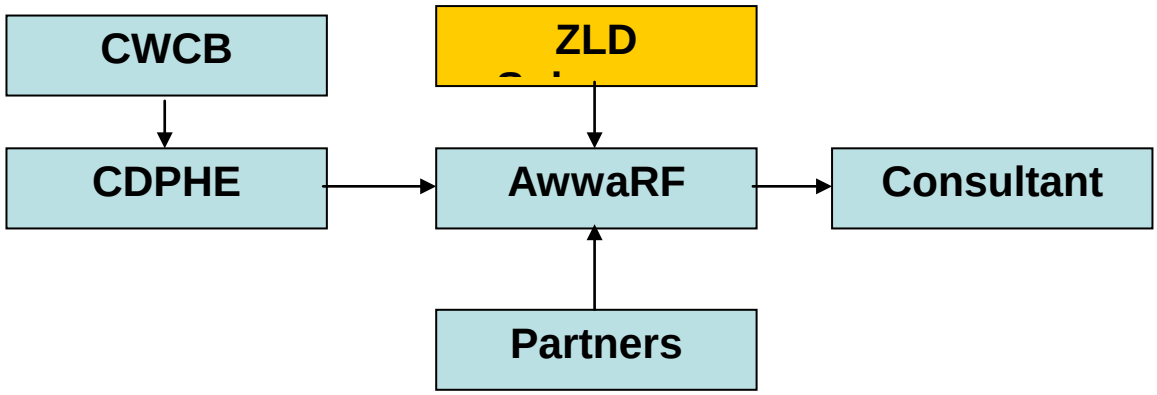

Figure 1. Project Management Structure

Pilot Study Approach

Pilot Sites

Pilot testing will occur at two sites with two different water qualities for Colorado. The first site at the City of Brighton's RO Water Treatment Plant (WTP) will represent water quality indicative of the South Platte River basin. The second site, located at the City of La Junta's RO WTP, characterizes typical Arkansas River basin water. These plants have distinct water quality challenges. In the case of Brighton, the concentrate disposal challenge is caused by nitrate, whereas, in the case of La Junta, the challenge is caused by selenium. Brighton is a rapidly growing community, in which increased municipal and industrial (M&I) demand is an immediate issue. La Junta is representative of a small agricultural community with limited financial resources that must confront a highly technical and costly disposal issue. These communities are representative of the statewide concentrate disposal issues facing utilities statewide.

Relationship to On-going Studies

A similar pilot study is being implemented by East Cherry Creek Valley Water and Sanitation District (ECCV) under a CWCB grant. The ECCV project will test a proprietary higher recovery secondary RO process developed by CDM, crystallizers, and the proprietary Vibratory Shear Enhanced Processing (VSEP) membrane by New Logic Research, Inc. While providing information that is important for evaluating ZLD processes, the ECCV pilot focuses on issues specific to ECCV. As such, the evaluation is limited to a single water quality, evaluates only proprietary technologies, and does not address broader statewide issues of interest to the MTW. In addition, through the involvement of AwwaRF, a non-profit organization devoted to researching water issues, this project will draw on the knowledge of experts in the field of concentrate disposal, and take advantage of experience of other projects completed outside of Colorado.

The proposed MTW study will augment the ECCV pilot study by providing more data on nonproprietary technologies as well as expanding the study to other state water qualities. Information from the ECCV pilot will be available for use by this project. In addition, this study will provide the State of Colorado a more complete database for means of developing thorough costs and feasibility analyses for ZLD.

Approach to Evaluation

Existing work on ZLD technologies for inland RO plants results in several categories of reducing the concentrate and minimizing impacts. These are:

1. High Recovery of RO Process - Membranes

   a) The primary RO system is optimized for the highest recovery possible (approximately 85 to 90 percent water recovery). The resulting concentrate is further treated by secondary processes described in b).

   b) Concentrate rejected from the primary RO process is treated using a high-recovery secondary RO process: Treatment of the concentrate is used to remove sparingly soluble salts (ion exchange, electro-coagulation, physical/chemical softening, etc) and allow a secondary RO membrane to process the water and increase the overall system recovery to more than 95 percent.

2. Treatment of Final Concentrate to Solids

   Most options must use some combination of evaporation pond, brine concentrator, and/or crystallizer for the small concentrate flow remaining. Options exist for enhanced solar evaporation such as Wind Aided Intensified Evaporation. Brine concentrators process the highly saturated RO concentrate and are usually the last step after solar evaporation. However, occasionally a crystallizer is used after the brine concentrator for additional dewatering and to capture revenue-producing by-products.

The water to be treated by the ECCV pilot study is similar in chemistry to the City of Brighton RO concentrate, and in the ECCV case will test one secondary RO process and two concentrate treatment processes. To provide valuable information for the State of Colorado, the following processes are recommended for testing with this pilot project by the MTW:

City of Brighton Site (Site 1):

- Alternative concentrate treatment process (i.e. electro-coagulation or electrodialysis reversal)

- High-recovery RO
- Brine concentrator

City of La Junta Site (Site 2):

- Alternative concentrate treatment process (i.e. VSEP)
- Brine concentrator

The MTW recognizes that ZLD is a dynamic field where new technologies are being developed that may be worthy of additional consideration. For this reason, the Consultant executing the pilot study will be able to propose substitute technologies for evaluation upon completion of the literature review task outlined below. None the less, the concept is to use high recovery processes along with additional final recovery steps that take the liquid concentrate all the way to a solid form. This approach will allow the generation of firm cost projections based on the amount of water treated and solids produced.

Detailed Scope of Work

The following sections provide details on the execution of the ZLD pilot project and are grouped according to the Colorado Water Conservation Board (CWCB) grant application guidelines.

I. Scope of Services

The following scope has been prepared to meet the suggested requirements set forth by the CWCB grant application instruction. Each task is divided into the following sections: description of task, method or procedure used to accomplish task, and task deliverables. In addition, any assumptions are included for the scope.

Task 1 – Perform Literature Review for Confirmation of Equipment/Processes Selected for Testing

Description: This task is comprised of a review of the work completed by the State of Colorado Membrane Treatment Workgroup and the available literature on high-recovery reverse osmosis processes and zero liquid discharge technologies. Initially, a review of the previously completed MTW report will be conducted to summarize all of the major conclusions of that report pertaining to the technologies to be tested. Once this step is completed, a review of the available literature will be conducted to update the conclusions of the MTW report, and determine the most suitable technologies for the Brighton and La Junta pilot sites. The literature review will include high-recovery reverse osmosis as well as concentrate minimization, or zero liquid discharge technologies. The efforts of the literature review will be summarized in a Technical Memorandum (TM). The TM will include a process flow diagram for each of the two sites showing major pieces of equipment, sampling locations and interface points for mechanical and electrical connections.

***Method/Procedure*:** Desk-top literature review and process flow schematics

***Assumptions*:** AwwaRF/MTW Project Advisory Committee (PAC) will approve the TM within two weeks.

Deliverables:

- Ten (10) hard copies of Technical Memorandum (TM)
- One (1) electronic copy of TM

Task 2 - Develop Experimental Plan

***Description*:** Develop the Experimental Plan for testing at the Brighton and La Junta sites. The plan will contain at a minimum the following: the objectives of the testing, equipment provided and site needs, success criteria of testing, analytical and operational parameters for sampling and on-line measurements, breakdown of responsibilities, and the weekly or monthly test plan of major activities. Quality control procedures and any health and safety plans will be prepared, as required by the individual plant sites.

Method/Procedure: Develop the plan in a logical order starting with the objective and outline the sequences necessary to produce the final delivery product for each site.

***Assumptions*:** AwwaRF/MTW Project Advisory Committee (PAC) will review the Draft Experimental Plan and approve the Final Experimental Plan, each within two weeks.

Deliverables:

- Five (5) hard copies of Draft Experimental Plan.
- Ten (10) hard copies of the Final Experimental Plan;
- One (1) electronic copy of both Draft and Final Experimental Plans.

Task 3 – Design of Pilot Equipment and Site Coordination

Description: This task requires the preparation of the overall design for the pilot plants at each site. The design involves both the equipment design and the piping and electrical interconnections.

Equipment lists, rough piping layouts, drainage requirements, equipment placement, and electrical connections/feeds will be designed. A schedule of activities will be prepared to outline the coordination and arrival of equipment and chemical feed systems.

Pilot equipment rental contracts will be established and additional equipment procured during this phase.

Method/Procedure: The Consultant will visit each site and establish the location and coordination requirement for installation of the pilot equipment.

Assumptions:

- AwwaRF/MTW Project Advisory Committee (PAC) will approve the Pilot Design within two weeks.
- All electrical supply as well as connections to existing electrical feed sources will be provided by the Cities of Brighton and La Junta;
- Concentrate supply will be provided uninterrupted by the two cities;
- Sewer or other drains will be provided for any pilot plant discharge by the two cities.

Deliverables:

- Five (5) hard copies of Pilot Design including;
  - General Arrangement Drawings showing equipment locations, major piping and electrical connections.
  - Equipment lists, rough piping layouts, drainage requirements

- A schedule of activities outling the coordination and arrival of equipment and chemical feed systems.

- Three (3) copies of pilot equipment rental contracts
- Three (3) copies of shop drawings for the pilot equipment at each site shall be submitted for informational purposes.

Task 4 – Installation of Pilot Equipment

Description: Once the equipment arrives on site, Consultant's pilot engineers shall arrive to coordinate the installation. Pilot technicians and plumbers (as needed) will be required to install the mechanical elements of the pilot plant including tanks, pumps, and piping. Electrical connections to the pilot's central control panel will be provided by the site owner. Electrical connections from the pilot's central control panel to other pilot equipment will be made by the Consultant.

In addition, the water quality laboratory contracts and procedures will be established during this phase. It is envisioned that composite samplers will be provided for the influent and treated waters at both sites by each of the cities.

Method/Procedure: Installation: In accordance with design drawings, local codes and National Electric Code (NECC).

Assumptions:

- Cities will provide labor for connections to any full-scale electrical and water connections.
- Cities will provide labor for disconnecting full-scale electrical and water connections upon completion of piloting.
- Consultant shall provide materials for connections to any full-scale electrical and water connections.
- Cities will provide level and accessible sites for installation of the pilot equipment.
- Consultant shall provide for delivery, unloading, handling, and placing pilot plant equipment.
- Consultant shall handle, load, and remove equipment from each site upon completion of pilot testing.

Deliverables: Complete and operable pilot plant equipment at both sites.

Task 5 – Operation of Pilot Plants

Description: This task requires the commissioning and start-up activities and operation of both pilot plants. During commissioning check-out of the hydraulics, electrical, and data and sampling collection methods will be established. Commissioning will include trouble shooting to minimize start-up activities.

Start-up of the pilot units involves determining the baseline conditions of each unit. Baseline conditions include the initial permeability or specific flux of RO membranes, cleaning procedures and frequencies and the feed flow rate. Establishing the baseline conditions is estimated to take between one and four weeks at each site depending on the equipment installed.

After the baseline conditions are established, the operation of the pilot plant will commence. Pilot equipment at each site will be operated for a minimum of three (3) months and a maximum of six (6) months. This will allow

the testing of multiple conditions and firm establishment of operating conditions to determine costs.

Method/Procedure: Operations according to the "Experimental Plan" prepared in Task 2.

***Assumptions*:**

- Consultant will provide "full-time" "technical/pilot support engineer(s)" at each of the two sites.
- It is not anticipated that both the Brighton and La Junta sites will be in start-up at the same time. It is anticipated that the second pilot plant will start up about three (3) months after the first site activity commences.
- While pilot plants may continue to operate over the weekends, operational changes and sampling is not expected to be conducted outside of the normal work week or normal working hours.
- Cities will provide:
    - Uninterrupted RO concentrate stream (except disruption for prescheduled maintenance and unexpected corrective or emergency repairs)
    - Once per day site checks of provided services (i.e. RO concentrate and electrical power) during normal work week hours
    - Any prescheduled amendments to WTP process for RO concentrate delivery during these once-per-day site checks.
    - Assistance with making unexpected repairs to pilot equipment and processes, if urgent and required.

Deliverables:

- Raw data from operating both plants under baseline and multiple conditions to establish operating conditions and determine capital and operating costs.
- Water samples as described under Task 6.

Task 6 – Water Quality Sampling & Solids Analyses

Task 6A: Water Quality Sampling and Analyses
Description: Sampling will be performed on the pilot equipment to monitor performance for real-time adjustments or optimization and to collect performance information for cost comparisons and capital and operational cost estimates. Some water quality sampling, such as pH, silt density index, and conductivity will be conducted on-site using handheld probes or test units. The remainder of the water quality will be collected with composite samplers. Samples will be sent to one of three laboratories. Two laboratories will be provided by the AwwaRF/MTW Project Advisory Committee (PAC), and one will be set up to cover the analyses not able to be provided by the AwwaRF/MTW Project Advisory Committee (PAC).

Method/Procedure:

- Water analyses will be conducted in accordance with Standard Methods, latest edition. Modifications to this requirement will be allowed for analyzing high salinity samples.
- The Consultant will provide sampling recommendations and plan. The sampling plan shall consider the following categories of samples:
    - Treatability;
    - Selected unregulated contaminants;
    - Regulated Safe Drinking Water Act Requirements, including radionuclides;

- Contaminants of concern at pilot sites, including nitrate at Brighton and selenium at La Junta;
- Indicators of wastewater impact;
- Quantities and characteristics of slurry concentrate.

***Assumptions*:**

- Samples will be 24 hour composites and analyzed for those parameters listed in Attachment A.
- Consultant shall collect samples and shall deliver or arrange for delivery of samples to laboratories.
- The two laboratories provided by the AwwaRF/MTW Project Advisory Committee (PAC) will process delivered samples in accordance with Standard Methods and provide results to Consultant within one week of delivery.

Deliverables:

- Three (3) hard copies of raw analytical results
- Three (3) hard copies of analysis of samples and analytical results
- One (1) electronic copy of raw analytical results and analysis of samples and analytical results.

Task 6B: Solids Sampling & Analyses

Description: Sampling will be performed on solids slurry streams to collect performance information for cost comparisons and capital and operational cost estimates as well as for characterization of salt recovery options. These samples will be grab samples. The solids analyses will be sent to the third laboratory as the laboratories provided by the AwwaRF/MTW Project Advisory Committee (PAC) will not be able to analyze these high salinity samples. In addition, the potential markets for recoverable salts will be identified for Colorado.

Method/Procedure:

- The contractor will provide sampling recommendations and plan. The sampling plan shall consider the following categories of samples:
  - TCLP and other considerations for mono- or land-filling of the solids;
  - Characterization of the solids (i.e. percentage solids);
  - Other tests as needed to determine recoverable salts for marketable products.

Assumptions:

- Samples will be grab samples
- Consultant shall collect samples and shall deliver or arrange for delivery of samples to laboratory.

Deliverables:

- Three (3) hard copies of raw analytical results
- Three (3) hard copies of analysis of samples and analytical results
- Three (3) hard copies of market analysis
- One (1) electronic copy of raw analytical results, analysis of samples and analytical results, and market analysis.

Task 7 – Energy Evaluation and Support of Renewable Energy Study

Description: This task will evaluate energy requirements and coordinate with a separate investigation and design project aimed at providing affordable renewable energy for ZLD.

Method/Procedure:

- Determine energy requirements for major equipment.
- Determine power consumption patterns (daily, weekly, and seasonal).
- Evaluate relationship between feed water and power consumption.
- Evaluate methods for decoupling treated water production and ZLD operation for the purpose of optimizing energy management.
- Coordinate with renewable energy study personnel.

Assumptions: Data will be developed with coordination triggered when energy project is funded.

Deliverables: Three (3) hard copies and one (1) electronic copy of process schematics and water mass balances and energy balances.

Task 8 – Prepare Final Report

Description: A final pilot testing report will be prepared within one (1) month of completing testing at the second site. The report will contain information established for the experimental plan such as objectives, success criteria and the equipment descriptions. In addition, all of the water quality and operational data will be summarized and analyzed. The optimum operating parameters of each unit process will be established with capital and operating costs for the sizes of plants determined by the MTW. A mathematical relationship will be prepared with a graphical illustration that can be used to project costs for varying plant sizes. The accuracy of the equation and graph will be estimated by the Consultant.

The report is to include a section regarding "next best alternative" for utilities with impaired water quality as their source water. In the Report prepared by the MTW, there is a short section that may serve as a reference point.

The results of the report will be presented to the AwwaRF/ MTW PAC for the purposes of reviewing the work and providing comments.

Method/Procedure: Use of the Experimental Plan as the basis and results from the pilot plant study to prepare the final report.

***Assumptions*:**

- Draft Final Report completed within 30 days of the completion of the testing at the "second site."
- Final project presentation will be made to the AwwaRF/MTW PAC and project participants in person by the principle-in-charge, overall project manager, on-site technical/pilot personnel, and others from the "expert panel" as needed. Presentation will be made after PAC review of the Draft Final Report and before completion of the Final Report..

- AwwaRF/ MTW Project Advisory Committee (PAC) will review the Draft Final Report and approve the Final Report, each within two weeks.
- Final Report completed and delivered within two (2) weeks of approval review by AwwaRF/ MTW Project Advisory Committee (PAC).

Deliverables:

- Five (5) hard copies of Draft Final Report
- Ten (10) hard copies of the Final Report
- One (1) electronic copy of both Draft and Final Reports

Task 9 – Project Management

Description: The overall management of the project will be though AwwaRF as part of its Partnership Program. AwwaRF will set up the PAC for the purposes of reviewing the project, ensuring the project meets all technical standards, and ensuring the input of the MTW group is incorporated. It is anticipated that the PAC will consist of both AwwaRF nominated members as well as MTW nominated members. The Consultant will be selected by the MTW, perform the execution of the project, and nominate their own Principal-in-Charge. The subtasks include updates made to the AwwaRF/MTW PAC as required through the AwwaRF guidelines. These updates will generally consist of monthly written progress reports and quarterly presentations.

Method/Procedure:

- Consultant's overall project manager will be in frequent contact with the AwwaRF project manager
- Written progress reports will be distributed electronically to the PAC
- Quarterly presentations will be made in person by the principle-in-charge, overall project manager, on-site technical/pilot personnel, and others as needed.
- Payment requests will be prepared in accordance with AwwaRF requirements and procedures.

***Assumptions*:**

- AwwaRF/MTW Project Advisory Committee (PAC) will review monthly reports and provide comments and advice/ direction for pilot project modifications, if necessary.
- AwwaRF/MTW Project Advisory Committee (PAC) will review monthly payment requests and forward for processing.

Deliverables:

- Monthly progress reports
- Monthly payment requests
- Three (3) quarterly in-person presentations to AwwaRF/MTW PAC

II. Personnel

This section is to be developed by the Consultant and will be used as part of the selection criteria. Reference is made to the organizational chart that includes project proponents and interface contact. Generally, the Consultant will conduct the work and be selected by the MTW. The organization will be:

Overall Project Manager – AwwaRF;
Project Advisory Panel – AwwaRF members and MTW members;
Principal-in-Charge – Consultant engineer responsible for oversight and technical direction;
Project Manager/Technical Lead – Consultant engineer responsible for execution of the project and piloting efforts;
Technical/Pilot Support Engineers – Consultant engineers who will set up the pilot and provide the day-to-day interface and data management of the pilot;
Expert Panel – From Consultant, ZLD Research and RO Specialists from the Consultant team who will provide internal review and advisory assistance on direction of the pilot.

III. Budget

See attached grant application form. This budget is a preliminary breakdown of the major tasks and expected Consultant hours required. A final detailed budget will be assembled once the pilot project is awarded to the Consultant. The purpose of this planning budget is to establish the anticipated level of effort.

Preliminary Cost Estimate for Pilot Study Work Scope

Task Description	Hours	Labor - $	Other Direct Costs - $	Total Project Costs - $
Task 1 - Literature Search	120	$25,000		$25,000
Task 2 - Experimental Plan	220	$39,000		$40,000
Travel			$1,000	
Task 3 - Design Layouts	200	$38,000		$40,000
Travel			$2,000	
Task 4 - Install Equipment	400	$80,000		$100,000
Travel and Incidentals			$20,000	
Task 5 - Pilot Operations	1500	$320,000		$500,000
Operators - perdiem			$36,000	
Operators travel			$24,000	
Equipment Rental			$120,000	
Task 6 - Water Sampling	150	$20,000		$220,000
Onsite data loggers			$10,000	
Composite samplers			$10,000	
Analytical work			$180,000	
Task 7 - Support Energy Study	120	$18,000		$20,000
Travel			$2,000	
Task 8 - Final Report	200	$30,000		$30,000
Task 9 - Project Management & QC	400	$80,000		$100,000
Travel and Production			$20,000	
TOTAL PILOT COST ESTIMATE				**$1,075,000**
In-Kind Contributions				
Water Quality Sampling			$50,000 *estimated*	
Site Services			$100,000 *estimated*	
PAC Service	200		$40,000 *estimated*	

IV. Schedule

It is expected that the pilot equipment will be on each site for a minimum of three (3) to six (6) months. The attached conceptual schedule outlines the key activities of the proposed project as well as its relationship to the proposed concurrent Renewable Energy Study (funded by others).

MILESTONES	January	February	March	April	May	June	July	August	September	October	November	December	January
Task 1 - Literature Search													
Review literature & reports	■												
Issure TM		^											
Review and Finalize TM		■											
Task 2 - Experimental Plan													
Site Visits	■												
Plan Preparation		■											
Issue Plan			^										
Review and Finalize Plan			■										
Task 3 - Design Layouts													
Equipment drawings		■											
Site layouts		■											
Finalize Design			^										
Task 4 - Install Equipment													
Ship Equipment			■										
Set Equipment				■									
Mech and Elec Connections				■									
Commissioning & Start-up					■								
Task 5 - Pilot Operation													
Site #1 - Operate						■	■	■					
Site #2 Operate								■	■	■			
Task 6 - Water Sampling													
Collect and Analyze Parameters						■	■	■	■	■	■		
Task 7 - Support Energy Evaluation													
Initial Energy Requirements				■									
Characterization of Streams										■			
Final Coordination													■
Task 8 - Final Report													
Prepare Report									■	■	■	■	
Issue Report													^
Review& Finalize Report													■
Task 9 Project Management													
Monthly Progress Reports	^	^	^	^	^	^	^	^	^	^	^	^	^
Presentations		^		^				^					^
Conceptual Schedule for Renewable Energy Study													
Issue RFP for Contractor	■												
Selected Contractor NTP				■	■								
Conduct Energy Study						■	■	■	■	■	■	■	■