

## Assessment of Osmotic Mechanisms Pairing Desalination Concentrate and Wastewater Treatment

PREPARED FOR: Dr. Saqib Shirazi, Texas Water Development Board  
PREPARED BY: CH2M HILL  
COPIES: Jorge Arroyo, Texas Water Development Board  
Robert Huehmer/WDC  
DATE: April 2, 2010  
TWDB CONTRACT NUMBER: 0804830852

Dear Dr. Shirazi,

Please find attached the project update for activities up to March 26, 2010.

We have substantially completed Task 1, Task 2 and Task 4 of our scope of work, while maintaining a small allowance for revision work. CH2M HILL's project manager and senior technical consultant are working on developing and refining the forward osmosis membrane performance and cost models. Information utilized for such tasks was developed as part of Tasks 1 and 2. Additional information required to refine both models will come out of the pilot effort being conducted by Colorado School of Mines. CH2M HILL staff is also preparing a draft of the final report. Information for the first three sections of the report is being edited. An invoice and supporting information summarizing the project financials through 3/26/10 was submitted by our project accountant last week. To date, no expenses have been occurred on travel. Please contact me if you have any questions regarding this progress report.

Sincerely,



Juan Gomez, Ph.D., P.E.  
CH2M HILL  
Direct Phone: (210) 321-6241  
Cell Phone: (210) 240-0084  
Fax: (972) 385-5153

## Section A - Summary of Total Expenses

|     |   |             |
|-----|---|-------------|
| (1) | CONTRACTOR's Vendor Identification Number:                          |             |
| (2) | TWDB Contract Number:   | 0804830852  |
| (3) | Total expenses for the billing period:                              | \$6.36      |
| (4) | Total Inkind Services:  |             |
| (5) | Total Services for this period:                                     | \$7,920.81  |
| (6) | Less LOCAL SHARE OF THE TOTAL STUDY COSTS for the billing period:   | \$4,225.32* |
| (7) | Total BOARD's SHARE OF THE TOTAL STUDY COST for the billing period: | \$3,695.49  |
| (8) | Amount of Retainage to be withheld for the billing period:          | \$370.19    |
| (9) | Total Costs to be Reimbursed by the BOARD for the billing period:   | \$3,331.67  |

\* Local share represents indirect overhead and profit based on CH2M HILL's rate structure.

An invoice for the value in Line (9) is appended to this project update.

I hereby certify that the expenses submitted for the billing period are a true and correct representation of amounts paid for work performed directly related to this contract.



Juan Gomez, Ph.D., P.E.  
Project Manager  
CH2M HILL

## Section B - Direct Costs

### EXHIBIT 1.

Direct Cost Summary Spent this billing period.

| <b>TASK Budget</b>     |                      |                    | <b>Previous</b>     | <b>Total</b>        |                      |                  |
|------------------------|----------------------|--------------------|---------------------|---------------------|----------------------|------------------|
|                        | <b>Total</b>         | <b>Expenses</b>    | <b>Total</b>        | <b>Expenses</b>     | <b>Balance</b>       | <b>Percent</b>   |
|                        | <b>Budget</b>        | <b>This Period</b> | <b>Expenses</b>     | <b>Incurred</b>     | <b>Remaining</b>     | <b>Remaining</b> |
| Task 1                 | \$ 10,039.00         |                    | \$ 10,239.21        | \$ 10,239.21        | \$ (200.21)          | -2%              |
| Task 2                 | \$ 9,120.00          |                    | \$ 10,714.27        | \$ 10,714.27        | \$ (1,594.27)        | -17%             |
| Task 3                 | \$ 52,507.00         | \$ 2,626.64        | \$ 23,682.66        | \$ 26,309.30        | \$ 26,197.70         | 50%              |
| Task 4                 | \$ 17,920.00         | \$ 3,476.12        | \$ 19,092.61        | \$ 22,568.73        | \$ (4,648.73)        | -26%             |
| Task 5                 | \$ 17,769.00         | \$ 1,824.41        | \$ 12,673.36        | \$ 14,497.77        | \$ 3,271.23          | 18%              |
| Task 6                 | \$ 28,228.00         |                    | \$ 357.60           | \$ 357.60           | \$ 27,870.40         | 99%              |
| <b>Total</b>           | <b>\$ 135,583.00</b> | <b>\$ 7,927.17</b> | <b>\$ 76,759.71</b> | <b>\$ 84,686.88</b> | <b>\$ 50,896.12</b>  | <b>38%</b>       |
| <b>EXPENSE Budget</b>  |                      |                    |                     |                     |                      |                  |
|                        | <b>Total</b>         | <b>Expenses</b>    | <b>Total</b>        | <b>Expenses</b>     | <b>Balance</b>       | <b>Percent</b>   |
|                        | <b>Budget</b>        | <b>This Period</b> | <b>Expenses</b>     | <b>Incurred</b>     | <b>Remaining</b>     | <b>Remaining</b> |
| Salaries & Wages       | \$ 28,579.00         | \$ 2,649.10        | \$ 9,233.84         | \$ 9,233.84         | \$ 19,345.16         | 68%              |
| Fringe                 | \$ 11,289.00         | \$ 1,046.39        | \$ 3,648.84         | \$ 3,648.84         | \$ 7,640.16          | 68%              |
| Travel                 | \$ 3,591.00          | \$ 6.36            | \$ -                | \$ -                | \$ 3,591.00          | 100%             |
| Subcontractor Services | \$ 45,000.00         |                    | \$ -                | \$ -                | \$ 45,000.00         | 100%             |
| Reproduction           | \$ 1,540.00          |                    | \$ -                | \$ -                | \$ 1,540.00          | 100%             |
| Overhead               | \$ 34,438.00         | \$ 3,192.17        | \$ 11,126.77        | \$ 11,126.77        | \$ 23,311.23         | 68%              |
| Profit                 | \$ 11,146.00         | \$ 1,033.15        | \$ 3,601.41         | \$ 3,601.41         | \$ 7,544.59          | 68%              |
| <b>Total</b>           | <b>\$ 135,583.00</b> | <b>\$ 7,927.17</b> | <b>\$ 17,312.60</b> | <b>\$ 27,610.86</b> | <b>\$ 107,972.14</b> | <b>80%</b>       |

See attached invoice for additional information.

## **Section C - Outside Contractors**

A subcontract with Colorado School of Mines was signed and approved by all parties. Two amendments to the contract were also approved by TWDB staff. Amendment #2 is of particular importance because it extends the contract schedule through August of 2010.

Currently, they are preparing equipment and pilot test plan to conduct pilot testing at a facility in Colorado using laboratory prepared seawater RO concentrate as the draw solution.

## **Section D - Travel and Subsistence**

Nothing to Report.

## Agenda

1. Invoicing and Contract Language
2. Subcontracting
3. Project Status
  - a. Draft Table of Contents – Report

## PROGRESS REPORT

### 1. Invoicing and Contract Language

CH2M HILL received payment for all invoices submitted to TWDB with the exception of April's invoice. Additional information for Invoice dated 5/29/09 covering project charges through 5/1/09 was requested by Phyllis Thomas and submitted by CH2M HILL for her review and approval.

An invoice for project charges through 12/25/09 was submitted to TWDB. TWDB staff requested additional information and clarification on charges per task. That information was provided in January. No additional information has been requested.

### 2. Subcontracting

A subcontract with Colorado School of Mines was signed and approved by all parties. This issue was finally resolved.

### 3. Project Status

#### 3.1 Draft Table of Contents.

CH2M HILL submits the following Table of Contents for the final report.

|                               |
|-------------------------------|
| Front Cover                   |
| Inside Cover                  |
| Executive Summary             |
| Table of Contents             |
| Table of Figures              |
| Table of Tables               |
| Acknowledgements              |
| Section 1. Introduction       |
| Desalination in Texas         |
| Concentrate Disposal in Texas |
| Forward Osmosis               |
| Objectives                    |
| Section 2: Background         |
| Fundamentals of Desalination  |
| Osmosis                       |
| Desalination                  |
| Forward Osmosis               |

## Costs of Forward Osmosis

### Section 3: Characterization of Waters in Texas

Desalination in Texas

Wastewater treatment facilities in proximity of desalination plants

Characteristics of brackish water concentrate

Characteristics of seawater concentrate

Characteristics of treated wastewater

Osmotic Potential of various waters in Texas

### Section 4: Performance of Spiral Wound Forward Osmosis Membranes

Introduction

Methodology

Results

Discussion

### Section 5: Development of a Forward Osmosis Cost Model

### Section 6: Feasibility Analysis of Osmotic Mechanisms

### Section 7: Conclusions and Recommendations

References

Glossary

Acronyms and Symbols

Appendices

CD-ROM

We are currently working on Section 1, 2, 3 and 4 which correspond to Task 1, Task 2 and Task 3 of our contract.

## **Progress by Task**

### **Task 1. Survey of Water Categories and Quality**

An initial review of desalination facilities in the State of Texas was conducted. This task is substantially complete. A small budget reserve is being maintained.

### **Task 2. Screening and Selection of Hybrid Forward Osmosis System Configurations**

This task is substantially complete. A small budget reserve is being maintained.

### **Task 3. Testing of the Novel Forward Osmosis Spiral Wound Membrane Element**

CSM contract is finally in place to conduct their portion of the work. CSM is ready to start testing the required water qualities identified under Task 1 and Task 2.

CSM will be testing a couple of membranes secured from two different suppliers. One of the suppliers is Hydration Technologies.

### **Task 4. System and Process Modeling**

This is substantially complete now. A small budget reserve is being maintained.

CH2M HILL staff developed a FO process sizing model that looks at total dissolved solids concentration and the effects of staging, hydraulics through the membrane elements and solute transport on both directions (from the draw solution to the feed solution and vice versa).

We are currently reviewing and finalizing the model as we develop the cost model. Some of the decisions made in the process sizing model may affect the cost model. So, they will have to be completely integrated as we complete the cost model.

#### **Task 5. Cost Modeling**

We have started and made substantial progress on our cost model based on the work performed under Task 4 during the months of December and January. We are also preparing/refining cost curves for the non-forward osmosis system components. Additional work will be required as Colorado School of Mines conducts the pilot testing phase of the project and the FO sizing module is refined.

#### **Task 6. Final Report Preparation**

We are preparing a draft of the final report for this project. We are incorporating text for the first three sections of the report.