

June 20, 2016

Julie Cunningham
Chief
Planning & Management Division
Oklahoma Water Resources Board (OWRB)
3800 N. Classen
Oklahoma City, OK 73118

Subject: CH2M ROM for Produced Water Recycling Opportunities Scoping Evaluation

Dear Ms. Cunningham,

CH2M HILL, Inc. (CH2M) is pleased to provide the attached indicative scope and rough order of magnitude (ROM) estimate to the Oklahoma Water Resources Board (OWRB) to perform the above referenced study. This draft was prepared based on our recent discussions and is intended to support OWRB in seeking matching funds through the U.S. Department of Energy to (USDOE).

The OWRB Produced Water Working Group is interested to evaluate options to beneficially reuse produced water from oil and gas exploration and production activities as an alternatives to disposal. CH2M's approach to this study is to identify representative opportunities to "match" localized produced water sources with potential beneficial reuse demands, and to evaluate the associated treatment and conveyance costs. We will compare these costs to the cost to dispose of the equivalent volume of produced water through forced evaporation. From these representative comparative cases, our objective would be to then draw some generalized conclusions about the opportunity, cost and benefit of extrapolating such a strategy state wide and what the potential impact might be on the individual operator's cost of production.

If you have questions, please contact Michael Dunkel at (469) 585-6468 or Michael.Dunkel@ch2m.com. We look forward to supporting you on this important project.

Regards,

CH2M HILL, Inc.

Michael Dunkel
Vice President
Principal Investigator

Bruce Thomas-Benke
Market Delivery Leader | Water for Upstream Oil & Gas

C: Anna Childers

Draft Statement of Work - Produced Water Recycling Opportunities Scoping Evaluation

Project Understanding

The Oklahoma Water Resources Board's (OWRB) Produced Water Work Group is charged with investigating solutions to promote recycling of produced water related to oil and gas production. As the oil and gas industry represents a significant portion of Oklahoma's economy, the state is interested in identifying sustainable alternatives to reduce the industry's reliance on deep well disposal while still balancing public interest and continued beneficial development of the state's valuable oil and gas resources.

One potential strategy is beneficial reuse of produced water from oil and gas operations. The objective of this proposed study is to investigate produced water reuse and recycling, including evaluating potential costs to treat and deliver produced water for alternative uses, compared to deep well injection and alternate disposal methods, namely, forced evaporation.

Scope of Services

Task 1 – Coordinate the Produced Water Work Group (PWWG)

Objectives

Coordinate the PWWG meetings in conjunction with the OWRB. Establish subcommittees and working meetings as needed. Coordinate the agenda for the PWWG meetings with OWRB. Use the expertise assembled with the PWWG to execute the study of produced water reuse, recycling and forced evaporation to reduce deep well water disposal.

Activities

1. Establish agenda's for each of the PWWG meetings to make the best use of members' expertise. Use input from the group as a resource for the study.
2. Plans are to establish a legal/regulatory subcommittee to identify obstacles to the various options being evaluated for reuse, recycling and reducing water disposal. The identified obstacles will be included in the final report. Other subcommittees may be created as needed.
3. Coordinate with PWWG members and other experts as each option is investigated. Meetings by industry are likely to better understand potential users of the treated produced water.

Task 2 – Estimate Produced Water Supply and Demands

Objectives

Identify produced water generators and potential users, categorized by water quality and organized by geographic area as a basis for prioritization, supply/demand matching, and routing and sizing of produced water recycling infrastructure. A significant focus being oil and gas reuse of produced water for other oil and gas hydraulic fracturing or water flooding operations.

Activities

1. Gather produced water volumes by geographical area and associated water quality: We will develop estimates of potential produced water generation, including volumes over time, and water quality. We believe the following steps will be involved:
 - a. Review potential data sources and develop estimate methodology. This is likely to be based upon direct and inferred reference information including reserve estimates and historic produced water production based on literature review and other available resources. Propose an estimating methodology based on available references and review with OWRB stakeholders
 - b. Aggregate the selected data, develop the estimates and document the methodology by produced water generation over time and by county, including estimated water quality.
 - c. Summarize estimates of produced water generation in tabular and GIS format
2. Determine largest users of water by geographical area, including agriculture and specific companies. The following activities are anticipated:
 - a. Review the potential data sources. Possible data sources may include water rights databases and industrial wastewater discharge and pretreatment permit information (i.e., big industrial dischargers are likely to be also big water users) and other publically available state water use references. Propose an estimating methodology based on available references and review with OWRB stakeholders.
 - b. Aggregate the selected data, develop the estimates and document the methodology by produced water generation over time and by county, including estimated water quality requirements.
 - c. Summarize estimates of water demand in tabular and GIS format. Based on the availability of location coordinate information, we will attempt to map specific facility locations for large, acute demands.
3. Prioritize supply/demand matches: Using the produced water supply/demand GIS information developed in the previous activities, we will identify, prioritize and recommend up to 10 matches where reusing produced water has the potential to meet demand and offset produced water disposal, taking into account water quality, proximity of the facility, sustainability of the arrangement over time, and proximity to areas of known induced seismic activity. We will use this to estimate the total potential for beneficial reuse to reduce produced water deep well disposal in these areas. We will identify and recommend up to three (3) example matches, taking into account capacity and treatment requirements to meet the demand water quality requirements. These will be used as a basis for design in the next task.
4. Progress presentation to review and endorse estimates and example match design basis: We will facilitate a discussion with OWRB stakeholders to review the methods, findings and recommendations from this task before moving on to the next task.

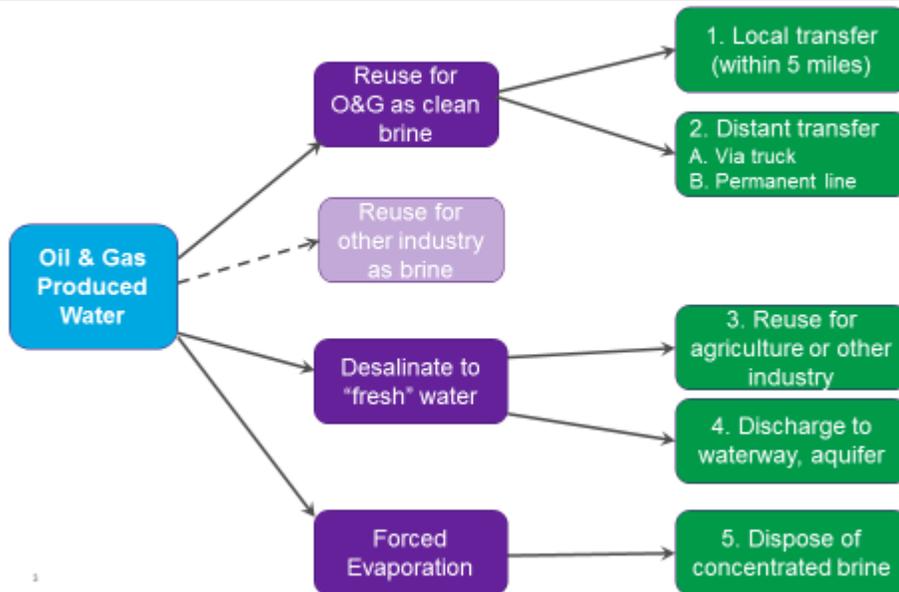
Assumptions and Clarifications

- We will host an up to 2 hour web conference to discuss and agree on the produced water generation and water demand estimating methodologies with stakeholders.
- The findings from this task will be summarized in presentation format and presented at a regular OWRB Produced Water Committee meeting.
- Final methods and results from this test, incorporating stakeholder input from the presentation in Activity 4 stated above will be documented in the final report in Task 4.

Deliverables

- Produced water generation estimate and maps
- Water demand estimate and maps
- Progress presentation to be presented at a regular OWRB meeting as described in Activity 4.

Options Overview



Task 3 – Evaluate Treatment

Objectives

Evaluate produced water treatment technologies and prepare conceptual designs for i) produced water treatment for beneficial recycling, and ii) produced water disposal via forced evaporation as a basis for comparison to deep well injection disposal.

Activities

1. Develop desalination conceptual designs and cost estimates: For each of the three (3) representative produced water supply/demand matches identified and agreed in Task 1, CH2M will develop a conceptual design for treatment and conveyance and associated order of magnitude capital and operating cost estimate for the purpose of estimating a lifecycle, present worth cost for comparison to other options. The objective is not to optimize the treatment strategy; rather, to evaluate costs based on a representative treatment approach based on CH2M’s professional judgment and other input from OWRB stakeholders. For each of the three selected scenarios, we anticipate the following activities:

Scenario 1

- a. Summarize design basis
- b. Prepare conceptual design, consisting of:
 - i. Block flow diagram

- ii. Material and energy balance
 - iii. Major equipment list
 - iv. General arrangement
 - v. Utility and reagent summary
 - vi. Operating labor requirements
 - vii. Capital Expenditure (CAPEX) estimate (Class 5¹, +75%/-50% accuracy)
 - viii. Annualized Operation Expenditure (OPEX) estimate (Class 5¹, +75%/-50% accuracy)
- c. Prepare cost sensitivity analysis: The objective here is to generate cost versus capacity estimates for the proposed example system, based on a factored estimate of those original project cost elements which are sensitive to capacity/size. The cost versus capacity relationships will be used in the subsequent task.

Scenario 2 – same as above

Scenario 3 – same as above

2. Develop forced evaporation disposal conceptual designs and cost estimates: We will evaluate large-scale forced evaporation disposal: CH2M will prepare conceptual design and cost estimates for the same three (3) scenarios evaluated under the previous activity for direct comparison. Again, the objective is to base the evaluation on a representative technical approach based on CH2M professional judgment and input from stakeholders. For each of the three (3) selected scenarios, we anticipate the following similar concept definition activities:

Scenario 1

- a. Summarize design basis (adapted from associated desalination evaluation for same scenario)
- b. Prepare conceptual design, consisting of:
 - i. Block flow diagram
 - ii. Material and energy balance
 - iii. Major equipment list
 - iv. General arrangement
 - v. Utility and reagent summary
 - vi. Operating labor requirements
 - vii. Capital Expenditure (CAPEX) estimate (Class 5¹, +75%/-50% accuracy)
 - viii. Annualized Operation Expenditure (OPEX) estimate (Class 5¹, +75%/-50% accuracy)
- c. Prepare cost sensitivity analysis: The objective here is to generate cost versus capacity estimates for the proposed example system, based on a factored estimate of those original project cost elements which are sensitive to capacity/size. The cost versus capacity relationships will be used in the subsequent task.

Scenario 2 – same as above

¹ Based on Association for the Advancement of Cost Engineering recommended practices.

Scenario 3 – same as above

3. Progress presentation to review and endorse conceptual designs and estimates for the desalination/reuse and forced evaporation disposal scenarios: We will facilitate a discussion with OWRB stakeholders to review concepts and findings from this task before moving on to the next task.

Assumptions and Clarifications

- We are assuming that for a particular beneficial reuse scenario to be viable in markedly reducing dependence on deep well injection disposal and to be a viable replacement for current water supplies, they will inherently need to be larger capacity, permanent facilities. Therefore we have assumed the technical concepts defined herein will necessarily be customized, fit for purpose facilities, for the purpose of this study, rather than modular/mobile treatment units. CH2M will leverage its own parametric design and cost estimating tools to the extent practicable to complete this task.
- We will assume some limited acceptable level of deep inject well use for concentrated waste disposal in developing the concepts, to be agreed in advance with OWRB.
- The findings from this task will be summarized in presentation format and presented at a regular OWRB Produced Water Committee meeting.
- Final methods and results from this task, incorporating stakeholder input from the presentation described in Activity 3 will be documented in the final report in Task 4.

Deliverables

- Desalination concept design narrative description, basis of estimate (i.e., design criteria and assumptions, concept definition drawings/exhibits), CAPEX/OPEX estimate and cost curves (included in final report)
- Forced evaporation disposal concept design narrative description, basis of estimate (i.e., design criteria and assumptions, concept definition drawings/exhibits), CAPEX/OPEX estimate and cost curves (included in final report)
- Progress presentation to be presented at a regular OWRB meeting as described in Activity 3.

Task 4 – Evaluate Economics

Objectives

For select, representative produced water recycling and disposal scenarios, evaluate economic options and order of magnitude costs in order to assess the conceptual feasibility of said scenarios. This comparative feasibility assessment, in turn, will be used to evaluate risks, barriers, priorities and other recommendations with respect to these alternatives to deep well injection produced water disposal.

Activities

1. Summarize existing public funding sources: CH2M will explore potential sources of funding for CAPEX and OPEX for conveyance and treatment facilities that would be required to implement the technical strategies developed in the previous task. This could include speaking to investment banking firms and reviewing public funding and incentive programs. The objectives of this activity are twofold:
 - Develop assumptions for financial modeling and analysis
 - To the extent practicable, identify funding gaps that may need to be addressed to incentivize execution of the strategy

2. Evaluate feasibility of produced water beneficial reuse: Develop comparative feasibility assessment of beneficial reuse versus forced evaporation disposal of produced water. The representative scenario costs developed in the previous task will be used to prepare both a project level direct comparison of the strategies as well as to extrapolate potential cost-benefit impacts of broadly applying the strategy in Oklahoma to mitigate produced water disposal-induced seismicity risk and occurrences. This activity is anticipated to include:
 - a. Compare economic feasibility of desalination versus forced evaporation disposal for each scenario
 - b. Develop estimate of state-level implementation. This is expected to take the form of a parametric extrapolation based on the results of item (a), above. CH2M will assess other methodologies including numeric modeling optimization with input from OWRB.
 - c. Develop a risk and opportunities assessment which may influence the outcome of the analysis, focusing on:
 - Technical risk
 - Financial/economic risk
 - Implementation risk
 - d. Prepare draft conclusions and recommendations, including additional data gathering and studies necessary to quantify and/or mitigate opportunities and risks in the analysis and to inform decision making.
3. Progress presentation to review financial assumptions and evaluation conclusions and recommendations: We will facilitate a discussion with OWRB stakeholders to review assumptions and findings from this task before finalizing the study report in the next task.

Assumptions and Clarifications

- The findings from this task will be summarized in presentation format and presented at a regular OWRB Produced Water Committee meeting.
- Final methods and results from this task, incorporating stakeholder input from the presentation described in Activity 3 will be documented in the final report in Task 4.

Deliverables

- Desalination concept design narrative description, basis of estimate (i.e., design criteria and assumptions, concept definition drawings/exhibits), CAPEX/OPEX estimate and cost curves (included in final report)
- Forced evaporation disposal concept design narrative description, basis of estimate (i.e., design criteria and assumptions, concept definition drawings/exhibits), CAPEX/OPEX estimate and cost curves (included in final report)
- Progress presentation to be presented at a regular OWRB meeting as described in Activity 3.

Task 5 – Prepare Final Study Report

Objective

Prepare a Final Study Report documenting the methods, data, findings and recommendations developed and endorsed by OWRB in previous tasks, to support future discussion, planning and policymaking.

Activities

1. Prepare Final Study report: We will prepare a Final Study report documenting the findings of the study.
 - a. CH2M will prepare a draft report.
 - b. After OWRB has reviewed the draft report, we will facilitate an up to two hour web conference with interested stakeholders to review and adjudicate comments.
 - c. The report will be finalized based on OWRB comments. Responses to individual, material (i.e., non-typographic or formatting) comments will be documented in CH2M's Quality Review Form (QRF) for tracking and closeout purposes.

Tentative outline includes:

- a. Executive Summary
- b. Introduction and Study Objectives
- c. Produced water estimate
 - i. Methods
 - ii. Findings
- d. Potential reuse estimates
 - iii. Methods
 - iv. Findings
- e. Representative Recycling Scenarios
 - v. Methodology
 - vi. Scenario 1:
 1. Beneficial reuse description
 2. Forced evaporation disposal description
 3. Cost and benefits
 - vii. Scenario 2 – same as above
 - viii. Scenario 3 – same as above
- f. Feasibility of broad scale implementation
 - ix. Methodology (including key financial assumptions)
 - x. Estimated cost - benefit range(s) (high, likely, low)
 - xi. Opportunities, Barriers and Risks:
 1. Technical
 2. Financial/economic
 3. Implementation (including policy gaps)
- g. Conclusions and Recommendations
 - xii. Conclusions and recommendations
 - xiii. Recommended Studies

xiv. Next Steps

h. References

Appendices:

- A – Produced water data and estimate detail
- B – Water demand data and estimate detail
- C – Desalination conceptual design and cost estimate detail
- D – Forced evaporation disposal conceptual design and cost estimate detail
- E – Broad scale implementation estimates and financial analysis detail

2. Prepare Executive Summary Presentation: We will prepare an executive summary presentation of the final report findings and recommendations that the OWRB Produced Water Committee can use/adapt to communicate to stakeholders and third parties. We will target a 20 to 30 minute presentation duration targeted towards general audiences. We will submit a draft presentation along with the draft Final Study Report described in the previous activity. We will review and adjudicate OWRB’s comments at the same review web conference as well and will finalize and submit the final presentation along with the Final Study Report.

Deliverables

- Final Study report (draft and final)
- QRF table documenting adjudication of reviewer comments
- Executive Summary Presentation (draft and final)

Assumptions and Clarifications

- Draft report will be submitted in MS Word 2013 read-write format to facilitate electronic editing/comments. The final report will be submitted in Adobe PDF read-only format. The Executive Summary Presentation will be submitted in MS PowerPoint 2013.
- An allowance of 20 business days is included for OWRB’s review of the draft report. OWRB will establish an internal “chain of command” to conduct the review, and, prioritize its comments, and will provide one consolidated set of written comments on CH2M’s QRF or similar mutually agreed format to facilitate tracking and adjudication of comments.

Project Management and Administration

Objective

Provide management, coordination and project controls to deliver the work in accordance with the project objectives, schedule and budget.

Activities

1. Project kickoff: CH2M will facilitate a project kickoff web conference with ORWB Produced Water Committee members and other stakeholders invited by OWRB. The kickoff is assumed to last two hours or less. Agenda will include but not be limited to:
 - Confirm objectives, requirements and other critical success factors
 - Confirm stakeholders
 - Review scope and approach
 - Review information furnished by OWRB and confirm other assumptions
 - Review schedule and milestones

- Quality assurance/review strategy
 - Project communications/meetings
2. Project management and administration:
- a. Charter project team: CH2M will prepare project instructions, including the project quality plan, and charter team members for efficient and effective delivery of the work. Draft project instructions will be reviewed with OWRB at the first kickoff/status call insofar as it addresses interfaces/coordination between OWRB and CH2M.
 - b. Project status meetings: CH2M will facilitate a weekly project status call with OWRB representative to review progress, actions and interim deliverables as required.
 - c. Change management: CH2M will evaluate trends and scope change, maintain a project change/trend register, and work proactively with OWRB representatives to mitigate or reduce impacts of change on the schedule and budget to the extent practicable.
3. Project controls: CH2M will develop baseline budget and schedule, track performance and trends against baseline, prepare forecasts, and prepare monthly reports.

Deliverables

- Project Change Log
- Action Register

Assumptions and Clarifications

- This is budgeted as a level of effort task assuming a project duration of 28 weeks.
- CH2M will use its own systems and tools for project controls and reporting. If OWRB has specific requirements they will provide this at the beginning of the project. Deviation from CH2M project control standards may result in a project change.

General Assumptions and Clarifications

The following general assumptions were made during the preparation of this ROM:

- We anticipate hosting regular progress calls with OWRB stakeholders to address data gaps and review/collaborate and endorse key approaches, assumptions and findings.
- The success of the study will depend on constructive and timely collaboration by OWRB and its individual Produced Water Committee members to develop and implement the approach to this study to maximize the technical veracity of the methods and findings and optimize usefulness of the study to inform constructive debate and policymaking.
- OWRB and individual Produced Water Committee members and stakeholders will provide data in their possession relevant to the study in a usable format to CH2M.
- As required, the OWRB Produced Water Committee will afford sufficient agenda time at their scheduled meetings to review study materials. CH2M will coordinate this in advance with the committee chair.

Project Team

CH2M's project manager and primary point of contact is:

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Subject matter experts and other project support staff will be engaged as needed. Resumes are available upon request.

Commercial Proposal

Schedule

CH2M understands that the ORWB would like to demonstrate progress on the subject of beneficial produced water reuse/alternate disposal and to plan follow-on actions prior to the end of 2016. We stand ready to begin work upon authorization.

The estimated time for the project is 28 weeks. Assuming a start date of June 6, the estimated completion would be approximately December 16th, 2016. A preliminary schedule is included in Attachment A.

Target milestones are:

- | | |
|---|-------------------|
| • Kickoff web conference | June 10, 2016 |
| • Meet to review Produced water supply and reuse demand estimates | August 12 |
| • Review representative treatment/disposal estimates | September 16 |
| • Review preliminary findings | November 4 |
| • Submit draft report/presentation for final review | November 11 |
| • Issue final report/presentation | December 16, 2016 |

The main schedule risks are identifying and obtaining necessary data in useful format in a timely manner, scheduling of progress meetings to obtain necessary direction and endorsement from OWRB, and OWRB's efficient and effective review of the final report and presentation to close out the study.

ATTACHMENT A – Proposed Project Schedule

