Mosier Watershed Council

Mosier Aquifer Recovery Feasibility Study

Oregon Water Resources Department Grant # GB001609 Completion Report

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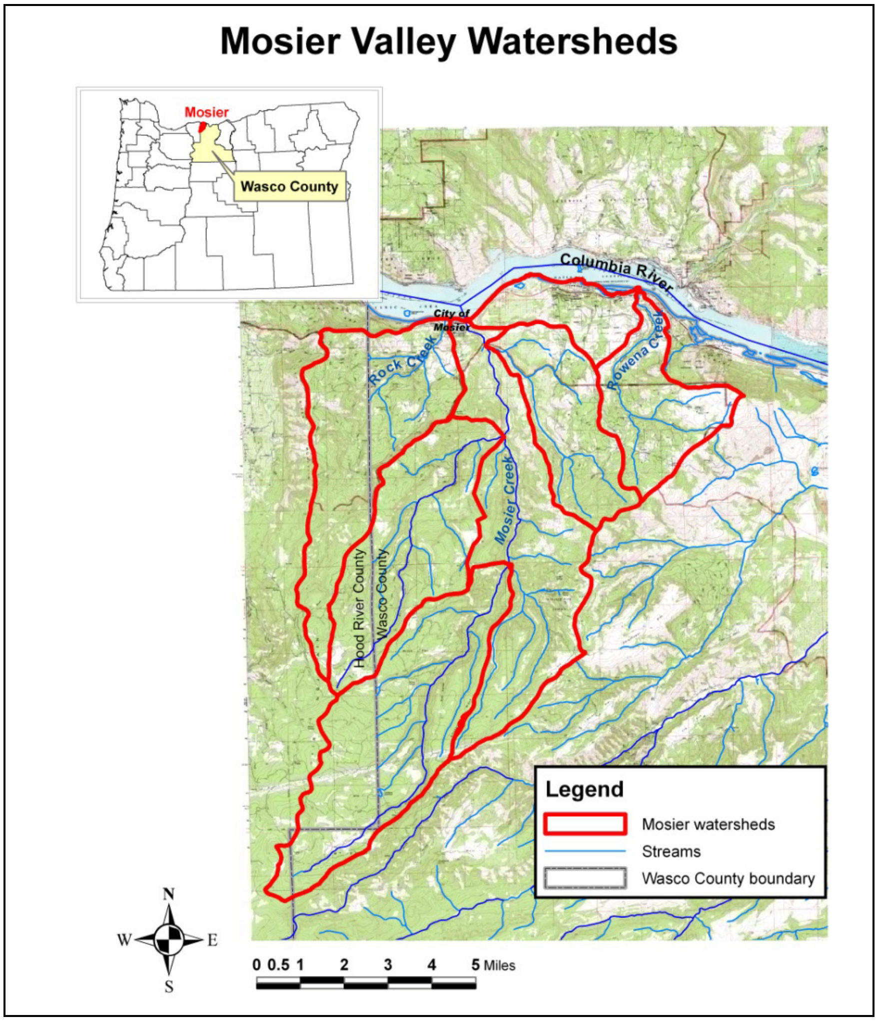
Table of Contents

Introduction and Project Background

The Mosier Valley is located in northwestern Wasco County, Oregon. It includes the Rock Creek, Mosier Creek, and Rowena Creek basins, which drain approximately 80 square miles from the east slope of the Cascades into the Columbia River from river mile 176 to river mile 182. The City of Mosier (population 438) is located at the base of the valley on the Columbia River's south bank. Land use in the valley's middle elevations is primarily agriculture, dominated by fruit orchards. Land use in the higher elevations is primarily forestry, with a mix of public and private ownership.



Groundwater in the Mosier Valley has been declining since significant irrigation pumping began in the 1970s. The attached GSI report provides an excellent overview of the Mosier area's hydrogeology and the history of groundwater use and decline in the area.

Declining groundwater levels (as much as 200 feet in some wells) have made it necessary for many well owners to deepen their wells or construct new ones. Irrigated agriculture is a cornerstone of the Mosier economy and depends on a reliable groundwater supply. Rural residents and Mosier city residents also obtain their water from wells. Further, aquifer declines have decreased groundwater discharge to

Mosier Creek, which provides habitat for native cutthroat trout throughout, and for threatened steelhead trout and Coho salmon below Mosier Creek falls.

The Mosier Watershed Council (MWC) identified declining groundwater levels and the consequent threat to a stable supply of water as their highest priority concern within the Mosier-area watersheds. Due to this concern, in 2005 the MWC and its fiscal agent the Wasco County Soil and Water Conservation District (SWCD) entered into a cooperative agreement with the Oregon Water Science Center of the U.S. Geological Survey (USGS) to investigate the hydrology of the Mosier Valley.

The USGS Mosier Groundwater Study was designed to provide a better understanding of the area's groundwater and surface water resources and their interactions. The study also aimed to produce a tool that could help the community develop a comprehensive, defensible plan for stabilizing the aquifers and managing them long-term as a shared resource. The tool that came out of the study is a hydrologic model that simulates groundwater flow through the system. The model can be used to predict the aquifer response to alternative management strategies.

In 2008, the USGS study was still underway when the MWC proposed to evaluate the feasibility of implementing Artificial Recharge (AR) or Aquifer Storage and Recovery (ASR) as a means of sustaining groundwater yield in the Mosier area. The Oregon Water Resources Department (OWRD) awarded the MWC a grant under the Conservation, Reuse and Storage program (Senate Bill [SB] 1069) to help carry out this "Mosier Aquifer Recovery Feasibility Study." The study has considered the feasibility of AR/ASR and alternative water management strategies from physical, regulatory, ecological, and economic perspectives.

One significant conclusion from the USGS Mosier Groundwater Study affected the direction of the SB 1069 Grant-funded feasibility study after the initial scope of work had already been developed. The USGS presented the final oral report on their conclusions in November 2009 (approximately seven months after the OWRD signed the grant agreement with the MWC). This report identified commingling wells, as opposed to groundwater extraction, as the leading cause of Mosier-area aquifer declines. Thus, the MWC decided that, in the course of conducting the Mosier Aquifer Recovery Feasibility Study, it would be imperative to analyze the impact of commingling wells on the feasibility of AR/ASR and alternative management strategies.

The MWC and Wasco County SWCD contracted with the USGS to complete some tasks within the Mosier Aquifer Recovery Feasibility Study. These were tasks that utilized the USGS groundwater model, which has not been released yet for public use. The MWC and Wasco County SWCD contracted with GSI Water Solutions, Inc. (GSI) to complete the remaining feasibility study tasks.

Grant Completion Report Format

In the following section, this report provides a Project Tasks outline, which references all tasks and subtasks listed in the Grant Agreement. The outline also identifies the entity/entities primarily responsible for completion of each task.

The outline is followed by a Project Accomplishments section. This is the core of the report, which describes work completed under each task. Project tasks were completed by three different entities that partnered with the Mosier Watershed Council. These three were Wasco County SWCD, the USGS, and GSI Water Solutions, Inc. (GSI).

The work completed by GSI is briefly summarized in this report but is thoroughly described in GSI's attached report. The GSI report also includes excellent background information on Mosier's hydrogeology and a review of previous groundwater studies in the area.

All work undertaken by the SWCD and the USGS is described in narrative form in the body of this report. The final report on the USGS Mosier Groundwater Study, which will contain sections on the tasks that the USGS completed as part of this AR/ASR feasibility study, is currently under review but has not yet been published. Therefore, this grant completion report includes a summary of the USGS results as presented in meetings to the MWC, instead of a report authored by the USGS.

The final section of this report describes project conclusions and anticipated next steps.

Project Tasks

The following outline lists the tasks included in the Mosier Aquifer Recovery Feasibility Study. [The organization of this outline differs slightly from the list of tasks in the OWRD Grant Agreement Revised Exhibit B; differences are noted in brackets for cross-reference with Exhibit B.]

The entities primarily responsible for completion of each project task are identified in *italics*.

PHASE 1: USGS MOSIER GROUNDWATER SUSTAINABILITY STUDY AND WATER NEEDS ASSESSMENT

USGS.

PHASE 2: COMPARATIVE EVALUATION OF WATER MANAGEMENT ALTERNATIVES

Task 1. Assess physical feasibility of AR/ASR and alternatives (includes assessing to what degree cross-connecting [commingling] wells may affect the feasibility of AR/ASR).

- 1.1. Assess the impacts of cross-connecting wells on AR/ASR projects, using both modeling and field verification of well commingling behavior [includes Exhibit B subtask (c): "develop an inexpensive method to measure inter-aquifer flow in well bores"].
  USGS lead, SWCD participation.
- 1.2. Determine the most feasible locations of an aquifer storage project [Exhibit B subtask (a)].
  GSI.
- 1.3. Source water analysis: assess availability and quality of Mosier Creek water [includes Exhibit B subtask (b): "determine the most feasible timing, duration, and location for water diversion from Mosier Creek"].
  GSI.

Task 2. Assess regulatory and ecological feasibility of AR/ASR and alternatives.

- 2.1. Fulfill required elements (see Task 5).
  GSI and SWCD.
- 2.2. Assess water rights issues and all relevant regulations.
  GSI.

Task 3. Assess economic feasibility of AR/ASR and alternatives (relying on general cost estimates rather than more detailed preliminary project designs).

- 3.1. Estimate costs for commingling well repair.
  GSI.

3.2. Estimate costs for infrastructure (diversion, treatment, injection, storage, extraction, distribution), operations and maintenance for ASR/AR or alternatives.
GSI.

Task 4. Describe stakeholder/public outreach and participation.
SWCD.

Task 5. Required Elements

5.1. Required Element (a): Analyses of by-pass, optimum peak, flushing and other ecological flows of the affected stream and the impact of the storage project on those flows.
GSI and SWCD.

5.2. Required Element (b): Comparative analyses of alternative means of supplying water, including but not limited to the costs and benefits of conservation and efficiency alternatives and the extent to which long-term water supply needs may be met using those.
GSI and SWCD.

5.3. Required Element (c): Analyses of environmental harm or impacts from the proposed storage project.
GSI.

5.4. Required Element (d): Evaluation of the need for and feasibility of using stored water to augment in-stream flows to conserve, maintain and enhance aquatic life, fish life and any other ecological values.
GSI.

5.5. Required Element (e): analysis of local and regional water demand and the proposed storage project's relationship to existing and planned water supply projects.
SWCD.

Project Accomplishments

This section lists accomplishments under each of the tasks identified in the preceding outline.

PHASE 1. US GEOLOGICAL SURVEY MOSIER GROUNDWATER STUDY

(funded without OWRD assistance)

The USGS began planning the Mosier Groundwater Study with the MWC in 2004 and began work on the study in 2005. The USGS study expanded on some of the earlier geological studies of the Mosier area, such as those conducted by Gay Jervey and Ken Lite. The USGS Mosier Groundwater Study was designed to advance overall knowledge of the local geology and hydrology, and to provide the science to support community or policy decisions. It culminated with the creation of a groundwater flow model, which represents the important hydrologic processes (recharge, pumping, discharge to streams) and hydrogeologic features (basalt layers, faults and folds, commingling wells) affecting groundwater movement in the Mosier study area.

The USGS study approach included the following components:

- Compile existing information and collect new data,
- Develop an updated geologic framework,
- Estimate a groundwater budget,
- Build a computer simulation model,
- And use the model to test hypotheses.
  More information on the background, objectives, and approach of this study can be found at http://or.water.usgs.gov/projs_dir/mosier/index.html.

The USGS completed the Mosier Groundwater Study (original scope of work, not including tasks added later under the Mosier Aquifer Recovery Study) in fall 2009. The USGS presented a summary of the study accomplishments and conclusions to the Mosier community in a public meeting on November 18, 2009. Minutes and slides from that presentation provide a good overview of the study; they are available online at www.wasco.oacd.org.

USGS hydrologist Erick Burns explained during his final presentation to the MWC that ultimately the study came down to one central question: what is causing the rapid declines in well water levels? The possibilities included pumping (taking out the groundwater faster than it naturally recharges), commingling (water flowing from one aquifer to another through a well that taps multiple aquifers), and climate change. Based on the Mosier study and groundwater model, the USGS concluded that commingling is the dominant cause of well water level declines in the Mosier study area.

In response to the USGS study conclusions, the MWC determined that it would be important to evaluate the impacts of commingling wells on ASR/AR feasibility. The new groundwater model was one tool that could be used in this evaluation. However, the model was not yet available for use by the general public or private consultants. Therefore, the MWC asked the USGS to complete the part of the Mosier Aquifer Feasibility Study that required use of the groundwater model. The USGS modeling work that was completed under the OWRD SB1069 Grant is reported under Phase 2, Task 1 below.

PHASE 2. COMPARATIVE EVALUATION OF WATER MANAGEMENT ALTERNATIVES

(funded by OWRD SB1069 Grant #GB001609 and project partners)

Task 1.1 Assess physical feasibility of AR/ASR and alternatives: Assess the impacts of cross-connecting wells on AR/ASR projects, using both modeling and field verification of well commingling behavior [includes Exhibit B subtask (c): "develop an inexpensive method to measure inter-aquifer flow in well bores"].

The majority of Task 1.1 was completed by the USGS. Additional information about alternative methods for measuring inter-aquifer flow in well bores was provided by GSI.

On behalf of Mosier Watershed Council, the Wasco County SWCD (fiscal agent for MWC) signed a Joint Funding Agreement with the USGS for completion of Task 1.1. Work under this Joint Funding Agreement was funded 50% by the USGS and 50% by the MWC/SWCD using OWRD grant funds.

The objective of the USGS work on Task 1.1 was to provide a comparative quantitative analysis of the potential effectiveness of AR/ASR in the Mosier Valley through simulation analysis and well testing. There were two primary components to the work approach:

1) Simulation analysis of the effects of AR/ASR on aquifer storage using the existing USGS model under a variety of commingling well repair scenarios, and
2) Field survey and testing of potential commingling wells (includes Subtask (c) Develop an inexpensive method to measure inter-aquifer flow in well bores).

Results of this work are reported below in the form of excerpts from MWC meeting minutes. On March 22, 2010, USGS hydrologists David Morgan and Erick Burns attended a MWC meeting to report on their progress on these two study components. On May 17, 2010 Erick Burns returned to the MWC to present a final report on the completion of the tasks.

1) Simulation analysis: First USGS update to the MWC (excerpted from the March 22, 2010 MWC meeting minutes)

Erick gave a presentation called "Potential Impact of Commingling Wells on Aquifer Recharge." He reminded the Council that we had a major question related to the feasibility of AR/ASR in Mosier. If the system is "short-circuited" by all the commingling wells, should we even bother to put any water into it? In other words, would recharged water just be lost through the "leaks" in commingling wells? To approach this overarching question, Erick ran groundwater model scenarios that were designed to investigate a few more specific questions.

One of these questions is: where would be the best places to start repairing commingling wells, assuming that you couldn't repair them all? To answer this question, Erick used the model to look at how the relative impact of a single commingling well changes depending on its location in the watershed. Basically, he told the model that there was just one commingling well in the system, and then he moved that well around to every potential location. He ran a simulation at each location to predict the impact that a commingling well would have if it were located there. Note that when we talk here about the "impact of commingling" we're talking about the impact on aquifer storage. Repairing wells can increase the total storage available with and without additional recharge from AR or ASR projects.

Erick showed a map of the watershed area with color-coded zones to illustrate relative impacts of commingling based on location. For example, in the red zone a commingling well would have the greatest impact, resulting in the most storage loss. This map helps define priority zones for well repair.

Another question is: under what conditions might aquifer recharge be beneficial? Erick modeled what would happen under the following scenarios:

- All wells repaired and no pumping
    - This is an unrealistic 100% recovery scenario, used for comparison, but not considered a realistic option
- No repairs and current pumping
    - This is the current situation, which provides 0% recovery
- All wells repaired but current pumping occurs
    - This would be the maximum recovery that could be expected due to repairs
- No wells repaired, current pumping, but add water to the system (AR/ASR scenario)
    - This would be the maximum recovery that could be expected due to recharge

The above scenarios were created to define the extremes. They were compared with scenarios in which there was some combination of repair and recharge. For example, in one scenario all the wells in zones 1, 2, and 3 were repaired and water was injected into the Frenchman Springs aquifer. The result of this analysis was another color-coded map, this one illustrating how much the system would benefit from water being injected at each spot. The point of these maps is that they provide a comparative look at preferred locations for recharge under a given repair scenario.

After giving this example, Erick went back to explain the results of the extreme scenarios and how they compare with other combination repair/recharge scenarios. In the "all wells are repaired" scenario, the expected recovery is 85%. In other words, in this model, 85% of the problem (i.e. the declining water levels) is due to commingling. Because eliminating all pumping is unreasonable, 100% recovery is unrealistic, so 85% recovery becomes the goal.

In stark contrast, in the "no repairs but add water" scenario (AR/ASR scenario), maximum modeled recovery is only 6%! However, this particular AR/ASR scenario was based on a single injection well that adds 125 gallons per minute to the target aquifer. A larger project may be more economically feasible and result in a much greater improvement. If the effect of each 125 gpm well were to increase storage 6%, then larger projects may be more significant. Erick suggested that management decisions on whether to pursue AR/ASR in conjunction with well repair will come down to economic analysis.

If only the 25 "Rank 1" wells (the worst comminglers, found in the red zone on the map) are repaired, modeled recovery is 11%. If those 25 are repaired *and* water is injected at the most effective location, modeled recovery is 17%. If the 50 "Rank 1" and "Rank 2" wells are repaired, modeled recovery is 23%, or 30% with injection at the best location. If 82 wells are repaired, modeled recovery is 54%, or 63% with injection at the best location.

Erick noted that the best location for injection (that is, the location at which injection will result in the greatest increase in storage) is very dependent on how many commingling wells are repaired. One injection site is best under a no-repair scenario, while a very different location is best if many wells are repaired first.

Erick showed a summary table (Percent Recovery table, below) that compared the expected percent recovery under a variety of repair and injection scenarios. From this table it was very clear that the value of injecting water into the modeled system increases as the number of well repairs increases.

	Percent Recovery			
Repair Scenario	**Repairs Only**	**Repairs + ASR**	**Value of ASR**	**Number of Wells Repaired**
All repaired	85.2%	**Not computed**	**Not computed**	146
Zones 1, 2, & 3	54.2%	63.1%	8.9%	82
Zones 1 & 2	23.1%	30.4%	7.3%	50
Zone 1	11.1%	17.2%	6.1%	25
No repairs	0.0%	5.9%	5.9%	0

Erick emphasized the point that we'll need more field data to determine the true number of commingling wells in the Mosier area. The groundwater model includes 146 commingling wells, a number that Erick called an "unbiased guess" based on well location, depth, and geology. This is a reasonable number that allows the model to be used as a tool for testing what is going on in the system. The results of the modeling exercises guide us to where we should look first when considering well repairs and aquifer injection. However, the recovery percentages predicted by the model should be used only for comparison among scenarios, not as predictors of absolute recovery values to be achieved in the real world.

1) Simulation analysis: Final USGS update to the MWC (excerpted from the May 17, 2010 MWC meeting minutes)

Erick reviewed the general problem of commingling wells and the specific questions that the USGS addressed under their contract to work on the aquifer recharge feasibility study. Those questions included:

- If only a subset of wells could be repaired, are there locations in the watershed that might result in the most benefit?

- Is injection of water into aquifers during the winter a good option to help alleviate water level declines? If so, do some well repairs need to be accomplished to achieve this benefit?

Since the last presentation, Erick ran the final model scenarios for this project. These scenarios looked at repairing *single confining layers* in wells in the "high value" zones. In this context, "confining layer" means the impermeable zone between two aquifers, which prevents flow in the absence of a commingling well. For example, one model run would repair all commingling across a certain layer (i.e. the layer between the flow top and the basal aquifer in the Pomona). This repair would only apply to those wells that perforated that particular layer. If those same wells perforate other layers, the commingling across those other layers would not be repaired under this scenario. This is a hypothetical scenario that likely would not be accomplished in reality, but it helps us understand strategies to repair the aquifer system.

Erick explained that the results of the single-layer repair scenarios were not what he initially expected, which was that repairs in deeper layers would have a higher value. It also turned out that focusing on single layer repairs would not be too helpful for narrowing down the list of first-priority repairs, because the layer that is most important to repair is also the layer that is perforated by the highest number of wells.

Erick illustrated the scenario results with a conceptual model of storage in the multiple aquifers. He explained that the best "bang for the buck" for the most people would come from repairs that raise the outfall that controls the water level (in other words, the lowest point at which water leaks out of the aquifer system through commingling wells). Repairing the well with the lowest outfall will allow all aquifers to fill until the system spills out at the next lowest outfall. Maps of the geometry of the actual aquifer system could be used to determine where this outfall is. These maps will be included in the yet-to-be-published USGS report on the Mosier Groundwater Study.

2) Field testing of potential commingling wells: First USGS update to the MWC (excerpted from the March 22, 2010 MWC meeting minutes)

Within their scope of work for this feasibility study, the USGS planned to run a series of geophysical tests on one suspected commingling well. This would provide much more detailed data on the extent of the commingling in that well. The chosen well is about 620 feet deep but it had a blockage around 400 feet, which needed to be cleared before the USGS cameras, flow meters, and other instruments could be lowered into the well. Unfortunately, when the contractor tried to clear the blockage, more material caved into the well, blocking it again! It was not possible to run all the planned tests in this well, and most of the money for this part of the study was used up in this failed attempt.

Also within their scope of work, the USGS was tasked with developing an inexpensive method to measure inter-aquifer flow in well bores [subtask (c) in Grant Agreement Revised Exhibit B].

Because it is expensive, time-consuming, and requires a specialist to do the kind of geophysical testing that was attempted on one well, the USGS worked on a new method to more quickly and easily screen wells to determine if they are commingling. Wasco County SWCD provided support for developing this method, and the end goal was for SWCD staff to be able to do the testing without hiring an outside expert.

The method involves lowering a very small temperature and pressure gauge into a well. Due to natural geothermal heating, we would expect that groundwater deeper in the earth will be warmer than groundwater closer to earth's surface. However, when commingling occurs in a well, water flows through the well, which mixes waters from multiple aquifers. If we can take temperature measurements at multiple depths, we can determine whether or not a temperature *gradient* exists in the well. If there is no commingling, we expect to observe a gradient, with warmer water at deeper depths. If there *is* commingling, we would expect less temperature variation with depth, because flow through the well mixes the water and evens out the temperature.

This method is to be used as a screening tool only; it will not provide the detailed data available from more expensive geophysical testing methods. However, it will allow the Watershed Council to proceed as desired with local SWCD technicians and instruments.

2) Field testing of potential commingling wells: Final USGS update to the MWC (excerpted from the May 17, 2010 MWC meeting minutes)

Erick gave an update on the new rapid screening tool for assessing whether wells are commingling. The tool consists of a tiny temperature and pressure sensor (used in tagging fish) attached to the end of a well measuring tape. The goal is to send this sensor and tape down through the well bore without having to remove the pump. Making a single detailed geophysical well log (which requires removal of the pump) costs more than ten times as much as using the rapid screening tool. The tradeoff is that the rapid screening tool can only help identify where commingling may be occurring, but cannot be used to estimate how much water is flowing through the well.

Dan Polette, a technician with USGS, and Kate Merrick tested out the tool on seven wells. The tool allowed collection of useful data from 5 of 7 tested wells, showing a variety of behaviors, some of which are indicative of commingling. Four more wells had been identified for testing, but complications prevented these wells from being tested at this time. In two wells, the tool got hung up on the pump and provided no data. In two other wells the tape detected cascading water. This is a sign that water is coming into the well from a zone above the main water level, indicating the well is open to multiple zones. If the water level in the well were higher (as it may have been in the past), water could move between the lower zone and the zone that is now producing the cascading water. The results from two more wells indicated likely commingling based on the patterns of temperature change versus depth.

The USGS conclusion was that the tool may be a useful tool as we move forward because it can allow us to collect data from many wells for much less cost compared to other methods, although it will not work in some wells due to access problems.

As noted at the beginning of the Task 1.1 section, GSI provided additional information about alternative methods for measuring inter-aquifer flow in well bores. This information is presented in the GSI report in Section 3.8, beginning on page 3-14. In summary, GSI outlined the different technologies that provide qualitative and/or quantitative information about aquifer commingling in wells and presented estimated costs for using these technologies. GSI suggested that it may be sufficient to take a statistical approach by testing only a sub-set of wells and then applying the results of those tests to other wells.

Task 1.2 Assess physical feasibility of AR/ASR and alternatives: Determine the most feasible locations of an aquifer storage project [Exhibit B subtask (a)].

Task 1.2 was completed by GSI and subcontractors. GSI identified potential locations for a surface infiltration recharge project and a direct well injection recharge project. Results are described in the GSI report beginning on page 2-4 for surface recharge and page 2-14 for well recharge.

For a surface recharge project, an area of interest was identified where the target aquifers (Priest Rapids and Pomona) are at or near ground surface in the vicinity of the water source (Mosier Creek). The area of interest was confined by steep topography to a 61.4-acre corridor along Mosier Creek. The area of interest was divided into ten equal-length reaches. The reaches were ranked for surface recharge feasibility based on: location, surface conditions, subsurface conditions, source water quality, and acquisition and maintenance costs. See the GSI report for the ranking results.

Significant data gaps must be addressed to better define surface recharge site feasibility. Data gaps include: precise location, thickness and extent of locally unconfined Priest Rapids or Pomona permeable zones; permeability of alluvium overlying the receiving basalt zone; and a better understanding of local surface water – groundwater interactions because a surface recharge project should not be located where the target aquifer is discharging to Mosier Creek.

For direct recharge, injection well site feasibility is based on hydrogeologic considerations, proximity to source water, availability of the well during the recharge season, and whether or not the recharge water is likely to be lost due to leakage either through commingling wells or to surface water. Assessment of existing wells indicated that a new dedicated injection well would likely be necessary to implement a well recharge program for aquifer recovery. The ideal location would be downstream within the Orchard Tract near the axis of the Mosier Syncline, though upstream sites may be nearer more suitable diversion sites.

Task 1.3 Assess regulatory and ecological feasibility of AR/ASR and alternatives: Source water analysis: assess availability and quality of Mosier Creek water [includes Exhibit B subtask (b): "determine the most feasible timing, duration, and location for water diversion from Mosier Creek"].

Task 1.3 was completed by GSI. The Diversion and Infrastructure section of the GSI report (beginning on page 2-19) includes assessment of potential diversion sites. The Legal Process report section (beginning on page 2-24) includes assessment of water availability based on unallocated flow. The Ecological and Peak Flow report section (beginning on page 5-1) includes assessment of water availability and diversion timing based on ecological factors. The Surface Recharge Feasibility and Well Recharge Feasibility sections discuss water quality considerations (pages 2-8 and 2-14).

In summary, water from Mosier Creek is available at 80 percent exceedance for Aquifer Storage and Recovery during the months of April, May, and July through November. Water is available at 50 percent exceedance for Artificial Recharge during all months of the year. In addition, there is a 6,400 acre-foot reservation for multipurpose storage on Mosier Creek, which could be used for AR but not ASR. Ecological factors would further influence how much of this "available" water could actually be diverted (see Task 5.1).

Water quality concerns in Mosier Creek include suspended solids, which could form a clogging layer in a surface recharge basin or clog a recharge well, and biological contaminants, which would have to be removed in the case of direct well recharge. If water were diverted through an infiltration gallery or shallow alluvial well that provided sufficient filtration, it is possible that water treatment would not be necessary prior to well injection.

Surface water diversion site feasibility was evaluated on the basis of physical constraints, geology, surface water depth, channel incision, operation and maintenance requirements, water quality, and cost. GSI was unable to identify any existing diversion sites that would be suitable for a recharge project. Three types of potential new diversions were identified: an infiltration gallery (or shallow alluvial well), a gravity surface diversion, and a pumped surface diversion. The first of the three is the preferred alternative because it would provide natural filtration in the shallow alluvial aquifer. See Figures 2.4 and 2.5 in the GSI report for maps of potential diversion sites.

Task 2.1 Assess regulatory and ecological feasibility of AR/ASR and alternatives: Fulfill required elements.

The required elements were primarily completed by GSI, with input from Wasco County SWCD. See Task 5.

Task 2.2 Assess regulatory and ecological feasibility of AR/ASR and alternatives: Assess water rights issues and all relevant regulations.

Task 2.2 was completed by GSI. The GSI report section on Legal Process for Managed Underground Storage Projects in Oregon (beginning on page 2-24) describes all relevant permitting considerations for an aquifer recharge project, including considerations related to source water permits and differences between AR and ASR.

Task 3.1 Assess economic feasibility of AR/ASR and alternatives: Estimate costs for commingling well repair.

Task 3.1 was completed by GSI, with input from subcontractors. Cost estimates can be found in the GSI report section on Commingling Well Remediation under Well Repair and Replacement Cost Estimates (beginning on page 3-11). Cost estimates are provided for several types of well repairs that would be applicable to “typical” wells in the Mosier study area. Repair estimates range from $29,000 - $47,000 per well. Cost estimates for well abandonment and new well construction are also provided. Well replacement estimates range from $35,000 - $47,000 per well.

All estimates are based on specified assumptions, and the GSI report notes that costs could vary significantly depending on the well contractor, the market conditions at the time of the work, and the individual well characteristics.

Task 3.2 Assess economic feasibility of AR/ASR and alternatives: Estimate costs for infrastructure (diversion, treatment, injection, storage, extraction, distribution), operations and maintenance for ASR/AR or alternatives.

Task 3.2 was completed by GSI, with input from subcontractors. Cost estimates are described for surface recharge beginning on page 2-12, for direct well recharge beginning on page 2-17, and for diversion beginning on page 2-22. The Comparative Analysis of Aquifer Recovery Alternatives summarizes all costs in a comparative matrix (Table 5.4 beginning on page 5-13).

Surface recharge costs are estimated at $520,000 - $710,000 in capital expenses and $10,000 - $20,000 per year for operations and maintenance. Direct well recharge costs without water treatment are estimated at $1,004,000 - $1,374,000 in capital expenses and $35,000 - $70,000 per year for O & M. Direct well recharge costs with water treatment are estimated at $3,500,000 - $3,800,000 in capital expenses and $65,000 - $100,000 per year for O & M.

Task 4. Describe stakeholder/public outreach and participation.

Task 4 was led by Mosier Watershed Council, with assistance from Wasco County SWCD. Public outreach and stakeholder participation in project planning and oversight began as early as the development of the grant proposal in August 2008. However, only those stakeholder meetings that were held just prior to and during the grant period beginning May 1, 2009 are reported below.

April 22, 2009: Mosier Watershed Council meeting.
The MWC Coordinator/Grant Manager Kate (Merrick) Conley shared the latest edits to the Mosier Aquifer Recovery Feasibility Study plan with the MWC. The plan had gone through several revisions during grant agreement negotiations with the OWRD. The changes were primarily in response to grant budget reductions due to state budget cuts, but also due to the USGS study conclusion that commingling wells are the major cause of Mosier's aquifer declines.

The original grant proposal did not emphasize the analysis of commingling wells' effects on the feasibility of aquifer storage. The MWC recommended adding that analysis to the project plan before the grant agreement was signed. On April 22, 2009, the MWC debated whether to accept the OWRD grant agreement. The MWC eventually voted to accept the agreement with the understanding that an appropriate piece of the feasibility study would be assessing the role of commingling wells and the extent to which commingling wells may need to be repaired to make AR/ASR a viable solution.

Also at the April 22, 2009 meeting, the MWC designated members of a grant steering committee.

October 5, 2009: Mosier Watershed Council meeting.
The USGS presented the MWC with their proposed Scope of Work for completing some components of the feasibility study. The USGS proposed to model the change in aquifer storage that may be expected with an AR/ASR project under various well repair scenarios. They also proposed to conduct some well testing to study the properties of the rock and the extent of commingling in a representative well.

Also on October 5, 2009, the MWC made plans for the USGS to present their Mosier Groundwater Study results in a public meeting. This meeting was an important component of the MWC's public outreach strategy.

November 18, 2009: Community Groundwater Meeting / USGS Final Presentation.
The MWC hosted a presentation by the USGS that summarized the Mosier Groundwater Study methods and conclusions from the past five years. Following the USGS presentation, the MWC led a community discussion about potential strategies for restoring or stabilizing the region's aquifers. The strategies discussed were aquifer storage, repair/replacement of commingling wells, continued water conservation, and new well construction standards. This public meeting allowed the MWC to describe the OWRD-funded feasibility study to a wider variety and larger number of community members.

March 22, 2010: Mosier Watershed Council meeting.
The USGS updated the MWC on work completed under the OWRD-funded feasibility study. Updates were provided regarding: (1) the effort to geophysically log one of the suspected commingling wells, (2) the development of a new tool to more quickly and inexpensively screen wells for the presence of commingling, and 3) the results of model scenarios designed to look at how commingling wells might affect the feasibility of AR/ASR projects. (More details on the presentation at this meeting are provided under Task 1.1 above.)

May 17, 2010: Mosier Watershed Council meeting.
The USGS provided the MWC with their final update on work completed under the OWRD-funded feasibility study. They used the groundwater model as a tool to produce maps that define predicted "high value" zones for repairing commingling wells. They also reported results from testing the new rapid screening tool for detecting commingling. (More details on the presentation at this meeting are provided under Task 1.1 above.)

The MWC also discussed the possibility of pursuing new Special Area Well Construction Standards for the Mosier area, and decided to discuss the topic further at future meetings.

October 20, 2010: Mosier Watershed Council meeting.
The MWC held a discussion with Doug Woodcock, OWRD Groundwater Section Manager, Ken Lite, OWRD hydrologist, and Erick Burns, USGS hydrologist, about the possibility of pursuing new Special Area Well Construction Standards.

October – December 2010: steering committee consideration of interested consultants.

November 19, 2010: Proposal Evaluation Committee meeting.
Stakeholders reviewed proposals from prospective contractors for completion of the remaining tasks in the Mosier Aquifer Recovery Feasibility Study.

December 8, 2010: Mosier Watershed Council meeting.
The MWC reviewed the Wasco County SWCD contract with GSI Water Solutions, Inc. for completion of the OWRD-funded feasibility study.

The MWC also discussed outreach strategies to involve more of the community in the discussion about potential new well construction standards.

January 26, 2011: Mosier Watershed Council meeting.
The MWC continued to discuss outreach strategies related to the proposal for new well construction standards.

The MWC Coordinator gave an update on GSI's progress and asked local residents for permission to access private property for field reconnaissance related to the feasibility study.

January 27 – 28, 2011: landowner phone calls
The MWC Coordinator contacted private landowners to describe the feasibility study and request permission to access property for site reconnaissance with GSI.

March 8, 2011: Mosier Watershed Council meeting.
GSI team members attended the meeting to introduce themselves to local residents and provide the MWC with an update on their progress.

April 12, 2011: Mosier Watershed Council meeting.
GSI presented a final report on their work under the feasibility study contract. The MWC had the opportunity to share their current concerns and strategies with several new attendees.

May 24, 2011: Mosier Watershed Council, Annual Planning Meeting.
The MWC met to draft its Annual Plan of Work for the 2011 – 2012 fiscal year. Conclusions from the feasibility study were used to help set future priorities.

Task 5.1 Required Element (a): Analyses of by-pass, optimum peak, flushing and other ecological flows of the affected stream and the impact of the storage project on those flows.

Task 5.1 was researched by Wasco County SWCD and GSI. Conclusions were reported by GSI in their report section Ecological and Peak Flow Analysis Road Map (beginning on page 5-1).

Task 5.2 Required Element (b): Comparative analyses of alternative means of supplying water, including but not limited to the costs and benefits of conservation and efficiency alternatives and the extent to which long-term water supply needs may be met using those.

Task 5.2 was completed by GSI with input from Wasco County SWCD.

The analysis of conservation and efficiency alternatives is described in the GSI report section Water Conservation Strategies (beginning on page 4-1). While significant improvements in water use efficiency have been made by irrigators and the City of Mosier to decrease groundwater withdrawals, the conservation measures have not produced a noticeable decrease in groundwater level declines of the Priest Rapids or Pomona aquifers. This is consistent with the premise that commingling wells are the primary cause for the observed groundwater declines.

The GSI report concludes with a comparative analysis of alternative strategies to achieve aquifer recovery and thus ensure a long-term water supply for the Mosier area. The alternatives analyzed include surface recharge, direct well recharge, commingling well repair/replacement, commingling well repair/replacement combined with aquifer recharge, and water conservation. The analysis considers several feasibility criteria including infrastructure requirements, physical feasibility, projected costs, and environmental/ecological impacts of the alternative strategies. Table 5.4 presents this analysis as a comparative matrix that summarizes how each alternative strategy measures up to the different feasibility criteria. In addition to this descriptive comparison matrix, the alternatives were also ranked for favorability by assigning numerical values to feasibility criteria. Table 5.5 presents the numerical ranking of the alternatives.

On page 5-12, the GSI report provides the following conclusions from the alternatives analysis:

- *Commingling well remediation receives the highest ranking of the alternatives because the effectiveness of other alternatives is predicated on reducing or eliminating commingling between aquifers. Further, commingling well remediation has the least amount of uncertainty with regard to physical feasibility. The one significant disadvantage of remediation of commingling wells in the ranking is cost. The cost ranking for this strategy was assigned assuming that most or all of the commingling wells within the Orchard Tract would be repaired or replaced; however, substantial benefit may be realized by remediation of fewer, select wells, which would significantly reduce the overall cost and increase the ranking of this strategy.*
- *The two aquifer recovery strategies, surface recharge and well recharge, scored equivalently. However, we would anticipate that well recharge would score higher for effectiveness in the event that (1) commingling wells were remediated, and (2) cost-effective source water treatment using an infiltration gallery is feasible.*

- *The conservation strategy was deemed to be not effective on the basis of data showing that conservation measures largely have been implemented by irrigators and the City of Mosier, but have not demonstrably reduced groundwater level declines in the basin.*

Task 5.3 Required Element (c): Analyses of environmental harm or impacts from the proposed storage project.

Task 5.3 was completed by GSI. Conclusions can be found in their report section Environmental Impact (beginning on page 5-7).

Task 5.4 Required Element (d): Evaluation of the need for and feasibility of using stored water to augment in-stream flows to conserve, maintain and enhance aquatic life, fish life and any other ecological values.

Task 5.4 was completed by GSI. Conclusions can be found in their report section Stream Flow Augmentation with Stored Water (beginning on page 5-11).

Task 5.5 Required Element (e): analysis of local and regional water demand and the proposed storage project's relationship to existing and planned water supply projects.

Task 5.5 was completed by Wasco County SWCD, as described below.

Part 1. Analyze local and regional water demand:
Water demand in the local project area, and the greater Columbia Gorge region, includes demand for domestic (city and rural residential) and agricultural water. The demand estimates below apply to the entire area (generally referred to as the "Mosier valley") that would be affected by any storage project included in this feasibility study.

The estimated present groundwater demand can be broken down into the following uses:

Estimated present groundwater demand (acre-feet per year)	
City (2008-2009 data)	128 afy
Rural residential (2005)	105 afy
Irrigation (2007)	850 – 1,500 afy
Total	**1,083 – 1,733 afy**

A hydrologic assessment by the OWRD in 1985 showed that about 600 acres were irrigated with groundwater. At that time, depending on the methods used, withdrawal volumes for irrigation ranged from 600 – 1,500 afy. In 2004, the OWRD listed 900 irrigated acres dependent on groundwater. Extrapolation of the 1985 figures provides a 2004 estimate for irrigation withdrawals of 900 – 2,250 afy. That estimate is likely on the high side given that the Wasco County SWCD has been working with orchardists in the Mosier area for the past several years to upgrade irrigation systems for increased water use efficiency. Conversion from impact sprinkler systems to micro and drip systems has enabled some orchardists to reduce their water application from three feet to as little as one foot of water per acre. The 2007 irrigation estimate above has been reduced from the 2004 estimate based both on assumed reduction due to efficiency upgrades and on measured reduction seen in data from flow meters installed on a subset of Mosier wells during the 2006 and 2007 irrigation seasons. Flow meters were also installed during the 2008 irrigation season, but not every flow meter functioned properly throughout the season. However, the general trend among the nine major wells that were metered in 2008 was a decrease in water used compared to the average of 2006 and 2007 use.

The average city water use from 1989 – 2005 was 97 afy. The city reported much lower usage in 2007 (53 afy) following repairs to the distribution system and installation of meters at homes. However, in 2008 – 2009, usage was back up to 71 afy. This "rebound" effect is common within a year or so after meters are installed.

Future groundwater demand estimates, below, assume full rural residential build out, full City of Mosier build out, and static irrigation demand at the higher end of current estimates (to leave room for potential expansion of irrigated acreage, but also considering the potential for further efficiency improvements).

Estimated future groundwater demand (acre-feet per year)	
City	128 afy
Rural residential	210 afy
Irrigation	1,500 afy
Total	**1,838 afy**

Part 2. Analyze the proposed storage project's relationship to existing and planned water supply projects:

Wells are the only existing and planned water supply in the project area, supplying city and rural residential domestic water needs and agricultural water needs.

The proposed storage project would ensure that these wells could continue to meet the Mosier Valley's water demands into the future. Currently, Mosier-area well water levels are dropping, making it more expensive, difficult, or even impossible for existing wells to fully supply their users' needs. Despite the implementation of water conservation practices among farmers and the City of Mosier, aquifer declines have continued.

If an AR/ASR project were deemed to be technically and economically feasible based on this study, then the storage provided by such a project would boost aquifer levels. Therefore, the proposed storage project would be directly related to the existing water supply for the Mosier Valley, because it would allow the Mosier Valley to continue to meet its water needs using wells. There is a possibility that existing wells may be sufficient for operation of an AR project, but it is likely that new wells would be necessary.

The USGS Mosier Groundwater study has determined that well levels would continue to decline even if pumping were stopped, due to commingling wells that act like leaks in the system. Therefore, it seems reasonable that if Mosier decides to pursue an AR or ASR project, it might be implemented in conjunction with repairs to some of the commingling wells. If repairs were made, then the proposed storage project could potentially go further toward restoring water levels in existing wells.

Conclusions and Anticipated Next Steps

The primary purpose of this SB 1069 Grant-funded feasibility study was to evaluate the feasibility of implementing aquifer storage to meet Mosier's long-term water supply needs. The conclusion of the study is that aquifer storage is not currently a feasible strategy for meeting Mosier's water needs, and it will not be feasible as long as commingling wells continue to impact Mosier's aquifer levels to the present degree. If the problem of commingling were first diminished, aquifer storage could possibly become an effective means of boosting Mosier's aquifer levels in the future. Even so, the cost may be prohibitive for the Mosier area.

This feasibility study has provided several suggestions and considerations that should be taken into account if an aquifer storage project were to be pursued for the Mosier area in the future:

- The project should follow the Oregon rules for Artificial Recharge rather than Aquifer Storage and Recovery;
- An Artificial Recharge project may be less expensive if recharge were accomplished via surface infiltration;
- An Artificial Recharge project may be able to more effectively target the desired locations if recharge were accomplished via direct well injection;
- Water treatment needs and the total project cost would be lower if the source water from Mosier Creek could be diverted through shallow alluvial deposits, which would provide some natural filtration; and
- The best location for an Aquifer Recharge project (i.e. the location at which injection would result in the greatest increase in aquifer storage) would depend on how many, and which, commingling wells were repaired first.

Based on this feasibility study, the MWC is interested in pursuing commingling well repair and/or replacement before giving further consideration to aquifer storage. Commingling wells should be addressed in a prioritized order, such that the "leaks" lowest in the aquifer system are repaired first. Further assessment is needed to identify the highest priority commingling wells for repair/replacement.

The MWC is interested in following the general process for commingling well prioritization and assessment outlined in the GSI report section 3.8 (beginning on page 3-13). The process recommended by GSI is based on the premise that it likely is impractical to test all wells for the occurrence of commingling, and evaluation and repair of commingling wells likely would occur individually or in small increments because of funding an/or access limitations. The process involves two general steps: (1) an initial screening to identify areas where wells may present a higher risk for commingling, followed by (2) testing of individual wells within higher risk areas to verify commingling and evaluate well repair feasibility.

The MWC is also interested in addressing the GSI suggestion that, for both commingling well repair and new well construction, there is a need to make the latest information and resources available to help inform decisions on which aquifers to target and how deep to set casing and seals.

The MWC has already begun discussion with OWRD regarding the need for either new Special Area Well Construction Standards or more diligent enforcement of existing regulations for the purpose of preventing the drilling of more commingling wells in the Mosier area. Continuation of these discussions with the OWRD and the Mosier community is a high priority for the MWC.

Another priority for the MWC is continued education and outreach to Mosier-area residents and other parties interested in Mosier's water availability and well construction rules. The MWC intends to hold another public outreach meeting, similar in format to the 2009 meeting at which the USGS presented their final report, in the fall of 2011. The meeting will cover the basics of Mosier's hydrogeology, the current concerns, and the conclusions of studies to date.

One of the MWC's greatest challenges is finding funding and the necessary technical expertise to pursue its anticipated next steps. Wasco County SWCD may be able to take on some of the commingling well assessment and prioritization steps if technical support were provided by agency partners or a private consultant, but even that would likely require outside funding. The design and implementation of commingling well repair/replacement projects will certainly require funding for outside contractors.

The MWC's overarching challenge of obtaining funding is influenced by several smaller issues:

- Funding sources accessible to watershed councils are often related to surface water issues. Groundwater certainly interacts with surface water in the Mosier Creek watershed, but the extent and intricacies of the interactions are incompletely understood at this point in time. An upcoming graduate student project should help clarify some of the uncertainties related to groundwater-surface water interactions in the watershed.
- Potential funders are also likely to focus on water conservation. The MWC views commingling well remediation as a water conservation strategy, in that it would retain more water in the "natural" location or source (an aquifer in this case), just as piping an irrigation ditch to conserve water that would otherwise be "lost" to infiltration maintains more water in the source stream. The MWC considers groundwater to be an important natural resource that should be conserved in aquifers, rather than allowed to take a "short cut" to surface water through commingling wells. Funders approached to date have not agreed with the MWC's interpretation and thus have declined to fund well remediation as a groundwater conservation strategy.
- Most commingling wells are owned by individuals, but the beneficiary of commingling well remediation would likely be the community of groundwater users and the natural system of groundwater and surface water resources. Therefore it will likely be difficult to assign the cost of commingling well remediation solely to the well owner, which complicates funding schemes.

The Wasco County SWCD recognizes the importance of Mosier's groundwater concerns. As a result, the SWCD has allocated local funds for commingling well assessment and eventual remediation in each of the last two fiscal years. The SWCD is likely to continue supporting these efforts but will need to work with the MWC to seek grants to fund more significant progress.

The MWC appreciates the support that the OWRD has provided to date, in the form extensive technical assistance and grant funding. The MWC plans to work in close cooperation with the OWRD as it pursues its next steps related to water resources management.

Appendix 1: GSI Water Solutions, Inc. Report

See the attached Mosier Aquifer Recovery Feasibility Study final report from GSI Water Solutions, Inc.