Memorandum

Date: July 22, 2014

To: Jeff Lux

From: Jeff Binder

Subject: Cimarron Groundwater Recovery and Hydrogeologic Testing for Remedial Design

Per your request, this memorandum has been prepared to provide a brief overview of groundwater recovery/injection alternatives as well as specifics on the investigative approaches and groundwater control techniques. General recommendations relating to hydrogeologic testing in the upland areas of the Cimarron site are also discussed in this memorandum.

Overview

Groundwater recovery involves the collection of impacted groundwater via facilities or structures to capture this water for treatment or disposal. Control and treatment of groundwater at the Cimarron site begins with recovery of groundwater through any number of techniques and methodologies. These control and recovery alternatives evaluated for the Cimarron site included installation and operation of vertical wells, angled (slanted) wells, recovery trenches, and horizontal wells. These alternatives can also be used for injection/infiltration (waterflood) to create a wave front to help sweep and/or mobilize product or contaminants toward the selected recovery systems to aid in the remediation of impacted groundwater at a site. Complicating factors for the implementation of functional and effective alternatives in the upland areas of the site and remediation include the presence of groundwater impact in the sandstone units that underlie the area and the existence of little to no site specific data on the nature of the joint and fracture network, as well as limited data on the hydraulic components of the upland hydrostratigraphic sequence. The following are brief descriptions and discussions of groundwater control and recovery configurations that have been considered as remedial measures for the site.

Vertical Wells

Vertical wells provide access to the natural formation matrix porosity and permeability, bedding planes, joints and fractures present within the vertical screened intervals. This type of construction and installation generally has a radius of influence that is limited by the permeability and porosity of the formation. Unless the formation permeability and porosity features are interconnected, groundwater recovery or fluids injection may only allow fluid movement in a limited zone of influence. This could result in the need to install numerous closely spaced borings/wells to meet the requirements for successful implementation of the remedial design.

Angled (Slanted) Wells

Similar to vertical wells, slanted wells provide access to the natural formation matrix porosity and permeability, bedding planes, joints and fractures present within the screened intervals but with the increased probability for potential interconnection of these features by increasing the surface area of formation that is in contact with the screen, due to the angled orientation of the well construction and installation. The limitations for the use of slanted wells includes the poor connectivity of the permeability and porosity features in the rock mass, thickness of the formation, and the potential need to install closely spaced wells to achieve the desired influence. The well spacing for the slanted wells could be wider than the use of vertical wells but there could be a need for numerous completions to accomplish the desired purpose of optimizing the recovery or injection of groundwater during remediation.

Recovery Trenches

Excavation and installation of recovery trenches can be completed using conventional excavation equipment as well as specialized one-pass technology to install shallow horizontal wells/drains along the length of the excavation. This provides interconnection of permeability and porosity features and potential preferential pathways to maximize the influence of the wells on fluids recovery or injection. Limitations of this approach include depth of excavation and th presence of competent/non-rippable bedrock.

Horizontal Directionally Drilled Wells

Horizontal directionally drilled (HDD) wells allows for installation of long horizontal screens that can provide for the interconnection of permeability and porosity features to enhance groundwater recovery and/or injection across a larger area. By using HDD, there is the capability to drill into and through competent rock as well as soil to depths over 100 feet below ground surface (bgs). Limitations of this method include the potential for a limited radius of influence due to the relatively small annular space if an interval of impact is relatively thick and the need for significant setback distance to reach a desired depth. For example, a setback ratio of approximately 5H:1V is needed to drill a curve of suitable minimum bend radius to get to 40 feet bgs. This would require a setback of approximately 200 feet.

Summary

The best way to maximize the effectiveness of any groundwater recovery or injection network is to have the greatest surface exposed within the screened interval which not only includes the soil and/or matrix but also any joints, fractures, and bedding planes that can act as preferential pathways for groundwater and fluid flow. To this end, the use of horizontal trenches or wells

would most likely accomplish this in the most effective manner. While slanted wells may provide this increased surface area and potential interconnecting of higher porosity pathways, the effectiveness and cost of these types of wells may be limited given that screened intervals are limited by formation thickness.

General Recommendation for Hydrogeologic Testing in Upland Areas

To obtain a hydrogeologic data set for the design of the recovery and injection elements for remedial design in the upland areas of the site, it is imperative to collect hydraulic conductivity and flow data for the sandstones. This data will be collected using packer testing and percolation/infiltration testing methods.

Packer testing is a test method that is used to measure hydraulic conductivity (permeability) and flow in consolidated bedrock. Inflatable packers are generally used to isolate intervals in a borehole to collect data on rock mass permeability and flow that is controlled by joints, fractures, and bedding planes. Percolation/infiltration testing is a simple method where water is introduced into a shallow boring or excavation to estimate to the infiltration rate that may be accepted by the formation. Both of these proposed methods can provide site specific hydraulic data needed for the remediation system design.

The first element of the proposed plan is to collect data using packer testing in vertical or angled borings to evaluate the hydrogeologic characteristics of Sandstone A and Sandstone B at depths that may be at depths greater than conventional trenching can reach but horizontal directional drilling or vertical/slanted wells may be considered as the remedial alternative. The packer testing will not specifically or singularly influence the decision to install horizontal wells as opposed to vertical or angled wells but will yield hydraulic properties needed for the design of a portion of the remediation system. This type of testing will be performed in the UP-1 and UP-2 areas but packer testing is also proposed for the BA#1 and near BA#3 to get a better spatial distribution in both sandstone units and areas that may have a greater degree of fracturing and/or increased porosity as opposed to areas that could have lower connectivity in the rock mass.

The proposed conceptual design is to inject/infiltrate treated groundwater into both Sandstone A and Sandstone B only in the UP-2 area. The likely injection/infiltration conveyance will be horizontally screened wells within each of these two hydrostratigraphic units to produce a wavefront to sweep contaminants toward recovery wells.

In locations where conventional excavation and trenching is a viable option for installation of groundwater recovery and/or injection system, the proposed plan is to perform percolation testing at the shallow rippable surface of Sandstone A in the 1206 drainage area and Sandstone B in the upland portion of BA#1. To allow for this testing, an excavator will attempt to advance

the trenches approximately 3 to 5 feet into the upper sandstone surface. This will allow for testing the feasibility of an injection trench for the injection/infiltration of treated groundwater. If successful the wavefront will push the contaminants toward recovery trenches.

They only planned ***recovery*** system that would be installed in sandstone is a recovery trench in BA#1 to capture impacted water in Sandstone B. Current plans for the 1206 drainage and the BA#1 transition zone are to collect the groundwater from recovery trenches installed in the transition zone material.

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