U. S. Army Corps of Engineers
Example Remediation System Evaluation
Ground Water Extraction System Report

1.0 Introduction

1.1 Purpose. The ___ District was tasked to perform an evaluation of the large ground water extraction system ("main plume" or "project area") at the site. The system was chosen because of its size and operating costs. The evaluation was intended to verify the protectiveness of the system in compliance with the National Contingency Plan, to identify potential cost savings in operations and maintenance, to confirm the validity and presence of an exit strategy for the system, and to verify adequate maintenance of Government-owned equipment.

1.2 Team Composition. Representatives of ______ District (or contractor) performed the evaluation. The participants included:

Name, Title, Organization

1.3 Documents Reviewed. The team reviewed the following documents:

Title, Date, Source or Author

1.4 Persons Contacted.

Name, Title, Organization/Vendor, etc.

2. Site Location, History, Characteristics (brief summary)

2.1 Potential Sources and Description of Groundwater Plume. Discharges to the Industrial Waste Lagoon (and the ditches that fed it) from operations within the Industrial Area and possibly other sources have created a plume of chlorinated organics in ground water. Operations in the Industrial Area primarily consisted of vehicle maintenance which entailed metal plating, sandblasting, vapor degreasing of vehicle parts, and engine re-manufacturing. Effluent from the industrial area discharged to four unlined, open ditches. The flows in these four ditches were directed into a single unlined ditch that terminated at the Industrial Waste Lagoon (IWL), an open, unlined impoundment. Effluent was an aqueous solution, reaching up to 140,000 gallons per day (gpd) at its peak. As a result of this operation, ground water beneath the discharge ditches and the IWL became impacted with the contaminants of concern (COCs), primarily trichloroethene (TCE), carbon tetrachloride, and 1,1 dichloroethane (1,1, DCA).

2.2 Plume Description. The main plume is approximately 3 miles in length and 2 mile wide. The plume extended approximately 1,500 feet north of the Installation boundary. Vertically the plume has been detected at a maximum depth of approximately 700 feet. Ground water is typically encountered at depths of 250 to 300 feet below grade. Another plume (the northeast plume) that apparently originates near the southern boundary of the former industrial area currently extends off the installation at its northeast boundary and may ultimately commingle with the main plume. The impacted ground water is an environmental concern of the State due to its presence in an aquifer potentially used for irrigation, livestock watering, and domestic use. The site is currently regulated under RCRA.

2.3 Source Remediation. The originally identified source areas have been partially remediated. Sludge from the distribution ditches was removed and placed within the IWL. Then, both the IWL and the distribution ditches were capped with a RCRA-type cap. It was felt that by capping the IWL and the distribution ditches, the further migration of the contaminants held within the vadose zone would be halted. However it is possible that lateral migration of contaminants, beyond the limits of the capped areas, has occurred within the vadose zone. A very substantial vadose zone, often exceeding 300 feet thick, exists beneath both the distribution ditches and the IWL. Other potential sources in the vicinity of the Industrial Area are currently being investigated.

2.4 Contaminant(s) of Concern. The primary COC is the volatile organic compound (VOC) TCE. Additional COCs identified in the Post-Closure Permit are Carbon Tetrachloride (CCl_4), 1,1-Dichloroethene (1,1-DCE) 1,2-Dichloroethene (1,2-DCE), 1,1-Dichloroethane (1,1-DCA), methylene chloride, 1,1,1-Trichloroethane (1,1,1-TCA), Tetrachloroethene, Chloroform, Chloroethane, 1,2-Dichloropropane (1,2-DCP), Benzene, Toluene, Ethylbenzene, Xylene, and Chromium. 2,4-Dimethylphenol (2,4-DMP) was identified in the initial characterization and the Post Closure Permit but was deleted in May 1995. The compound had only been detected in one well since monitoring began and the last detection was in 1988.

2.5 Historical Contaminant Concentrations. The highest ground water contaminant concentrations associated with the IWL and ditches were recorded as follows (well in which concentration occurred and date are given in parentheses): 250 ppb TCE (T-1, T-3; 11/86, 8/84, respectively), 54 ppb CCl_4 (B-26, 3/96), 4.2 ppb 1,1-DCE (B-15, 10/86), 340 ppb 1,1,-DCA (N-2C, 8/84), 12 ppb methylene chloride (B-13, 10/86), 200 ppb 1,1,1-TCA (N-2C, 3/88), 5.8 ppb chloroform (B-5, 9/91), 6.78 ppb benzene (B-18, 6/90), 35 ppb toluene (A-7, 4/88), 2.6 ppb ethylbenzene (B-5, 9/91) and 3.8 ppb xylene (N-2C, 3/88). For many of the COCs, the highest detected concentrations were in the ground water directly beneath or near the IWL or distribution ditches during the early years of the investigation. Concentrations have since diminished, in some areas to undetectable levels, with time and with the implementation of the ground water treatment system. Only the COCs TCE, CCl_4, and 1,1-DCA currently persist in the plume generated by the IWL and the associated distribution ditches. TCE is the most widespread and the most concentrated COC, and TCE defines the lateral and vertical extent of the plume. The CCl_4 plume is much smaller than the TCE and 1,1-DCA is only currently found in well B-20.

2.6 Aquifer System. The aquifer system impacted in the main plume area is composed primarily of coarse-grained alluvial materials with some lake deposits. The unconsolidated materials, which are generally hundreds of feet thick, are underlain by a bedrock aquifer consisting of various strata, including quartzite, sandstone, and limestone. In a portion of the study area near the former IWL, an uplifted block of the bedrock aquifer is encountered at much shallower depths and the water table actually resides in the bedrock. This "bedrock block" has a significant impact on the ground water flow system. Extremely steep horizontal piezometric gradients are observed in the vicinity of the southern edge of the uplifted bedrock block and another area of steep, though less pronounced, gradients are found on its northern edge. The piezometric gradients within the bedrock block are comparable to the gradients in the alluvium. Although the permeability of the bedrock material itself is very low, there is strong evidence for extensive fracturing in the bedrock that allows considerable ground-water flow. The steep gradients on both sides of the bedrock block may indicate low-permeability material along its margins that inhibits flow into the block. Beyond the Installation's northern boundary, a deeper aquifer with distinctly different water quality (higher TDS) has been found.

2.7. Ground Water Depths and Flow Direction. Depth to ground water within the project area varies from slightly over 100 feet near the northern Installation boundary to as much as approximately 400 feet within the Industrial Complex. Ground water is typically found at depths of 150-300 feet within the project area. Ground water recharge occurs along the valley margins and flows generally northwestward beneath the Installation toward discharge areas in the central and northern parts of valley. Ground water flow in the project area is northwest. The ground water within the northeast plume flows to the northeast. Piezometric gradients are low in the alluvium and within the bedrock block, from less than 0.001 ft/ft to 0.0025 ft/ft. The higher gradients along the edges of the bedrock block may exceed 0.1 ft/ft.

2.8 General Hydraulic Properties of the Aquifer. In general, the aquifer system beneath the Installation is considered to be very productive. Discharges to production wells range over 1,000 gallons per minute (gpm) with specific capacities of greater than 20 gpm/foot. Hydraulic conductivities of the bedrock aquifer were determined by various means and found to vary significantly, ranging from 2 gallons per day per square foot (gpd/ft^2) in quartzite with clay-filled fractures to 2,000 gpd/ft^2 in quartzite with open, interconnected fractures. The alluvial aquifer displays a variety of hydraulic conductivities. Short- and long-term pumping yielded horizontal hydraulic conductivities ranging from 1 to 5,300 gpd/ft^2 and averaging approximated at 1,500 gpd/ft^2, while the average vertical hydraulic conductivity was approximately 225 gpd/ft^2.

2.9 System Description.

2.9.1 System Overview. The remediation system consists of:

- 16 extraction wells (one of which is not currently operating),
- 13 injection wells,
- extraction pumps,
- extraction and injection water piping,
- a 50,000 gallon surge "equalization" tank,
- three large transfer pumps (4,000 gpm capacity each, one is a standby unit),
- a chemical feed system for the addition of sodium hexametaphosphate (SHMP), and
- two 12-foot diameter, 60-foot tall air strippers operated in parallel.

The plant is capable of treating 8000 gpm. SHMP is added to influent water prior to air stripping to control the formation of inorganic precipitates that caused pipeline and well plugging early in the operation of the plant.

2.9.2 Extraction and Injection Wells. The extraction well system recovers water from multiple depths. Although a number of wells only extract from shallow (above a depth of approximately 325 feet) or deep (deeper than approximately 325 feet) parts of the plume, some wells (E-2-1, 2-2 and E-3-1, 3-2) are paired; one "shallow" and one "deep," while other wells (E-6, 9, 13, 14, and 15) are screened across multiple depths, both shallow and deep. Extraction wells near the leading edge of the plume are typically shallow and wells drilled into the bedrock block are typically classified as deep. Wells in the middle of the plume are either paired or screened both shallow and deep. Each well is equipped with a submersible pump driven by a variable speed motor controllable from the plant. Injection wells are located just downgradient of the leading edge of the plume. All extraction wells are constructed of stainless steel continuous-slot screens and steel casing and the well heads are finished with a pitless adapter. Injection wells are believed to be constructed in a manner similar to extraction wells, although they have long screens extending up into the vadose zone. Injected water is gravity-fed to the injection wells and is conveyed to below the top of the water column in the injection well by a drop pipe.

2.9.3 Treatment System. Ground water is pumped from the extraction wells directly into a 50,000 gallon surge tank. The water levels in the surge tank are interlocked with the well pumps and the transfer pumps. If the water level in the tank rises to the high level sensor, the valve in the water line from the wells to the surge tank closes. The resulting pressure buildup causes the well pumps to shut off. If the water in the surge tank falls to the low level sensor, the transfer pumps stop pumping water to the air stripper. During normal operation, water is pumped from the surge tank by two 4,000 gpm centrifugal pumps (with a third pump on standby), to the top of the two air strippers. The water line from the pumps to the air strippers is instrumented for measuring the flow rate. SHMP is also metered into the water line to sequester any calcium carbonate that may precipitate from the water. At the top of the two air strippers, water is distributed uniformly over the 3.5 inch Lanpac plastic packing. The depth of the packing is 29 feet. The water from the bottom of the air strippers flows by gravity through piping to the injection wells. Two 25,000-CFM blowers, with a third blower on standby, provide air to the air strippers. The VOCs stripped from the water are emitted from the top of the air strippers directly to the atmosphere without treatment.

3. System Objectives, Performance and Closure Criteria

3.1 Current System Objectives and Closure Criteria. The current goal of the treatment system is to both contain and remediate the ground water to maximum contaminant levels (MCLs). The current contract for operations requires TCE to be reduced to less than 1 ppb in treated water, however the action level for TCE in the IWL Post Closure Permit is 5 ppb. Two wells have been designated as compliance wells; A-7A and B-56 are shallow and deep (bedrock) wells, respectively, immediately down gradient of the IWL. The permit will allow the remedial action to be terminated if the concentrations of the COCs in these compliance wells are reduced to below the action levels. There are no potential users of ground water immediately downgradient of the plume. The ultimate future receptor of the contaminated water is a very large nearby lake. The current contract for operations calls for the plant to continuously (24 hours per day, seven days a week) treat water from all designated active extraction wells at least 95% of the time.

3.2 Action Levels. Action levels as identified in the permit are as follows:

Benzene	5.0 µg/L
Carbon Tetrachloride	5.0 µg/L
Chloroethane	1.3 µg/L
Chloroform	0.5 µg/L
Chromium	50.0 µg/L
1,1-Dichloroethane	170.0 µg/L
1,1-Dichloroethene	7.0 µg/L
1,2-Dichloroethane	0.2 µg/L
1,2-Dichloropropane	1.4 µg/L
Ethylbenzene	1.0 µg/L
Methylene Chloride	5.0 µg/L
Tetrachloroethane	0.3 µg/L
1,1,1-Trichloroethane	45.0 µg/L
Trichloroethene	5.0 µg/L
Toluene	45.0 µg/L
Xylenes	3.2 µg/L

3.3 Potential Future Changes in System Objectives. The Installation and USACE are currently evaluating alternative remediation system objectives. The risk posed by the ground water contamination is currently being re-evaluated, and alternate clean up standards of 20 ppb or 50 ppb of TCE are being considered.

4. Site Visit and Data Analysis Summary and Recommendations

4.1 Findings. In general, the RSE team found the system to be well maintained, and operating as intended. The design appears to have been appropriate given what was known about the site at the time of construction. The observations and recommendations given below are not intended to imply a deficiency in the work of either the designers or operators, but are offered as constructive suggestions in the best interest of the Department of Defense and public. These recommendations obviously have the benefit of the operational data unavailable to the original designers.

4.1.1 Treatment System Performance. The system has exceeded the requirement for the plant to continuously treat water from all active extraction wells at least 95% of the time. The system has been up and running about 98% of the time. Most of the 2% downtime has been due to events not under the Contractors control (e.g., power disruptions).

4.1.2 Subsurface Performance and Response – Water Levels. The water levels for both shallow and deep zones from March of 1997 were contoured by hand to determine if the existing system as currently operated is successfully containing the plume. It appears that the system is successfully capturing at both the shallow and deep plumes. Apparent piezometric gradients within the plumes are everywhere directed toward an extraction well. It is not clear that the current high pumping rates or all of the well locations are necessary. For example, wells E-5 and E-1 may not be needed given their locations relative to wells E-9 and E-11, respectively. The latter wells have capture zones that adequately cover those parts of the plume. The USACE remediation system evaluation recommends a more elaborate optimization study.

4.1.3 Subsurface Performance and Response – Contaminant Levels. Concentrations of contaminants in the extracted water prior to treatment have declined from near 50 μg/L after startup to near 25 μg/L more recently. Contaminant levels in all extraction wells have declined to some degree since start-up of the system or since installation. Since the system has been in operation, the concentrations of contaminants in the ground water near the leading edge of the shallow plume have been substantially reduced (e.g., 36 μg/L to 4.6 μg/L in Monitoring Well B-19). In fact, extraction well 12, the most downgradient extraction well, has been shut down due to the drop in concentration in the extracted water from 3.8 μg/L to non-detectable levels (1.0 μg/L reporting limit). While this reduction would indicate that the remediation is achieving its goals, this trend is not site wide. Contaminant concentrations in monitoring wells elsewhere have generally not declined or in a few cases may have actually risen slightly. Clearly, the remediation of the plume to current goals may involve pumping over decades, or perhaps longer, if it can be remediated to current goals at all. This is not unusual for ground water extraction projects.

4.1.4 Effectiveness of the System to Protect Human Health and the Environment. The system is currently protective of human health and the environment. There is currently no human or ecological exposure to contaminated ground water or soil at this site. Although there is no treatment of the offgas from the air strippers, this discharge to the atmosphere is relatively small and the distance to the installation boundary is relatively large and it seems unlikely that the discharge poses a risk to the nearby population.

4.1.5. Component Performance .

4.1.5.1 Wells. The extraction and injection wells have performed well, although periodic rehabilitation is necessary to maintain performance. On a weekly basis, pumping water levels in the extraction wells are measured by hand and the specific capacities of the wells are computed. If the specific capacity declines 30 to 50% from a baseline value, the well is identified for rehabilitation. Rehabilitation of the extraction wells consists of swabbing with a wire brush. Approximately 9 of the 16 extraction wells have been cleaned at least once. A recent video of extraction well E-1 indicated serious clogging of the screen by both inorganic scaling and biomass. The injection wells were cleaned with a sulfamic acid solution and swabbing in 1995 following significant inorganic scaling. Scaling has apparently been controlled since then by the use of the SHMP. Wells are also rehabilitated by bailing if 50% of the screen is occluded by sediment. Wellhead vaults appear in excellent shape.

4.1.5.2. Well Pumps. Extraction well pumps have been a significant problem. The power supply is plagued by voltage irregularities that often cause the well pump controllers to shut the pumps down (see Sec. 4.1.7.1 Power Outages). The electric motors driving the submersible pumps have a history of failure after approximately two years. The failures appear to be a short in the motor windings. The manufacturer guarantees these motors for two years, but according to the operator they seem to fail not long after the warranty period. When removing the pump and motor for motor repair, the pump is also serviced (wear rings, bearings, etc.) as necessary. The pumps themselves have held up well. It costs about $3,000 to pull the pump / motor assembly, about $1,000 to service the pump, about $5,000 to replace the motor, and about $3,000 to re-install the pump / motor assembly; for a total cost of about $12,000.

4.1.5.3. Air Strippers. The air strippers are consistently reducing TCE levels to below detection limits (less than 1 ppb). The strippers were designed to reduce TCE levels from of 250 to 0.78 ppb. However, since 1995 influent TCE levels have been between 20 and 30 ppb. SHMP is currently being fed upstream from the strippers to prevent precipitation in piping and injection wells (see Sec. 4.2.3.3. Sequestration of Inorganic Precipitates). However, even before SHMP was being used, scaling or fouling of the stripper packing was not found to be a problem. And there has not been evidence of scaling or fouling of the stripper packing since the use of the SHMP was initiated.

4.1.5.4. Piping. There have not been recent problems with the piping; however, prior to the addition of the SHMP, scale collected in the piping near the injection well head, especially at the valves. This accumulation had to be removed by hand.

4.1.5.5. Chemical Feed System. A chemical feed system is being used to feed SHMP into the process stream through injection ports between the transfer pumps and the air strippers. The SHMP being used is a Calgon product (CL-50), and is delivered to the site as a concentrated solution in plastic containers. The feed-rate is not automatically regulated based on the flow rate of water being pumped to the strippers, but is adjusted manually if there is a significant change in influent flow rate. The target concentration for SHMP in process water is 8 mg/L. Although SHMP could be added downstream from the air strippers, it was more convenient to locate the feed system inside the treatment plant building.

4.1.6. Components or Processes that Account for Majority of Costs

4.1.6.1. Electricity. Electricity costs approximately $500,000 per year (5.1 - 5.2 cents per kW-hr).

4.1.6.2. SHMP. Costs for SHMP now exceed $200,000 per year.

4.1.6.3. Labor. The staff consists of a manager and a staff of three with an estimated annual cost exceeding $300,000.

4.1.6.4. Chemical Analysis. Sampling of approximately 45 monitoring wells occurs semiannually. Treatment plant influent/effluent, and individual extraction wells concentrations are determined quarterly. Analysis includes VOCs by methods 8010 and 8020 and chromium by method 6010. Estimated annual cost for these analyses is $15,000-20,000. The existing staff conducts sampling.

4.1.6.5. Well and Pump Maintenance. Pump motors require replacement approximately every two years. At a cost of $12,000 per well and assuming that seven extraction wells require work each year, the total cost per year is approximately $85,000.

4.1.6.5. Other Costs. Total annual O&M costs now exceed $1,800,000. Other items beyond those listed above must therefore be approximately $600,000.

4.1.7. Recurring Problems or Issues

4.1.7.1. Power Outages. Frequent power outages and power surges have been experienced. From Jan. 1997 through March 1998 there were 35 power disruption events. This number only includes events that occurred during off-duty hours. Power surges and outages are due to direct lightning strikes to lines or poles on-site, or, more frequently, are due to lightning and other factors that affect the power provided by the local utility company. Power surges or fluctuations may cause all, or some, of the extraction wells to shut down. The variable frequency drive (VFD) motor of each extraction well pump is protected from changes in voltage. Increases or decreases in voltage of greater than 10 % will shut off power to the motor. Extraction wells must be manually re-started after a power outage. A considerable amount of time is required to drive from the plant to each of the extraction wells. After a power outage, it takes about 4 hours to re-start the extraction wells and return the plant to normal operation.

4.1.7.2. Roads. When conditions are wet, travel on the dirt roads becomes difficult. This typically occurs in March, April, and May. Precipitation combined with thawing of the ground creates the greatest problems. As part of normal operations, injection and extraction wells must be checked by operators. Vehicles often become stuck in the mud in transit. Improving the roads should be considered.

4.1.8. Regulatory Compliance. The installation has an approval order from the State to discharge directly from the air strippers to the atmosphere in accordance with State Air Quality Regulations.

4.1.9. Treatment Process Excursions and Upsets, Accidental Contaminant/Reagent Releases. Based on information made available to the team, there have been a few uncontrolled releases of contaminated water to the environment during operation of the plant. On one occasion, a pipeline connection failed. On another occasion, the surge tank overfilled because the treatment plant shut down after a power failure, but the wells continued to operate. In this instance, a large quantity of untreated water was released. Corrective measures have been put in place to prevent similar occurrences. Soil sampling along the path of the released water failed to detect contaminants. There had also been a very minor accidental release of several gallons of purge water from well sampling during transport back to the treatment plant. All incidents had been reported to the proper regulatory authorities and addressed as required by them.

4.1.10. Safety Record. The plant appears to have had an excellent safety record with over 1900 consecutive days without a lost-time accident.

4.2 Recommendations.

4.2.1. Technology Changes.[1]

4.2.1.1. Source Removal. There is some evidence that a continuing source of contamination may be present. Lateral migration may have occurred in the vadose zone so that the capped areas (i.e., the IWL and ditches) are not fully preventing infiltration through the contaminated soil. Vadose zone investigations should be considered. If source areas near the IWL and ditches are located, then vadose zone removal actions should be considered (e.g., SVE or co-metabolic bioventing). The ongoing investigations regarding other sources in the Industrial Area should continue and actions taken as appropriate to remove significant sources. Source removal has the potential to shorten the required operational time for the ground water extraction system.

4.2.1.2. Re-evaluation of Cleanup Criteria. The RSE team supports the current re-evaluation of cleanup goals. The consideration given to alternate cleanup goals of 20 μg/L (or higher) of TCE appears to make sense given the exposure potential at the site.

4.2.2. Possible Component Changes[1]

4.2.2.1. Elimination of the Transfer Pumps. Currently water is pumped from the extraction wells to the surge tank, and transfer pumps move water from the surge tank to the air stripping towers. If there is enough head available from the extraction well pumps, and if an elevated or taller surge tank is installed, then it may be possible to feed the air strippers through gravity flow from the surge tank. The savings in electricity from this change are estimated to be $7,000 per year. This and the reduced maintenance would probably not offset the capital cost of modifying the piping and modifying or replacing the existing surge tank. The volume of a new surge tank of the same diameter is approximately 208,000 gallons. Using an order-of-magnitude parametric cost estimate, the estimated installed cost of the new tank would be $147,000. Thus, replacing the existing tank with an elevated or taller gravity-fed tank is probably not justified. John Doe, Project Manager for XYZ, the operating contractor at the site, suggested that another alternative would be to totally bypass the surge tank and pump the water directly from the wells to the top of the air stripper. This suggestion deserves further consideration if the influent flow rate is expected to remain fairly constant and the well pumps can provide the additional head. This would eliminate the need for the transfer pumps, and could result in power and maintenance savings. A new section of piping would have to be installed. Also valves would have to be installed to allow the operator to either route the water directly to the strippers, or to route the water to the surge tank. This may also require that a new system of interlocks be designed and installed. The savings would be in reduced maintenance and power savings from reduced head loss. The savings in power from reduced head loss would be at least the same as those from using an elevated or taller surge tank ($7,000)

4.2.2.2. Extraction Pump Longevity. The rate at which the extraction pumps are failing at the site appears to be excessive and poses a significant maintenance cost. The cause of the failures should be further investigated since there currently is inadequate data to determine the cause. The motor design may be inappropriate for variable frequency drive controllers. The alternating voltage as output by the controller may be too irregular. In addition, the long leads from controller to pumps may allow the development of overvoltages. Recommend that the manufacturer of the controller be contacted regarding the problem as well as the motor manufacturer. Analysis of the motor winding failure mode should be provided. Furthermore, suggest that, for the pump motors running at or near full frequency,

[1] Technology is the general action or process in place at the site. The technology is implemented by combinations of one or more components. Several technologies can be used simultaneously. Examples include Ground Water Extraction, Soil Vapor Extraction, Landfill Covers, etc. Components are pieces of equipment, facilities, or actions that serve a particular purpose to extract, contain, or treat the contaminants as part of an applied technology. Examples include wells, piping, air strippers, carbon treatment, thermal treatment units, a monitoring program, treated water discharge, etc.

the controller be bypassed (as long as some surge voltage protection is still provided) to allow the motors to use the line frequency directly rather than a recreated waveform.

4.2.2.3. Remote Pump Restart. Because of the frequent power disruptions (see Sec. 4.1.7.1, Recurring Problems or Issues), modifying the control of the extraction wells, to include an remote VFD pump re-start option should be considered. Although it is recognized that in some cases the cause of the pump shutdown should be confirmed, if the operator has clear indication that power fluctuations occurred at the time the pumps went down, then an inspection is not necessary and the remote restart capability could be used. This would potentially save 100 person-hours per year (25 outages times 4 hours per restart).

4.2.2.4 Conduit Protection. Seasonal cattle grazing is allowed in the site area. Conduit to the extraction well heads have been severed by cattle rubbing up against the well heads. Reinforcing the attachment of the conduit to the well head should be considered to make the well heads 'cattle-proof'.

4.2.3. Operating Parameter Changes

4.2.3.1 Air Stripper Operation. Currently two blowers, with a third on standby, are providing air to the two air strippers. The air strippers were designed to reduce TCE levels from 250 ppb to 0.78 ppb. The number of gas transfer units (N) is a measure of the capacity to remove contaminants by air stripping. Given information about the contaminant (including concentration), packing material, and the air and water flow rates both the required and actual (operational) number of gas transfer units can be estimated. The higher the N, the more ability the stripper has to remove contaminants. As currently configured, the air strippers are estimated to offer a 5.7 N capacity. The current level of TCE in the influent is about 20 ppb. The Ns needed to reduce the TCE levels from 20 ppb to 0.78 ppb are estimated to be 3.4, less than what is currently available. Thus, the strippers have excess capacity to remove TCE. Reducing the depth of the packing would result in lower energy consumption by the blowers and estimated electricity savings of about $300 per month. The cost of removing packing would have to be recovered within a relatively short period of time to justify the change. The cost (mostly labor) of removing the packing was not estimated. Reducing the air input to the strippers should also be evaluated. If the air rate is reduced by half with, the input concentration of TCE at 20 ppb, and the required effluent concentration remaining at 0.78 ppb, an estimated capacity of only 0.8 Ns are needed. Performance curves should be obtained from the manufacturer to determine if the blower will operate efficiently and correctly at the reduced rate. This would also result in lower energy consumption. Using a combination of both reduced airflow and reduced packing should also be evaluated. If both the airflow rate and the packing height can be reduced, a single blower may be able to provide sufficient air to both air strippers at the lower required pressure. The N values are based on a flow rate through each air stripper of 13,425 cfm (from the AE design analysis) and 4-inch of water pressure drop across the packing (observed during the site visit). If the actual values are different, the above figures need to be adjusted accordingly. Finally, if at a later time the influent concentration approaches the concentration that can be reinjected, it may be possible to strip only a portion of the water and recombine it with the other portion for reinjection.

4.2.3.2. Extraction Rates. If groundwater modeling and water level data indicates that capture of the plume can be accomplished at reduced extraction rates, then reducing the groundwater extraction rate should be considered. In extraction well E-9, where galvanic corrosion has been observed, the flow rate was decreased from 800 to 300 gpm, and capture of the plume has apparently not been compromised. As stated above, wells E-1 and E-5 (and perhaps others) may not be needed at all. (See above paragraph on Subsurface Performance and Response.) Reducing the flow rates can directly save power costs for the well pumps, reduce pump repair costs, and perhaps allow changes in the air strippers that further save power. Taking these two wells off line would save an estimated $49,000,not counting savings in well and pump maintenance. In order to more accurately evaluate the extraction system, recommend that spinner logging of the multiple-screened-interval wells (e.g., E-6, E-13) be considered. A spinner log allows one to identify the proportion of flow contributed from each depth interval. There are no identifiable cost savings associated with this, but the data allows improvement in the computer model used in design and optimization of the system. Finally, the removal of accumulated sediment should be conducted before it reaches a thickness equal to 50% of the screened interval, say at 20% of the screened interval.

4.2.3.3. Sequestration of Inorganic Precipitates. SHMP is being fed up stream from the air strippers at a concentration of 8 mg/L to prevent deposition of solids in the piping and the injection wells. Metcalf & Eddy performed the original sequestrant study, in consultation with Calgon, the SHMP supplier, to determine the concentration of SHMP that should be added to the influent. The annual cost for SHMP has ranged from $175,000 to $225,000. The Sequestrant Study Report should be reviewed again to assess whether it would be possible to reduce the dosage of SHMP and still control inorganic precipitates. If the concentration of SHMP could be reduced to 6 mg/L, costs for SHMP would be reduced by $50,000 annually. Note that the Sequestrant Study Report was not available for the RSE team to review.

4.2.3.4. Alternatives to SHMP. The use of carbon dioxide to control precipitates (in place of SHMP) deserves further investigation. Carbon dioxide is stripped from the water in the air stripper. This causes the pH of the water to rise and subsequently causes calcium carbonate to precipitate. Feeding carbon dioxide replaces that which was air stripped and reduces the pH of water and can reverse or prevent precipitation of calcium carbonate, the primary inorganic precipitate. A preliminary cost estimate indicates that the capital costs of installing a carbon dioxide feed system (approximately $22,000) are well below the annual costs for SHMP. The annual costs for a carbon dioxide feed system was estimated to be $57,000 per year ($12,000 to lease a storage tank, $3,000 for electricity, and $42,000 for carbon dioxide). To further refine the cost estimate, the required dosage of carbon dioxide should be verified. To verify carbon dioxide dosage, a test should be performed using a sample of treated groundwater from the site. The test could be performed either at the site, or in a laboratory, and would involve adding carbon dioxide while monitoring pH. This test should be completed, and used to prepare a refined cost estimate for a carbon dioxide feed system. The preliminary estimate indicates cost savings of approximately $121,000 in the first year, and $143,000 per year for each year thereafter. The condition of the road serving the treatment plant may make delivery of carbon dioxide in typical tanker trucks difficult a few times during the winter/spring. Adding extra storage capacity for carbon dioxide, improving the road, or maintaining the SHMP feed system as a backup may be needed to assure adequate prevention of scale.

4.2.3.5. Monitoring Program.

4.2.3.5.1. Sampling Method. Currently over 40 wells are being sampled every 6 months. Sampling requires about 3-4 weeks to complete. Because of the distance to the water table, and purging requirements, it usually takes about a half a day to sample one well. Use of diffusion groundwater sampling devices would eliminate the need to purge wells during sampling, and should be considered. Diffusion samplers are generally polyethylene bags filled with de-ionized water and lowered into the screened interval by inert rope or wire. Contaminants diffuse through the polyethylene into the bags and over time concentrations inside and outside of the bag equilibrate. After some period of time the bags are retrieved, water is decanted into vials, packaged for shipment, and sent for standard chemical analysis. Studies by Vroblesky and Hyde ("Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water," Ground Water Monitoring and Remediation, Summer 1997, p. 177-184) have indicated that the recoveries of typical VOCs, including TCE, are very good and compare to the best of the traditional sampling methods. Assuming a reduction of three hours in sampling time per well, a two-person crew, and semiannual sampling of 45 wells, this would translate into a potential saving of 540 person-hours per year. Initially, however, a couple of studies may be required, including a study to determine the length of time needed to reach equilibrium (2-4 weeks) and a comparability study that would allow the determination of the changes in concentration due to the change in sampling method. Possibly, a study to determine precision using this sampling method should also be undertaken. The use of diffusion samplers will undoubtedly require regulatory approval.

4.2.3.5.2. Analytical Suite. Currently, the ground water and influent/effluent samples are being analyzed for the full analyte list by USEPA methods 8010 and 8020. A reduction in the suite of parameters being tested in groundwater samples should reduce analytical costs, and is strongly encouraged. Given the five years worth of sampling results now available, the site contaminants are well characterized and consist of only five parameters of interest; TCE, carbon tetrachloride, 1,1, DCA, and some detections of 1,2 DCE and chloroform. Some savings in costs (perhaps as much as 15-20%) particularly for validating the analytical results and for managing the data could be achieved if only these parameters were quantified. Methods 8010 and 8020 are now outdated. The use of method 8021 or 8260 should be considered. Replacing the 8010/8020 combination with a single method such as 8021 would cut costs by 15%. These would translate into total potential analytical savings of approximately $4,500 per year or more. Note that certain wells can be analyzed for the full list of VOCs at some interval.

4.2.3.5.3. Electronic Data Transfer for Analytical Data. Currently laboratory data must be manually entered into a database by the Operations staff. Since there are a considerable number of monitoring wells, it would save time if the contract included a requirement for the laboratory to provide the analytical data in a format compatible with that used by the Operations staff. This would result in a reduction in labor costs.

4.2.3.5.4. Regulatory Acceptance. The RSE team recognizes the difficulties in implementing changes to the permit under which the system operates and the costs for obtaining regulatory acceptance. If the changes to the monitoring program could be proposed as a package to the State of Utah, then some cost efficiency could be achieved.

4.2.3.6. Piping. Given the past problems with inorganic precipitates collecting at the injection wellhead valves, suggest that the head loss through the full length of the injection pipelines be compared with either initial head loss or that loss predicted in design. Although adequate velocities probably exist in the piping to prevent collection of soft scale at low points in the piping, encrustation may have occluded some of the piping.

4.2.4. Regulatory Changes. The Installation is in the process of re-evaluating the clean up goals and may seek a modification to the permit to less stringent risk-based objectives. The Installation has initiated a scope of work with an independent contractor to look at optimizing the treatment system and to explore alternatives to enhance the current technology. The study also includes a new look at risks posed by the ground water and addresses alternative action levels for the COCs. The RSE team supports these actions.

4.2.5. Recommended Studies outside the Scope of the RSE.

4.2.5.1. Recommended Studies. As stated above, the Installation and _____ District are currently re-evaluating the risk posed by the site in order to reconsider the cleanup goals. The RSE team concurs with this action which was outside the scope of the RSE. More detailed computer modeling optimization studies of the pumping system should be considered using the existing MODFLOW model and an algorithm such as MODMAN. In addition, the team recommends the spinner logging of wells with both shallow and deep screened intervals, re-evaluation of the SHMP dosage by an independent authority, the determination of the required dosage of CO_2 to control pH of the influent/effluent, and the studies necessary to support the conversion to the use of the diffusion samplers.

4.2.5.2. Estimated Costs for the Recommended Studies. Spinner logging of extraction wells with both shallow and deep well screens would cost approximately $7,000, based on costs obtained from Welenco, Inc. of Bakersfield, CA. The re-evaluation of the SHMP dosage could be done strictly through a review of the previous M&E/Calgon study or through a new study at cost comparable to the earlier study. The treatability study for the conversion to the use of CO_2 may be done at no cost by a CO_2 vendor (based on contacts made by RSE team members). The diffusion sampler studies would potentially require duplicate analysis for at least one round at a possible analytical cost of $7,500-10,000 and approximately 90 person hours.

5. Summary. In general, the RSE team found the system to be well maintained, and operating as intended. The system design appears to have been appropriate given what was known about the site at the time of construction. The system performance appears to be protective of the public and the environment. Reductions of contaminant concentrations in ground water have been observed, but the drop in concentrations has slowed, consistent with the normal behavior of ground water extraction systems. A number of changes in the remedial approach or the operation of the system are suggested to possibly reduce future operations and maintenance costs. These changes are listed below. Rough estimates of potential savings are shown in parentheses, where available.

1) changing either the dosage of SHMP or using CO_2 to control inorganic precipitate formation ($50,000-143,000 annually),

2) defining source areas and removal of residual mass from the vadose zone undertaken if determined to be a continued threat to ground water,

3) continuing to evaluate alternate cleanup levels and the current risk posed by the contamination (very large savings possible),

4) reducing or eliminating flows from selected wells, such as E-1 and E-5 ($49,000 annually); and determining flow contributed from various depths in the multiple-screened-interval extraction wells,

5) evaluating the compatibility of the submersible pump motors with the current variable frequency drive controller equipment, possibly bypassing the VFD controller for wells that are normally running at full frequency (possibly $38,000 per year if pump motor maintenance interval can be doubled),

6) using diffusion samplers instead of traditional monitoring well sampling techniques ($30,000 annually),

7) consider pumping water directly from the wells to the air stripper and bypassing the surge tank and transfer pumps (at least $7,000 annually, not considering the reduced maintenance of the pumps and the replacement costs for the pumps at some point in the future),

8) monitoring head losses in injection well piping to determine the degree of scaling/precipitation, if any,

9) switching to current analytical methods, reducing the number of analytes, use electronic data transfer ($4,500 annually),

10) modifying the air stripper packing and blower configuration to account for the significantly lower than anticipated influent concentrations ($3,600-4,000 annually),

11) adding a remote pump restart capability (perhaps $6,000 in labor cost, annually), and

12) adding more protection for the conduit to the extraction well heads to avoid damage from cattle (perhaps a thousand dollars annually).