TECHNICAL MEMORANDUM REMEDIAL STRATEGIES FOR VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER KANSAS CITY MO

9/29/2000

CH2M HILL

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Remedial Strategies for VOCs in Groundwater

PREPARED FOR: AFBCA and AFCEE

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DATE: September 29, 2000

Introduction

CH2M HILL recently completed a Remedial Investigation (RI) at the former Richards-Gebaur Air Force Base (RGAFB), Kansas City, Missouri. Of the sixteen sites that were evaluated, five were found to have groundwater contaminated with volatile organic compounds (VOCs). The principal VOCs consist of trichloroethene (TCE), cis-1,2 dichloroethene (DCE), and vinyl chloride (VC).

The five sites with VOCs in groundwater are:

1. SS 003 (Oil Saturated Area)
2. SS 006 (Hazardous Materials Storage Area)
3. SS 009 (Fire Valve Area)
4. CS 004 (Waste Acid Tank)
5. ST 005 (POL Yard)

For ease of reading, we have provided as Appendix A a review of the current regulatory framework governing remediation of the sites; a summary of the current understanding of geologic and hydrogeologic conditions at the Base (including a summary of aquifer test results); and a risk evaluation for VOCs in groundwater.

Appendix B contains several Figures that are referenced in the text contained in Appendix A. Figure 1 is a map of the Base that shows the relative positions of each site. Figures 2 through 6 are individual site maps that depict the locations of groundwater monitoring wells. Concentrations of VOCs detected in groundwater at concentrations above applicable action levels are indicated on the figures.

Problem Statement

Current concentrations of VOCs in groundwater at the five sites listed above exceed MDNR regulatory action levels. However, site geologic and hydrogeologic conditions are such that meeting site action levels would be exceedingly difficult given the present state of available remedial technologies. In addition, the low permeability of the subsurface formations and the natural salinity of the groundwater present at the Base and throughout the surrounding area indicate that potable use of groundwater is unlikely.

Given existing site conditions and the existing regulatory environment, what is the best strategy to address the VOCs-in-groundwater issue, given the Air Force's (AF) goal of achieving Last Remedy in Place (LRIP) by September 2001?

Several factors influence the selection of a groundwater strategy for the site. These include:

- site geology (shallow, fractured limestone or shale)
- hydrogeology (low hydraulic conductivity, low yield, seasonally perched water table)
- water quality (high salinity)
- water use (shallow wells not used for drinking water supply)
- future land use (residential use is preferred scenario)
- regulatory climate (all groundwater currently considered potential drinking water)
- AF schedule (short time-frame for instituting LRIP)

Of the above factors, the most significant in terms of meeting the LRIP schedule, is the regulatory environment. Any remedial action will need to be considered within this context.

The quality of the AF-MDNR/EPA relationship is important in addressing this factor. At Richards-Gebaur, a strong rapport exists between AF and the regulators. This means that decisions can be made quickly in a spirit of co-operation, minimizing potential delays resulting from miscommunication and misdirection.

Solution Approach

Several strategies exist for resolving the VOCs in groundwater problem at the site. The principal strategies include the following:

- No Remedial Action
- Monitored Natural Attenuation (MNA)
- Passive and/or Active Treatment Technologies

It is CH2M HILL's understanding that the AF prefers obtaining the no-action alternative for contaminated groundwater at the Base, and that the least-favored approach involves the time-consuming design, testing, and installation of passive or active remediation systems.

To arrive at the best strategy for resolving the VOCs-in-groundwater problem, it is necessary to examine the above strategies from several perspectives, particularly the ability of the strategy to be implemented by the 2001 LRIP timeline, the likelihood of regulatory acceptance, technical practicability, and the relative costs of implementation.

CH2M HILL proposes the following groundwater strategy for the site.

1. Use the substantial body of knowledge regarding Base geology, hydrogeology, aquifer suitability, and human health risk, to develop a strong position for implementation of the No Remedial Action Strategy to submit to the MDNR
2. Use the current regulatory climate that indicates that some flexibility in clean up goals may be achieved. This potential shift is exampled by proposed Senate Bill 334, which requires the State's Clean Water Commission to establish procedures to determine on a case-by-case basis if remediation of groundwater is appropriate. We propose leveraging this pending legislation as a means of convincing the MDNR of the appropriateness of the No Action Strategy.
3. Leverage the current goodwill between the AF and MDNR to achieve the No Action strategy.
4. Concurrently, as a contingency, develop the technical approach needed to implement the Monitored Natural Attenuation Strategy.
5. Use the feasibility study pathway to document the difficulty, uncertainty and cost benefit analysis of implementing passive or active remediation at the site.

Given the time-critical nature of the site remediation, it is important to develop each strategy in parallel, rather than sequentially, to maximize the likelihood of achieving the September 2001 LRIP target.

The developing groundwater strategy for the site should be considered a living document that will need to be modified and refined based upon our scheduled October meeting with the AF. After our meeting, which will fully involve the entire AF team, CH2M HILL will finalize the forward-looking strategy document that is created.

In order for the AF to have a clear understanding of the potential ramifications of each strategy, detailed descriptions of the three potential strategies are provided in the following sections.

No Action Alternative

The No Action alternative is plausible for the five sites with groundwater contamination because of the geological and hydrogeolgical conditions that prevail at the Base. In addition the saline nature of the groundwater would likely render shallow groundwater non-potable even in the absence of site contaminants. The current lack of viable exposure pathways from contaminated groundwater to human and environmental receptors, is further evidence of the reasonableness and viability of the No Action Alternative.

Because of the low yields and marginal water quality found at each site, it is considered unlikely that water supply wells would be installed at these locations to withdraw water from the shallow overburden or near-surface bedrock units. This contention is supported by the fact that only six wells currently operate within a 5-mile radius of the Base, and each of these is drilled over 200 feet deep in order to obtain water of sufficient volume and quality. Furthermore, State regulations require a minimum of 40 feet of surface casing to be installed when constructing water wells in the vicinity of the Base, effectively precluding the inflow of shallow contaminated groundwater from the sites into a new water well.

Conversely, MDNR and EPA have a mandate to protect groundwater, including requiring cleanup of contaminated groundwater. The State has a groundwater antidegradation policy and a track record of enforcing groundwater remediation regardless of the results of site-specific risk assessments

The following sections further explore the viability of successfully making a No Action argument for contaminated groundwater at the Base. Two strategic options for pursuing No Action are examined and a preliminary schedule for implementing the recommended approach is provided.

Strategic Options

Options available to AF to pursue a No Action alternative appear to be limited to obtaining a Technical Impracticability waiver, or pursuing a demonstration of negligible impact under the State Water Quality regulations, specifically section 10CSR 20-7.015 (7)(F).

Since recent investigations revealed the presence of contaminants at concentrations resulting in risks in excess of applicable State water quality standards (see Appendix A), the only paths forward toward No Action would be (1) where AF convinces the State the contamination cannot be remediated; or (2) where AF convinces the State that the contamination is not causing a significant impact on, and is unlikely to cause a significant future impact on, any human or environmental receptor.

Pursuing either option will require AF to expend considerable effort both in making the technical demonstrations needed to successfully support these requests, and the negotiations with the MDNR and other potential stakeholders. The chances of success with either approach is uncertain.

Option 1: Technical Impracticability Waiver

Technical impracticability (TI) waivers were introduced by the EPA to allow parties pursuing groundwater remedial actions to stop or to reduce efforts when it was demonstrated that no further reduction of contaminant levels could be achieved. Sites where TI waivers have been granted almost exclusively are sites where dense non-aqueous phase liquids, or DNAPLs, cannot be removed from the subsurface using current technology.

However, even these TI waivers are not strictly No Action: they still require a lengthy period of aggressive attempts to remediate the subsurface conditions to acceptable levels prior to the waiver being granted. Furthermore, they include long term monitoring and re-evaluations of the waiver every few years to assess whether or not a new technology might now allow the complete remediation of the site.

To pursue this option, AF would probably have to initiate some form of remedial action to gather the data needed to support a TI waiver. In other words, an attempt at remediation is necessary to prove that such remediation isn't feasible. However, because the relatively low contaminant concentrations at the five sites do not indicate the presence of DNAPLs, these sites may be considered inappropriate for this form of regulatory relief.

Option 2: Demonstration of Negligible Impact on Water Quality

A demonstration of negligible impact on water quality under the State rule on Effluent Limitations for Subsurface Waters (10 CSR 20-7.015 (7)(F)) might allow AF relief from a costly remedial action which would have little chance of success at ever cleaning up groundwater to State standards.

This demonstration considers the impact on beneficial uses, existing and potential, of the contaminated groundwater. The demonstration, however, must show that the impact will not pose an unreasonable risk to the public. The site-specific risk assessment indicates that all five sites pose risks in excess of Missouri cleanup guidelines. Therefore, making a successful demonstration to support the contention of acceptable or reasonable risk will be difficult, especially considering that all groundwater is viewed by the State as a potential drinking water supply.

Such a demonstration would need to focus upon the integrity and reasonableness of considering groundwater ingestion a complete exposure pathway, as opposed to an *a priori* acceptance of the State's position that all groundwater is a potential source of drinking water. Because the contaminated sites at the Base are underlain by low permeability geologic units that clearly do not yield significant amounts of water to users or potential users, it should be possible to demonstrate that the contaminated sites have a negligible impact on beneficial use.

However, it should be recognized that this argument could well prompt the State into requiring deed restrictions or other administrative assurance from the AF that no-one would be allowed to drill into the contaminated sites and install drinking water wells. Leaving onsite any contaminants at concentrations in excess of the State water quality standards also means that the State would probably require AF to implement a long-term monitoring program for the residual contamination at each site to assure the public that no unacceptable risks remain. Such deed restrictions would also adversely affect the ability of the sites to be developed for unrestricted use.

In summary the following regulatory obstacles will need to be overcome for the negligible impact option to be successful:

- all groundwater is viewed by the State as a potential drinking water supply
- the regulations dictate that the State cannot accept any alternate concentration limits that would impair beneficial uses of the aquifer; therefore, deed restrictions might not suffice or be possible
- the State has shown a reluctance to grant relief from requirements to remediate to drinking water standards, regardless of the results of a site specific risk assessment

Recommendation

CH2M HILL recommends pursuing Option 2 because arguing for and obtaining a TI Waiver would in all likelihood require onsite demonstrations of the impracticability of several remediation options. This is therefore the higher cost alternative, and has the longest implementation schedule.

Option 2 while difficult, has the higher chance of meeting the September 2001 LRIP goal, and is also less costly. Option 2 leverages the AF's strong relationship with MDNR at a time when legislation is being written that offers some relief from the conservative groundwater action levels currently in place. In addition, MDNR is well aware of the site-specific geologic and hyrdogeologic constraints that are characteristic of the Base, and have indicated to the BCT that they recognize that consumptive use of groundwater represents a highly unlikely and unreasonable current or future exposure scenario.

Pursuit of the negligible impact option could easily parallel the early stages of a MNA feasibility demonstration for VOC-contaminated groundwater. Proving the viability of MNA also consists of compiling sufficient technical data to support a minimal impact argument. This approach is discussed in further detail below.

Preliminary Schedule

Should AF wish to pursue a parallel course of demonstrating negligible impact on beneficial use and demonstrating the applicability of MNA for the groundwater contaminants, the following steps must occur to maintain a September 2001 LRIP target:

- Week 1 – initiate discussions with state personnel to assess agency acceptance of both options
- Week 2 – prepare reports indicating successful site characterization, including delineation of nature and extent of contamination, results of risk assessments, and understanding of site hydrogeology
- Week 3 – Meet internally with AF personnel to finalize reports prior to submittal to MDNR and EPA
- Weeks 4 to 7 - Regulatory review of documents
- Week 8 – Request meet with State to arrive at remedial strategy decision
- Weeks 9 to 32 – Long-term remedial action design, planning and construction, as necessary
- Weeks 33 to 52 – Initial performance monitoring and demonstration that preliminary results are consistent with the site conceptual model

Monitored Natural Attenuation (MNA)

As mentioned previously, the MNA remediation approach would be developed in parallel with pursuit of the negligible impact No Action remedial alternative because this strategy optimizes the ability of the project to stay on track for the September 2001 LRIP target. However, it is recommended that the AF pursue the MNA alternative with the regulators only if the No Remedial Action strategy proves futile. The proposed approach for demonstrating the applicability of MNA for groundwater contamination is described below.

Description

MNA is a plume management strategy that relies upon in-situ physical, chemical, and biological processes to attenuate groundwater contamination to acceptable levels. Natural attenuation of contaminants in groundwater is the combined effect of several naturally occurring mechanisms—dispersion, dilution, sorption, abiotic oxidation, hydrolysis, volatilization, and biodegradation—that reduce the concentration of dissolved-phase contaminants. These mechanisms include both destructive and nondestructive processes, with biodegradation being the most important destructive process. MNA is often implemented as the final remedial component at sites such as Richards-Gebaur AFB where the contaminant source has been removed and only dissolved-phase contamination persists.

Chlorinated hydrocarbons, such as TCE, may biodegrade by three different pathways: through use as an electron acceptor, through use as an electron donor, or through co-metabolism (Wiedemeier et al., 1998).

The most common process in anaerobic groundwater environments is for the chlorinated hydrocarbon to be used as an electron acceptor through reductive dechlorination. When the chlorinated hydrocarbon is used as an electron acceptor, an electron donor such as native organic carbon or anthropogenic carbon from fuel spills, landfill leachate, or other sources must be present for the reaction to take place. Reductive dechlorination of chlorinated solvents yields an accumulation of daughter products such as cis-1,2-dichloroethene (DCE), and vinyl chloride (VC), and increased levels of chloride in the plume.

Approach

Both AFCEE and EPA have published MNA guidance documents. These include AFCEE's *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (Wiedemeier, et al., 1998), and EPA's OSWER Directive *Use of Monitored Natural Attenuation AT Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (EPA-OSWER, 1999).

Consistent with the guidance, the first step toward demonstrating the efficacy of MNA is to conduct an initial screening of the site. The preliminary screening involves comparing available site data to a list of criteria, provided in the EPA protocol, for suitable site conditions. Points are assigned based on how closely the site matches the ideal conditions for natural attenuation.

The screening process is designed to recognize geochemical environments where reductive dechlorination is plausible. Preliminary sampling for MNA indicator parameters has already been conducted at the Base and the results indicate that some level of reductive dechlorination is occurring. However, a complete screening in accordance with EPA protocol would require some additional data collection, as described below.

In addition to the screening process, an examination of historic contaminant concentrations, an estimation of the areal extent of the contaminant plume, and an evaluation of plausible future contaminant migration pathways must be conducted. This information is needed to determine whether natural attenuation processes will be capable of attaining site-specific remediation objectives in a reasonable time period compared to other alternatives. Based on the available site data, it is evident that daughter products exist at three of the five sites. That is, reductive dechlorination has already occurred at the Base.

Once it has been determined that MNA is a viable remedial alternative for VOCs in groundwater at the Base, a Long Term Monitoring (LTM) Plan needs to be prepared. The LTM plan should identify appropriate monitoring well locations, performance evaluation criteria, and describe site-specific groundwater sampling techniques such as low-flow sampling. The following data is typically included in the LTM plan:

- Contaminant Analytical Data – this involves an analysis of historical trends for site contaminants at specific wells, such as observing a reduction in contaminant concentrations along the flowpath downgradient of the apparent contaminant source, and observing a reduction in the total mass of contaminants present.
- Geochemical Analytical Data – this includes an evaluation of key geochemical indicators including O_2, NO_3^-, Fe^{+2}, Mn^{+2}, SO_4^{-2}, methane [CH_4], TOC, CO_2, and alkalinity. The purpose of these analyses is to show that decreases in contaminant and electron acceptor concentrations can be correlated with increases in metabolic byproduct concentrations, thereby providing evidence of biodegradation. For chlorinated hydrocarbon attenuation, the evaluation would also examine if decreasing parent compound concentrations can be correlated with increasing daughter compound concentrations.
- Direct Microbial Evidence – these tests consist of sampling and identifying the types of microorganisms present at the site that would cause reductive dechlorination, or demonstrating biodegradation through laboratory microcosm studies.

The EPA and AFCEE protocols require that the first two lines of evidence or the first and third lines of evidence be evaluated, at a minimum, to document natural attenuation.

The first line of evidence is simply an observed reduction in the contaminant concentrations at the site, and does not prove that contaminants are being destroyed through reductive dechlorination. The second and third lines of evidence are needed to show that contaminants are being biodegraded, not just diluted. The second and third lines of evidence also provide biodegradation rate constants that can be used in fate and transport modeling to predict downgradient contaminant concentrations and assess risk at the compliance points.

In the event that MNA is pursued as an alternative for the Base, one option to consider is enhancement of the biodegration process through addition of an electron donor, such as methane. This process is referred to as co-metabolism and involves the use of a primary substrate such as methane to produce enzymes which are capable of degrading a secondary substrate, such as TCE, when the second substrate on it's own does not have sufficient energy to sustain the microbial population.

The addition of methane or methanol supports methanotrophic activity, which has been shown to effectively degrade chlorinated solvents through co-metabolism. Although toluene, propane, and butane are used to stimulate a different class of microorganisms, not methanotrophs, they have been also used to successfully support co-metabolism of TCE. Application of the amendments typically involves injection of a liquid containing dissolved methane, nutrients, etc. into the groundwater through monitoring wells. Again, because of the documented low permeabilities of the overburden at upper bedrock units, such an approach may prove to be unsuccessful.

Data Requirements

The majority of the required data necessary to evaluate MNA as a potential alternative has been collected at each of the five sites with groundwater contamination. However, additional data will be required to construct a defensible and compelling argument that natural attenuation of chlorinated hydrocarbons is taking place at Richards-Gebaur AFB.

The following additional groundwater parameters need to be evaluated: Carbon dioxide, total organic carbon, Redox, and Hydrogen

Schedule

In order to implement this alternative by September 2001, the following tasks will need to be completed:

- Collecting another round of groundwater data from existing monitoring wells including all parameters necessary to evaluate reductive dechlorination at the site (a quarterly groundwater sampling event is currently scheduled for October 2000)
- Conducting an initial screening of natural attenuation at each site following recommended EPA/AFCEE protocols (December 2000)
- Prepare a Long Term Monitoring Plan (LTM) for each site based upon the results of the above tasks (January 2001)
- Submit AF-approved LTM to MDNR and EPA for review (February 2001)

Potential Treatment Technologies

To allow for the eventuality that the No Remedial Action and MNA groundwater strategies are unsuccessful with the regulators, CH2M HILL has developed a list of remediation alternatives that we believe have the highest potential for successful application. The screening of these alternatives took into consideration the complex geology and hydrogeology of the site, and the ability for a particular remedial alternative to be implemented by September 2001.

This section presents three potential treatment technologies for remediation of VOC-contaminated groundwater at the Base: Permeable Reactive Subsurface Barrier, Dual Phase Extraction, and Six-Phase Heating. These technologies, together with MNA, are the current industry choices for remediation of chlorinated compounds in groundwater, given the subsurface conditions present at the Base.

However, it is our opinion that implementation of the screened alternatives would be unreasonably expensive and have a low likelihood of success in reducing contaminant concentrations to below drinking water standards.

Treatment Technology Descriptions

Permeable Reactive Subsurface Barrier

This alternative involves the use of a permeable reactive subsurface barrier with zero-valent iron (Fe^0) as the reactive substrate to treat the dissolved chlorinated compounds found in groundwater at the site. This technology has undergone thorough laboratory research, pilot testing, and is currently being used as a full-scale remedial technology at a number of sites throughout the country.

The technology is based on the oxidation of the zero-valent iron resulting in the reduction of the chlorine compounds. The reactive subsurface barrier is designed to provide sufficient contaminant residence time for intermediate products, such as cis-1,2-DCE and vinyl chloride, to fully degrade to ethene and ethane.

A permeable reactive barrier is designed to intercept groundwater flow and treat the contaminant in this case through chemical reaction with the zero-valent iron (Fe^0). Two basic designs have been used thus far, a funnel and gate system where the contaminant plume is captured and directed toward a permeable section of the barrier containing the reactive iron, and a continuous trench set up where the entire trench is permeable and contains the reactive iron. However, this approach is probably not viable in areas of the site where groundwater is encountered within the fractured limestone unit.

Dual Phase Extraction

Dual-phase extraction (DPE) is a technology that uses a high vacuum system to simultaneously remove various combinations of contaminated groundwater, separate-phase petroleum product, and contaminated vapor from the subsurface. Extracted liquid and vapor are treated and collected for disposal.

Dual phase extraction involves removal of soil pore water to a desired depth followed by extraction of soil pore gas within the vadose zone, which has been enlarged by the dewatering. In addition, dual phase extraction captures dissolved phase contaminants through removal of the pore water and enhances biodegradation by providing aeration to the vadose zone.

This approach can be enhanced by the use of hydrofracturing to increase the permeability of low permeability formations. However, it is unlikely that hydrofracturing would improve the permeability of the units at the Base enough to significantly impact contaminant removal.

Six Phase Heating

Six-phase electrical current heats the subsurface in order to enhance volatilization and biodegradation of contaminants present in the groundwater and soil. The increase in the rate of contaminant removal is related to the temperature dependency of several biological processes and the physical and chemical properties of the constituents.

To implement the technology, electrodes are placed in the ground in the contaminated region and a voltage is applied. Electrical current conducts through the soil, heating the soil resistively. The technology can be controlled to heat and maintain any temperature below the boiling point of water. Heating to 20°C to 40°C enhances biodegradation and volatilization. Heating to 100°C volatilizes contaminants and water (producing steam) in the soil, effectively steam-stripping contaminants in situ. The volatilized contaminants and steam then are removed by soil venting and are treated above ground as necessary.

A unique aspect of SPSH is the patented use of multiphase 60-Hertz (Hz) electricity to create a relatively even heating distribution. Although 60-Hz systems are generally desirable because of their low capital cost and the availability of robust, large-scale systems, 60 Hz typically has not been used because of the tendency to prematurely dry the soil adjacent to the electrode. When the soil dries, it becomes very resistive, preventing dissipation of the power into the bulk soil region to be treated.

With the SPSH system, standard three-phase electricity is converted to six electrical phases, with each phase being applied to a separate electrode placed in a hexagonal pattern. Because each phase is 60 degrees out of phase with the adjacent phase, every electrode fires to every other electrode and to a central neutral electrode, creating a more uniform heating pattern that potentially enables larger volumes of soil to be treated with fewer electrodes.

Screening of Potential Treatment Technologies

The following section presents a preliminary screening of the potential treatment technologies discussed above. In Table 1, the treatment alternatives are screened against the following three criteria: the overall effectiveness of the alternative, the implementability of the alternative, and the relative cost to implement the alternative.

Effectiveness pertains to the capability of the alternative to treat the estimated volumes of contaminated groundwater and to prevent or minimize migration of the groundwater. Implementability refers to actual construction of the alternative, including the time needed to implement the alternative. Relative cost considers both capital and operation and maintenance costs of the proposed alternative.

Table 1 – Screening of Potential Alternatives

Remedial Alternative	Overall Effectiveness	Implementability	Relative Cost
Permeable Reactive Subsurface Barrier	Treatment will be slow due to low hydraulic conductivity	Involves trenching, and has a moderate level of difficulty for implementation. Would not apply to areas where contaminants exist in fractured rock.	Moderate
Dual Phase Extraction	Likely to have low radius of influence due to tight soils. Likely require tighter well spacing.	Involves well and vacuum system installation, more difficult to implement. Treatment of water and off gas required.	Moderate – High
Six Phase Heating	SVE may have low radius of influence due to tight soils.	Involves installation of heating and SVE systems, more difficult to implement. May be difficult to capture off gas contaminants.	High

Discussion

Results of the preliminary screening exercise indicate that all three active treatment technologies are constrained by the geology and hydrogeology at the Base. In addition, because the sites requiring remediation are relatively small and are not connected, they would require separate systems to be installed. Also, each of the alternatives described would require pilot testing prior to full-scale implementation.

If a Permeable Reactive Subsurface Barrier was selected, it would need to be placed in an area where a dominant groundwater flow pattern has been demonstrated. Consequently, it would not be applicable to the fractured flow regime that occurs in the limestone bedrock at the Base. However, one advantage is that reactive barriers are a passive remediation option with limited maintenance and no treated waste disposal, both of which reduce cost.

Both Dual Phase Extraction and Six Phase Soil Heating would involve optimizing groundwater and soil gas flow within the clay overburden and limestone or shale bedrock. Because of the low permeability site characteristics, implementation of either of these two technologies at the Base would be prohibitively expensive.

Data Needs

Review of the June and August 2000 data indicates that some of the data necessary to evaluate the potential alternatives discussed above is currently available. However, in order to fully evaluate the effectiveness of these technologies under site conditions, it is likely that site-and treatment-specific pilot studies would need to be conducted.

Required data to support evaluation of a Permeable Reactive Subsurface Barrier alternative would include: degradation rates; groundwater flow rates through the barrier; and an assessment of the ability of the barrier to plug or lose reactivity quickly. The data will also be used to calculate required residence time in the treatment zone and, therefore, the required thickness of the reactive zone.

A Dual Phase Extraction pilot study would require the following data: grain size analysis, vacuum pressures, fluid flow rates, contaminant removal capacity, and enhanced biodegradation rates. This data would be used to configure well spacing, blower sizes, and off-gas treatment options.

Data collected during the Six Phase Heating pilot test would include: grain size analysis, heating capabilities, vacuum pressures, flow rates, and enhanced volatilization and biodegradation rates. This data would be used to configure well and electrode spacing, optimal operating temperatures, blower sizes, off-gas treatment options, and health and safety issues.

Schedule

In order to implement any of these alternatives by September 2001, the following tasks would need to be completed:

- Collecting additional site data, and performance of a detailed feasibility study
- Receiving regulatory approval
- Designing, installing, and operating pilot tests
- Designing a full-scale remediation system
- Obtaining regulatory approval of final design
- Selecting by bid a remedial contractor
- Installing approved treatment system

The exact timeline for implementation of one or more of the remedial alternatives evaluated is difficult to determine. However, given the need for performance of a detailed feasibility study, regulatory review, the need for pilot testing and contractor bid solicitation and selection, it is unlikely that a final remedy would be in place by September 2001.

APPENDIX A

Regulatory Framework, Site Conditions and Risk Assessment Summary

Regulatory Framework

Current Conditions

The Missouri Department of Natural Resources (MDNR) considers groundwater to be Waters of the State. Waters of the State are protected through an antidegradation policy detailed in the Missouri Water Quality Standard (10 CSR 20-7.031(2)). Standards for groundwater are defined in Column VII of Table A of the Missouri Water Quality Standard (10 CSR 20-7.031).

MDNR has always had avenues to approve alternate water quality standards For example, 10 CSR 20-7.031(5)(D) states "For aquifers in which contaminant concentrations exceed Column VII criteria or other protection criteria, and existing and potential uses are not impaired, alternative site-specific criteria may be allowed." To allow alternative criteria, it must be demonstrated to the Water Pollution Control Board that the alternative criteria will not impair existing and potential uses in accordance with the factors and requirements of 10CSR 20-7.015(7)(F). To our knowledge, there is no documented case where the use of alternative criteria has been granted by the Water Pollution Control Board.

Recent Developments

During the 1999 legislative session, the Missouri General Assembly passed Senate Bill 334, which was signed into law on August 28, 1999. This law requires MDNR to establish procedures for risk-based groundwater remediation through the rulemaking process. The new law is contained in the Missouri Revised Statutes Chapter 644 Water Pollution Section 644.143.

A draft of the proposed rule was submitted to interested stakeholders for review and comment on September 5, 2000. The purpose of the rule is to codify the allowances and limitations for risk-based cleanup projects involving groundwater. The rule further defines the procedures for obtaining alternative cleanup criteria under the Missouri Water Quality Standard 10 CSR 20-7.031(5)(D). Unless site-specific alternative groundwater cleanup standards are approved by the procedures in the proposed rule, the values in Table A of the Missouri Water Quality Standards remain the cleanup standards for groundwater. Hopefully there will be some changes in the final rule; however, we expect that the vast majority of the elements contained in the draft will make it into the final rule.

Based on the eligibility requirements defined in the proposed rule, RGAFB appears eligible for alternative cleanup levels (ACLs). There is an application process and an Application Fee of $1,500. Upon acceptance a site must enter into a groundwater remediation oversight agreement with MDNR and submittal and approval of a Groundwater Remediation Plan is required. The purpose of the plan is to present the basis for ACLs. Furthermore, ACLs can only be requested at sites where it can be demonstrated that the plume will not migrate beyond the boundaries of currently contaminated properties. MDNR will also not approve ACLs until all institutional controls restricting groundwater use are in place.

The proposed rule allows for the development of risk-based cleanup levels to serve as ACLs, but calculating these must be done in accordance with Missouri Department of Health (MDOH) methodology. Currently the rule states that the methodology presented in the United States Environmental Protection Agency (USEPA) Risk Assessment Guidelines for Superfund (RAGS), is required. The rule allows for altering the point of compliance (POC). Previously the MDNR considered the POC to be the contaminated groundwater beneath the site. This is still the POC if there are no MDNR-approved institutional controls (ICs) in place. If MDNR-approved ICs are in place, then the POC can be established at the property boundary or at the property boundaries of adjacent sites currently overlying the contaminant plume.

Monitored Natural Attenuation (MNA) can be used under the draft proposed rule as long as the following requirements are met:

- Implementation of source control measures
- Implementation of durable ICs preventing the usage of groundwater
- Demonstration that the plume is stable and will not migrate horizontally or vertically
- Identification of the natural attenuation processes that are reducing contaminant levels
- Demonstration of the rate of attenuation
- Implementation of a detailed monitoring program that includes quarterly sampling for 2 years after the approved ACL is achieved throughout the plume

Prior to receiving approval for implementation of MNA a draft plan for a contingency remedial technology must be submitted and approved by MDNR.

Conversations with the MDNR indicate that MNA for chlorinated hydrocarbons in groundwater has been proposed at several sites in Missouri, particularly under the Missouri Voluntary Cleanup Program (VCP). To date no site has made it completely through the process and obtained authorization for use of MNA where an impact to groundwater from chlorinated hydrocarbons is involved. According to MDNR, this is not because they are opposed to the idea, but rather because the modeling required to demonstrate an attenuation rate is a lengthy process, as indeed is MDNR's review. MDNR currently has a minimal staff capable of providing an adequate review of modeling data.

Though the proposed rule is currently only in draft form, it is likely that it will be final sometime next year. Therefore, it is CH2M HILL's opinion that pursuit of MNA at the RG-AFB would require ICs preventing the future use of groundwater, and implementation of a long-term groundwater monitoring program.

Summary of Site Conditions

Soils

The unconsolidated surficial materials consist of red-brown residual clays containing abundant chert fragments derived from in situ weathering of the near-surface limestone bedrock. At higher elevations, the residual clays are sometimes in turn overlain by wind-blown silt deposits. The unconsolidated materials overlying the bedrock range in thickness from zero to 20 feet thick (Gentile, 1998). The soils belong to the Macksburg-Urban Series and are characterized as poorly drained silt and silt-clay loams (Versar, 1996).

Geology

The geology at Richards-Gebaur consists of interbedded limestones and shales belonging to the Kansas City Group of the Missourian Series, Pennsylvanian System. The uppermost bedrock unit present at these sites is the Argentine Member of the Wyandotte Formation which crops out at higher elevations on the Base. It consists of light gray limestone characterized by thin, wavy bedding, and is approximately 30 feet to 35 feet thick. Exposed Argentine limestone develops solution cavities, and existing joints can be enlarged to several feet in width. The solution-widened joints extend throughout the Argentine and are commonly filled with red clay and chert fragments. The Argentine underlies site SS 006.

Beneath the Wyandotte Formation (Argentine Limestone) is the Lane Formation. The Lane Formation consists of a medium-gray to bluish-gray shale that is commonly silty to sandy in the upper portion. The Lane Shale is typically 25 feet to 40 feet thick and is considered impermeable and forms a barrier to vertical groundwater flow (Gentile, 1998). The Lane underlies SS 003 and ST 005.

The Iola Formation occurs below the Lane and is primarily limestone with a thin bed of shale at its base. It has a maximum thickness of 10 feet at RGAFB. The upper member of the Iola Formation is the Raytown Limestone Member, generally a massive bluish-gray, wavy bedded limestone ranging from 6 feet to 8 feet in thickness and locally containing interbedded lenses of shale that are approximately 3 inches thick. The upper two or three feet of the Raytown Limestone Member is massive and weathers to a deep red-brown color. However, unlike the Wyandotte Formation limestones, the Raytown Limestone Member is a hard, finely crystalline rock that is not readily susceptible to solution weathering. The Raytown passes downward into a thin shale (Muncie Creek Member) and a second limestone band, known as the Paola Limestone Member. Thin layers of limestone, either Raytown or Paola, underlie sites SS 009 and CS 004 before giving way to the Chanute Shale.

The Chanute Formation underlies the Iola and is a maroon and green claystone and shale with local occurrences of cross-bedded sandstone and conglomerate. The formation ranges from 25 feet to 30 feet in thickness, and consists of an upper gray shale overlying two or three feet of hard, resistant sandstone near its top, and maroon to greenish-gray shales interbedded with a thin nodular limestone near the middle of the formation. About 10 feet of greenish-gray shale lies at the base of the formation. The high percentage of shale and claystone and the tightly-cemented sandstone in the upper part of the formation prevents the Chanute from transmitting significant amounts of fluids (Gentile, 1998).

Structural Geology

The Kansas City Group rocks underlying RGAFB have been gently folded into a series of synclines, domes, and anticlines that, taken overall, dip north-northwest at approximately 10 feet per mile. Subsurface water that becomes perched on top of impermeable shale units would tend to drain in a generally north or northwesterly direction (Gentile, 1998).

The limestone formations are well-jointed. The regional joint pattern consists of two major sets that trend NE-SW and NW-SE and are essentially vertical, oriented almost at right angles to one another (Gentile, 1991). It is these joints that weather to form solution channels that are the principal conduits for groundwater flow at the Base.

Hydrogeology

Groundwater Occurrence

Richards-Gebaur AFB is located in the Osage Plains groundwater province of the Central Lowland-Nonglaciated Plains region. Groundwater in the Osage Plains province occurs in Pennsylvanian and Mississippian age sedimentary aquifers. Yields reportedly range from 1 to 20 gallons per minute (gpm), although regionally the Pennsylvanian rocks act as a confining unit because of the thick sequences of impermeable strata that make up the formations.

Because of the geological setting, springs are rare, and if present have small and intermittent discharges (MDNR, 1997). Under ideal conditions, groundwater may flow along bedding planes between permeable and impermeable strata and produce larger springs, such as those historically reported in the Kansas City area (Gentile, 1998).

Groundwater occurrence at RGAFB is erratic. The presence of shallow groundwater in unconsolidated overburden soils and weathered near-surface bedrock is largely dependent on seasonal rainfall. Shallow lenses of groundwater are developed when vertically percolating rainwater infiltrates the ground surface and encounters a relatively impermeable layer of shale. Because perched water conditions are seasonal, shallow wells drilled at the Base are often found to be dry upon construction.

Groundwater Movement

As described above, the Argentine limestone contains two sets of tightly fitted joints oriented almost at right angles to one another. The joints are subject to solution widening by groundwater, and this can result in large orthogonal-shaped blocks of limestone measuring 30 feet - 40 feet on a side. A well drilled into the interior of a joint block will be dry; a well drilled along a joint may produce a limited amount of water. A well drilled at the intersection of the two joint planes has the best opportunity to deliver water and may produce 2-3 gallons per minute until the source is depleted. The solution-widened joints extend down to the top of Lane Shale Formation. At this point the jointing becomes tight because the shale is not susceptible to dissolution and joints extending downward to a greater depth also tend to become increasingly tight.

The Lane Shale is regarded as impermeable and groundwater at this depth would either pond or flow gradually along Argentine-Lane interface in the direction of dip of the sedimentary beds. At Richards-Gebaur AFB, the direction of dip is to the north-northwest (Gentile, 1998). Thus, it is expected that groundwater that reaches the Lane Shale would move toward the north and not necessarily toward Scope Creek, although the creek is topographically downgradient of the five sites in question.

The Lane Shale has been thinned or removed by erosion at lower elevations. Erosion has removed the Lane Formation at sites adjacent to Andrews Road and further northwest. Consequently, at these sites the Raytown Limestone is exposed at the surface or directly underlies the soil. Because of its hard, crystalline composition, joints in the Raytown are relatively tight and are not widened as a result of chemical solution. Nonetheless, should shallow groundwater penetrate the Raytown, it would stop at the top of the underlying Chanute Formation shales, and again flow north in the direction of the local bedrock dip.

Groundwater Quality

The groundwater in the vicinity of the Base may be classified as moderately saline, sodium-chloride type, particularly with regard to Pennsylvanian (e.g., Kansas City Group) rocks near the surface. Total dissolved solids (TDS) range from 330 ppm to 7,000 ppm because high concentrations of sodium and chloride equate to high TDS values. The wide range of concentrations is a reflection of the relative proximity of wells to the freshwater-saline water interface that runs southwest – northeast through the province. The recommended US EPA Secondary Maximum Contaminant Level for TDS is 500 ppm.

Because of poor groundwater quality in Cass, Johnson, Jackson, Lafayette, and Saline counties, sources other than groundwater are used for public water supplies. The minimal use of groundwater contributes to the lack of available groundwater quality data for these areas (MDNR, 1997).

Aquifer Test Results

To quantify the apparent low yields and lack of groundwater movement, aquifer tests were conducted this summer at each of the five sites. The tests were run over periods of up to one week. Dedicated, downhole digital pressure transducers were used to continuously record changes in water levels in the test and observation wells following removal of all well-bore water from the test well. The resulting data were analyzed using several standard methodologies.

The results of the aquifer test analyses are consistent with previous interpretations of the hydrogeology, as described above. The tests indicate that hydraulic conductivities within the overburden and bedrock at each of the five sites are relatively low, with values on the order of those that characterize silt and other fine-grained materials. There are hydraulic connections between some areas at some of the sites, as demonstrated by observable drawdown in wells up to 65 feet or so away from test wells. However, the connections appear to be limited because typically the tests in the wells produced only small, if any, drawdown in nearby observation wells.

Although there appears to be hydraulic connection across some of the sites, the connection is limited, primarily constrained by the fine-grained nature of the silty clay and weathered shale and what likely is fracture filling by silt and clay in the limestone. It is not possible to say for sure whether there is hydraulic connection between sites, but the limited connection within sites argues for only very limited, if any, connection between them.

The results of the aquifer testing, combined with the fine-grained nature observed in much of the subsurface materials and the fact that wells typically purge dry during groundwater sampling, suggest that the groundwater contamination occurring at the site would not be easily remediated using an approach such as pump and treat. It may be of limited value to extract groundwater from selected wells exhibiting elevated levels of contamination. However, the approach will not efficiently remediate large volumes of the subsurface.

Occurrence and Distribution of VOCs in Groundwater

TCE, DCE, and VC were detected in groundwater samples from five sites. Concentrations range up to maximums of 507 ppb of TCE at SS 006, 282 ppb of DCE at SS 009, and 90 ppb of VC at SS 006. Figures 2 through 6 depict the location and concentration of these VOCs in groundwater at each site. Other contaminants detected at low concentrations in groundwater at RGAFB include additional VOCs such as benzene, toluene, xylenes, n-propylbenzene, and isopropylbenezene, and other clorinated VOCs such as tetrachloroethene, chlorobenzene, chloroform, and methylene chloride. Two semi-volatile organic compounds (SVOCs), napthalene and styrene were detected at low concentrations in one well at site SS006.

The likely contaminant sources, including an Underground Storage Tank at CS 004, drums and other hazardous materials storage at SS 006 and ST 005, and stained soil at SS 003 have all been removed from the sites. Therefore, additional releases of contaminants is no longer a threat. Investigations at RGAFB have successfully delineated the extent of contamination at each site. Results of these investigations indicate that the contaminants are contained above the impermeable shale layer.

Because chlorinated hydrocarbons are heavier than water, they will tend to sink through the groundwater column and pool at impermeable horizons. At RGAFB, the underlying shale units act as vertical barriers to groundwater flow and are therefore potential horizons where dense non-aqueous phase liquids (DNAPLs), such as trichloroethene (TCE), can collect. The deep wells were installed to monitor potential DNAPL accumulations at the limestone/shale interface.

Shallow and deep monitoring well pairs were installed at three sites: CS 004, SS 009, and ST 005. The approach is designed to ensure that monitoring wells are screened across the deeper limestone/shale interface to intercept any DNAPLs that may have accumulated on top of the impermeable shale. This allows the shallow (unconsolidated/bedrock) and deep (limestone/shale) interface zones to be screened and sampled independently.

Based upon drilling logs and rock cores, CS 004, SS 009, and ST 005 are underlain by several feet of weathered Raytown Limestone overlying the Chanute Shale formation. Figure 7 is a schematic of the shallow and deep well-nested pair construction.

At site SS 003, the uppermost bedrock unit is the relatively impermeable Lane Shale. Consequently DNAPLs would not be expected to migrate downward through this stratum, and drilling through it would be ill-advised, potentially providing an unwanted vertical pathway for groundwater movement. Therefore, shallow and deep wells were not installed at this site.

At site SS 006, the uppermost bedrock unit is the Argentine Limestone. The bedrock outcrops near or at the ground surface, precluding construction of a shallow overburden/top of limestone monitoring well. The wells at the site are drilled through the Argentine Limestone and screened to straddle the base of Argentine Limestone/top of Lane Shale interface.

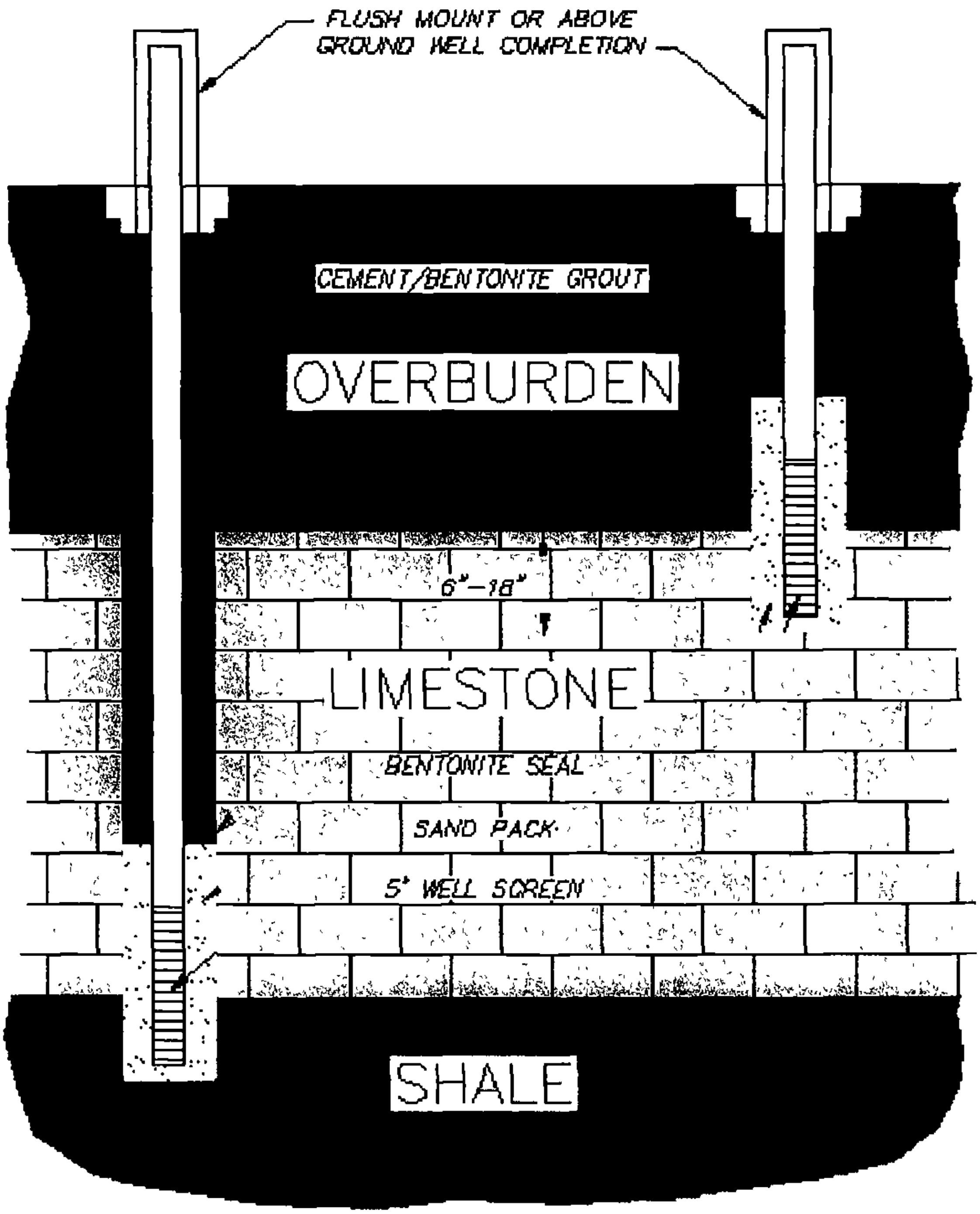


FIGURE 7
Schematic of Nested Monitoring Wells

Groundwater Risk Evaluation

A preliminary evaluation of human health risks associated with chlorinated VOCs in groundwater was conducted, based on the assumption that there will be future residential land use at the Base. The residential land use assumption was selected because this represents the highest beneficial potential use of groundwater at the Base. The risk assessment used the groundwater data obtained from the recent RI, as presented above in Figures 2 through 6.

The conclusions from this evaluation are that estimated risks associated with hypothetical residential use of groundwater would warrant consideration of remedial action, under risk management guidelines used by the State of Missouri.

However, this was a very conservative risk evaluation based on a residential use of groundwater, therefore it should be kept in mind that the calculated risk estimates are conservatively high.

Exposure Assessment

Available information indicates that there are unlikely to be potential exposure pathways to VOCs in groundwater for potential future residents. A water well search within one, two, and five miles of RGAFB conducted by Missouri Department of Natural Resources (MDNR) Division of Geology and Land Survey. The well search verified that shallow groundwater under and in the vicinity of RGAFB is not commonly used for domestic purposes – only six water wells were found within a 5-mile radius of the base. One well was found within 1-mile radius and the other five were found within 5-mile radius. The wells were installed between 1988 and 1998 and they are owned by six individuals. Total depths of the wells vary from 200 to 268 feet. Well screen intervals appear to be set from about 30 feet below ground surface to the bottoms of the wells. Static water levels occur at depths around 70 to 80 feet for five of the wells and at 160 feet for the remaining well. The recorded yields are typically low, varying from 0.4 to 4 gallons per minute.

No record of shallow water wells was found during this search. The Base and nearby communities of Belton, Pleasant Hill and Grandview obtain their domestic water supply from the Kansas City Water and Pollution Control Department (KCWPCD). The former municipal well field at Belton was abandoned several decades ago when supplies of Missouri River water became available to local residents via the KCWPCD.

While future residential groundwater use is unlikely to occur, health risks were evaluated under the assumption that shallow groundwater at the base could be consumed, for the purpose of evaluating groundwater remedial alternatives. Potential exposure pathways considered in this evaluation were ingestion of drinking water and inhalation of VOCs emitted from domestic-use water. Standard default exposure assumptions for residential land use, and USEPA-derived toxicity factors (USEPA, 1999, *Region 9 Preliminary Remediation Goals*. Revised October) were used to characterize risks associated with groundwater. Analytical results from individual monitoring wells were used to develop exposure point concentrations, based on the assumption that the monitoring wells represent the hypothetical locations of drinking water wells.

Quantitative Risk Characterization

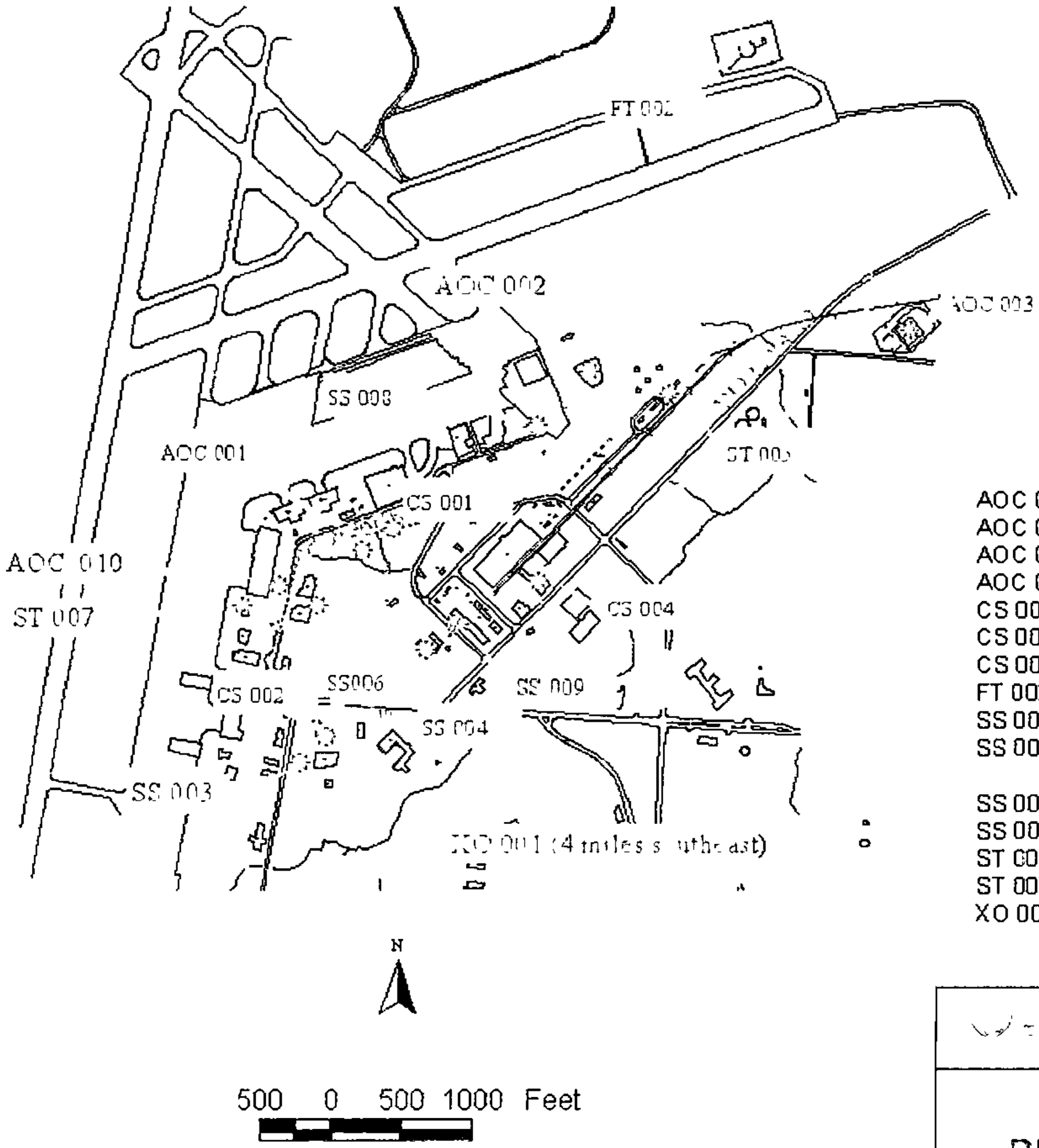
Under a residential land use scenario, excess lifetime cancer risks (ELCR) associated with vinyl chloride and TCE in groundwater were 1×10^{-5} or greater at all five sites. The highest estimated risks were found at CS-004, SS-006 and ST-005; risks higher than 1×10^{-4} were calculated for all three sites. Noncancer hazard indices higher than one were found at all five sites. In general, hazard quotients ranged from 2 to 10.

The quantitative results from the risk evaluation indicate that concentrations of VOCs in shallow groundwater are associated with risks consistently higher than State of Missouri guidelines triggering remedial action, when evaluated assuming a future residential use scenario. The risk-based thresholds are an excess lifetime cancer risk of 1×10^{-5} and a noncancer hazard index greater than one.

While the quantitative risk estimates are based on the highest beneficial use of groundwater (residential use), available survey information indicates that shallow groundwater is not likely to be used by residents. Therefore, risks associated with VOCs in groundwater are likely to have been considerably overstated.

APPENDIX B

Site Figures



SITE DESCRIPTIONB

AOC 001	CENTRAL DRAINAGE AREA
AOC 002	NORTH DRAINAGE POND
AOC 003	FIRING RANGE
AOC 010	BUILDING 918 PARKING LOT
CS 001	FUEL LINE -942 SECTION
CS 002	OWS AT BUILDING 704
CS 004	UST 620A
FT 002	NORTH BURN PIT
SS 003	OIL SATURATED AREA
SS 006	HAZARDOUS MATERIAL STORAGE AREA
SS 008	TEST CELL AREA]
SS 009	FIRE VALVE AREA
ST 005	POL STORAGE YARD
ST 007	FORMER UST AREA
XO 001	BELTON TRAINING COMPLEX

FIGURE 1

GENERAL SITE PLAN
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI

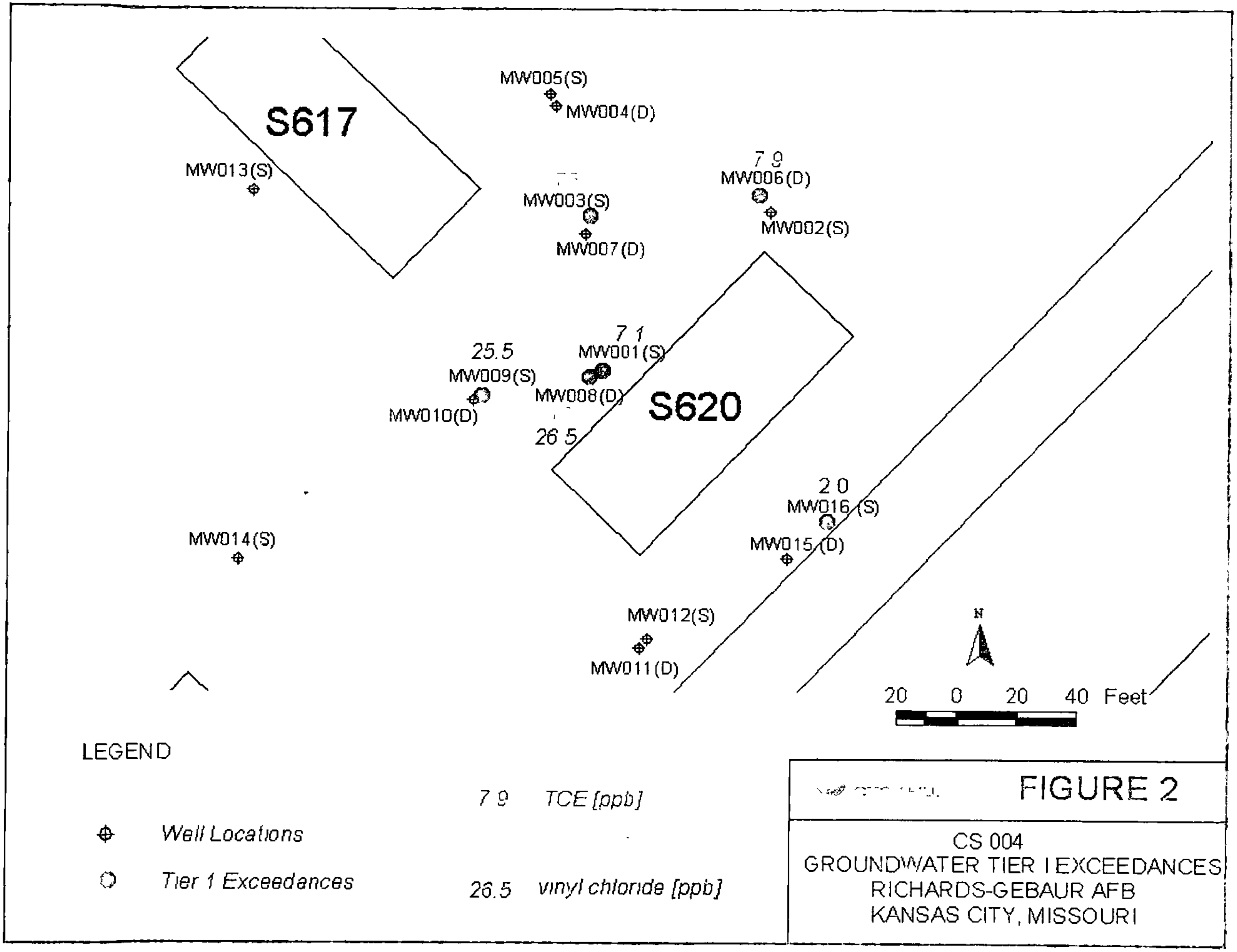


FIGURE 2

CS 004
GROUNDWATER TIER I EXCEEDANCES
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI

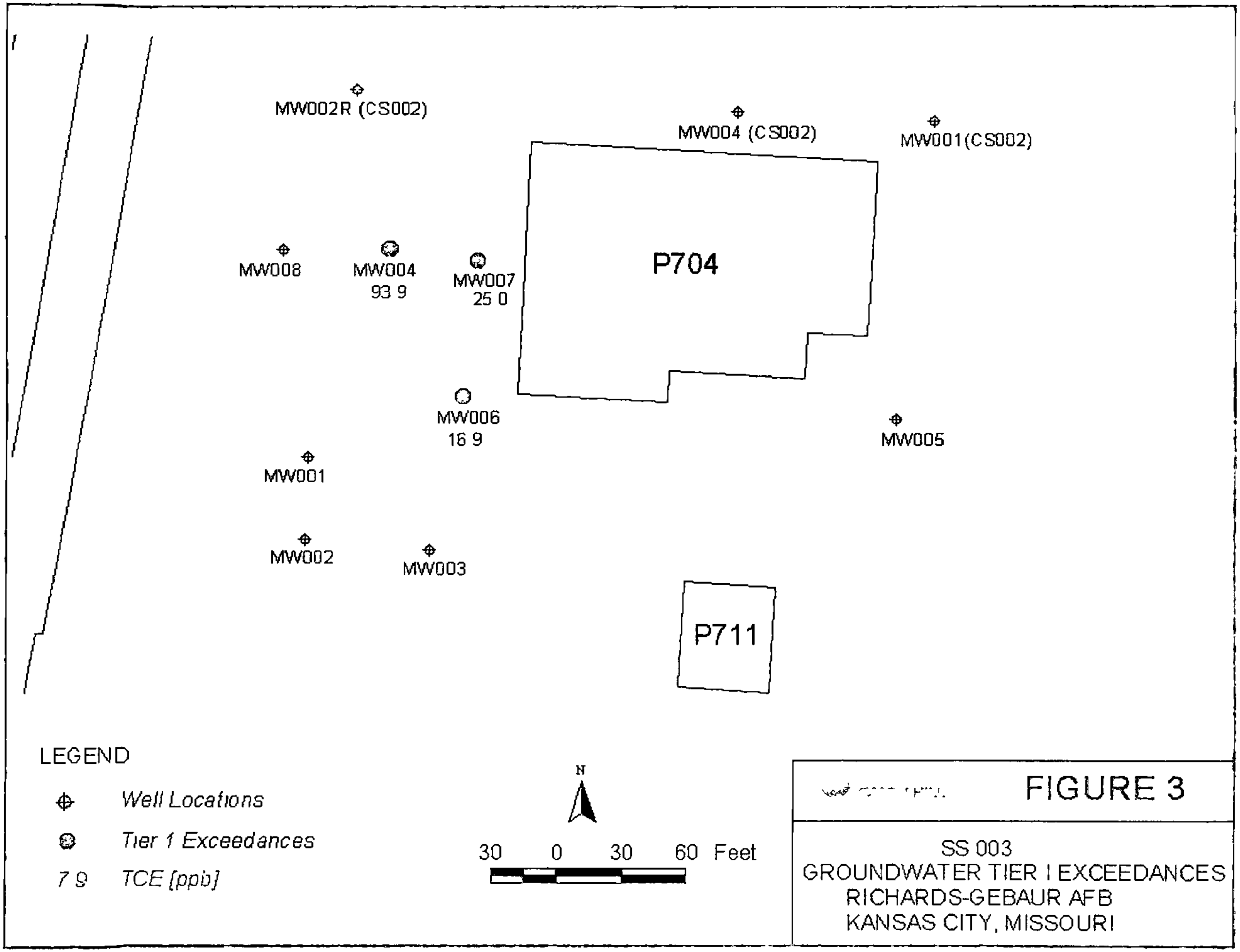
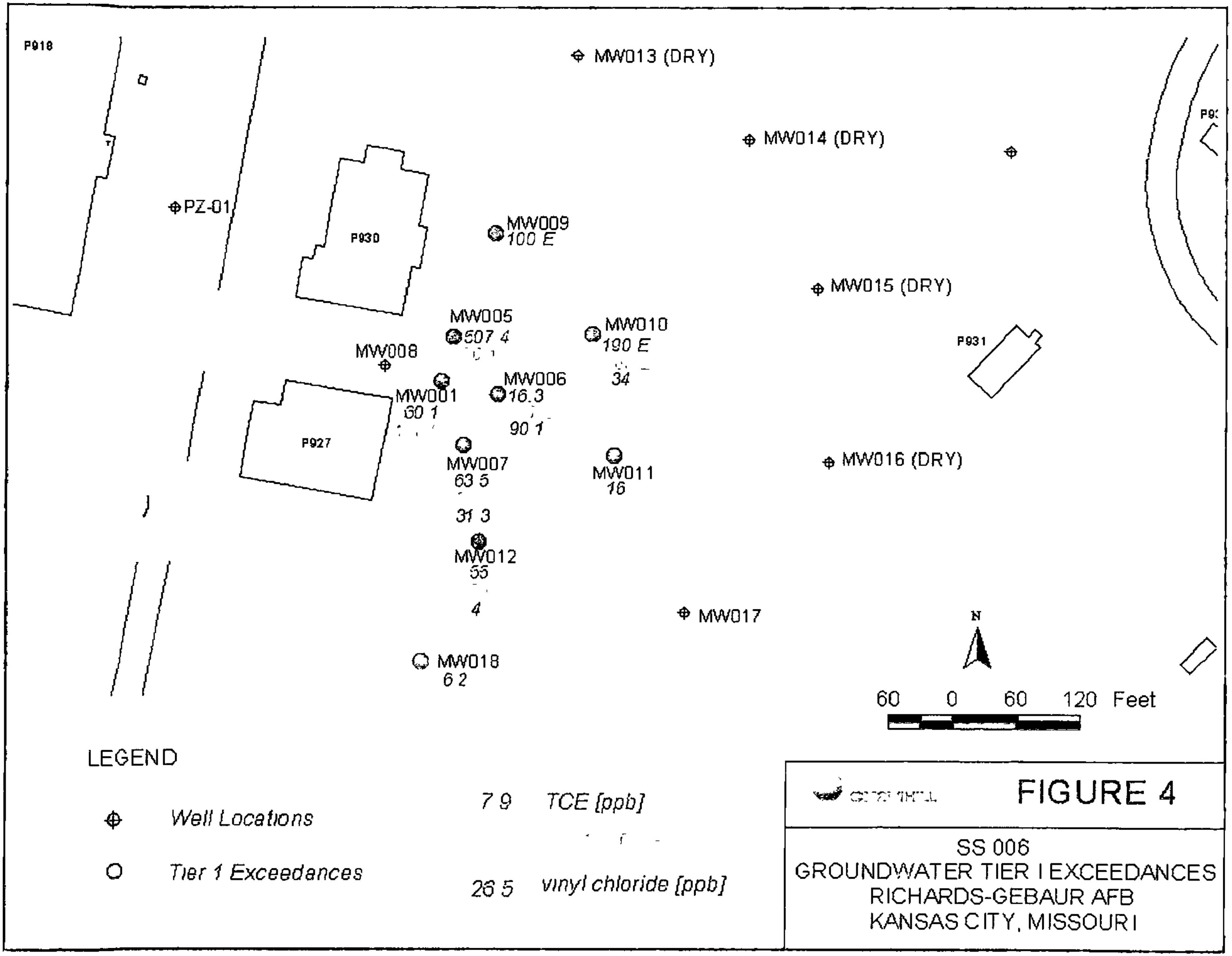


FIGURE 3

SS 003
GROUNDWATER TIER I EXCEEDANCES
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI


P918
PZ-01
P930
P927
P931
MW013 (DRY)
MW014 (DRY)
MW015 (DRY)
MW016 (DRY)
MW017
MW009
100 E
MW005
507 4
MW010
190 E
34
MW008
MW001
60 1
MW006
16.3
90 1
MW007
63 5
31 3
MW011
16
MW012
55
4
MW018
6 2
N
60 0 60 120 Feet
LEGEND
Well Locations
Tier 1 Exceedances
7 9 TCE [ppb]
26 5 vinyl chloride [ppb]
FIGURE 4
SS 006
GROUNDWATER TIER I EXCEEDANCES
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI

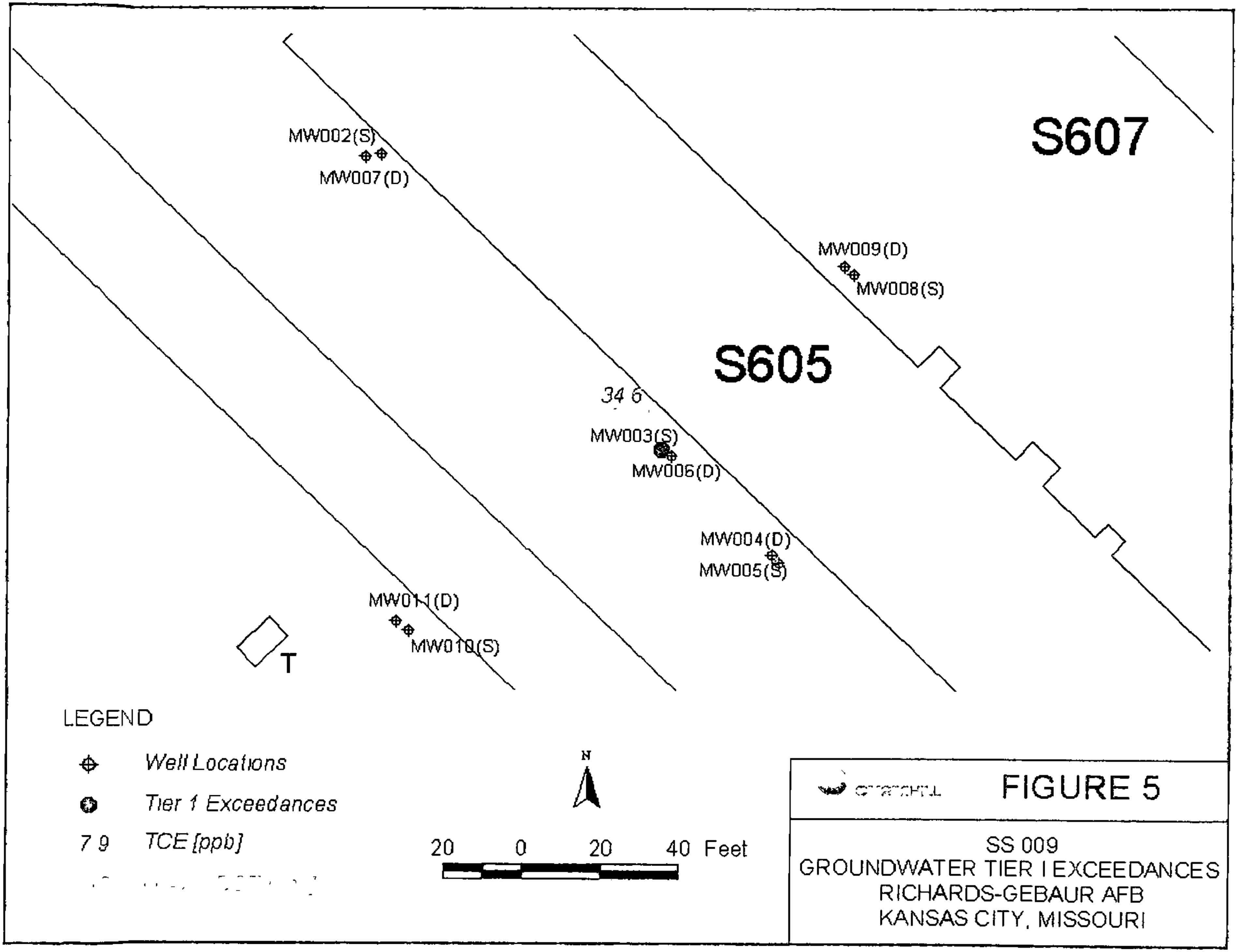


FIGURE 5

SS 009
GROUNDWATER TIER I EXCEEDANCES
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI

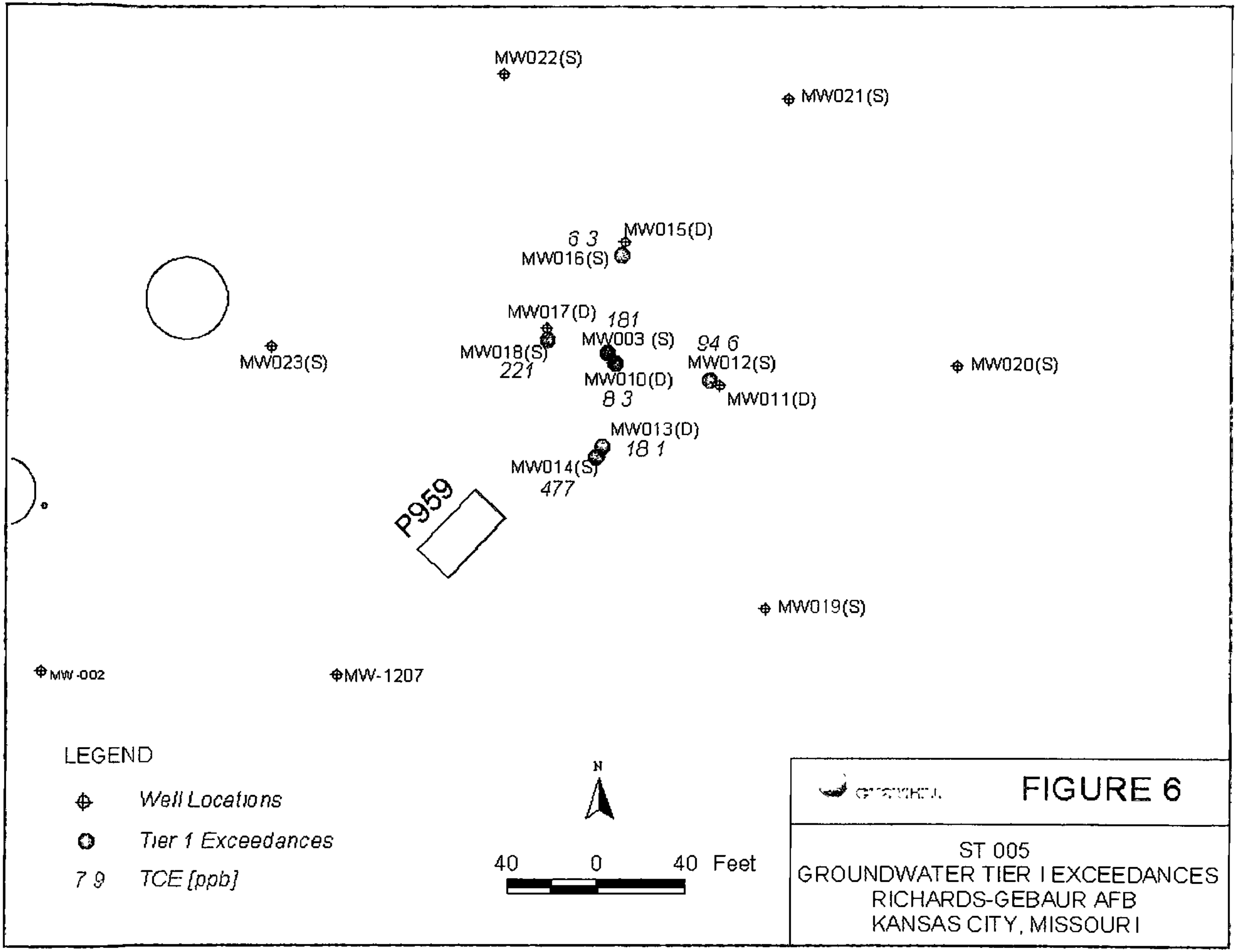


FIGURE 6

ST 005
GROUNDWATER TIER I EXCEEDANCES
RICHARDS-GEBAUR AFB
KANSAS CITY, MISSOURI

215 31

Title 10-DEPARTMENT OF NATURAL RESOURCES
Division 20-Clean Water Commission
Chapter -

PROPOSED RULE

10 CSR 20- Risk-Based Groundwater Remediation Rule

PURPOSE: It is recognized that the department may consider a risk-based groundwater cleanup under several state environmental statutes as discussed in Section 2 of this rule. It is not intended that this rule would replace any of the requirements in any other environmental statute or regulation. The purpose of this rule is to codify the allowances and limitations for risk-based cleanup projects involving groundwater, as authorized in chapter 644.143. This rule further defines the procedures that are presently allowed under the Missouri Water Quality Standards 10 CSR 20-7.031(5)(D). Unless site-specific alternative groundwater cleanup standards are approved by these procedures, the values in Table A or other parts of the Missouri Water Quality Standards remain the cleanup standards for groundwater. Alternative standards may be approved to reflect site-specific, risk-based exposure conditions, the institutional controls, continuing monitoring, and other aspects of remedial action plans described below.

(1) Definitions.

(A) *Ambient groundwater quality* - General groundwater quality beneath and/or in the vicinity of a site that is not impacted by the site, but may have been impacted by background chemical constituents and/or anthropogenic constituents from off-site sources.

(B) *Background chemical constituent* - Naturally-occurring elements and compounds.

(C) *Groundwater* - Water below the land's surface in or below a zone of saturation.

(D) *Institutional Controls* - Legally binding and durable conditions applied to properties which are the subject of risk-based cleanups of contaminants. These institutional controls may include but are not limited to restrictive covenants, easements, etc.

(E) *Karst* - Areas characterized by geologic features developed from the dissolution of soluble bedrock. These geologic features include but are not limited to sinkholes, losing streams, caves, bedrock conduits and springs.

(F) *Maximum Contaminant Levels (MCLs)* - Refer to 10 CSR 60-2

(G) *Monitored Natural Attenuation (MNA)* - The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods.

(H) *Person* - The same as presented in Section 644.016(7) RSMo

(I) *Point of Compliance (POC)* - The geographic point at which the site's cleanup standards must be met.

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(J) *Potable groundwater* - Groundwater that is safe for human consumption, in that, it is free from impurities in amounts sufficient to cause disease or harmful physiological effects.
(K) *Private groundwater* supply - A well or spring that is used as a domestic water supply and that is not a public water supply.
(L) *Public water* supply - A system for the provision to the public of piped water for human consumption, if the system has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals daily at least sixty (60) days out of the year.
(M) *Public* well - A well that supplies water to a public water system.
(N) *Risk assessment* - The characterization of the potential adverse health and environmental effects of exposure to environmental hazards.
(O) *Site* - The property under the ownership of the participant.

(2) Site Eligibility.
(A) Risk-based groundwater cleanup projects, as authorized by Chapter 644.143 RSMo, may be considered under the following state statutes:
1. Missouri Clean Water Law (Chapter 644 RSMo)
2. Solid Waste Management Law (Chapter 260 RSMo)
3. Hazardous Waste Management Law (Chapter 260 RSMo)
4. Underground Storage Tank Law (Chapter 319 RSMo)

(B) Sites will not be eligible under this rule if any of the following conditions exist:
1. If the site presently impacts or is likely to impact a drinking water supply then groundwater must be remediated to meet department approved established contaminant levels. The likelihood that the site will impact a drinking water supply shall be based on the following criteria:
   A. The site is within an area that has been designated by the Missouri Department of Natural Resources (MDNR) Public Drinking Water Program (PDWP) as a wellhead protection area or a source water protection area for a public water supply well.
   B. A private groundwater supply is within 2,000 feet or 10 year groundwater travel distance, whichever is greater, as measured from the closest property line of the site.
2. If the site presently impacts or is likely to impact groundwater that is not currently used as a public water supply or private water supply but is suitable for use as a public water supply or private water supply then the site must be remediated to meet Maximum Contaminant Levels (MCLs) and or other health based criteria.
3. If the site presently impacts or is likely to impact any natural spring, or any water which contributes to a natural spring, which is recognized for its recreational or aesthetic value and is located in a state park, national park, conservation area, or any area protected by a conservation easement.
4. Conditions at a site constitute an imminent and substantial threat to public health or the environment.

5. Conditions at a site are determined to be inappropriate for risk-based remediation based on relevant scientific factors including but not limited to transfer of contaminants from one environmental media to another (e.g., groundwater to air).

(3) Application Process. In order to receive oversight and approval from MDNR for risk-based groundwater cleanup to remediate real property, persons shall make application for that oversight and approval. Persons remediating a site under an existing state statute as discussed in Section 4 need not submit a separate application but may pursue risk-based groundwater cleanup under the governing statute provided that they comply with Chapter 644.143 RSMo and the intent of this rule.

(A) The application form shall be filled out completely and returned to MDNR with the one thousand five hundred dollar ($1,500) application fee.

(B) MDNR will review the form for completeness. If MDNR determines that the form is incomplete, it will be returned to the person for completion. Upon receipt of all requested information, MDNR will notify the person that the application form is complete and proceed according to Section 4 of this rule.

(C) The initial application shall contain at a minimum the following site specific information in support of the request for approval to proceed with a risk-based groundwater remediation project:

1. Site owner
2. Site location with latitude and longitude coordinates
3. Proximity of the site to public or private drinking water source(s)
4. Information regarding the existence of any karst features within 5 miles of the site property boundary
5. The specific contaminants identified at the site
6. Known existing contaminant levels and corresponding MCLs, HALs or other potentially applicable health based criteria.
7. Present and former uses of the site
8. The intended use of the site
9. Adjacent and surrounding owners within ¼ mile of the site property boundary
10. Proximity of site to springs or other waters of the state
11. Consent for MDNR access to the site
12. Certified copy of deed(s) for site
13. Application fee of $1500

(D) Within 90 days of receipt of a complete application MDNR will make a determination whether to accept or deny the site as a risk-based groundwater remediation candidate.

1. During this period MDNR will seek input from its relevant programs and divisions as well as that of the Missouri Department of Health (MDOH).
2. The site must meet all eligibility criteria before pursuing risk-based groundwater remediation in accordance with Chapter 644.143 RSMo.

(E) Upon approval of the application MDNR shall enter into a site-specific groundwater remediation oversight agreement with the person. This agreement shall set forth the responsibilities of the person and MDNR.

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(4) Site Characterization

(A) If a site s entered through a program of MDNR in which site characterization or assessment regulations, policies, established practices or guidance already exist those will take precedence. In the absence of such, the overseeing program will specify an assessment protocol as used at Resource Conservation and Recovery Act, (RCRA), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or Missouri's Voluntary Cleanup Program (VCP) sites. MDNR may require the submission of work plans, reports or other deliverables as necessary to address the following site-specific information requirements.

(B) The applicant is responsible for supplying scientific information to support their request including but not limited to:

1. Characterization of ambient groundwater quality including background chemical constituents within the plume of groundwater contamination.
2. Hydrogeologic parameters of impacted and potentially impacted geologic materials including transmissivity, storativity, vertical and horizontal hydraulic conductivities and gradients, and the nature and location(s) of significant hydrologic boundaries in the vicinity of the plume of groundwater contamination.
3. Groundwater yield potential of the affected aquifer and any potentially interconnected aquifers.
4. Historical use of groundwater from the affected aquifer and any potentially interconnected aquifers in the vicinity of the plume of groundwater contamination.
5. Availability of alternative drinking water sources.
6. Analysis of whether the site presently impacts or is likely to impact a drinking water supply based on the following criteria:
   A. The site is within an area that has been designated by the MDNR, PDWP as a wellhead protection area or a source water protection area for a public water supply well.
   B. A private groundwater supply is within 2,000 feet or 10 year groundwater travel time, whichever is greater, as measured from the closest property boundary of the site.
7. An analysis of whether the site presently impacts or is likely to impact groundwater that is not currently used as a public water supply or private water supply where groundwater quality and quantity is such that it could be suitable for use as a public water supply or private water supply.
8. An analysis of whether the site presently impacts or is likely to impact any natural spring, or any water which contributes to a natural spring, which is recognized for its recreational or aesthetic value and is located in a state park, national park, conservation area, or any area protected by a conservation easement.
9. Any off site groundwater impacts that may influence the ambient groundwater conditions at the site.
10. Other relevant information deemed necessary by the MDNR to demonstrate that site specific risk-based groundwater cleanup levels are protective of human health and the environment.

(C) The data, information and reports identified above shall be submitted in a site characterization report that has been sealed or stamped by a geologist registered in the State of Missouri according to a schedule approved by the department or no later than thirty (30) days following notice that they are required. An extension may be granted at MDNR's discretion. The department shall review and comment on the site characterization report(s). If the report(s) do not contain sufficient information to adequately characterize the site, the department shall notify the person that additional site characterization information or data are needed and that a revised site characterization report is required.

(5) Exposure Assessment (Placeholder)
DNR is seeking input on this issue.

(6) Risk Assessment.
(A) Required submittals:
1. A copy of the MDNR reviewed and approved site characterization report
2. Risk Assessment – The assessment will be reviewed by MDOH
If a risk is found, and cleanup is proposed to levels other than the maximum contaminant levels.
3. A Determination of Risk-based Cleanup Goals – Reviewed by MDOH

(B) Guidelines for Conducting Risk Assessments and Determining Risk-Based Cleanup Goals
1. Risk assessments and determinations of cleanup goals will be conducted and submitted to MDNR, be reviewed by MDOH and then approved by MDNR to assure the submission's accuracy, compliance with recommended guidance, and protectiveness of the public. All submissions should follow MDOH approved methodology. Currently, the methodology presented in the Environmental Protection Agency's (EPA) Risk Assessment Guidelines for Superfund (RAGS, EPA 1991) is required.
2. The determination of cleanup goals shall be made after the risk assessment is complete and shall be protective of current and future populations at and surrounding impacted groundwater areas.
3. Risk assessments and determinations of cleanup goals will include:
   A. The oral ingestion, inhalation of volatiles and dermal pathways.
   B. A residential scenario included in both the risk assessment and the determination of cleanup goals.
   C. An occupational scenario may be included in those cases where there are institutional controls.
   D. Cleanup levels will be based on a residential exposure, except when approved by all involved agencies in relation to a site with strong, permanent institutional controls that assure that no greater exposure will occur than that of an occupational scenario.
4. Total carcinogenic target risks for the groundwater pathway will be set at a 1 x 10(-6) risk, unless otherwise approved by MDNR. The total non-carcinogenic target hazard index for the groundwater pathway will be set at unity (1.0).

5. Cleanup goals other than MCLs should account for all potential adverse health effects from exposure to all contaminants and all exposure pathways combined. The determined cleanup goals are site-specific and not applicable to any other site.

(7) Groundwater Remediation Plan.

(A) The plan shall explain in detail how the contaminant plume will be remediated to attain MCLs.

(B) If the person requests consideration of alternative cleanup levels (ACLs), the basis for use of less stringent standards and the measures that will be taken to adequately manage site risks shall be explained.

1. ACLs may only be requested at sites where the plume of contamination will not migrate beyond the boundaries of currently contaminated properties.
2. MDNR shall not approve any plan requesting consideration of ACLs until all institutional controls restricting groundwater usage are in place.

(C) MDNR will review the site characterization report, human health and ecological risk assessment and the groundwater remediation plan in determining whether the requested ACLs are appropriate for the site. MDNR will consider the following factors in reviewing the proposed groundwater remediation plan:

1. Overall Protection of Human Health and the Environment
2. Attainment of Media Cleanup Standards
3. Controlling the Source(s) of Releases
4. Compliance with Standards for Management of Wastes
5. Other Factors (Balancing Criteria for Final Remedy Evaluation)
   A. Long-Term Reliability and Effectiveness
   B. Reduction of Toxicity, Mobility, or Volume of Wastes
   C. Short-Term Effectiveness
   D. Implementability
   E. Cost
   F. Community Acceptance

(D) The groundwater remediation plan shall be submitted to MDNR no later than 90 days following approval of the risk assessment and site characterization reports. The person shall submit a groundwater remediation plan that has been sealed or stamped by a geologist registered in the State of Missouri.

(8) Public Participation.

(A) Public participation regulations, policies, established practices or guidance already in existence will take precedence.

(B) In the absence of such the public participation guidance as described in MDNR's Cleanup Levels for Missouri (CALM) guidance document will be used by MDNR to guide the public participation aspects of the risk-based groundwater cleanup project. Public notification and participation requirements shall be approved by the department and tailored to each site, due to the variety of factors involved in each cleanup site.

(C) At a minimum, the proposed groundwater remediation plan, site characterization report, risk assessment and any other supporting information related to the proposed remedy shall be made available for public review at a local information repository to be approved by the department. The availability of this information and the associated public review and comment period shall be advertised locally. The duration of the public review and comment period shall be a minimum of thirty calendar days. As part of the public participation process for the proposed remedy, a public availability session may be held at the discretion of the department. A public hearing may also be held if requested in writing during the public comment period. A statement of the issues to be raised during the hearing must accompany any written request for a public hearing. The department will consider all written comments made during the comment period and any oral comments received during the public hearing in deciding whether to allow ACLs.

(9) Approval for Alternative Cleanup Standards/Approval of Final Remedies incorporating Risk-Based Groundwater Cleanup Standards.

(A) Following the close of the 30-day public comment period for the groundwater remediation plan, the department will review and respond to any public comments on the proposed final remedy. The department may accept, modify or reject the proposed final remedy in response to public comments.

(B) Conditions of Release: Complete remediation to MCLs or MDNR approved levels with continued management including institutional controls

(C) Conditions of Continued Management:

1. Monitoring
2. Establishment of Point(s) of Compliance, which shall be no farther than the boundary(ies) of the property(ies) currently overlying the groundwater contamination plume
3. Reporting
4. Remediation to attain ACLs
5. Institutional Controls (Use restrictions, restrictive covenants)
6. Maintenance of site - Engineering controls
7. Contingency Plan to be used if conditions worsen as determined by MDNR

(D) MDNR may require a reevaluation of the selected remedy if it is determined that the remedy as implemented is not effective or fails to provide adequate protection of human health and the environment.

(10) Point of Compliance (POC). This concept applies to the groundwater remediation component of a site cleanup by establishing the geographic point at which the site's groundwater cleanup standards must be met.

(A) Contaminated groundwater below the site is the POC if there are no MDNR approved institutional controls on the property;

(B) If there are department approved institutional controls on the site, the site property boundary may be the POC with MDNR approval.

(C) The POC may be established off-site, at the boundary(ies) of property(ies) currently overlying the plume of contamination. Also, department approved institutional controls must be in place before MDNR will approve an off-site POC. Persons shall obtain or provide at a minimum the following:

1. Right of entry to the property for parties conducting cleanup and government agencies supervising cleanup; and

2. Authorization to conduct monitoring, including installation of wells; and
3. MDNR approved language to ensure that the landowner(s) understands the contaminants and risks, restrictive covenants and legal matters.

(11) Monitored Natural Attenuation.

(A) The groundwater remediation plan may request approval of monitored natural attenuation (MNA) to remediate the groundwater at the site. The decision to allow MNA will be based on information supplied in the site characterization report and human health and ecological risk assessment. MDNR shall consider the impact on human health and the environment in determining whether MNA is an appropriate technology for the site.

(B) A groundwater remediation plan requesting consideration of MNA will be evaluated and approved by MDNR only after the following have occurred:

1. Source control measures have been implemented that prevent future releases of contaminants to groundwater.
2. Durable institutional controls as approved by MDNR preventing the usage of groundwater are in place.

(C) The plan must provide details about the source control measures taken at the site and documentation of the institutional controls. In addition, the plan must include:

1. At sites where the source control involved the treatment or containment of wastes, a demonstration that the wastes are no longer acting as a significant source of groundwater contamination.
2. A demonstration that the plume is stable and will not migrate vertically or horizontally across the boundary(ies) of the currently contaminated property(ies). Containment of the plume, in order to prevent it from migrating off the property(ies), through pump and treat or other approved technologies is acceptable.
3. Identification of the natural attenuation processes that are reducing contaminant levels.
   A. Actual site hydrogeologic and geochemical field sampling data supporting this must be provided.
   B. It is preferred that data demonstrating actual reductions in contaminant concentrations be provided.
4. Data demonstrating the rate at which contaminant levels are expected to attenuate, and the timeframe needed to attenuate the entire plume to achieve MCLs or approved ACLs. MDNR shall approve the attenuation rate and attenuation timeframe.
5. A detailed monitoring program.
   A. The monitoring program must be designed to detect further migration of the plume, provide data on contaminant concentration changes over time and distance, detect changes in background water quality, and provide data on degradation or transformation products.
   B. The monitoring program must collect data at least quarterly (four times per year), until 8 quarters after MCLs or approved ACLs have been achieved throughout the plume.

6. A reevaluation of the remedy shall be required if the MNA is determined by MDNR to be ineffective. The reevaluation shall be implemented if monitoring data fails to demonstrate that MNA has achieved the approved attenuation rate.
   A. The period of time allowed to demonstrate that MNA is achieving the desired rate of attenuation will be determined on a site-specific basis.
   B. MDNR may grant variances or extensions based on site-specific conditions.
7. A draft plan for a contingency remedial technology shall be submitted for approval prior to receiving approval to implement MNA. This draft plan shall be fully developed and implemented, following approval by MDNR, if MNA is determined to be ineffective.

(12) Reimbursement.

(A) All participants, not already reimbursing MDNR pursuant to work performed under the authority of other state statutes as identified in Section 2 shall reimburse the department for site-specific administration and oversight costs associated with risk-based groundwater cleanups. A complete accounting of the costs incurred by the state agencies will be billed to the participant by mail in accordance with the following:

1. Personnel. The state's personnel hourly rates multiplied by a fixed factor of three and one-half (3 ½) will be the basis for time accounting billing. This fixed factor is comprised of direct labor costs; fringe benefits, calculated at a rate developed by MDNR; indirect costs, calculated at a rate approved by the United States Department of the Interior; and direct overhead, including but not limited to, the cost of clerical support and supervisory review and MDNR administrative and management support;
2. Expenses. The direct expenses incurred during administration and oversight and any analytical costs associated with sampling; plus indirect costs calculated at the approved United State Department of the Interior rates;
3. Long Term Oversight Costs. For sites which require engineering and/or institutional controls (e.g., capping, restrictive covenants), the person shall submit a fee to cover MDNR's long-term costs. MDNR's project manager shall establish a site-specific fee, ranging from five thousand dollars to fifteen thousand dollars ($5,000-$15,000). The amount of the fee shall be dependent upon the complexity of the site and the type of engineering and/or institutional controls

(B) The participant shall reimburse MDNR as follows:

1. Initial MDNR expenses shall be reimbursed from the one thousand five hundred dollar ($1,500) fee accompanying the application form.
2. MDNR shall bill the participant for any further expenses. The participant shall reimburse the department within sixty (60) days following notice from MDNR that reimbursement is due. Failure to submit timely reimbursement may be grounds for termination of the groundwater remediation oversight agreement.

(C) The participant may appeal to the commission any charge within thirty days of receipt of the bill in accordance with procedures outlined in Section 15 of this rule. Upon appeal to the commission, the disputed amount shall be placed in escrow pending resolution of the appeal.

(13) Financial Assurances. MDNR may require financial assurance instruments to ensure completion of any remedy implemented pursuant to this rule. If MDNR determines that financial assurance is required, the amount and timing of the instrument and the acceptability of particular instruments will be negotiated with the participant and will be approved on a case-by-case basis.

(14) Penalties. Nothing in this rule shall prevent MDNR from seeking penalties for violations of the law or the rules.

(15) Natural Resources Damages. Nothing in this rule shall prevent MDNR from seeking the payment of actual damages including natural resources damages and investigative or cleanup costs related to pollution or other violations of the law or rules.

(16) Dispute Resolution.

AUTHORITY:

PUBLIC ENTITY COST: This proposed rule will . . . .

PRIVATE ENTITY COST: This proposed rule will . . . .