Expert Opinion of Daniel B. Stephens in the matter of the application of the New Mexico Oil Conservation Division for repeal of existing rule 709, 710, and 711 concerning surface waste management and adoption of new rules governing surface waste management

Case No. 13586

**Prepared for** 

Yates Petroleum Corporation and the Committee for Science Based Regulations

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# **Table of Contents**

Se	ction Pa	IGe						
1.	Introduction	1						
2.	Vadose Zone Processes in Areas of Low Precipitation	1						
3.	Predicted Permissible Chloride Concentrations in Petroleum Waste Landfarms	5 6 6 9						
4.	NMOCD's Proposed Monitoring	. 11						
5.	NMOCD's Proposed Treatment Zone Closure Standards	.12						
6.	Conclusions	. 14						
Re	References							







# 1. Introduction

I have been asked by Yates Petroleum Corporation and the Committee for Science Based Regulations to review the draft regulation revisions dealing with surface waste management *L* facilities, that is, land farms and landfills for petroleum contaminated materials. I have been asked to focus on subsurface fate and transport issues, especially for chloride, a constituent in petroleum-derived wastes.

By way of brief introduction, I am a hydrogeologist with approximately 30 years experience, much of which is in New Mexico and includes numerous projects in the oil and gas industry. I have a B.S. degree in geological science from Pennsylvania State University, an M.S. degree in hydrology from Stanford University, and a PhD in hydrology from the University of Arizona. I was a professor on the faculty at New Mexico Tech for 10 years and was chairman of the geoscience department for three of those years. Currently, I am an adjunct faculty there as well as at the University of New Mexico. I have published more than 30 professional papers in peer-reviewed scientific journals, more than 95 conference presentations, one book (Vadose Zone Hydrology) and four book chapters.

In preparing this report, I have relied on the existing scientific literature and my own research and professional experience. A list of reference citations is included in this report, along with other relevant supporting reference materials.

In this report, I will first summarize some of the vadose zone processes that are most relevant to the proposed waste management regulations. Next I will present comments and suggestions on the New Mexico Oil Conservation Division (NMOCD) proposed regulations in areas dealing with waste acceptance criteria, monitoring, corrective action, and closure. This report is a companion to the PowerPoint presentation that I have also prepared for this hearing.

### 2. Vadose Zone Processes in Areas of Low Precipitation

Understanding the nature of movement of soil water in the vadose zone is highly relevant to developing regulations dealing with potential migration of chloride and other chemicals from



surface waste management (landfarm) units. Key processes include precipitation, infiltration, redistribution, evapotranspiration, and drainage. These processes lead to net infiltration below the root zone, which potentially becomes recharge to groundwater if that percolating water reaches the water table.

In areas of low precipitation, on a regional basis or on a basin scale, natural recharge occurs primarily along mountain fronts and local areas where water is standing on the land surface, and to a lesser extent in other areas. Thus, Daniel B. Stephens & Associates, Inc. (DBS&A) considers three primary recharge mechanisms: mountain front, local, and diffuse natural recharge. Mountain front recharge occurs largely where snow melt and storm runoff flow across alluvial fans and percolate into permeable alluvium. Local recharge sources include seepage from ephemeral flood flows in arroyos and standing water in ponds above a deep water table, including playa lakes. Diffuse natural recharge may take place in areas in between those where mountain front and local recharge occur.

Diffuse natural recharge is the recharge process most relevant to surface waste management regulations. In accordance with these proposed regulations, landfarms must be at least 200 feet from a water body or water course. Consequently, the landfarm will not be located in a mountain front or an area of channelized surface water. Instead, if recharge occurs beneath a landfarm site, it would be considered diffuse natural recharge. Studies of diffuse natural recharge are summarized by Stephens (1996), Stephens et al. (1996), and Hogan et al. (2004). Examples of recharge rates in New Mexico are included in Table 1. In New Mexico, typical diffuse natural recharge rates are roughly a few to less than 10 millimeters per year (mm/yr), or fractions of an inch per year.





	Estimated Annual Recharge	
Site	(mm/yr)	Reference
Socorro, New Mexico	2.0-7.0	Phillips et al., 1988
El Paso, Hudspeth County, Texas	0.9-7.0	Scanlon, 1992
Las Cruces, New Mexico	1.5–9.5	Phillips et al., 1988
Sunland Park, New Mexico	0.0660.19	Stephens and Coons, 1994
Ogallala Aquifer of Texas High Plains	2.3	Baker and Wall, 1976
Ogallala Aquifer at Portales, New Mexico	3.2-16.9	Theis, 1937
Ogallala Aquifer in Lea County, New Mexico	9.6	McAda, 1984

#### Table 1. Diffuse Recharge In Areas of Low Precipitation

mm/yr = Millimeters per year

Factors enhancing diffuse natural recharge include soil texture, slope, and vegetation. Sandy soils tend to allow the majority of precipitation to infiltrate, but then the water beneath the surface is largely prevented from escaping as the soil surface dries and inhibits upward liquid transport by evaporation out of the soil. Soil surfaces that are concave upward (form bowls), tend to enhance soil moisture beneath these areas, thus increasing hydraulic conductivity and the tendency for downward water migration. Sparse or poorly vegetated landscapes allow more of the infiltrated water to escape transpiration by plants.

The natural recharge rates today are much less than they were during cooler climates 10,000 years ago or so. Evidence for this difference is found in the distribution of natural chloride found in soil in areas of low precipitation. A common spatial pattern known as a "chloride bulge" is where high concentrations of chloride are found a few feet below land surface, sometimes at concentrations up to 540 milligrams per kilogram (mg/kg). The natural chloride is derived from low concentrations in precipitation that are concentrated slowly over time due to evapotranspiration processes of native plants, which remove the infiltrated soil water but not the chloride. The more evapotranspiration, the less deep percolation is available to migrate below the root zone and the more concentrated will be the remaining pore water. Thus, chloride concentrations in the soil deposited by high precipitation 10,000 years ago will be much lower than those that occur during the more recent low precipitation period. This relatively older water



lies just below the chloride bulge in the soil profile, while the more recently infiltrated water lies within and above the chloride bulge.

The areas where chloride bulges are found in soil demonstrate that water thousands of years old and younger has not yet reached the water table. At rates of natural recharge of a few millimeters per year, infiltrated water would take centuries to reach the water table in most areas where the water table is a few tens of feet below land surface; at lower recharge rates, this time period would be even longer. The chloride bulge also suggests that although the concentration of salts in the pore water may cause the density of the water to exceed that of fresh water, the chloride in the pore water has not migrated downward, owing to the very low hydraulic conductivity of the soil at the in situ water content.

Some chloride bulges have also been explained by upward moving soil water. In places, especially where the water table is relatively shallow and there are an abundance of drought tolerant and deep rooted native plants, water can move upward from the water table to the land surface. This upward water transport is facilitated by the natural geothermal gradient that causes soil temperature to increase with depth below land surface (Walvoord and Scanlon, 2004). Natural recharge would not occur in areas where soil water moves naturally upward. Stephens and Coons (1994) found upward hydraulic head gradients at a site near Sunland Park, New Mexico.

The operation of a landfarm is superimposed on these natural recharge processes. It is important to take the natural recharge, or lack of it, into account to predict the extent of potential impacts to groundwater. Landfarms typically operate for only a few years to perhaps a decade. After that, the sites are vegetated with native vegetation and the site returns to the natural recharge conditions. With this in mind, we have conducted simulations of the potential impacts of chloride in landfarms on groundwater. Our simulations conservatively assume that the post-operational condition is that of diffuse natural recharge, with soil water movement downward.





# 3. Predicted Permissible Chloride Concentrations in Petroleum Waste Landfarms

To evaluate the acceptable level of chloride in waste placed in a landfarm, we conducted vadose and saturated zone modeling of chloride releases for potential landfarms over the Ogallala Aquifer in southeast New Mexico. The purpose of this modeling was to assess the maximum soil concentration of chloride that can remain in a given landfarm without impacting groundwater above the U.S. Environmental Protection Agency's (EPA's) secondary limit for chloride (250 milligrams per liter [mg/L]). These maximums can be used as guidance for developing regulations on chloride in landfarms by the NMOCD.

#### 3.1 Conceptual Model

The conceptual model for the simulations is a 2-foot-thick landfarm on top of the ground surface covering 2 or 2.5 acres. The unsaturated zone of soil (vadose zone) between the ground surface and the water table is 50 feet thick based on the NMOCD proposed regulation (NMOCD, 2006). The depth from the top of the landfarm to the water table is 52 feet. Groundwater is flowing at a uniform rate and direction based on a gradient of 0.004 foot per foot (ft/ft) (Blandford et al., 2003). The aquifer thickness is conservatively assumed to be 10 feet, which is the screen length of a hypothesized monitoring well. A greater aquifer thickness would allow for more mixing and dilution of any mass flux from the vadose zone. The monitoring well is located at the center of the downgradient edge of the landfarm, which is the location of the maximum concentration.

The landfarm is operated for three years, with the water content of the landfarm initially set at 80 percent of field capacity, which is an amount considered appropriate to maximize bioremediation (EPA, 1993). After three years, the waste is either removed or left in place with an evapotranspirative cover. The evapotranspirative cover is expected to take seven years to fully establish. The simulation continues in all cases until the peak chloride concentration has passed the monitoring well.





#### 3.2 Numerical Models

DBS&A utilized three numerical models to simulate the different components of water flow and chloride transport from the landfarm to a receptor well in groundwater. HYDRUS-1D (Simunek et al., 2005) was used to simulate water flow and chloride transport in the vadose zone. MODFLOW 96 (Harbaugh and McDonald, 1996) was used to simulate groundwater flow in the aquifer. MT3DMS (Zheng and Wang, 1999) was used to simulate the transport of chloride in the aquifer. MT3DMS is the latest version of the popular saturated zone transport code MT3D. HYDRUS-1D, MT3DMS, and MODFLOW are widely accepted modeling programs (e.g., Scanlon, 2004; Prommer, 2005; Poeter, 2005) and are all free and publicly available.

#### 3.3 Parameters

Table 2 summarizes soil properties used in the modeling simulations. Soil parameters including saturated hydraulic conductivity, total porosity, residual water content, bulk density, and the van Genuchten empirical parameters were obtained from the averages reported by Carsel and Parrish (1988). Parameters from Carsel and Parrish (1988) are widely accepted and are provided with HYDRUS-1D and other models such as VADSAT (API, 1995). Bulk densities were calculated from the total porosity and an assumed rock grain density of 2.65 grams per cubic centimeter (g/cm<sup>3</sup>) (Domenico and Schwartz, 1998). The effective porosity of the aquifer was assumed to be 0.3 based on the specific yield of sand reported by Domenico and Schwartz (1998).

The transport of chloride from the landfarm considers advection and dispersion. Retardation of chloride is not considered. The vertical dispersivity in the vadose zone is based on the distance from the ground surface to the water table. The VADSAT manual (API, 1995) provides an equation from Gelhar et al. (1985) to estimate the dispersivity in the vadose zone, which gives an estimated vertical dispersivity of 1.05 feet based on a depth to water of 50 feet. The longitudinal dispersivity in the saturated zone was conservatively set to a minimal value of 1.5 feet based on a transport distance of 10 feet and measurements of scale and dispersivity provided by Gelhar (1992). The actual transport distance beneath the landfarm ranges from more than 300 feet to 0 foot. The lateral and vertical dispersivities were 1/10 and 1/20 of



longitudinal, which were 0.15 foot and 0.07 foot, respectively. Although dispersivity is usually a sensitive parameter for contaminant transport, it was not sensitive for these simulations because the receptor is located along the centerline of the plume.

Recharge is one of the most important parameters in determining the chloride impact to groundwater, and for a given location, vegetation plays a key factor in infiltration. We conducted two phases of modeling, the first of which was previously presented at the January 2006 stakeholders meeting. In the first phase, we set the recharge rate constant at 17 mm/yr and removed the landfarm materials after three years. This recharge value is near the upper end of the range reported by Theis for the southern Ogallala (2.3 to 17 mm/yr) (API, 1996), but this rate may be high because at the aquifer scale it may include some local recharge components in addition to diffuse recharge.

In the second and more recent modeling, we varied the recharge rates taking into account operations and revegetation. During the first three years, we assumed that there was no evapotranspirative cover and assumed a steady, long-term recharge rate of 19 mm/yr. Keese et al. (2005) reports that the median recharge for nonvegetated texturally variable soils in the High Plains of Texas is 19 mm/yr. Thus, the 19 mm/yr rate was selected for the period when the landfarm was not vegetated (the first three years).

The steady recharge rates for subsequent periods when there was an evapotranspirative cover were based on recharge studies by Phillips et al. (1988) and Keese et al. (2005). A recharge rate of 9.5 mm/yr was selected for the period when vegetation was becoming established (3 to 10 years). For the final stage after 10 years, we conducted simulations with a steady recharge rate of 2.5 mm/yr and 0.8 mm/yr rate. Keese et al. (1988) found that with vegetation established, the recharge decreases drastically to 0.8 mm/yr, as compared to the unvegetated condition where recharge rate was 19 mm/yr. Phillips et al. (1988) used three techniques to estimate recharge in Las Cruces, New Mexico: tritium peak, chlorine-36 peak, and chloride mass balance. The recharge rates estimated by the tritium peak, chlorine-36 peak, and chloride mass balance techniques were 9.5 mm/yr, 2.5 mm/yr, and 1.5 mm/yr, respectively. These studies provide a reasonable basis for predicting net infiltration and recharge to groundwater. For example, all of these rates are greater than the upper end of the range estimated by

Walvoord and Scanlon (2004) (0.03 to 0.1 mm/yr) for interplaya regions of the southwest where plants are well established in sufficiently deep soils.

The initial concentration of chloride in the landfarm soil was 1,000 mg/kg. Once the maximum concentration in groundwater is observed at the monitoring well, the chloride soil concentration limit can be estimated for the landfarm, as follows:

$$C_{\text{limit}} = 1,000 \text{ mg/kg} \left( \frac{C_{\text{EPA}} - C_{\text{background}}}{\Delta C} \right)$$

where Climit = the limit of chloride soil concentration in the landfarm estimated by the simulation

C<sub>EPA</sub> = the EPA secondary standard for chloride (250 mg/L)

C<sub>background</sub> = the background concentration of chloride in the aquifer

ΔC = the maximum change in concentration observed at the monitoring well in the model simulation

The U.S. Geological Survey (USGS) reports a median background concentration of 66 mg/L in the southern Ogallala (USGS, 2003).

Soil properties used for modeling are summarized in Table 2.



Parameter	Silty Loam	Clay <sup>a</sup>	Sand	Loamy Sand	Source
Saturated hydraulic conductivity (K <sub>e</sub> ) (ft/d)	0.35	0.16	23.4	11.5	Carsel and Parrish, 1988
Total porosity (Φ) (unitless)	0.45	0.38	0.43	0.41	Carsel and Parrish, 1988
Residual water content (θ <sub>w</sub> ) (unitless)	0.067	0.068	0.045	0.057	Carsel and Parrish, 1988
van Genuchten inverse air entry pressure (ɑ) (1/m)	2	0.008	14.5	12.4	Carsel and Parrish, 1988
van Genuchten curve fitting parameter (n) (unitless)	1.41	1.09	2.68	2.28	Carsel and Parrish, 1988
Bulk density (g/cm <sup>3</sup> )	1.46	1.64	1.51	1.56	Calculated from Φ and rock grain density (2.65 g/cm <sup>3</sup> ) as given by Domenico and Schwartz, 1998
Effective porosity			0.3	0.3	Based on specific yield given in Domenico and Schwartz, 1998
Average initial water content	0.329	0.364	0.063	0.085	Based on HYDRUS-1D steady-state result for natural infiltration
Saturated zone seepage velocity (ft/d)		****	0.3	0.15	Calculated

#### Table 2. Summary of Soil Properties

<sup>a</sup> Clay is agricultural clay as used by Carsel and Parrish, 1988 (60% clay, 30% silt, 10% sand).

ft/d = Feet per day

m \_= Meter(s)

g/cm<sup>3</sup> = Grams per cubic centimeter

- = Not used in saturated zone

#### 3.4 Results

Conservative simulations using the steady recharge rate of 17 mm/yr were conducted for a variety of soils under a landfarm of 2.5 acres (approximately 8,100 cubic yards). Results for these simulations are summarized in Table 3. Figure 1 shows a plot of concentration over time at the monitoring well for these simulations. The combination of sand with a 3-foot-thick clay layer (27 to 30 feet below ground surface) in the vadose zone and a loamy sand in the aquifer gives the minimum limit of chloride in the landfarm (4,000 mg/kg). A similar result to this combination was found using a uniform soil in the vadose and saturated zones of loamy sand.



The chloride limit using all loamy sand was 4,400 mg/kg. Because the vadose zone and saturated zones are not expected to have different soils, the uniform combination of loamy sand was used for the evapotranspirative simulations.

Vadose Zone Soil	Aquifer Soil	Maximum Change in Concentration for 1,000 mg/kg source (ΔC) (mg/L)	Time to Reach Maximum Concentration at Receptor (years)	Recommended Limit for Chloride Concentration in Landfarm Soil (mg/kg)
Sand	Sand	29	56	6,420
Loamy sand	Loamy sand	42	59	4,350
Loamy sand	Sand	21	57	8,850
Sand with clay layer	Sand	23	88	7,990
Sand with clay layer	Loamy sand	47	91	3,890
Loamy sand with clay layer	Loamy sand	32	92	5,680
Loamy sand with clay layer	Sand	16	90	11,650

### Table 3. Results for 2.5-Acre Landfarm with Source Removed After Three Years

mg/kg = Milligrams per kilogram

mg/L = Milligrams per liter

Results of the evapotranspirative simulations where the landfarm waste is not removed are summarized on Table 4.





Vadose Zone Soil	Aquifer Soil	Long-Term Recharge (mm/yr)	Maximum Change in Concentration for 1,000 mg/kg source (ΔC) (mg/L)	Time to Reach Maximum Concentration at Receptor (years)	Recommended Limit for Chloride Concentration in Landfarm Soil (mg/kg)
Loamy sand	Loamy sand	0.8	3.6	1,395	51,000
Loamy sand	Loamy sand	2.5	19	485	9,500

	Table 4.	<b>Results</b> fo	or 2-Acre	Permanent	Landfarm with	Evap	otrans	pirative	Cover
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mm/yr = Millimeters per year mg/kg = Milligrams per kilogram

mg/L = Milligrams per liter

The simulation for a low-sensitivity area with a recharge rate of 0.8 mm/yr gives an upper chloride limit of 51,000 mg/kg in landfarm soils. The simulation for a moderately sensitive area with a recharge rate of 2.5 mm/yr gives an upper chloride limit of 9,500 mg/kg. The maximum chloride at the monitoring well was observed after 480 years for the 2.5 mm/yr rate and after 1,400 years for the 0.8 mm/yr rate.

# 4. NMOCD's Proposed Monitoring

NMOCD's proposal to monitor incoming waste, waste in the landfarm treatment zone, and waste seepage in the vadose zone beneath the landfarm is excessive. The proposed monitoring includes sampling, analyzing, and certifying that the landfarm materials in the transported material do not contain chloride concentrations in excess of 1,000 mg/kg. Furthermore, the landfarm treatment zone must be sampled semiannually for chloride, as well as other constituents, to be sure no chloride concentration is detected above 1,000 mg/kg. Additionally, the vadose zone soils beneath the treatment zone must be sampled and monitored to demonstrate that chloride concentrations do not exceed 1,000 mg/kg. Certifying the composition of the transported material and monitoring the vadose zone should be sufficient to protect groundwater. Sampling the treatment zone seems unnecessary, except if the operator is using the bioremediation endpoint approach to close a lift.





I believe that the NMOCD's intent in developing the the vadose zone monitoring program is intended to protect fresh groundwater, in accordance with the requirements of the New Mexico Water Quality Control Commission (NMWQCC). Unfortunately, the approach is much more stringent than is reasonable to comply with these regulations. The proposed regulations actually preclude any impact to the vadose zone soils beneath the landfarm. That is, the NMOCD is establishing an antidegradation policy for soil.

In my experience, this antidegradation policy is unprecedented in New Mexico, inasmuch as dischargers are allowed to discharge to groundwater up to the groundwater quality standards at a point of reasonable foreseeable future use, as established in Section 3103 of the NMWQCC regulations. Additionally, it is standard practice in setting soil cleanup standards that constituents in the 3103 list may be present in soil as long as they do not pose a threat of exceeding the groundwater standards. Voluntary cleanup standards and risk-based corrective action programs at the New Mexico Environment Department (NMED) recognize that it may be acceptable for soil to be impacted above background concentrations. The practical significance of the NMOCD's antidegradation policy is that if any of the constituents in the 3103 list are detected above background concentrations, then a corrective action program must be implemented, and landfarm closure could potentially be imposed prematurely.

# 5. NMOCD's Proposed Treatment Zone Closure Standards

NMOCD has proposed a list of standards that must be met within the treatment zone to achieve closure. In general, this list appears to be based on calculations used to derive soil screening levels (SSLs) set by the NMED for establishing voluntary cleanup levels. The SSLs are intended to establish the concentrations that can be left in soil after cleanup is complete, and they take into account the concentration of the pore water percolating into an aquifer. The first step in the NMED analysis to set an SSL is to find the NMWQCC groundwater standard for the chemical, and assume that concentration is the maximum concentration in pore water that could be allowed in leachate if there were no dilution of the pore water by groundwater; that is, this step determines a dilution and attenuation factor (DAF) of 1, which means that there is no dilution at all. However, NMED and EPA guidance recognize that dilution will of course occur in the aquifer, and that the amount of dilution of the pore water leachate depends on the rate of



flow in the aquifer and the mass flux of leachate into it. Thus, according to the NMED and EPA, DAFs of 7 to 20 or more are recognized as highly likely in New Mexico (NMED, 2004) and protective of groundwater.

In deriving these DAFs, NMED made numerous conservative assumptions to protect groundwater. For example, among other assumptions, NMED assumed that (1) there was no dilution of constituents in the vadose zone, (2) there would be leachate mixing within all or a portion of the aquifer, and (3) the point of compliance would be a monitor well located at the edge of the downgradient discharging facility. NMED indicates that they established the DAF of 1 only to facilitate calculating a site-specific SSL when site-specific data are available, so that in the second step in the process, the site-specific SSL would be obtained simply by multiplying the SSL associated with the DAF of 1 by the site-specific DAF. The voluntary cleanup program therefore gives a discharger flexibility to establish cleanup levels based on actual site data and modeling.

In contrast, the NMOCD has established SSLs for the treatment zone based on a DAF of 1. In essence, the NMOCD proposal requires pore water in the treatment zone to achieve groundwater standards. This approach is entirely inconsistent with that of its sister agency, the NMED, and is inconsistent with EPA guidance as well. In some instances, the proposed treatment zone standards will not likely ever be achieved, especially as vadose zone processes concentrate pore water constituents in the same manner that led to the development of the "chloride bulge".

The proposed treatment zone closure standards are also inconsistent with the vadose zone corrective action strategy proposed by NMOCD. Recall that in the vadose zone strategy, pore water is not allowed to contain any of the 3103 constituents above background concentrations in soil. However, according to the treatment zone closure strategy, the pore water is allowed to contain 3103 constituents from background up to the groundwater standard concentration. If it is protective of groundwater for the treatment zone to contain 3103 constituents, then it should also be equally protective of groundwater for the vadose zone to contain 3103 constituents. Oddly, with the vadose zone monitoring and corrective action trigger set to background, the DAF in the vadose zone is essentially zero, which is inconsistent with the treatment zone



closure standard proposed at a DAF of 1. With the proposed treatment zone standards, the NMOCD proposed regulation would not allow water that meets treatment zone remediation standards to pass through the vadose zone because such water would be above background. That is, by the proposed regulations, one could have closed the site with respect to the treatment zone, but be required to undertake corrective action because the vadose zone is impacted above background. Thus, a site might only be completely closed if a remedy is in place to clean up the vadose zone to background levels, regardless of whether the constituents constitute a risk to groundwater.

Not only are the treatment zone closure standards unreasonably stringent, but many of the constituents cannot be detected at the prescribed levels by commercial analytical testing laboratories. Table 5 lists the 3103 constituents and NMOCD's proposed standards in soil, along with the practical quantification limit (PQL) for a leading commercial analytical testing laboratory in New Mexico. Of the proposed standards, 13 standards are too low to be detected. Thus, the proposed treatment zone closure standards are not fully implementable.

### 6. Conclusions

- 1. Natural vadose zone processes at likely waste management (landfarm) sites in New Mexico have very low diffuse recharge, and at some sites where water moves upward from the water table, there is no recharge.
- Vadose zone and groundwater modeling shows that using site-specific data, concentrations of chloride far in excess of the 1,000 mg/kg limit proposed by the NMOCD are protective of groundwater.
- 3. Waste acceptance criteria should be set based on an approach that allows operators and NMOCD flexibility to take into account site-specific data.
- 4. The NMOCD's proposed monitoring strategy is excessive and the treatment zone monitoring requirements should be eliminated, except where the operator elects to use a bioremediation endpoint approach to closure.



- 5. The NMOCD's proposed corrective action trigger as any detection above background in the vadose zone is unreasonable, precedent setting, and inconsistent with treatment zone closure criteria.
- 6. The NMOCD's treatment zone closure criteria are also unreasonable. Any treatment zone closure criteria should be based on impacts to groundwater in a monitor well in which some dilution in the aquifer is taken into account.



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	NMWQCC Standard	NMOCD Proposed Standard	POI °
Constituent	(mg/L <sup>a</sup> )	(mg/kg <sup>*</sup> )	(mg/kg)
Arsenic (As)	0.1	0.0146	1.0
Barium (Ba)	1.0	108	0.1
Cadmium (Cd)	0.01	1.37	0.1
Chromium (Cr)	0.05	2.10	0.3
Cyanide (CN)	0.2	7.35	
Floride (F)	1.6	329	0.3
Lead (Pb)	0.05	400	0.25
Mercury (Hg), total	0.002	0.105	0.03
Nitrate (NO <sub>3</sub> as N)	10.0	17.1	0.3
Selenium (Se)	0.05	0.953	1.0
Silver (Ag)	0.05	1.57	0.25
Uranium (U)	0.03	16	0.5
Radioactivity (radium-226 + radium-228)	30 pCi/L	30 pCi/g	
Polychlorinated biphenyls (PCBs)	0.001	0.0224	
Toluene	0.75	0.347	0.05
Carbon tetrachloride	0.01	0.000988	0.05
1,2-Dichloroethane (EDC)	0.01	0.000248	0.05
1,1-Dichloroethylene (1,1-DCE)	0.005	0.133	0.05
1,1,2,2-Tetrachloroethylene (PCE)	0.02	0.00215	0.05
1,1,2-Trichloroethylene (TCE)	0.1	0.000131	0.05
Ethylbenzene	0.75	1.01	0.05
Total xylenes	0.62	0.167	0.05
Methylene chloride (dichloromethane)	0.1	0.00853	0.15
Chloroform	0.1	0.000414	0.05
1,1-Dichloroethane	0.025	0.201	0.05
Ethylene dibromide (EDB)	0.0001	0.000029	0.05

# Table 5. NMOCD Proposed Standard and Practical Quantification Limits Page 1 of 2

Bold indicates that the practical quantification limit (PQL) exceeds the proposed standard.

<sup>a</sup> Unless otherwise indicated

<sup>b</sup> From NMOCD, 2006

<sup>C</sup> From Hall Environmental 2005 price book; the PQL represents the level to which laboratories can accurately determine the concentration of a constituent. The PQL is often 2 to 10 times the calculated method detection limit (MDL).

NMWQCC = New Mexico Water Quality Control Commission mg/L = Milligrams per liter

NMOCD = New Mexico Oil Conservation Division

- = Milligrams per kilogram
- Picocuries per liter
   Picocuries per gram







Table 5.	NMOCD Proposed	Standard	and Practical	Quantification	Limits	
Page 2 of 2						

	NMWQCC Standard	NMOCD Proposed Standard	PQL°
Constituent	(mg/L ")	(mg/kg *)	(mg/kg)
1,1,1-Trichloroethane	0.06	1.34	0.05
1,1,2-Trichloroethane	0.01	0.000498	0.05
1,1,2,2-Tetrachloroethane	0.01	0.000172	0.05
Vinyl chloride	0.001	0.000143	0.1
PAHs: total naphthalene + monomethylnaphthalenes	0.03	0.0197	
Benzo-a-pyrene	0.0007	0.621	0.2
Chloride (Cl)	250.0	1,000	0.3
Copper (Cu)	1.0	51.5	0.2
Iron (Fe)	1.0	277	1.0
Manganese (Mn)	0.2	334	0.1
Phenois	0.005	2.37	
Sulfate (SO₄)	600.0	Background	1.5
Total dissolved solids (TDS)	1,000.0		
Zinc (Zn)	10.0	0.0682	0.25
pH	6-9 units		
Aluminum (Al)	5.0		1.0
Boron (B)	0.75		2.0
Cobalt (Co)	0.05		0.3
Molybdenum (Mo)	1.0		0.4
Nickel (Ni)	0.2		0.5

Bold indicates that the practical quantification limit (PQL) exceeds the proposed standard.

<sup>a</sup> Unless otherwise indicated

<sup>e</sup> From Hall Environmental 2005 price book; the PQL represents the level to which laboratories can accurately determine the concentration of a constituent. The PQL is often 2 to 10 times the calculated method detection limit (MDL).

NMWQCC = New Mexico Water Quality Control Commission

mg/L = Milligrams per liter

NMOCD = New Mexico Oil Conservation Division

mg/kg pCi/L pCi/g

- = Milligrams per kilogram = Picocuries per liter = Picocuries per gram

<sup>&</sup>lt;sup>b</sup> From NMOCD, 2006





Figure 2