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Steve,

Attached are the revised sections regarding the MULTIMED modeling approach for the Groundwater Monitoring Waiver Request document. Please review the revisions based on your comments and provide us with feedback at your earliest convenience so that we may finalize the document.

Thank you for your time,

Leah Wolf

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5.2.2 Alternative Modeling Approach

Numerous discussions were held with NMED regarding the modeling requirements for a waiver demonstration. Based on these discussions, the following criteria for the modeling effort were developed.

- A one-dimensional flow and transport model, MULTIMED, should be used to evaluate the potential travel times through the Lower Dockum.
- A travel time of 800 years should be considered as a minimum to justify a waiver from groundwater monitoring.
- Conservative input parameters should be utilized for all modeling runs. During this discussion, the most conservative assumptions and parameters will be highlighted in the text using the initials MCA (Most Conservative Assumption).

Based on the criteria discussed above, a one-dimensional flow and transport model, MULTIMED, was used to evaluate potential travel times through the lower Dockum as well as travel times along the Upper Dockum/Lower Dockum contact to an assumed perched aquifer 3600 feet east of the landfill. The approach presented in this sections differs from the previous model in several areas and was developed to be as conservative as possible (i.e. to predict the maximum transport rate and the minimum transport time through the Lower Dockum). Because of the different approach used in the current calculations, the results are not directly comparable to those reported in Section 5.2.1. Several important assumptions were changed in the current model as shown below in Table 5.1.

Table 5.1
Assumptions Used to Develop Alternative Modeling Approach

Assumption	Current Model	Previous Model	Justification
Flow dimensionality	1-dimensional flow	3-dimensional flow	A one dimensional flow simulation will require less water to reach a given depth and is therefore more conservative although the 3-d approach is more physically correct (MCA).
Saturated hydraulic conductivity	6.8 X 10^{-6} cm/s	5.7 x 10^{-8} cm/s	The hydraulic conductivity value used in the previous model was the average value based on core measurements. The value used in the current model was obtained by taking the maximum measured value (6.8 x 10^{-6} cm/s) from core measurements (MCA).
Saturation	Based on MULTIMED modeling	Based on Bumb and McKee model (1988) and HELP model predictions	The previous model used an exact steady-state solution to estimate saturation. The current model used a completely saturated system (MCA). Completely saturated conditions are considered highly unlikely given the arid conditions at the site but were used to present a maximum bound on the calculations.
Unsaturated hydraulic conductivity	Van Genuchten Model	Brooks-Corey Model	The Van Genuchten and Brooks-Corey Model are commonly used to estimate unsaturated conductivity.
Hydraulic gradient	Assumed to be unity	Assumed to be unity	This assumption ignores artesian conditions in the Santa Rosa Formation, which would result in a lower gradient and is therefore conservative.

The computer transport model MULTIMED was used to analyze the hypothetical leak into the subsurface below the landfill. The semi-analytical model consists of a number of modules, which predict contaminant transport through the Lower Dockum. A steady state, one-dimensional, semi-analytical module simulates flow in the unsaturated zone. The output from the unsaturated zone model is expressed as water saturation as a function of depth. This output is then used as input for the one-dimensional, unsaturated transport module, which can calculate transient and steady state contaminant concentrations. The results from both of these models are input into the one-dimensional flow and transport saturated zone module. The boundary conditions, input parameters, and MULTIMED output for each simulation is located in Appendix C.

Two MULTIMED simulations calculated the travel times through the Lower Dockum using different infiltration rates as boundary conditions:

- Assumes an infiltration rate equal to the saturated hydraulic conductivity of 0.84 in/yr (MCA). This approach is considered the most conservative and assumes that the formation has access to as much leachate as it can physically accept.

- Assumes as infiltration rate equal to the net recharge of 0.42 in/yr. for this site. This is based on a regional water balance assessment that does not account for any of the liner or cover barrier layers in the landfill. This approach more accurately models the long-term annual conditions at the site, but is still considered conservative.

A MULTIMED simulation also calculated the travel time to the east along the Upper Dockum/Lower Dockum contact to a perched aquifer approximately 3,600 feet downgradient of the proposed landfill. This simulation assumed an infiltration rate of 0.60 in/yr. Note that the MULTIMED output from this simulation reported a warning that the amount of infiltration input into the model was slightly more than the system could accept. This supports that the most conservative approach would require a slightly smaller infiltration rate and would generate a greater travel time.

The results from these simulations are shown below in Table 5.2

TABLE 5.2
SIMULATION RESULTS

Infiltration Rate in/yr (cm/s)	Travel time (years)	Description
0.84 (6.8×10^{-8}) – Trial 1	1606	Assumes vertical migration through the entire section of Lower Dockum sediments. Utilizes maximum infiltration rate in Lower Dockum sediments (MCA). This is considered very conservative
0.42 (3.4×10^{-8}) – Trial 2	3211	Assumes vertical migration through the entire section of Lower Dockum sediments. Utilizes realistic but still conservative infiltration rate.
0.60 (4.76×10^{-6}) – Trial 3	3600[1]	Assumes lateral migration to nearest potential aquifer to the east. Permeability is representative of Upper Dockum sediments.

[1]Travel time to receptor well 3600 feet east of the landfill

5.2.3 Discussion of Modeling Results

Two different approaches have been presented for evaluating the potential releases from the landfill to impact groundwater. Both of these evaluations have concluded that it would require an extremely long time for potential leaks to reach groundwater (over a thousand years). Extremely conservative assumptions were used in the most recent evaluation of transport time to groundwater and these are assumptions are not likely to occur during the lifetime of the facility or the extended future (greater than 1,000 years). The factors contributing to the long periods of time for potential release from the facility to reach the Santa Rosa Formation include the low permeability of the Lower Dockum, the thickness of the unit (600 feet) and the arid conditions at the site. These conditions combine to make the Gandy Marley facility an ideal location for the proposed landfill activities.

5.3. VADOSE ZONE MONITORING

Due to the extremely long travel times in the Lower Dockum and along the Upper Dockum/Lower Dockum contact, groundwater monitoring data from the Santa Rosa formation or the perched aquifer downgradient of the site will not provide meaningful information concerning potential releases from the proposed facility. It is therefore recommended that a Vadose Zone Monitoring System (VZMS) be used to detect potential release from the facility. The VZMS will provide the most effective method for detecting potential releases from the facility in a timely manner. Before potential contaminants can reach the uppermost aquifer, these systems can detect leaks and help to initiate corrective actions for preventing impacts to the environment.

APPENDIX C
MULTIMED FLOW MODELING RESULTS

C-1 MULTIMED Boundary Conditions

Model boundary condition are important for successful simulations since they define the theoretical constraints of the model and reflect inherent assumptions necessary to translate a real physical system into the virtual mathematical system of the computer model. The boundary conditions used for the model are described below in Table C-1, Triassic Park MULTIMED Model Boundary Conditions.

Table C-1
Triassic Park MULTIMED Model Boundary Conditions

Parameter	Parameter Value	Justification
Recharge	0.0 m/yr – all Trials	To keep infiltrating contaminants over the area outside the landfill from being diluted by rainfall (MCA). This condition will result in more conservative contaminant concentrations at the receptor well
Leachate Infiltration Rate	0.84 in/yr – Trial 1 0.42 in/yr – Trial 2 0.60 in/yr – Trial 3	Equal to the unsaturated hydraulic conductivity (MCA) – Trial 1 Equal to the net recharge rate – Trial 2 Maximum infiltration rate that model will accept – Trial 3
Area of Waste Disposal Unit	9.00 m^2 – all Trials	This is the size of the hypothetical liner flaw in the vicinity of the leachate sump. Due to construction quality assurance programs, a liner flaw of this magnitude is highly improbable (MCA).
Contaminant Concentration	1.0 ppm – all Trials	This condition implies that the contaminant mass in the system will not be depleted by setting it to a constant 1.0 ppm during the entire transport simulation period
Contaminant Decay	0.00 – all Trials	To allow the maximum concentration of leachate to travel through the subsurface (MCA)
Retardation	0.00 – all Trials	To allow the fastest possible contaminant transport through the subsurface (MCA)
Groundwater Table Mixing Zone	0.1 m – all Trials	To reduce the dilution effects of the untainted groundwater on the contaminant concentration

C-2 MULTIMED Unsaturated and Saturated Zone Input Parameters

Since the model simulates flow and transport in the unsaturated and saturated zones, geologic characteristics of the subsurface are necessary as input to the model. These variables, derived from published literature and the site-specific geologic investigation are discussed below in Table C-2, Triassic Park MULTIMED Unsaturated Zone Input Parameters and Table C-3, Triassic Park MULTIMED Saturated Zone Input Parameters.

Table C-2
Triassic Park MULTIMED Unsaturated Zone Input Parameters

Parameter	Parameter Value	Justification
Saturated Hydraulic Conductivity	6.8 x 10^{-8} cm/s – Trial 1 6.8 x 10^{-8} cm/s – Trial 2 1.0 x 10^{-6} cm/s - Trial 3	Maximum value obtained from core samples of Lower Dockum tested in the lab (MCA) – Trials 1 & 2 Maximum value obtained from core samples of Upper Dockum tested in the lab – Trial 3
Effective Porosity	0.23 – Trial 1 0.23 – Trial 2 0.30 – Trial 3	50% of literature value for siltstones (Dean et al. 1989) for the most conservative value– Trials 1 & 2 Estimated literature value for aquifer-type materials –Trial 3
Residual Water Content	0.116– all Trials	Average in-situ moisture content of the Chinle Formation claystones as measured in 10 core samples (Weaver et al, 1997)
Air Entry Pressure	1.00 m – all Trials	Selected from published literature value for siltstone (Weaver et al., 1997)
Van Genuchten Alpha (α) coefficient	0.005 – all Trials	Selected from published literature value for silty clays and clayey silts (Weaver et al., 1997)
Van Genuchten Beta (β) coefficient	1.09 – all Trials	Selected from published literature value for silty clays and clayey silts (Weaver et al., 1997)
Thickness of Layer	183 m – Trial 1 183 m – Trial 2 1.0 m – Trial 3	Thickness of vadose zone in Lower Dockum – Trial 1 Thickness of vadose zone in Lower Dockum – Trial 1 To create a lateral simulation to a perched water table along the Upper Dockum/Lower Dockum contact
Longitudinal Dispersivity	1.00 – all Trials	To avoid excessively high dispersion as suggested in the MULTIMED program documentation

Table C-3
Triassic Park MULTIMED Saturated Zone Input Parameters

Parameter	Parameter Value	Justification
Saturated Hydraulic Conductivity	30.0 m/yr – Trial 1 30.0 m/yr – Trial 2 3.15 m/yr - Trial 3	Estimated value for Lower Dockum aquifer – Trial 1 Estimated value for Lower Dockum aquifer – Trial 2 Estimated value for lateral travel along Upper/Lower Dockum contact – Trial 3
Aquifer Thickness	30.0 – Trial 1 30.0 – Trial 2 3.00 – Trial 3	Estimated value for Lower Dockum aquifer – Trial 1 Estimated value for Lower Dockum aquifer – Trial 2 Estimated value for perched aquifer along Upper/Lower Dockum contact – Trial 3
Hydraulic Gradient	.01 – all	Estimated value for site
Distance to Receptor Well	1.00 m – Trial 1 1.00 m – Trial 2 1120 m – Trial 3	To obtain point of compliance for upper aquifer – Trial 1 To obtain point of compliance for upper aquifer – Trial 2 To perched aquifer approx. 1120 m from the landfill