# OFFICE OF THE NEVADA ENVIRONMENTAL RESPONSE TRUST TRUSTEE

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May 3, 2017

Mr. Weiquan Dong, Ph.D.
Bureau of Industrial Site Cleanup
Nevada Division of Environmental Protection
2030 E. Flamingo Rd, Suite 230
Las Vegas NV 89119

RE: Phase 5 Transient Groundwater Flow Model, Response to Comments
Nevada Environmental Response Trust
Henderson, Nevada

Dear Mr. Dong:

The Nevada Environmental Response Trust (NERT) is pleased to present our Response to Comments associated with the Nevada Division of Environmental Protection (NDEP) comments on the Phase 5 Transient Groundwater Flow Model dated March 7, 2017. Following NDEP's approval of the attached responses, NERT will incorporate the agreed upon changes into the Phase 6 Contaminant Transport Model. As previously discussed, the Phase 6 Contaminant Transport Model will be submitted to NDEP following integration of geologic and hydrogeologic data collected during Phase 2 and 3 Remedial Investigation field efforts.

If you have any questions or concerns regarding this matter, feel to contact me at (702) 960-4309 or at steve.clough@nert-trust.com.

Office of the Nevada Environmental Response Trust

Stephen R. Clough

Stephen R. Clough, P.G., CEM
Remediation Director
CEM Certification Number: 2399, exp. 3/24/19

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Allan DeLorme, Ramboll Environ
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| **Essential Corrections** | |
| 1. The flow model must be able to simulate vertical gradients properly for contaminant transport modeling purposes. Measured and simulated vertical hydraulic gradients were calculated at selected locations where multilevel head data were measured. The locations of these sites are shown in Figure 1. Table 1 shows the measured and simulated vertical hydraulic gradients at these locations. Measured vertical gradients are generally upward which is consistent with the overall conceptual model. Five of the seven locations showed significant deviations between the simulated and measured magnitude by an order-of-magnitude or more. At site 1 the measured gradient was downward and the model simulated upward flow but with a magnitude near zero. The conclusion is that the model is able to generally match the vertical flow direction, but the magnitude of the vertical gradient tends to be under-predicted. The under-prediction is more pronounced at greater depths which may indicate that the model requires smaller vertical hydraulic conductivities in the deeper sediments or an explicit representation of a low permeable unit at depth. In summary, additional calibration is needed to properly simulate vertical gradients. | 1. Additional investigation of vertical hydraulic gradients between the shallow and middle water bearing zones (WBZs) is being conducted as part of Phase 2 of the NERT Remedial Investigation (RI), which is currently underway. Based on data collected during the Phase 2 RI, the Phase 3 RI, and other relevant investigations, the conceptual model of flow and transport in the middle and deep WBZs will be refined and incorporated into Phase 6 of the NERT groundwater model. This work will include refinement of the model calibration to better match vertical gradients. |
| 2. More effort is needed on the steady-state calibration. Steady-state calibration creates a balance between the boundary fluxes and hydraulic conductivity. It appears that there is a conceptual problem (or imbalance) in the lower model layers as evidenced by the large head residuals. The logic behind the comment is given in the following bullets:<br>a. According to the Phase 5 modeling report the hydraulic conductivity field is largely dependent on the Phase 4 steady-state calibration. Reviewing the observed versus simulated groundwater level plot in the Phase 4 report (Figure 12 in the Phase 4 report and Figure 2 | 2. As described in the response to comment #1 above, model calibration will be further refined during Phase 6 model development. One of the main objectives of the Phase 2 and Phase 3 RI is to refine the conceptual model of the deeper geologic layers. Based on this refinement, the Phase 6 Model will be updated to better represent geologic conditions in the deeper layers that may affect fate and transport of chemicals of concern. However, many of the calibration targets in deeper model layers are from wells screened more than 200 feet below ground surface (bgs), which is generally below the maximum vertical extent of chemicals of concern (see Table 1). In addition, several of |

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| herein) there is evidence that the calibration was poorer in the lower layers (see red outline). The Phase 4 model relied on 2015 measured water levels so there were only a limited number in the lower layers so it did not appear to be a big problem.<br>b. In the Phase 5 transient model a larger groundwater level dataset was used because the model covered a longer period (2000-2015). The calibration problems become more pronounced in the lower layers (Figure 17b in the Phase 5 report and Figure 3 herein) as shown in the points in the red outline. In general, the model is under-predicting hydraulic heads in the lower layers by as much as 70 feet.<br>c. Inspection of the spatial distribution of the Phase 5 model head residuals (Figure 4) at early time (2000) in layer 1 suggests that calibration is quite good in the shallow aquifer. The magnitude of the residuals is small (few feet) and do not have any spatial bias.<br>d. The calibration gets significantly worse in the lower model layers. Figure 5 shows the Phase 5 model residuals at early time (2000-2001) in layers 3-5. The residuals are larger and indicate under-prediction on the east side and a few over-predictions on the west side.<br>e. In summary, the steady-state model calibration should be redone to ensure reduce residuals in lower model layers. The goal should be residuals on the order of 10 feet in all layers. | the wells in the lower layers of the model are under artesian conditions that may be caused by confining layers present only locally. In order to accurately simulate the fate and transport of chemicals of concern present in shallower units, it may not be necessary to include a detailed representation of geologic conditions at all locations in deeper layers as long as vertical flows into the shallower units are accurately represented. One of the objectives of the Phase 6 model is to refine the representation of vertical gradients and groundwater flows within the NERT On-Site and Off-Site RI Study Areas based on Phase 2 and 3 RI results so that the fate and transport of chemicals of concern can be accurately simulated. |
| 3. The southernmost general head boundary conditions may need to be revisited as detailed below:<br>a. It is not clear why the southern boundary condition was changed from a specified flow to general head between Phase 4 and 5. Generally specified flow up-gradient boundary conditions provide a more robust steady-state calibration as the assumed inflow must | 3a. The southern boundary was switched from specified flux to head-dependent flux in the Phase 5 model to allow the boundary inflow to change over time in response to changes in pumping and recharge within the model domain. We will revisit the parameterization of the southern boundary condition in the Phase 6 model in order to improve the calibration of heads in the lower layers. An explanation for |

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| balance with the specified hydraulic conductivity. It can be difficult to specify the boundary fluxes with varying hydraulic conductivities and to properly simulate vertical gradients, but it may be worth revisiting to improve the lower layer calibration problems. At a minimum the report should state why the change was made from specified flow to general head boundaries and potential implications for the calibration. | the choice of boundary condition type that describes the implications for calibration will be included in the Phase 6 model documentation. |
| b. The southern general head boundary conditions are only applied to cells within the alluvium and UMCf-cg units. At first glance it seems reasonable to apply the general head boundary to coarse-grained units, but the hydraulic conductivity of the UMCf-fg is nearly the same as the UMCf-cg (0.72 versus 1.2 ft/day for UMCF-fg and UMCf-cg, respectively). Essentially there is a disconnect between the geologic conceptualization and hydraulic parameters used to define the coarse and fine-grained Muddy Creek deposits. The best solution would be to include boundary conditions to all geologic units. Otherwise, the authors should explain why this was not done. | 3b. The boundary conditions will be refined during Phase 6 model development with boundary inflows included in all geologic units or an explanation will be provided if an alternative approach is used. |
| c. Section 5.4.1, 2nd paragraph, last sentence: The authors state that the boundary fluxes were adjusted to achieve agreement between the simulated and conceptual water budget. General head boundaries require a head and conductance as input, so flux cannot be adjusted directly. Was the conductance adjusted during calibration? Reword this statement to clarify. | 3c. Yes, the boundary conductance was adjusted during model calibration while keeping the boundary reference heads constant. The approach used for calibrating the boundary conditions will be described in the documentation for the Phase 6 model. |
| d. It is not clear how the vertical gradients calculated in Appendix E-3 were applied to the southern general head boundary. Table 2 shows the heads applied to two cells along the southern boundary for each of the model layers. Gradients are both upward and downward in various layers but the linkage to | 3d. In general, the limited measured vertical gradient data were averaged over time and interpolated along the southern boundary, with consideration also given to measured heads in nearby wells. The boundary reference heads were also adjusted so that they did not fall below the bottom elevation of the model layer. As described in |

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| Appendix E-3 is not clear. Were the vertical gradients averaged over time and then extrapolated to the boundary condition cells? This process and associated general head boundary conditions may be the cause of the poor calibration in the deeper portions of the model. The authors need to provide more detail on how the vertical gradients were applied and discuss any implications of using relatively noisy head data as a basis for boundary conditions. | response #1 above, the conceptual model of vertical gradients will be refined based on new data being collected as part of the Phase 2 and 3 RI. The boundary conditions of the Phase 6 model will be updated to incorporate this refined conceptual model, and the Phase 6 model documentation will describe the basis of these updates. |
| 4. Ramboll Environ's transport modeling approach will be highly dependent on the temporal history of advective and diffusive transport to and from the UMCf. Ramboll Environ proposed using one-dimensional Hydrus results to help guide the MT3D dual-domain modeling. Though the Hydrus results are helpful to understand the processes that control contaminant migration to the UMCf, they will not be easily transferable to the MT3D modeling because of scale and abstraction issues. Appendix B describes a simplified modeling analysis to determine the efficacy of using MT3D's dual porosity approach without simulating the historical plume development. The results suggest that a current estimate of the immobile domain concentration can be used to initiate predictive modeling into the future. In the Phase 6 model Ramboll Environ should note the time period that will be simulated by the contaminant transport model. In other words, will they attempt to recreate the plume evolution or start with current conditions and simulate into the future. | 4. Although the approach to be used for the Phase 6 transport model is still under development, our current plan is to simulate only recent and future concentrations and not to simulate the period during which chemicals of concern were released. The release period was included in the HYDRUS simulations to improve our conceptual understanding of vertical concentration profiles and vertical mass flux. |
| 5. Ramboll Environ is suggesting that density effects due to high TDS fluid may not be important for contaminant transport calculations. Generally, TDS concentrations greater than 10,000 mg/L require density-dependent simulations. A review of the TDS concentrations in the second quarter of 2015 indicates that concentrations are as high as 78,000 mg/L is isolated areas and fairly large | 5. Ramboll Environ has begun conducting further evaluations of the significance of density effects on flow and transport, which will be described in the Phase 6 model documentation. These evaluations are being performed with a simple 3D model of the NERT Site using the SEAWAT model code developed by the US Geological Survey. The SEAWAT code includes a combination of MODFLOW and |

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| areas are in excess of 10,000 mg/L. Given these concentrations, it would be important to at least investigate the importance of density dependent solutions. This could be done with a simpler abstraction model to help quantify the effects. Ramboll Environ should include language in the report that a density-dependent model will at least be tested or otherwise provide a more detailed argument as to why a density-dependent model is not needed. | MT3D that have been modified to include density effects. The significance of density effects is being evaluated by comparing the results of simulations of perchlorate transport both with and without density effects. Preliminary SEAWAT modeling results suggest that density effects do not significantly affect the transport of perchlorate under current conditions. Also, we will evaluate correcting water levels for density effects (i.e., fresh water head corrections). A detailed analysis of the significance of density effects will be provided in the Phase 6 model documentation. |
| **Minor Corrections/Comments** | |
| 1. The evaporation rate from surface water was estimated as the reference ET for short grass multiplied by 1.05 (Allen et al., 1998), which yielded 78 in/yr. Ramboll Environ should consider subtracting precipitation from this estimate which would reduce the effective evaporation rate. | 1. We will refine the ET estimate in the Phase 6 Model by subtracting precipitation. |
| 2. The Nevada Division of Water Resources well log database shows a number of wells drilled within the model domain. It may be worthwhile to see if there are any large capacity wells in the area. | 2. A comprehensive review of permitted groundwater pumping over the period from 2000 to the present was conducted based on the Nevada Division of Water Resources (NDWR) well log database and annual water use reports for the Phase 5 model. There were no significant groundwater withdrawals (other than the remediation pumping) identified within the model domain during this period. Another review of the NDWR well log database will be conducted before the Phase 6 model is completed. A detailed summary of this review will be provided in the Phase 6 model documentation. |
| 3. Regional recharge rates were evaluated using the PRISM (PRISM Climate Group, 2017) precipitation model and an independent empirical recharge model that relates PRISM precipitation to groundwater recharge (Epstein et al., 2010). Ramboll Environ should at a minimum elaborate on the uncertainty associated with empirically derived | 3. The uncertainty in the boundary flux estimations will be discussed further in the Phase 6 model documentation. As part of this discussion, a comparison of alternative approaches such as that of Epstein et al. (2010) will be provided. |

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| recharge estimates and perhaps also refer to the Epstein et al., 2010 method results as an independent estimate of recharge (See Appendix A for more detail explanations about this comments). | |
| 4. Section 4.2, 2nd paragraph, 2nd to last sentence: What is meant by a vertical to lateral anisotropy ratio of 0.3 in this context. Ramboll Environ may want to note that this has nothing to do with anisotropy in hydraulic conductivity. | 4. The vertical to lateral anisotropy ratio referred to in this section describes the parameters used in the Leapfrog model for the interpolation of geologic surfaces. As noted in the comment, this anisotropy ratio is not related to hydraulic conductivity. A more detailed clarification will be provided in the Phase 6 model documentation. |
| 5. The geometric mean of the measured vertical hydraulic conductivity of the UMCf is 1.0 x 10-3 ft/day while the values used in the model are 7 x 10-2 and 1 x 10-1 ft/day for the UMCf-fg and UMCf-cg, respectively. The vertical conductivity used in the model is large relative to the measured values. The authors should at least comment on the fact that the modeled value of vertical hydraulic conductivity is near the upper end of the measurements. | 5. The vertical conductivities used in the model were adjusted during the calibration so that they were within the range of measured values. The vertical conductivities will be further revised in the Phase 6 model during recalibration of the lower model layers. A more detailed discussion describing how model conductivity values compare to measured values will be added in the Phase 6 model documentation. |
| 6. The stream package is being used with the ICALC parameter being negative such that stream stage is not being calculated based on flow. This has implications for solute transport modeling because solute mass flux into and out of the Las Vegas Wash cannot be simulated unless the fluid water balance is being calculated (i.e. ICALC > 0). The high resolution grid is such that the width of the Las Vegas Wash is larger than a model cell and calculation of stream stage is not support for parallel reaches in a single stream. The inability to simulate the fluid mass balance in the Las Vegas Wash will not allow one to simulate solute concentrations the Las Vegas Wash. This could be important if modeled concentrations in the Wash itself are needed to predict Lake Mead concentrations. The inability to simulate concentrations in the Las Vegas Wash should not have a significant impact on simulated solute | 6. The stream stage of Las Vegas Wash is being specified as an input parameter rather than being calculated by the model based on stream flow and stream channel characteristics. This approach allows for the water balance of the stream to be simulated, as has been done in the Phase 5 model. Similarly, the model can be used to calculate chemical mass discharge at various points of interest in Las Vegas Wash by post-processing the model results in order to combine mass discharge from parallel reaches. It has been confirmed that this approach will work during testing using the Phase 5 model and the MT3D-USGS transport code. The modeling objectives do not include attempting to simulate in detail chemical concentrations in Las Vegas Wash. |

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| migration in the aquifer. The authors should discuss the implications of this limitation on future solute transport modeling. | |