MEMORANDUM

northgate environmental management, inc.

From: Deni Chambers, CEM
Josh Otis, CEM

Date: October 5, 2012

To: Shannon Harbour, PE
Nevada Division of Environmental Protection

RE: Revised Response to Comments on the Groundwater Model for the Nevada Environmental Response Trust Site, Henderson, Nevada

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INTRODUCTION

On March 15, 2012, the Nevada Division of Environmental Protection (NDEP), ENVIRON International Corp. (ENVIRON), and Northgate Environmental Management, Inc. (Northgate) participated in a conference call to discuss comments provided by NDEP in their April 5, 2011 letter regarding the *Capture Zone Evaluation Report, Tronox LLC, Henderson, Nevada* (CZE Report) dated December 10, 2010 and the associated groundwater flow model (the model) for the Nevada Environmental Response Trust Site (the Site). During this call, NDEP requested that the following items be submitted for review: the groundwater flow model, supporting documentation, and the subset of responses to comments on the CZE Report from the April 5, 2011 letter that pertain only to the model.

In a memo dated April 25, 2012, Northgate provided responses to NDEP comments regarding the model and a complete set of model input files. NDEP provided follow-up comments in a letter dated August 1, 2012 on the initial response provided by Northgate. Responses to all NDEP comments regarding the model, including those in the April 5, 2011 and August 1, 2012 letters, are provided below. Since no significant changes have been made to the model in response to NDEP comments, the model files provided along with the April 25, 2012 memo are not being resubmitted.

RESPONSE TO NDEP COMMENTS REGARDING THE MODEL

NDEP's letter dated April 5, 2011, contained twenty-eight comments regarding the CZE Report. As agreed during the March 15, 2012 conference call, only responses to comments specifically pertaining to the model are included in this memo. Comments #15, #16, #23, and #28 were identified as being directly related to the model development and inputs. The comments and responses are provided below:

NDEP Comment #15. Section 6.2.3, page 37, NDEP noted the use of no flow boundaries; please clarify whether these boundaries were tested for induced boundary effects.

Response:

The eastern and western edges of the active model domain were chosen to coincide as closely as possible with observed streamlines. This allowed the lateral boundaries to be treated as no-flow boundaries. The lateral extent of the model domain was selected to be sufficiently large such that potential induced boundary effects from the no flow boundaries, if present, would not impact model results at the NERT well fields. The computed hydraulic heads in the central portions of the model domain, which contain the NERT well fields and are the areas of interest for the CZE, show good agreement with observed hydraulic heads. The good match between the observed and computed hydraulic heads in the center of the domain gives us confidence that the lateral boundaries are not interfering with the capture zone evaluation results.

NDEP Comment #16. Section 6.2.4, page 38, NDEP noted the use of harmonic and arithmetic means to set bounds for hydraulic conductivity during model calibration. While the use of the harmonic mean appears to allow for the effects of lower conductivities, the use of the arithmetic mean would appear to preclude the effects of higher conductivities. Please discuss whether this method of calibration would skew model results towards that of lower hydraulic conductivity.

Response:

The hydraulic conductivity field was modeled based on the concept of effective conductivity. As discussed in a number of references (e.g., Matheron, 1967; Batchelor, 1974; de Marsily, 1986; Rubin, 2003), effective hydraulic conductivities are bounded between the harmonic mean and the arithmetic mean of the local scale hydraulic conductivities. This applies when groundwater flow is uniform and regardless of the spatial correlation of the hydraulic conductivity and the number of dimensions. Therefore, using the harmonic and arithmetic means as upper and lower bounds is appropriate and does not skew the results towards that of lower hydraulic conductivity.

In response to a comment in NDEP's August 1, 2012 letter, additional model calibration activities were performed to test the effect of using the arithmetic mean as an upper bound for Qal hydraulic conductivity. The results of this work are described below in the response to Comment #2 of the August 1, 2012 letter.

NDEP Comment #23. Table 3-3, TRX listed a number of well data points as “not used”. Please explain why each data point was not used.

Response:

Table 3-3 has been updated with footnotes explaining why certain hydraulic conductivity measurements were not used to calculate the ranges of hydraulic conductivity for the Qal or UMCf for the model calibration (see Attachment 1). Specifically, the points were not used because (1) they were measured in the channel deposits and were therefore not appropriate to use for non-channel deposit Qal or for the UMCf or (2) a discrepancy existed between the lithology classification described in the ‘All Wells Database’ and the technical report. In addition, Well MCF-BW-12A was not used because it was not listed in the ‘All Wells Database’.

NDEP Comment #28. Appendix E, Section 3.7.1, page 12, please note that AMPAC have been testing and will be operating (approximately February 2012) new extraction wells south of Warm Springs Road. These wells should be included in any future predictive modeling.

Response:

We have noted this comment. The model will be updated to include the new AMPAC wells as well as any other changes in hydrogeologic conditions prior to any future predictive modeling. The AMPAC wells are located up- and cross-gradient of the Site, are screened in the deep water-bearing zone, and are not expected to affect the current operation of the GWETS.

The August 1, 2012 letter from the NDEP included two comments on Northgate’s memo of April 25, 2012. The comments and responses are provided below:

NDEP Comment #1. Page 1, third paragraph, the memorandum states that “…only comments #15 and #16 [from the NDEP letter RE: Capture Zone Evaluation dated April 5, 2011] were identified as being directly related to the model development and inputs.” NDEP disagrees with this appraisal; NDEP believes that comments #23 and 28 also related to model development and inputs. Please include responses to these comments in the revision of this memorandum.

Response:

Responses to comments #23 and #28 are provided above.

NDEP Comment #2. Page 2, fourth paragraph. NDEP notes that auto-calibration of hydraulic conductivity of the Qal (Model Report Table E·8) resulted as the *highest value of the employed calibration range, the arithmetic mean of all listed Qal conductivities (Model Report Table E·1). It appears that the calibration process could have arrived at a higher conductivity value had the range been extended beyond the arithmetic mean, which may have led to better model performance (e.g., calibration statistics). NDEP requests that the model calibration be re-run using some significantly higher upper bound for Qal hydraulic conductivity, in order to determine if calibration statistics may be improved.*

Response:

In order to address Comment #2, the upper bound on the range of Qal horizontal hydraulic conductivity (K_x) values specified in PEST (a model-independent parameter estimation tool, Watermark Numerical Computing, 2004) was increased from 35 feet/day (ft/d) to 150 ft/d. This new upper bound is 15% greater than the maximum hydraulic conductivity of 131.4 ft/day measured by aquifer tests in the Qal (see Table E-2 of the Hydrogeologic Model Report [Northgate, 2010]). The model was re-calibrated with all other parameters kept the same as during the original 2010 calibration, with the exception of the Qal vertical conductivity (K_z) which was set equal to one-tenth of the Qal horizontal hydraulic conductivity value. This modification was made based on the observation that for the cases where K_z was allowed to be un-tied from K_x during the calibration process and was run using different initial values for Kx, it became clear that the final calibrated hydraulic conductivity values were dependent on the initial parameter value, indicating that there is a non-unique solution to the model optimization problem and that there may be several local minima in the parameter space. This resulted in variability of the vertical conductivity without a significant change to the calibration statistics, and without a large range of variability in K_x. The fixed anisotropy ratio of K_x/K_z of 10 to 1 is consistent with the anisotropy ratio used in the BMI calibrated flow model (DBSA, 2008).

The model auto-calibration, performed using the extended upper bound of 150 ft/d and with an initial Qal K_x value of 35 ft/d, resulted in a final calibrated horizontal Qal K_x value of 34.8 ft/d. Two additional re-calibration runs were performed using different starting horizontal Qal K_x values in order to determine if this would have a significant effect on the final calibrated Qal K_x value. Using initial values of 13 ft/d and 150 ft/d, the model auto-calibration resulted in optimized Qal K_x values of 34.5 ft/d and 35.1 ft/d, respectively, which suggests that when K_x/K_z and other input parameters are constrained that the initial value does not have a significant effect on the final optimized Qal K_x value. Furthermore, the final optimized Qal K_x values are not significantly different from the final value of 35.0 ft/d presented in the 2010 calibration results (Northgate, 2010). The calibration inputs and results for the final Qal K_x and K_z values are summarized in Attachment 2.

The results were compared with the 2010 calibration results to assess possible improvements in the calibration statistics as requested by NDEP, as well as to assess any other potential changes to model results such as travel times, spatial distribution of hydraulic heads, spatial distribution of wet/dry cells, or other model related conclusions in the CZE report. The calibration statistics from the model re-calibration were very similar to the 2010 calibration results (see Attachment 3), and the spatial distribution of hydraulic heads and wet/dry cells very closely match the 2010 results. Re-calibration with the expanded range of Kx did not result in significant changes to either model results or to model related conclusions in the CZE report due to the re-calibration.

MODEL FILES AND SUPPORTING DOCUMENTATION TO THE MODEL

Groundwater model input files and supporting documentation were provided as attachments to the April 25, 2012 memo from Northgate. Since the recalibration exercise performed in response to NDEP Comment #2 did not result in a significant change in the model, the model files and documentation are not being resubmitted.

ATTACHMENTS

1 Revised Table 3-3
2 Qal Hydraulic Conductivity Re-Calibration Summary
3 Calibration Statistics

REFERENCES

Batchelor, G.K., 1974. Transport properties of two-phase materials with random structure, Ann. Rev. Fluid Mech., 6, 227-254.

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Rubin, Y., 2003. Applied Stochastic Hydrogeology, Oxford University Press, USA, 416 p.

Watermark Numerical Computing , 2004. PEST: Model-Independent Parameter Estimation, User Manual: 5th Edition.

ATTACHMENT 1
Table 3-3
Measurements of Hydraulic Conductivity in the Study Area

Site	Well	Aquifer thickness (ft)	Lithology[1]	K (ft/d)	S	Test type	Analysis	Notes	Used to calculate Qal/MCf hydraulic K range for model calibration?	Report Source[2]
Pittman Lateral	PC-70	32	Qal	207		pumping test	Jacobs, drawdown	channel deposits	not used[3]	(1)
Pittman Lateral	PC-70	32	Qal	292		pumping test	Jacobs, recovery	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	201	0.08	pumping test- PC-17 obs	Jacobs, drawdown	channel deposits	not used[3]	(1)
Pittman Lateral	PC-70	33	Qal	227	0.03	pumping test- PC-17 obs	Theis, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	190	0.04	pumping test- PC-17 obs	Boulton, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	321		pumping test- PC-17 obs	Jacobs, recovery	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	166	0.03	pumping test- PC-18 obs	Jacobs, drawdown	channel deposits	not used[3]	(1)
Pittman Lateral	PC-70	33	Qal	220	0.08	pumping test- PC-18 obs	Theis, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	218	0.09	pumping test- PC-18 obs	Boulton, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	33	Qal	438		pumping test- PC-18 obs	Jacobs, recovery	channel deposits		(1)
Pittman Lateral	PC-70	37	Qal	239	0.11	pumping test- PC-55 obs	Jacobs, drawdown	channel deposits	not used[3]	(1)
Pittman Lateral	PC-70	37	Qal	169	0.03	pumping test- PC-55 obs	Theis, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	37	Qal	143	0.04	pumping test- PC-55 obs	Boulton, drawdown	channel deposits		(1)
Pittman Lateral	PC-70	37	Qal	477		pumping test- PC-55 obs	Jacobs, recovery	channel deposits		(1)
A, Pittman Lateral	PC-70	30	Qal	228		tracer & hydraulic tests		channel deposits	not used[3]	(2)
B, COH-RIBs	PC-98R	25	Qal	295		tracer & hydraulic tests		channel deposits	not used[3]	(2)
C, Lower Ponds/Seeps	PC- 99R	32	Qal	616		tracer & hydraulic tests		channel deposits	not used[3]	(2)
TIMET Facility	CLD1-R	8	Qal	70		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	CLD3-R	10	Qal	12		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	J2D2-R2	9	Qal	125		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	PC-54	19	Qal	118		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	PC-65	13	Qal	19		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	PC-67	25	Qal	22		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	TMMW-101	25	Qal	2		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	TMMW-102	15	Qal	0.07		slug test	Bouwer and Rice, 1976		not used[4]	(3)
TIMET Facility	TMMW-103	14	Qal	1.4		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	TMMW-104	16	Qal	1.3		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
TIMET Facility	TMPZ-110	8	Qal	5		pumping test	Cooper & Jacob, recovery		Y for Qal	(3)
Tronox Industrial area	M-2	4	Qal	41.8		slug test	Bouwer and Rice, 1976		Y for Qal	(4)
Tronox Industrial area	M-2	4	Qal	60.6		pumping test	Jacob			(4)
Tronox Industrial area	M-3	2	Qal	131		slug test	Bouwer and Rice, 1976		Y for Qal	(4)
Tronox Industrial area	M-4	5	Qal	6.7		slug test	Bouwer and Rice, 1976		Y for Qal	(4)
Tronox Industrial area	M-8	4	Qal/xMCf/UMCf	111		slug test	Bouwer and Rice, 1976		Y for Qal	(4)
Tronox Industrial area	M-15	15	UMCf	40.9		slug test	Bouwer and Rice, 1976		not used[4]	(4)
Tronox Industrial area	M-27	16	Qal	200		slug test	Bouwer and Rice, 1976	channel deposits	not used[3]	(4)
Stauffer Chemical	H-36	13	Qal/UMCf	235	0.09	delayed yield	Boulton	channel deposits	not used[3]	(5)
Stauffer Chemical	H-36	11	Qal/UMCf	245	0.051	distance drawdown	Jacob	channel deposits		(5)

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Stauffer Chemical	H-53	20	Qal	136	0.09	delayed yield	Boulton	channel deposits	not used[3]	(5)
Stauffer Chemical	H-53	16	Qal	125	0.064	distance drawdown	Jacob	channel deposits		(5)
Stauffer Chemical	H-54	11	Qal	130	0.083	delayed yield	Boulton	channel deposits	not used[3]	(5)
Stauffer Chemical	H-54	20	Qal	235	0.035	distance drawdown	Jacob	channel deposits		(5)
Stauffer Chemical	H-54	20	Qal	116	0.043	distance drawdown	Jacob	channel deposits	not used[3]	(5)
Stauffer Chemical	H-10	10	Qal	2		drawdown			Y for MCf	(5)
Stauffer Chemical	H-10	10	Qal	3		slug			Y for MCf	(5)
Stauffer Chemical	H-17	14	Qal	79		drawdown		channel deposits	not used[3]	(5)
Stauffer Chemical	H-43	14	Qal/UMCf	301		drawdown			not used[3]	(5)
Stauffer Chemical	H-49A	18	Qal	84		drawdown		H-49 in report, H49A in db	Y for Qal	(5)
Stauffer Chemical	H-51	24	Qal	81		drawdown			Y for Qal	(5)
Stauffer Chemical	H-52	2	Qal	9		slug		small diameter well	Y for Qal	(5)
Stauffer Chemical	H-52	2	Qal	15		slug		small diameter well		(5)
Stauffer Chemical	MC21	4	Qal/UMCf	51		slug		small diameter well	Y for Qal	(5)
Stauffer Chemical	MC25	5	Qal/UMCf	6		slug		small diameter well	Y for Qal	(5)
Stauffer Chemical	MC32	5	Qal	4		slug		small diameter well	Y for Qal	(5)
Stauffer Chemical	H-18	14	Qal/UMCf	618		drawdown		channel deposits	not used[3]	(6)
Stauffer Chemical	H-19	8	Qal/UMCf	22		drawdown			not used[4]	(6)
Stauffer Chemical	H-19	8	Qal/UMCf	382	0.016	drawdown	Theis H-46 obs well		not used[4]	(6)
Stauffer Chemical	H-21R	15	Qal	129		pumping		H-21 in report, H-21R in db	Y for Qal	(6)
Stauffer Chemical	H-14	2	Qal/UMCf	45		drawdown			Y for Qal	(6)
Stauffer Chemical	H-14	2	Qal/UMCf	110	0.0027	drawdown	Theis H-37 obs well			(6)
BMI Common Area	AA-23R	10	Qal	8.84		Slug in 1	Bouwer and Rice, 1976		Y for Qal	(7)
BMI Common Area	AA-23R	10	Qal	10		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-23R	10	Qal	8.6		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-23R	10	Qal	12.5		Slug out 2	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-16	10	Qal	0.87		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	DBMW-16	10	Qal	0.38		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-19	10	Qal	1.35		Slug in 1	Bouwer and Rice, 1976		Y for Qal	(7)
BMI Common Area	DBMW-19	10	Qal	2.75		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-19	10	Qal	0.83		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-19	10	Qal	2.9		Slug out 2	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-26	5	Qal	4.1		Slug in 1	Bouwer and Rice, 1976		Y for Qal	(7)
BMI Common Area	AA-26	5	Qal	1.58		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-26	5	Qal	2.45		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-26	5	Qal	1.65		Slug out 2	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-08B	10	Qal	50		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	AA-08B	10	Qal	70.1		Slug out 1	Bouwer and Rice, 1976			(7)

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BMI Common Area	AA-08B	10	Qal	40		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	AA-08B	10	Qal	62.1		Slug out 2	Bouwer and Rice, 1976			(7)
Tronox	AA-30		Qal	29.6		Slug	Hvorslev		Y for Qal	(8)
Tronox	AA-30		Qal	24.1		Slug	Bouwer and Rice			(8)
BMI Common Area	AA-20		Qal	29		Slug in 1	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-20		Qal	32.5		Slug out 1	Bouwer-Rice			(9)
BMI Common Area	AA-20		Qal	44		Slug out 2	Bouwer-Rice			(9)
BMI Common Area	MCF-16C		Qal	0.24		Slug in	Bouwer-Rice		not used[4]	(9)
BMI Common Area	AA-13		Qal	12.2		Slug in 1	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-13		Qal	14.2		Slug out 1	Bouwer-Rice			(9)
BMI Common Area	AA-13		Qal	11.2		Slug in 2	Bouwer-Rice			(9)
BMI Common Area	AA-13		Qal	12.5		Slug out 2	Bouwer-Rice			(9)
BMI Common Area	AA-07		Qal	8		Slug in 1	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-07		Qal	6.5		Slug out 1	Bouwer-Rice			(9)
BMI Common Area	AA-07		Qal	5		Slug in 2	Bouwer-Rice			(9)
BMI Common Area	AA-07		Qal	8		Slug out 2	Bouwer-Rice			(9)
BMI Common Area	AA-22		Qal	0.6		Slug in 1	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-22		Qal	0.3		Slug out 1	Bouwer-Rice			(9)
BMI Common Area	AA-22		Qal	0.5		Slug in 2	Bouwer-Rice			(9)
BMI Common Area	AA-22		Qal	0.6		Slug out 2	Bouwer-Rice			(9)
BMI Common Area	AA-09		Qal	67.3		Slug out 1	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-09		Qal	58.4		Slug out 2	Bouwer-Rice			(9)
BMI Common Area	AA-09		Qal	62		Slug out 3	Bouwer-Rice			(9)
BMI Common Area	MCF-06C		Qal	1.5		Slug in	Bouwer-Rice		Y for Qal	(9)
BMI Common Area	AA-09		Qal	12		Step test			Y for Qal	(9)
BMI Common Area	AA-09		Qal	9.6		Constant rate pump test				(9)
BMI Common Area	AA-09		Qal	15.4		Constant rate pump test				(9)
BMI Common Area	AA-09		Qal	9.6		Recovery (pump test)				(9)
BMI Common Area	AA-09		Qal	14.4		Recovery (pump test)				(9)
BMI Common Area	AA-20		Qal	33.6		Step test			Y for Qal	(9)
BMI Common Area	AA-20		Qal	22.7		Constant rate pump test				(9)
BMI Common Area	AA-20		Qal	69		Constant rate pump test				(9)
BMI Common Area	AA-20		Qal	29.7		Recovery (pump test)				(9)
BMI Common Area	AA-20		Qal	52.1		Recovery (pump test)				(9)
BMI Common Area	AA-08		Qal	192		Step test			Y for Qal	(9)
BMI Common Area	AA-08		Qal	654		Constant rate pump test				(9)
BMI Common Area	AA-08		Qal	564		Constant rate pump test				(9)
BMI Common Area	AA-08		Qal	846		Constant rate pump test				(9)
BMI Common Area	AA-08		Qal	417		Recovery (pump test)				(9)
BMI Common Area	AA-08		Qal	446		Recovery (pump test)				(9)

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BMI Common Area	AA-08		Qal	451		Recovery (pump test)				(9)
CAMU	AA-BW-01		Qal	4.5		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	AA-BW-01		Qal	5		Slug out 1	Bouwer-Rice			(10)
CAMU	AA-BW-01		Qal	4.5		Slug in 2	Bouwer-Rice			(10)
CAMU	AA-BW-01		Qal	5		Slug out 2	Bouwer-Rice			(10)
CAMU	AA-BW-07A		Qal	4.5		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	AA-BW-07A		Qal	5		Slug out 1	Bouwer-Rice			(10)
CAMU	AA-BW-07A		Qal	4.7		Slug in 2	Bouwer-Rice			(10)
CAMU	AA-BW-07A		Qal	5.1		Slug out 2	Bouwer-Rice			(10)
CAMU	AA-BW-07A		Qal	4.9		Slug in 3	Bouwer-Rice			(10)
CAMU	AA-BW-07A		Qal	5.3		Slug out 3	Bouwer-Rice			(10)
CAMU	B-17		Qal	6.4		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	B-17		Qal	9.5		Slug out 1	Bouwer-Rice			(10)
CAMU	B-17		Qal	6.1		Slug in 2	Bouwer-Rice			(10)
CAMU	B-17		Qal	8.7		Slug out 2	Bouwer-Rice			(10)
CAMU	B-17		Qal	6.25		Slug in 3	Bouwer-Rice			(10)
CAMU	B-17		Qal	9.5		Slug out 3	Bouwer-Rice			(10)
CAMU	B-18		na	2.02		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	B-18		na	2		Slug out 1	Bouwer-Rice			(10)
CAMU	B-18		na	2.2		Slug in 2	Bouwer-Rice			(10)
CAMU	B-18		na	2.42		Slug out 2	Bouwer-Rice			(10)
CAMU	B-18		na	2		Slug in 3	Bouwer-Rice			(10)
CAMU	B-18		na	2.45		Slug out 3	Bouwer-Rice			(10)
CAMU	B-14R		Qal	72.5		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	B-14R		Qal	80		Slug out 1	Bouwer-Rice			(10)
CAMU	B-14R		Qal	62.5		Slug in 2	Bouwer-Rice			(10)
CAMU	B-14R		Qal	65		Slug out 2	Bouwer-Rice			(10)
CAMU	B-14R		Qal	67		Slug in 3	Bouwer-Rice			(10)
CAMU	B-14R		Qal	67		Slug out 3	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	20.8		Slug in 1	Bouwer-Rice	not in all wells	not used[5]	(10)
CAMU	MCF-BW-12A		Qal	23.1		Slug out 1	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	38		Slug in 2	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	27.5		Slug out 2	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	22		Slug in 3	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	31		Slug out 3	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	31		Slug in 4	Bouwer-Rice			(10)
CAMU	MCF-BW-12A		Qal	18.8		Slug out 4	Bouwer-Rice			(10)
CAMU	AA-BW-08A		Qal	22.6		Slug in 1	Bouwer-Rice		Y for Qal	(10)
CAMU	AA-BW-08A		Qal	26		Slug out 1	Bouwer-Rice			(10)
CAMU	AA-BW-08A		Qal	31		Slug in 2	Bouwer-Rice			(10)

ATTACHMENT 1
Table 3-3
Measurements of Hydraulic Conductivity in the Study Area

Site	Well	Aquifer thickness (ft)	Lithology[1]	K (ft/d)	S	Test type	Analysis	Notes	Used to calculate Qal/MCf hydraulic K range for model calibration?	Report Source[2]
CAMU	AA-BW-08A		Qal	32		Slug out 2	Bouwer-Rice			(10)
CAMU	AA-BW-08A		Qal	30.5		Slug in 3	Bouwer-Rice			(10)
CAMU	AA-BW-08A		Qal	26		Slug out 3	Bouwer-Rice			(10)
		Qal deposits	***n=158***							
			average=	***90.1***	*ft/day*					
			geometric mean=	***22.7***						
			minimum=	***0.1***						
			maximum=	***846***						
AMPAC	TWE-15		xMCf	74.7		Slug	Bouwer-Rice		not used[4]	(11)
AMPAC	TWE-15		xMCf	102		Slug	Bouwer-Rice			(11)
AMPAC	TWE-15		xMCf	40.4		Slug	Bouwer-Rice			(11)
AMPAC	TWE-15		xMCf	23.6		Slug	Bouwer-Rice			(11)
AMPAC	TWE-18		xMCf	6		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	TWE-18		xMCf	6.2		Slug	Bouwer-Rice			(11)
CAMU	EC-1		Qal/UMCf	0.65		Slug in 1	Bouwer-Rice		Y for MCf	(10)
CAMU	EC-1		Qal/UMCf	0.65		Slug out 1	Bouwer-Rice			(10)
CAMU	EC-1		Qal/UMCf	0.61		Slug in 2	Bouwer-Rice			(10)
CAMU	EC-1		Qal/UMCf	0.68		Slug out 2	Bouwer-Rice			(10)
CAMU	MCF-BW-10A		UMCf	2.5		Slug in 1	Bouwer-Rice			(10)
CAMU	MCF-BW-10A		UMCf	2.82		Slug out 1	Bouwer-Rice			(10)
CAMU	MCF-BW-10A		UMCf	2.85		Slug in 2	Bouwer-Rice			(10)
CAMU	MCF-BW-10A		UMCf	2.9		Slug out 2	Bouwer-Rice			(10)
CAMU	MCF-BW-11A		UMCf	1.01		Slug in 1	Bouwer-Rice		Y for MCf	(10)
CAMU	MCF-BW-11A		UMCf	1		Slug out 1	Bouwer-Rice			(10)
CAMU	MCF-BW-11A		UMCf	1.1		Slug in 2	Bouwer-Rice			(10)
CAMU	MCF-BW-11A		UMCf	1.05		Slug out 2	Bouwer-Rice			(10)
BMI Common Area	MCF-03B		UMCf	0.18		Slug in	Bouwer-Rice		Y for MCf	(9)
Tronox Industrial area	M-17	8	UMCf	24.3		slug test	Bouwer and Rice, 1976		Y for MCf	(4)
Tronox Industrial area	M9		Qal	7.3		Slug			Y for Qal	(4)
Tronox Industrial area	M11		Qal/xMCf/UMCf	1.1		pumping test	Jacob drawdown		Y for Qal	(4)
Tronox Industrial area	M11		Qal/xMCf/UMCf	0.9		Slug				(4)
TIMET	TPMZ-202	40	xMCF	0.15		single well, pumping test	Cooper & Jacob, recovery		Y for MCf	(12)
TIMET	TPMZ-203	40	xMCF	0.24		single well, pumping test	Cooper & Jacob, recovery		Y for MCf	(12)
TIMET	TMPZ-201	40	xMCF	0.08		single well, pumping test	Cooper & Jacob, recovery		Y for MCf	(12)
TIMET	TMPZ-201	40	xMCF	2.5	0.037	pumping test	Hantush			(12)
TIMET	TMPZ-204	60	xMCF	0.38	na	single well, pumping test	Cooper & Jacob, recovery		Y for MCf	(12)
TIMET	TMPZ-204	70	xMCF	16.85	0.089	pumping test	Theis- TMPZ-603 obs well			(12)
TIMET	TMPZ-204	60	xMCF	2.7	0.004	pumping test	Theis- TMPZ-604 obs well			(12)
TIMET	TMPZ-204	60	xMCF	1.5	0.007	pumping test	Hantush- TMPZ-605 obs well			(12)

ATTACHMENT 1
Table 3-3
Measurements of Hydraulic Conductivity in the Study Area

Site	Well	Aquifer thickness (ft)	Lithology[1]	K (ft/d)	S	Test type	Analysis	Notes	Used to calculate Qal/MCf hydraulic K range for model calibration?	Report Source[2]
BMI Common Area	DBMW-2	10	Qal	0.04		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	DBMW-2	10	Qal	0.1		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-4	10	Qal	2.00		Slug in 1	Bouwer and Rice, 1976		Y for Qal	(7)
BMI Common Area	DBMW-4	10	Qal	2.10		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-4	10	Qal	1.9		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-4	10	Qal	2.0		Slug out 2	Bouwer and Rice, 1976			(7)
	Qal/xMCf/Qal and MC		***n=37***							
			average=	***9.1***	***ft/day***					
			geometric mean=	***1.7***						
			minimum=	***0.04***						
			maximum=	***102***						
AMPAC	AMX-40		UMCf	4.3		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	AMX-40		UMCf	4		Slug	Bouwer-Rice			(11)
AMPAC	AMX-40		UMCf	4.4		Slug	Bouwer-Rice			(11)
AMPAC	TWE-33		UMCf	0.41		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	ADX-112		UMCf	0.001		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	AMX-98		UMCf	4.4		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	MW-AL		UMCf	3.7		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	MW-AL		UMCf	3.8		Slug	Bouwer-Rice			(11)
AMPAC	TWA-180		UMCf	0.027		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	TWE-51		UMCf	0.16		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	MW-C		UMCf	3.6		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	MW-D2D		UMCf	2.6		Slug	Bouwer-Rice		Y for MCf	(11)
AMPAC	MW-D2D		UMCf	2.7		Slug	Bouwer-Rice			(11)
AMPAC	MW-D2D		UMCf	2.6		Slug	Bouwer-Rice			(11)
Tronox Industrial area	M12		UMCf	2.6		Slug			Y for MCf	(4)
Tronox Industrial area	M13		UMCf	4.8		Slug			Y for MCf	(4)
BMI Common Area	DBMW-8	10	Qal	0.5		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	DBMW-8	10	Qal	0.59		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-8	10	Qal	0.52		Slug in 2	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-8	10	Qal	0.59		Slug out 2	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-9	5	Qal	0.08		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	DBMW-9	5	Qal	0.079		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	DBMW-22	10	Qal	0.06		Slug in 1	Bouwer and Rice, 1976		not used[4]	(7)
BMI Common Area	DBMW-22	10	Qal	0.08		Slug out 1	Bouwer and Rice, 1976			(7)
BMI Common Area	MCF-24B		MCf	0.005		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-24B		MCf	0.006		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-28A		MCf	0.004		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-28A		MCf	0.004		Slug	Bouwer and Rice			(8)

ATTACHMENT 1
Table 3-3
Measurements of Hydraulic Conductivity in the Study Area

Site	Well	Aquifer thickness (ft)	Lithology[1]	K (ft/d)	S	Test type	Analysis	Notes	Used to calculate Qal/MCf hydraulic K range for model calibration?	Report Source[2]
BMI Common Area	MCF-28B		MCf	0.044		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-28B		MCf	0.043		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-29A		MCf	0.077		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-29A		MCf	0.066		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-29B		MCf	0.021		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-29B		MCf	0.02		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-30A		MCf	0.032		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-30A		MCf	0.034		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-30B		MCf	0.03		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-30B		MCf	0.029		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-31A		MCf	0.005		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-31A		MCf	0.005		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-31B		MCf	0.007		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-31B		MCf	0.009		Slug	Bouwer and Rice			(8)
BMI Common Area	MCF-32B		MCf	0.077		Slug	Hvorslev		Y for MCf	(8)
BMI Common Area	MCF-32B		MCf	0.076		Slug	Bouwer and Rice			(8)
Tronox Industrial area	M-162		MCf	0.106		Slug in 1	avg of Hvorslev & Bouwer Rice		Y for MCf	(13)
Tronox Industrial area	M-162		MCf	0.123		Slug out 1	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-162		MCf	0.117		Slug in 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-162		MCf	0.096		Slug out 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-162		MCf	0.087		Slug in 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-162		MCf	0.037		Slug out 3	avg of Hvorsleve & Bouwer Rice			(13)
Tronox Industrial area	M-163		MCf	0.00504		Slug in 1	avg of Hvorslev & Bouwer Rice		Y for MCf	(13)
Tronox Industrial area	M-163		MCf	0.0041		Slug out 1	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-164		MCf	0.071		Slug in 1	avg of Hvorslev & Bouwer Rice		Y for MCf	(13)
Tronox Industrial area	M-164		MCf	0.096		Slug out 1	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-164		MCf	0.063		Slug in 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-164		MCf	0.073		Slug out 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-164		MCf	0.079		Slug in 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-164		MCf	0.078		Slug out 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.008		Slug in 1	avg of Hvorslev & Bouwer Rice		Y for MCf	(13)
Tronox Industrial area	M-187		MCf	0.004		Slug out 1	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.014		Slug in 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.006		Slug in 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.011		Slug out 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.015		Slug in 4	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-187		MCf	0.009		Slug out 4	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-188		MCf	0.068		Slug in 1	avg of Hvorslev & Bouwer Rice		Y for MCf	(13)
Tronox Industrial area	M-188		MCf	0.083		Slug out 1	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-188		MCf	0.028		Slug in 2	avg of Hvorslev & Bouwer Rice			(13)

ATTACHMENT 1
Table 3-3
Measurements of Hydraulic Conductivity in the Study Area

Site	Well	Aquifer thickness (ft)	Lithology[1]	K (ft/d)	S	Test type	Analysis	Notes	Used to calculate Qal/MCf hydraulic K range for model calibration?	Report Source[2]
Tronox Industrial area	M-188		MCf	0.043		Slug out 2	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-188		MCf	0.070		Slug in 3	avg of Hvorslev & Bouwer Rice			(13)
Tronox Industrial area	M-188		MCf	0.080		Slug out 3	avg of Hvorslev & Bouwer Rice			(13)
		UMCf deposits K	***n=71***							
			average=	***0.7***	***ft/day***					
			geometric mean=	***0.08***						
			minimum=	***0.001***						
			maximum*=	***5***						
Seep Area	M9	35	na	457	na					(14)
Historic Lateral		38	na	526	0.08	pumping test				(14)
Rainbow Gardens		38	na	474	0.1 -0.22	pumping test				(14)
	Las Vegas Wash deposits K		***range=***	***457-526***	***ft/day***					

Notes:

[1] Lithologic unit classification for other companies' wells taken from the 'All Wells Database' dated December 22, 2009, or if not available from 'All Wells Database', the description from technical report was used.

[2] References for hydraulic properties measured within the Study Area

[3] Not used because the values correspond to the channel deposits K.

[4] Not used because of discrepany between lithology classification in the 'All Wells Database' and the technical report.

[5] Not used because well was not listed in the 'All Wells Database' dated December 22, 2009

(1) Kerr-McGee Chemical, Preliminary Report on a Hydrogeologic Investigation of Channel-fill Alluvium at Pittman Lateral, Oct 19, 1998

(2) Errol Montgomery & Associates, Analysis of Rate of Groundwater Movement Based on the Results of Tracer and Hydraulic Tests, Dec 19, 2000

(3) Titanium Metals Corp., Conceptual Site Model, Titanium Metals Corp. Facility, Henderson, Nevada, April 25, 2007

(4) Kerr-McGee, Hydrogeological Investigation, July 1985

(5) Stauffer Chemical Company, Hydrogeologic Investigation Report, March 14, 1983

(6) Gerharty & Miller (1980) referenced in the Stauffer Chemical Company Hydrogeologic Investigation Report, March 14, 1983

(7) Kleinfelder, Slug Test Results for the BMI Common Area, Nov. 29, 2007

(8) Converse Consultants, Limited Hydrogeologic Investigation, BMI Common Areas, Nov. 25, 2009

(9) Kleinfelder, Slug test Results, Implementation of Revised Aquifer Testing Work Plan, BMI Common Area, Nov. 16, 2007

(10) Klenifelder, Slug Test Results, CAMU Area, Jan. 25, 2008

(11) Geosyntec/AMPAC, Groundwater Flow Model South of Warm Springs Study Area, Henderson, NV., Feb. 2010

(12) Timet, Design Data Gap Investigation, June 12, 2009

(13) Tronox, Capture Zone Evaluation Work Plan, Henderson, NV., March 25, 2010

(14) McGinley and Associates, Las Vegas Wash Initial Perchlorate Modeling Report, 2003

ATTACHMENT 2
Qal Hydraulic Conductivity Re-Calibration Summary

Calibration Run Number	Parameter	Units	Zone	Initial Value	Calibration Lower Bound	Calibration Upper Bound	Optimized Final Value
1	Kx2	ft/d	Qal	35	4	150	34.8
	Kz2	ft/d	Qal	3.5	NA	NA	3.48
2	Kx2	ft/d	Qal	150	4	150	35.1
	Kz2	ft/d	Qal	15	NA	NA	3.51
3	Kx2	ft/d	Qal	13	4	150	34.5
	Kz2	ft/d	Qal	1.3	NA	NA	3.45

Notes:
All parameters not shown were fixed during the auto-calibration and equal to the 2010 calibration optimized values.
Kx2 = Qal horizontal hydraulic conductivity
Kz2 = Qal vertical hydraulic conductivity
Qal = Quaternary alluvium
NA= Value not applicable because vertical conductivity is tied to the horizontal conductivity at a ratio of 1:10.
ft/d = feet per day

ATTACHMENT 3
Calibration Statistics

	Run 1[a]	Run 2[a]	Run 3[a]	2010 Calibration[b]
Number of targets	263	263	263	263
Range in Observed Values	285.84	285.84	285.84	285.84
Minimum Residual	-19.66	-19.61	-19.69	-19.68
Maximum Residual	21.01	21.09	21.65	21.03
Sum of Squared Residuals	9984	9889	10306	10100
RMS Error	6.16	6.13	6.26	6.21
Residual Mean	1.14	1.15	1.17	0.97
Absolute Residual Mean	4.7	4.68	4.74	4.77
Standard Deviation	6.05	6.02	6.15	6.13

Notes:
a: See Attachment 2 for details on calibration inputs and results for Runs 1, 2, and 3
b: See Table E-7 of the Hydrogeologic Model Report (Northgate, 2010)