Fate and Transport Issues

It should be noted that this application is a flow model and, as such, only considers the movement of water in the subsurface. Constituents dissolved in groundwater may be subject to processes that result in migration that cannot be explained exclusively by groundwater velocity (i.e., advection).

Groundwater velocities generated by the model and presented in the CSM, Rev.1 (ENSR, 2006) require input of a value for porosity for each of the geologic materials. There are no site-specific data on porosities, and they are likely to be very variable. Literature values were used. It should be recognized that the calculated velocities are directly dependent on these input values of porosity. Changes to the porosity values could potentially change estimate velocities by more than an order of magnitude.

5.0 SUMMARY AND CONCLUSIONS

Numerical groundwater models for the BA #1 and the WA areas have been conceptualized, developed, and calibrated to provide tools by which groundwater flow can be evaluated and changes to groundwater flow can be assessed as different remedial alternatives are simulated. In particular, in consideration of a bioremediation approach, the model may be used design scenarios for injection of reagents that will enhance stabilization of U and to demonstrate the permanence of uranium stabilization in groundwater.

The objective was achieved by developing and calibrating the numerical models to include key data that characterize groundwater flow at the site consistent with the CSM-Rev 01 (ENSR, 2006). Specifically, the BA #1 model domain included portions of the uplands at the site, which are underlain by a series of sandstone and mudstone layers, the transition zone, which is characterized by silts and clays underlain by sandstone and mudstone, and the alluvial valley where the geology is predominantly sand with smaller fractions of silt and clay. The BA #1 model was bounded on the south, in part, by the reservoir and on the north by the Cimarron River. The WA model included only the alluvial materials (sands, silts, clay) from the escarpment that forms the northern edge of the uplands to the Cimarron River. In the WA area, the alluvial materials are underlain by sandstone. Upgradient sandstones in both models are assumed to contribute groundwater to the alluvial soils and overlying sandstone and mudstone units. The Cimarron River is a discharge boundary to which all modeled groundwater flows.

Calibration targets included measured groundwater elevations, flow budgets, and flow path data. The flow models achieved good calibration to the observed groundwater elevation data, to the estimated water budgets, and to observed flow path trajectories. Discrepancies between observed and predicted elevations were reasonable. The simulated water table configuration for each model was consistent with flow paths suggested by observations of U concentrations. Overall hydrogeological concepts as presented in the Conceptual Site Model, Rev 01 (ENSR, 2006) were captured by the numerical models. A sensitivity evaluation established that the model simulations will be most sensitive to boundary conditions, especially the recharge from upgradient sandstone units. Uncertainties, especially associated with boundary conditions, are important when interpreting and using model predictions in remedial designs.

Ultimately, the resulting numerical models have captured key hydrologic and geologic features that shape the groundwater flow directions, patterns, and rates, thus satisfying the objective to provide useful tools to consider remediation design options. For instance, groundwater extraction can be simulated to create capture zones that include areas of high U concentration. Injection scenarios can also be simulated to ensure adequate distribution of reagents. Even the calibrated model itself can yield valuable information about groundwater flow directions and rates. For instance, the design of the bioremediation system requires estimates of groundwater flux to the plume area, which can be extracted from the model. The calibrated BA #1 model indicates that there are 19 gpm to the plume area. The calibrated WA area model indicates that there are 31 gpm to the impacted area. ARCADIS will use the model further to help design the bioremediation effort; their uses of the model will be documented in their work plan.

6.0 REFERENCES

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Tables

Table 1
Summary of Slug and Aquifer Test Results
Cimarron Corporation
Crescent, Oklahoma

		Hydraulic Conductivity (cm/s)									
		Analysis Methodology									
Geology	**Well**	**Slug Test Bouwer & Rice**	**Slug Test Hvorslev**	**Sieve Analysis**	**Pumping Test - Jacob Straight Line**	**Pumping Test - t/t'**	**Pumping Test - distance-drawdown**	**Butler and Garnett**	**Cooper-Bredehoeft-Papadopulos**	**Geometric Mean (cm/s)**	**Geometric Mean (ft/day)**
Alluvium	TMW-09***	6.01E-03	1.20E-03							2.69E-03	7.61
	TMW-13	6.99E-02	6.20E-02							6.58E-02	186.61
	02W2*	1.92E-05								1.92E-05	0.05
	02W10*	3.36E-04	2.80E-04							3.07E-04	0.87
	02W11***	3.24E-03	4.00E-03	1.70E-03						2.80E-03	7.95
	02W15	1.09E-02	1.80E-02	1.00E-02						1.25E-02	35.49
	02W16	3.66E-02	3.90E-02	1.10E-02						2.50E-02	70.98
	02W17	3.25E-02	6.00E-02	6.00E-03						2.27E-02	64.35
	02W22				8.90E-02					8.90E-02	252.28
	02W33	1.30E-02	1.90E-02	1.70E-03						7.49E-03	21.23
	02W46*	3.56E-05	1.37E-05							2.21E-05	0.06
	02W56**	4.20E-02	7.10E-02	1.70E-02	8.30E-02	8.30E-02	8.60E-02			5.58E-02	158.04
	02W58				9.60E-02	8.60E-02				9.09E-02	257.56
	02W59	1.40E-02	3.30E-02		9.60E-02	8.00E-02				4.34E-02	123.03
	02W60				1.10E-01	8.60E-02				9.73E-02	275.70
	02W61	2.20E-02	2.30E-02		1.10E-01	8.90E-02				4.72E-02	133.73
	02W62							2.80E-02		2.80E-02	79.37
	TMW-24							4.13E-02		4.13E-02	117.07
Sandstone B	TMW-01	6.35E-05	2.70E-05							4.14E-05	0.12
	TMW-20	9.97E-04	4.10E-04							6.39E-04	1.81
	02W40								5.50E-04	5.50E-04	1.56
	02W51	7.10E-05	2.39E-05							4.12E-05	0.12
Sandstone C	02W48		7.85E-05							7.85E-05	0.22

Notes:
All data presented is summarized from the Burial Area #1 Groundwater Assessment Report (Cimarron Corporation, 2003).
* Clay present at or near this well; data excluded from calculating ranges, mean.
** Pumping Well
*** Some clays/silts present in well screen; data excluded from calculating ranges, means.

October 22, 2006

Table 2
Summary of Groundwater Elevation Data used for Calibration
Cimarron Corporation
Crescent, Oklahoma

Summary ID	9/16/03 Water Level (feet)	12/16/03 Water Level (feet)	Aug/Sep 04 Water Level (feet)	5/24/05 Water Level (feet)	Avg WL Elevation (feet)
**1206				n/a-SEEP	-----
**1206				n/a-SEEP	-----
**1208				n/a-SEEP	-----
**1208				n/a-SEEP	-----
1311	965.48	964.83	966.02	962.70	964.76
1312	962.66	963.64	964.48	964.66	963.86
1312				964.66	964.66
1313	963.60	963.19	964.04	963.97	963.70
1314	944.02	943.67	944.14	944.57	944.10
1315R	932.31	934.73	935.46	936.45	934.74
1315R				936.45	936.45
1316R	931.57	932.89	936.84	936.12	934.35
1319 A-1	969.86	969.63	970.37	969.88	969.93
1319 A-2	969.74	969.49	-	969.79	969.68
1319 A-3	968.46	968.56	968.45	968.35	968.45
1319 B-1	946.73	947.13	948.35	pumping	947.40
1319 B-1				pumping	-----
1319 B-2	947.73	948.25	949.44	950.06	948.87
1319 B-3	946.67	947.12	948.37	949.02	947.79
1319 B-4	946.18	946.52	947.84	948.54	947.27
1319 B-5	945.61	944.87	946.24	947.37	946.02
1319 C-1	942.27	943.81	946.01	pumping	944.03
1319 C-1				pumping	-----
1319 C-2	939.80	940.69	941.94	941.50	940.98
1319 C-3	939.06	939.78	941.07	940.85	940.19
1320	967.04	966.58	968.34	968.20	967.54
1321	935.97	936.45	937.74	938.07	937.06
1322	967.97	966.43	967.95	968.48	967.71
1323	941.84	942.49	943.29	944.19	942.95
1324	968.10	967.45	969.20	969.28	968.51
1325	971.25	970.62	972.44	972.31	971.66
1326	970.85	970.49	971.45	971.54	971.08
1327	966.02	965.95		966.62	966.19
1327B	966.05	965.55	966.01	966.63	966.06
1328	948.85	950.79	950.71	?	950.12
1329	968.26	967.97	968.00	968.62	968.21
1330	967.97	967.72	969.37	970.07	968.78
1331	965.80	965.30	967.02	966.63	966.19
1332	940.00	940.47	941.75	942.43	941.16
1333	967.92	967.16	968.48	969.03	968.15
1334	966.51	966.58	968.20	967.72	967.25
1335A	969.81	969.07	970.78	970.45	970.03
1336A	959.65	959.57	960.53	960.08	959.96
1337	965.90	965.48		966.95	966.11

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Cimarron Corporation
Crescent, Oklahoma

Summary ID	9/16/03 Water Level (feet)	12/16/03 Water Level (feet)	Aug/Sep 04 Water Level (feet)	5/24/05 Water Level (feet)	Avg WL Elevation (feet)
1338	943.71	943.62	945.25	939.32	942.98
1339	951.68	952.74	938.46	955.13	949.50
1340	961.49	961.42		962.42	961.78
1341	936.75	936.75		939.39	937.63
1342	929.95	930.13		930.40	930.16
1343	928.37	928.57		929.40	928.78
1344	925.84	926.22		928.62	926.89
1345	933.74	933.63	935.32	936.30	934.74
1346	937.60	937.31	938.81	939.22	938.23
1347	965.13	964.47		965.96	965.18
1348	975.27	975.26	977.96	977.50	976.49
1348			977.96	977.50	977.73
1349	971.74	971.23	973.71	973.83	972.63
1349			973.71		973.71
1350	974.98	974.69	977.08	980.01	976.69
1350			977.08		977.08
1351	969.93	969.78	971.33	970.80	970.46
1351			971.33		971.33
1352	966.49	966.06	967.89	967.50	966.99
1352			967.89	967.50	967.70
1352			967.89		967.89
1353	985.70	988.00	988.31	988.04	987.52
1353			988.31		988.31
1354	965.51	965.24	967.00	966.46	966.05
1354			967.00		967.00
1355	967.64	967.01	968.71	968.85	968.05
1355			968.71		968.71
1356	968.83	968.24	969.38	969.57	969.00
1356			969.38	969.57	969.47
1357	969.51	968.88	970.72	970.47	969.89
1357			970.72		970.72
1358	971.26	970.53	972.67	972.49	971.74
1358			972.67	972.74	972.71
1359			972.79		972.79
1359			972.79	974.82	973.80
1360			974.88		974.88
1360			974.88		974.88
02W01	930.56	932.92	934.49	934.51	933.12
02W02	928.87	930.72	932.30	932.25	931.03
02W03	926.43	927.99	930.33	930.40	928.79
02W04	927.64	928.09	929.64	929.81	928.79
02W04				929.81	929.81
02W05	927.43	927.86	929.56	929.77	928.65
02W06	927.37	927.77	929.56	929.78	928.62

Table 2
Summary of Groundwater Elevation Data used for Calibration
Cimarron Corporation
Crescent, Oklahoma

Summary ID	9/16/03 Water Level (feet)	12/16/03 Water Level (feet)	Aug/Sep 04 Water Level (feet)	5/24/05 Water Level (feet)	Avg WL Elevation (feet)
02W07	927.53	927.98	929.53	929.76	928.70
02W07				929.76	929.76
02W08	927.57	928.02	929.57	929.80	928.74
02W08				929.80	929.80
02W09	933.09	935.51	936.32	936.57	935.37
02W10	931.73	934.39	935.54	935.62	934.32
02W11	927.27	927.85	929.57	929.73	928.61
02W12	927.29	927.83	929.69	929.71	928.63
02W13	927.41	927.91	929.71	929.89	928.73
02W14	927.27	927.77	929.50	929.70	928.56
02W15	927.34	927.81	929.60	929.80	928.64
02W16	927.37	927.81	929.50	929.77	928.61
02W17	914.25	927.87	929.55	929.80	925.37
02W18	927.30	927.75	929.47	929.69	928.55
02W19	927.56	927.95	929.47	929.41	928.59
02W19				929.41	929.41
02W20	936.42	937.88	938.04	937.99	937.58
02W21	927.43	927.84	929.46	929.74	928.62
02W22	927.42	927.85	929.50	929.72	928.62
02W23	927.42	927.74	929.56	929.79	928.63
02W23				929.79	929.79
02W24	927.32	927.75	929.53	929.75	928.59
02W25	940.60	941.84	947.51	946.01	943.99
02W26	934.13	936.34	937.00	937.14	936.15
02W27	930.37	931.97	934.48	933.97	932.70
02W28	931.52	934.17	935.30	935.41	934.10
02W29	932.59	935.12	936.19	936.65	935.14
02W30	932.19	934.13	937.03	937.17	935.13
02W31	931.19	933.83	934.97	935.02	933.75
02W32	927.31	927.84	929.61	931.65	929.10
02W33	927.44	927.85	929.52	929.77	928.65
02W33				929.77	929.77
02W34	927.44	927.71	929.39	929.66	928.55
02W35	938.70	927.92	929.36	929.60	931.39
02W36	927.42	927.83	929.46	929.71	928.60
02W37	934.00	934.40	935.82	936.03	935.06
02W38	926.67	927.10	929.47	929.64	928.22
02W39	933.00	935.46	936.43	936.90	935.45
02W40	938.36	939.05	940.18	940.18	939.44
02W41	936.42	937.80	938.62	938.66	937.88
02W42	934.42	936.09	941.05	940.34	937.98
02W43	927.35	927.91	929.29	929.53	928.52
02W43				929.53	929.53
02W44	929.23	927.77	929.35	929.55	928.97

Table 2
Summary of Groundwater Elevation Data used for Calibration
Cimarron Corporation
Crescent, Oklahoma

Summary ID	9/16/03 Water Level (feet)	12/16/03 Water Level (feet)	Aug/Sep 04 Water Level (feet)	5/24/05 Water Level (feet)	Avg WL Elevation (feet)
02W45	927.55	927.86	929.32	929.56	928.58
02W46	927.97	929.10	930.88	930.73	929.67
02W47	937.87	939.46	941.28	???	939.54
02W48	925.58	926.13		929.09	926.93
02W50	939.89	940.20	941.60	941.70	940.85
02W51	949.20	949.84	952.77	952.03	950.96
02W52	938.96	939.45	940.74	940.97	940.03
02W53	930.40	932.03	934.70	934.13	932.81
02W62	927.68	928.02	929.44	929.69	928.71
02W62				929.69	929.69
T-51	929.26	929.25		930.45	929.66
T-52	929.07	929.14		930.42	929.55
T-53	929.09	929.16		930.57	929.61
T-54	929.65	929.88	930.94	931.61	930.52
T-55	929.30	929.58		931.25	930.04
T-56	929.21	929.54		931.27	930.01
T-57	929.83	929.90	930.94	931.85	930.63
T-58	929.87	929.83	930.77	931.87	930.58
T-59	928.94	929.04		930.60	929.53
T-60	928.89	969.49		930.89	943.09
T-61	928.65	928.65		930.79	929.36
T-62	930.14	930.14	930.82	932.15	930.81
T-63			931.48	932.01	931.75
T-63	930.02	930.02	931.48	932.01	930.88
T-63			931.48		931.48
T-64	930.31	930.31	931.57	932.43	931.15
T-65	930.06	929.93	930.90	932.05	930.74
T-65				932.05	932.05
T-66			931.71		931.71
T-67			931.17		931.17
T-67			931.17		931.17
T-67			931.17		931.17
T-67			931.17		931.17
T-68			930.81		930.81
T-69			930.93		930.93
T-70					-----
T-70R			931.24		931.24
T-71					-----
T-72			930.96		930.96
T-73			931.02		931.02
T-74			931.20		931.20
T-75			930.88		930.88
T-76			931.04		931.04
T-77			930.82		930.82

Table 2
Summary of Groundwater Elevation Data used for Calibration
Cimarron Corporation
Crescent, Oklahoma

Summary ID	9/16/03 Water Level (feet)	12/16/03 Water Level (feet)	Aug/Sep 04 Water Level (feet)	5/24/05 Water Level (feet)	Avg WL Elevation (feet)
T-77			930.82		930.82
T-77			930.82		930.82
T-78			930.87		930.87
T-79			930.53		930.53
T-81			930.80		930.80
T-82			930.35		930.35
TMW-01	939.36	940.23	942.38	943.82	941.45
TMW-02	940.65	940.99	941.29	941.62	941.14
TMW-05	930.74	933.29	934.56	934.02	933.15
TMW-06	932.81	935.77	936.02	936.05	935.16
TMW-07	930.17	932.54	933.41	933.05	932.29
TMW-08	933.75	935.89	936.50	936.99	935.78
TMW-09	931.68	934.32	935.02	935.28	934.08
TMW-09				935.28	935.28
TMW-13	927.66	928.18	929.36	929.77	928.74
TMW-13				929.77	929.77
TMW-17	932.23	933.08	933.97	934.11	933.35
TMW-17			933.97		933.97
TMW-18	927.30	927.76	930.18	930.05	928.82
TMW-19	dry	dry		n/a	-----
TMW-20	938.43	939.35		939.91	939.23
TMW-21	936.45	937.09	944.33	942.49	940.09
TMW-23	928.33	928.87	929.94	930.37	929.38
TMW-24	927.71	928.05	928.73	929.19	928.42
TMW-25	936.83	938.41	938.42	938.32	937.99

Table 3
BA #1 Summary of Model Inputs
Cimarron Corporation
Crescent, Oklahoma

Burial Area (BA#1)				
Subsurface Units:		**Value**	**Units**	**Reference**
Fill	K_H	3.30E+00	ft/day	Average of Silt, Sand, & Clay
	K_V	3.30E-01	ft/day	10% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (Kh/Kv)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Silt	K_H	2.83E-01	ft/day	ENSR CSM Sec-3.2.1
	K_V	2.83E-02	ft/day	10% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (Kh/Kv)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	20	%	Freeze & Cherry, 1979 Table 2.4
Sand	K_H	2.53E+02	ft/day	Average of pumping tests in alluvial wells
	K_V	2.53E+01	ft/day	10% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Clay	K_H	5.00E-01	ft/day	Artificially high to improve model stability
	K_V	5.00E-02	ft/day	10% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	20	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-A	K_H	4.00E+01	ft/day	Calibrated to high end of range in ENSR CSM Sec-3.2.1
	K_V	2.00E+00	ft/day	5% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4

Table 3
BA #1 Summary of Model Inputs
Cimarron Corporation
Crescent, Oklahoma

Burial Area (BA#1)				
Subsurface Units:		**Value**	**Units**	**Reference**
Siltstone	K_H	8.43E+00	ft/day	
	K_V	4.22E-01	ft/day	5% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	1	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-B	K_H	5.00E+00	ft/day	Calibrated to high end of range in ENSR CSM Sec-3.2.1
	K_V	2.50E-01	ft/day	5% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-C	K_H	3.00E+00	ft/day	Slug test results at well 02W48
	K_V	1.50E-01	ft/day	5% of K_H
	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
	Specific Storage	NA	-----	Not required for steady-state simulation
	Specific Yield	NA	-----	Not required for steady-state simulation
	Long. Disp.	NA	-----	Not required for flow model
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4

Cimarron River:	**Value**	**Units**	**Reference**
Upstream Elevation	924.8	feet	Based on Dover and Guthrie gage datums
Downstream Elevation	924.8	feet	Based on Dover and Guthrie gage datums
Conductance	10,000	$(ft^2/day)/ft$	Estimate to for high river/aquifer connectivity

Areal Boundaries:	**Value**	**Units**	**Reference**
Recharge	5.48E-04	ft/day	ENSR CSM Sec-3.1.1 & 3.1.4

Table 4
WA Summary of Model Inputs
Cimarron Corporation
Crescent, Oklahoma

Western Alluvial Area (WA)				
Subsurface Units:		**Value**	**Units**	**Reference**
Clay	K_H	5.00E-01	ft/day	ENSR CSM Sec-3.2.1
Clay	K_V	5.00E-02	ft/day	10% of K_H
Clay	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
Clay	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
Clay	Specific Storage	0.001	-----	Default
Clay	Specific Yield	0.001	-----	Default
Clay	Long. Disp.	10	-----	Default
Clay	Porosity	20	%	Freeze & Cherry, 1979 Table 2.4
Sand	K_H	2.35E+02	ft/day	Average of pumping tests in alluvial wells
Sand	K_V	2.35E+01	ft/day	10% of K_H
Sand	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
Sand	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
Sand	Specific Storage	0.001	-----	Default
Sand	Specific Yield	0.001	-----	Default
Sand	Long. Disp.	10	-----	Default
Sand	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-C	K_H	3.00E+00	ft/day	Slug test results at well 02W48
Sandstone-C	K_V	1.50E-01	ft/day	5% of K_H
Sandstone-C	Horozontal Anisotropy	1.0	-----	No horizontal anisotropy
Sandstone-C	Vertical Anisotropy (K_H/K_V)	1.0	-----	No vertical anisotropy
Sandstone-C	Specific Storage	0.001	-----	Default
Sandstone-C	Specific Yield	0.001	-----	Default
Sandstone-C	Long. Disp.	10	-----	Default
Sandstone-C	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4

Cimarron River:	**Value**	**Units**	**Reference**
Upstream Elevation	924.8	feet	Based on Dover and Guthrie gage datums
Downstream Elevation	924.8	feet	Based on Dover and Guthrie gage datums
Conductance	20,000	$(ft^2/day)/ft$	Medium estimate based on prior experience

Areal Boundaries:	**Value**	**Units**	**Reference**
Recharge	5.48E-04	ft/day	ENSR CSM Sec-3.1.1 & 3.1.4

Figures

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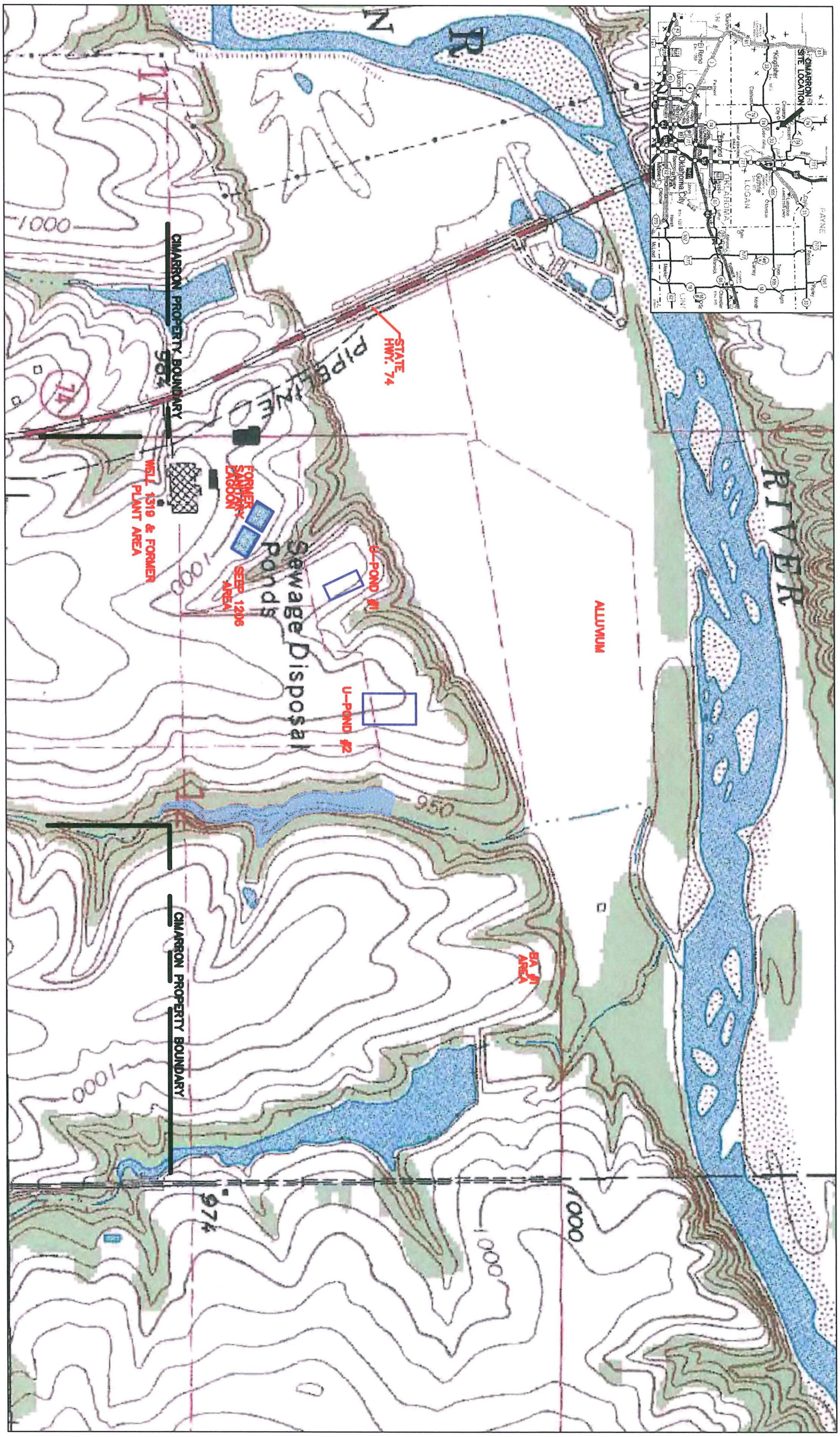


REFERENCE: UNITED STATES GEOLOGICAL SURVEY
CRESCENT QUADRANGLE, OKLAHOMA-LOGAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC), 1970 (PHOTOINSPECTED 1981).

0 800 1600
SCALE IN FEET

SHEET NUMBER:	FIGURE NUMBER:
1	1

FIGURE 1
SITE LOCATION MAP
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

SCALE:	DATE:	PROJECT NUMBER:
1" = 800'	9/22/06	04020-044-327

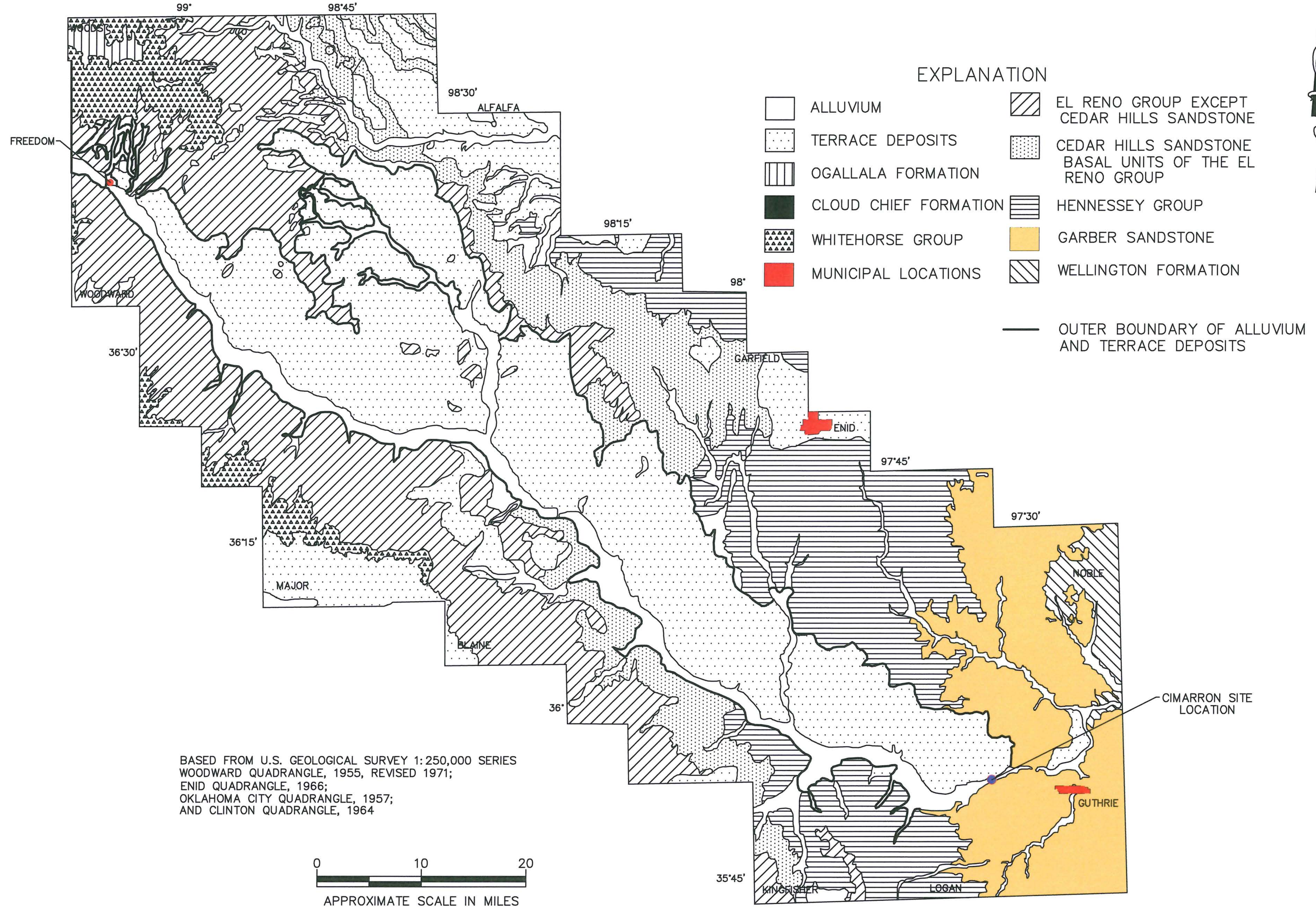
ENSR | AECOM

ENSR CORPORATION
4888 LOOP CENTRAL DRIVE, SUITE 600
HOUSTON, TEXAS 77081-2214
PHONE: (713) 520-9900
FAX: (713) 520-6802
WEB: HTTP://WWW.ENSR.AECOM.COM

DESIGNED BY:	
DRAWN BY:	JAS
CHECKED BY:	DJF
APPROVED BY:	DJF

REVISIONS

NO.:	DESCRIPTION:	DATE:	BY:
1.		4/01/05	JAS
2.		6/17/05	JAS
3.		6/8/05	JAS



REVISIONS		
NO.: DESCRIPTION:	DATE:	BY:
1.	4/10/05	JAS
2.	6/17/05	JAS

DESIGNED BY:
DRAWN BY: JAS
CHECKED BY: DJF
APPROVED BY: DJF

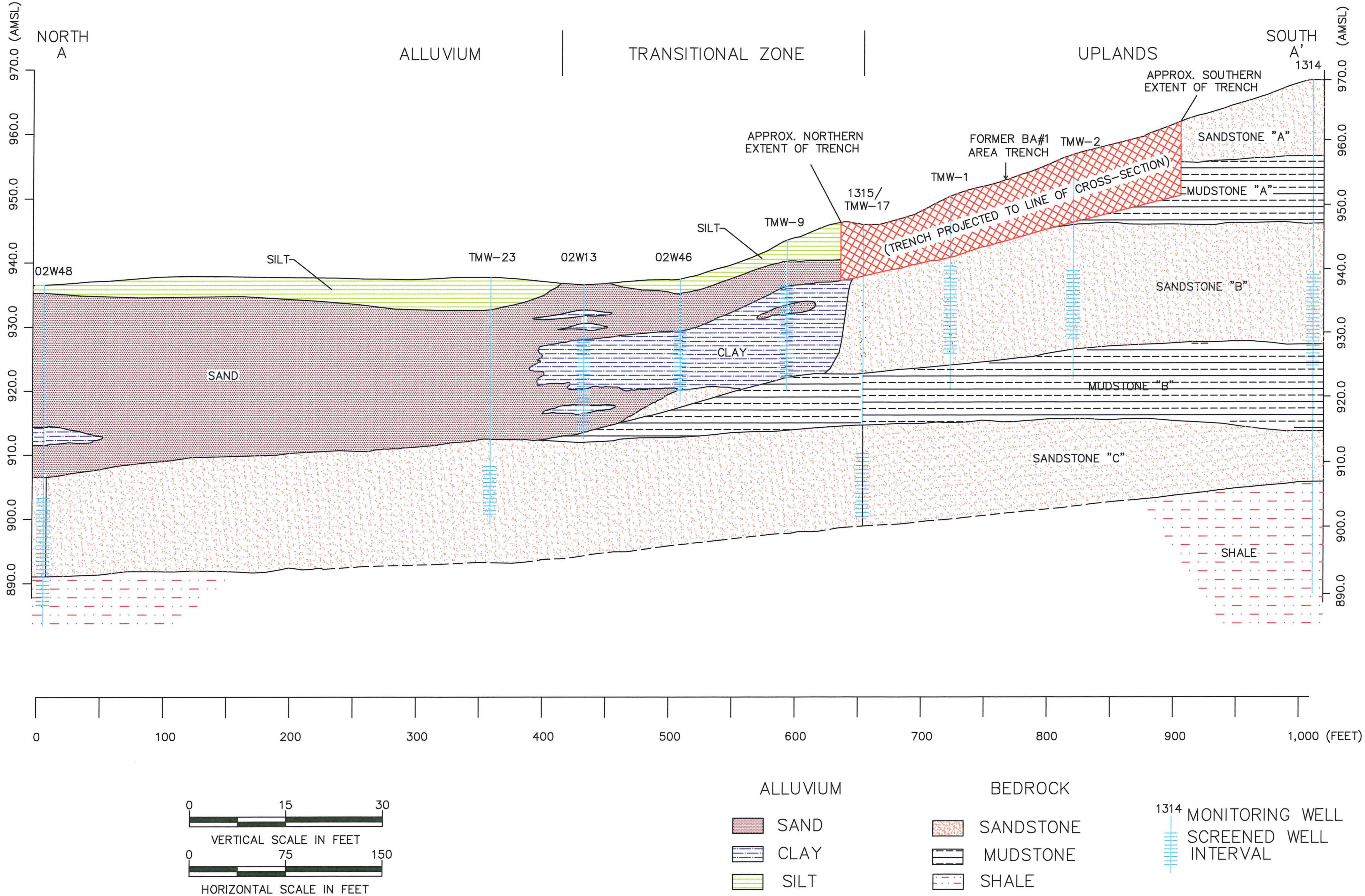
ENSR | AECOM
ENSR CORPORATION
4888 LOOP CENTRAL DRIVE, SUITE 600
HOUSTON, TEXAS 77081-2214
PHONE: (713) 520-9900
FAX: (713) 520-6802
WEB: HTTP://WWW.ENSR.AECOM.COM

FIGURE 2
GEOLOGY ALONG THE CIMARRON RIVER FROM FREEDOM TO GUTHRIE, OKLAHOMA
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

SCALE: 1"=10 miles
DATE: 9/22/06
PROJECT NUMBER: 04020-044-327

FIGURE NUMBER: 2
SHEET NUMBER: 1

DWG. NO. 040200012



REVISIONS			
NO.:	DESCRIPTION:	DATE:	BY:
1.		4/01/05	JAS
2.		6/17/05	JAS

DESIGNED BY:
DRAWN BY: JAS
CHECKED BY: DJF
APPROVED BY: DJF

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ENSR CORPORATION
4888 LOOP CENTRAL DRIVE, SUITE 600
HOUSTON, TEXAS 77081-2214
PHONE: (713) 520-9900
FAX: (713) 520-6802
WEB: HTTP://WWW.ENSR.AECOM.COM

FIGURE 3
BA #1 AREA
REPRESENTATIVE GEOLOGICAL CROSS-SECTION
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

SCALE: 1" = 75'
DATE: 9/22/06
PROJECT NUMBER: 04020-044-327

FIGURE NUMBER: 3

SHEET NUMBER: 1

DWG. NO. 040200005

DWG. NO. 040200009

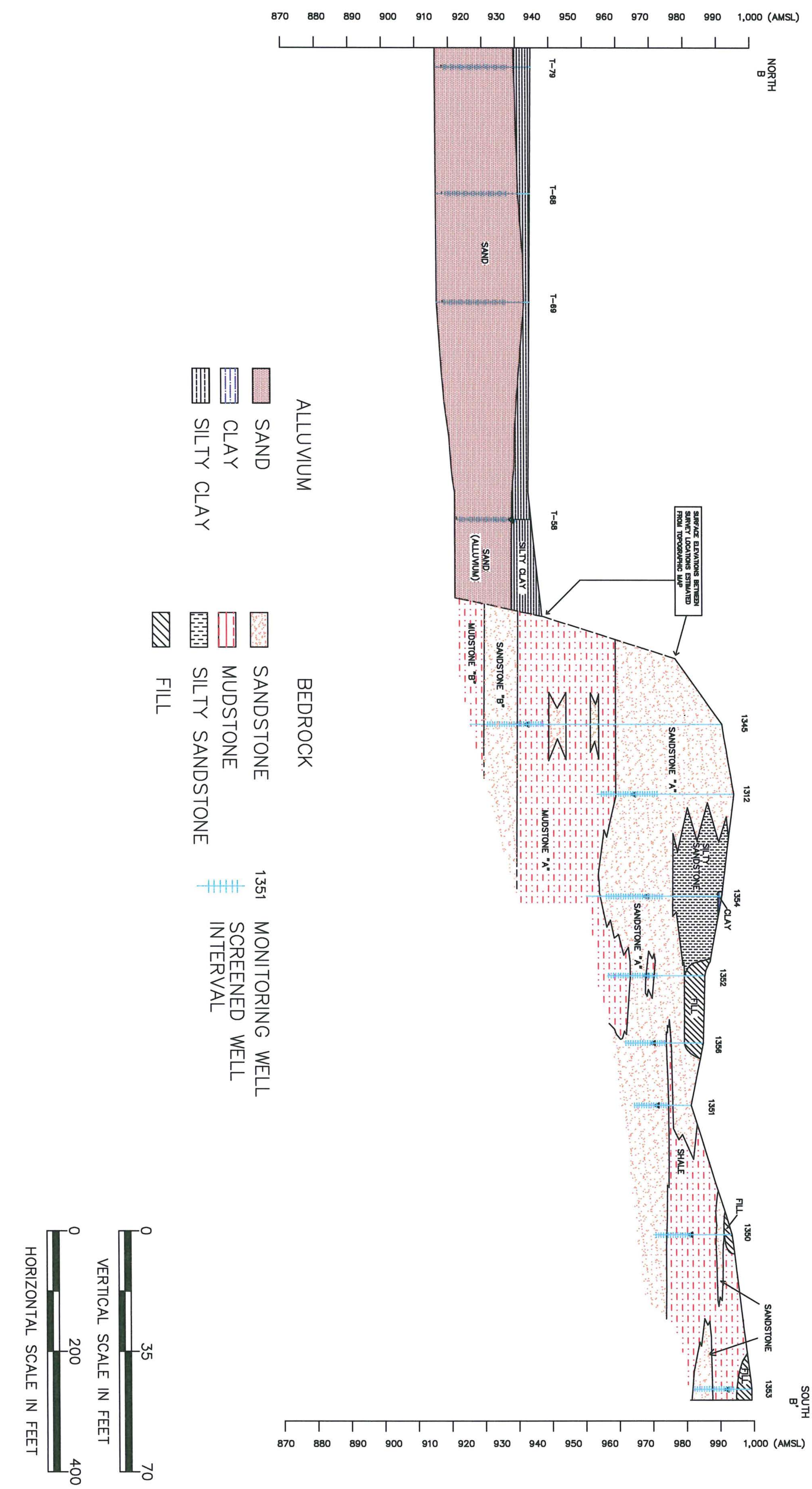

FIGURE NUMBER:	SHEET NUMBER:
4	1

FIGURE 4
REPRESENTATIVE GEOLOGICAL CROSS-SECTION WESTERN UPLAND AND ALLUVIAL AREAS CIMARRON CORPORATION CRESCENT, OKLAHOMA

SCALE:	DATE:	PROJECT NUMBER:
1" = 200'	9/22/06	04020-044-327

ENSR | AECOM

ENSR CORPORATION
4888 LOOP CENTRAL DRIVE, SUITE 600
HOUSTON, TEXAS 77081-2214
PHONE: (713) 520-9900
FAX: (713) 520-6802
WEB: HTTP://WWW.ENSR.AECOM.COM

DESIGNED BY:	
DRAWN BY:	JAS
CHECKED BY:	DJF
APPROVED BY:	DJF

REVISIONS

NO.:	DESCRIPTION:	DATE:	BY:
1.		4/01/05	JAS
2.		6/17/05	JAS

N

BA #1 Boundary

NOT TO SCALE

BA #1 Model Domain
Cimarron Corporation
Crescent, Oklahoma

DATE	PROJECT
October 2006	04020-044-300

ENSR | AECOM

Figure
5

J:\Water\PROJEC~2\P40\4020\044-CI~1\modeling\MODEL_~1\GIS\figure5.mxd

N

WA Area Boundary

NOT TO SCALE

WA Area Model Domain
Cimarron Corporation
Crescent, Oklahoma

ENSR | AECOM

DATE	PROJECT
October 2006	04020-044-300

Figure
6

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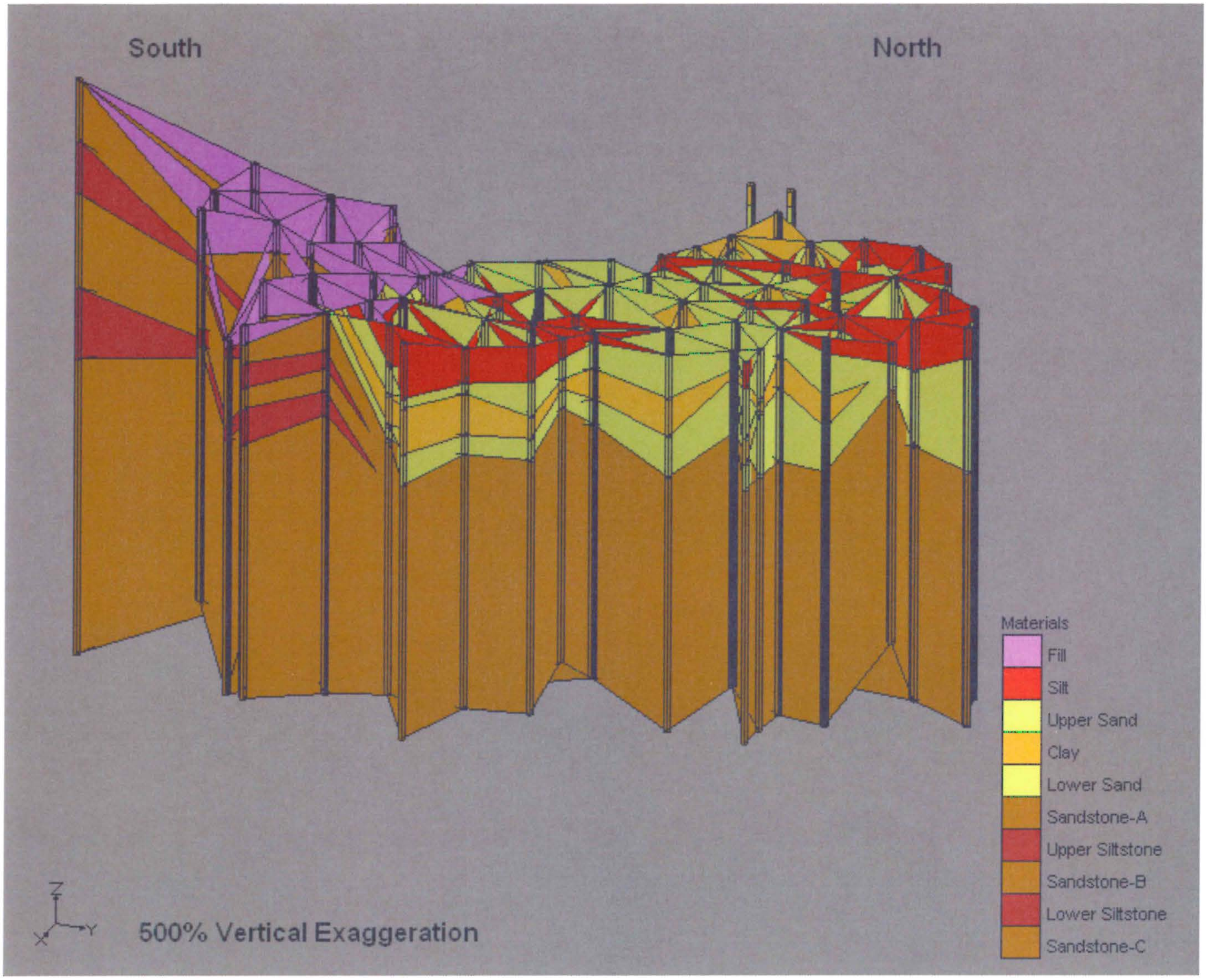

	BA #1 Boreholes and Cross-sections Cimarron Corporation Crescent, Oklahoma		ENSR | AECOM
	DATE	PROJECT	Figure 7
	October 2006	04020-044-300	

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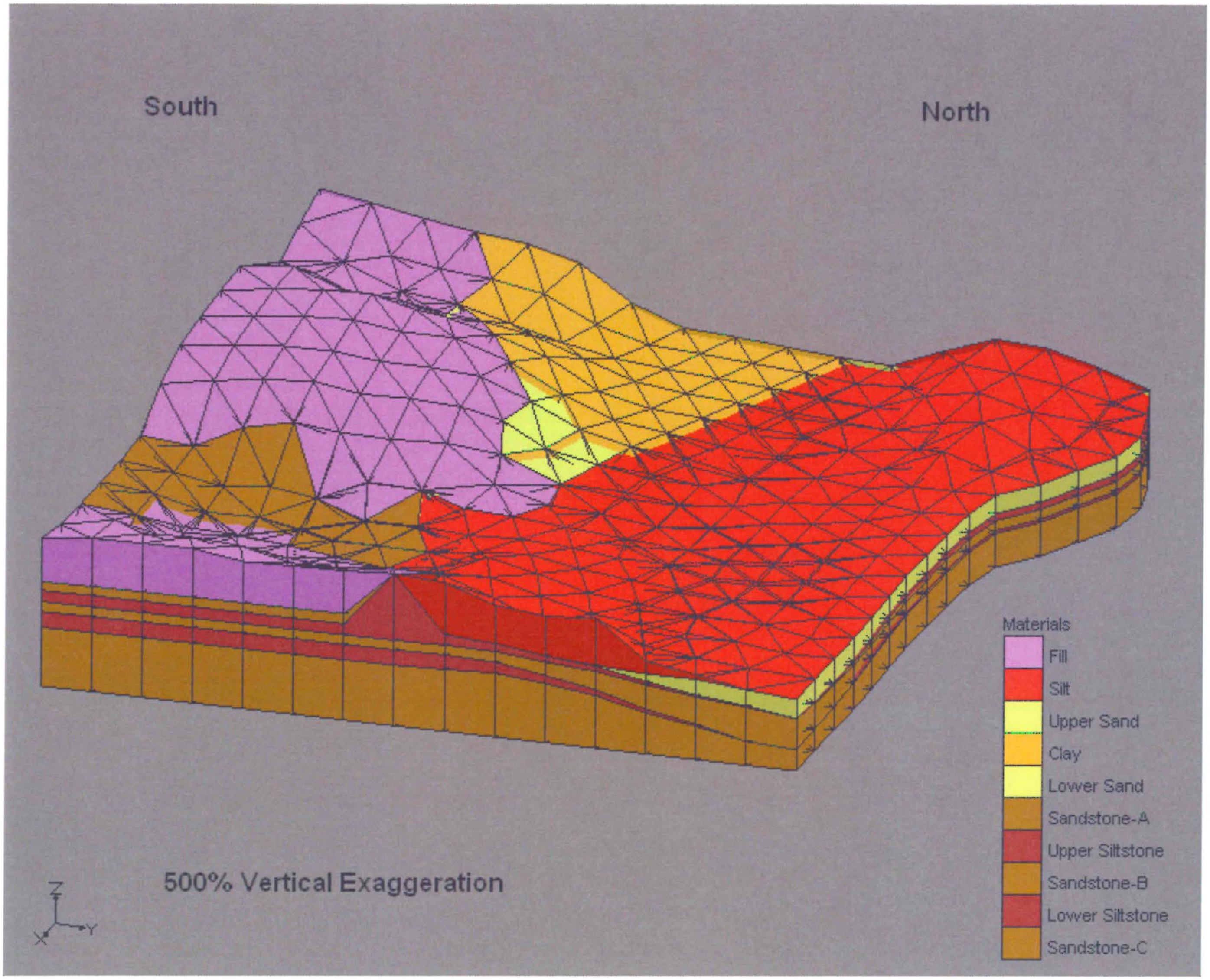

BA #1 Solids Developed
from Borehole Data
Cimarron Corporation
Crescent, Oklahoma

ENSR | AECOM

DATE	PROJECT
October 2006	04020-044-300

Figure
8

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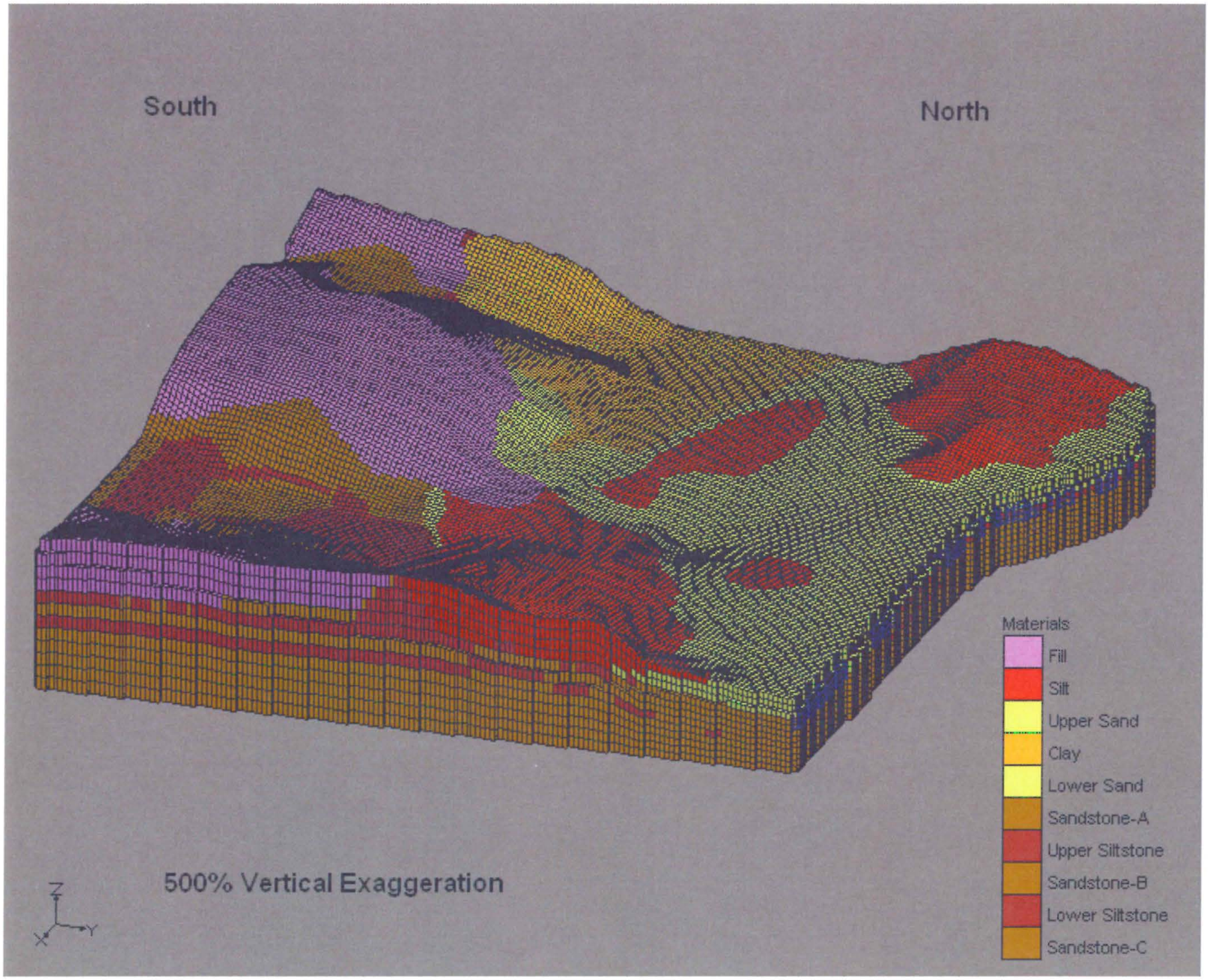

BA #1 3D Grid Incorporating Geologic Information Cimarron Corporation Crescent, Oklahoma		ENSR | AECOM
DATE	PROJECT	Figure **9**
October 2006	04020-044-300	

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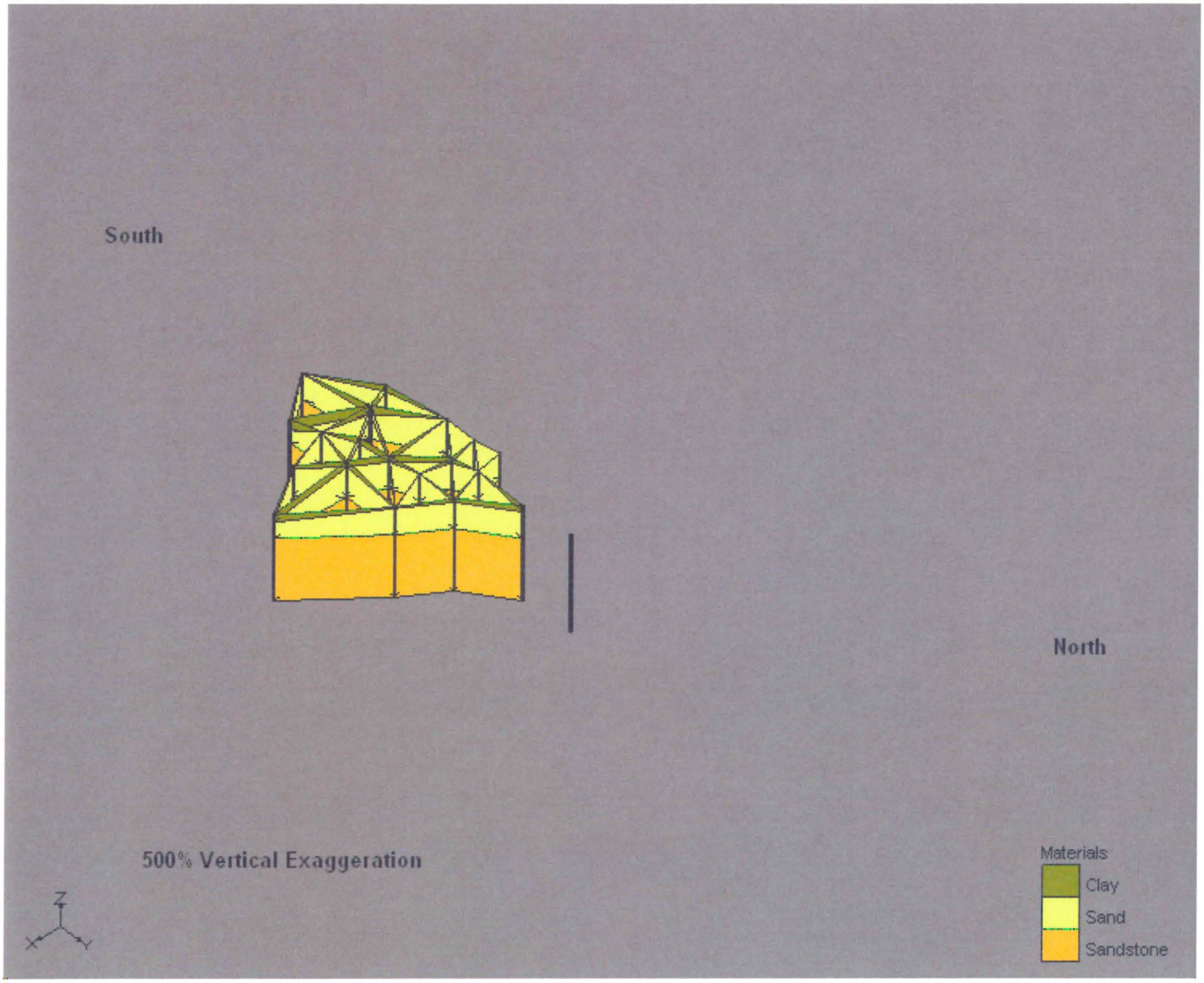
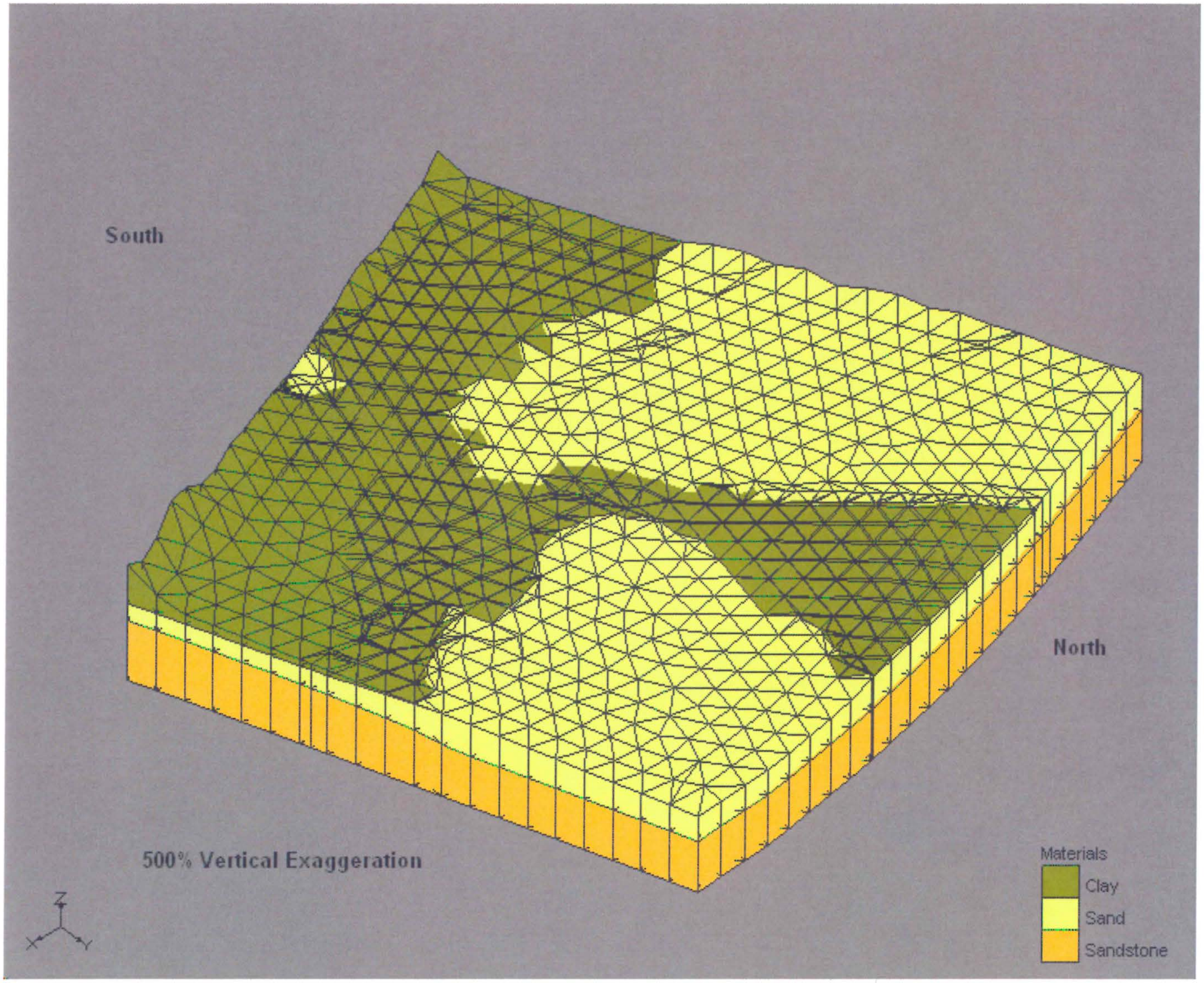


Note:
Shows extent of borings
and cross-sections.
Figure 11 shows extrapolation
of geology to model domain.

WA Area Boreholes and Cross-sections Cimarron Corporation Crescent, Oklahoma		ENSR | AECOM
DATE October 2006	PROJECT 04020-044-300	Figure **10**



	WA Area Solids Developed from Borehole Data Cimarron Corporation Crescent, Oklahoma		ENSR | AECOM
	DATE	PROJECT	Figure **11**
	October 2006	04020-044-300	

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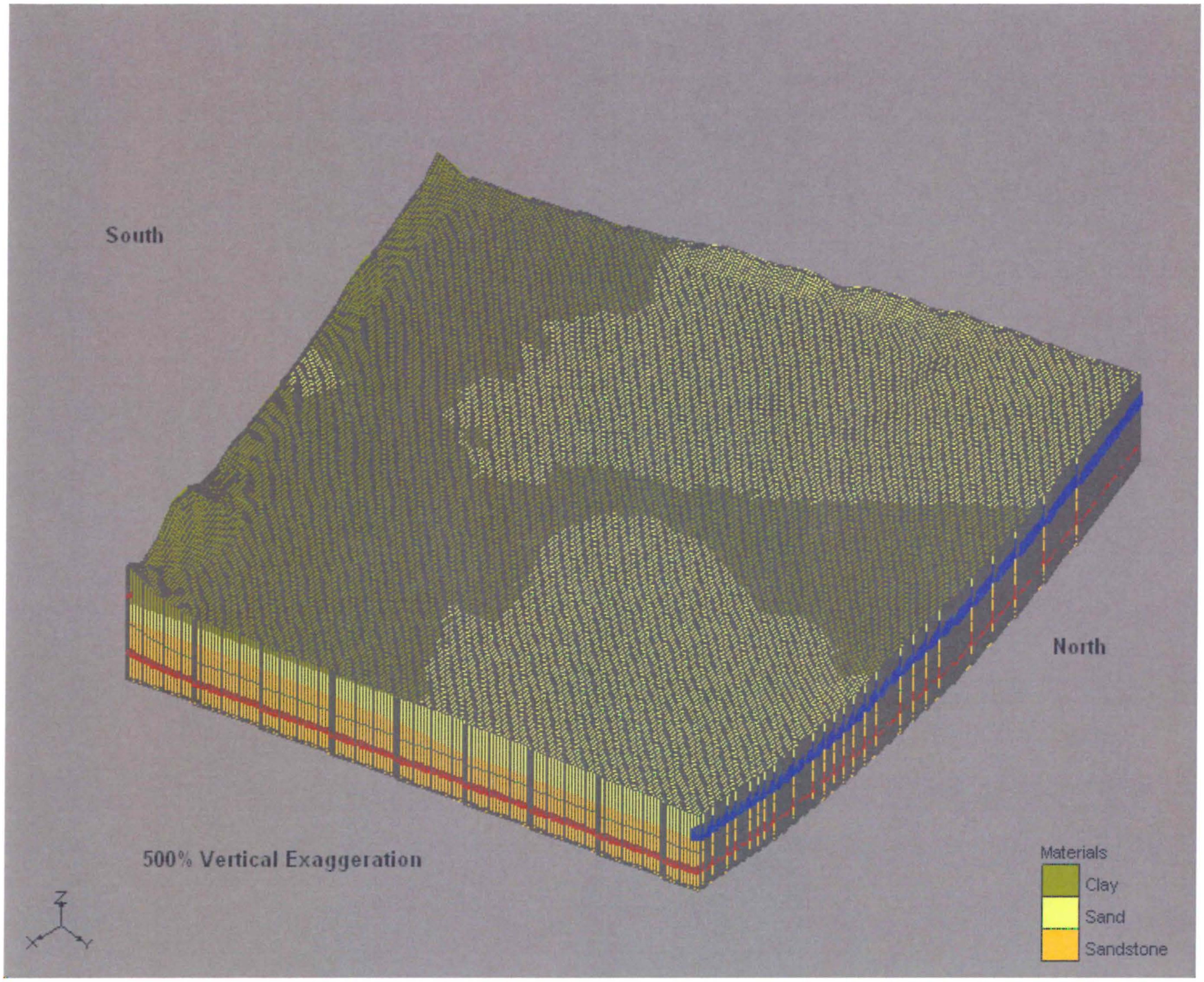


WA Area 3D Grid Incorporating Geologic Information
Cimarron Corporation
Crescent, Oklahoma

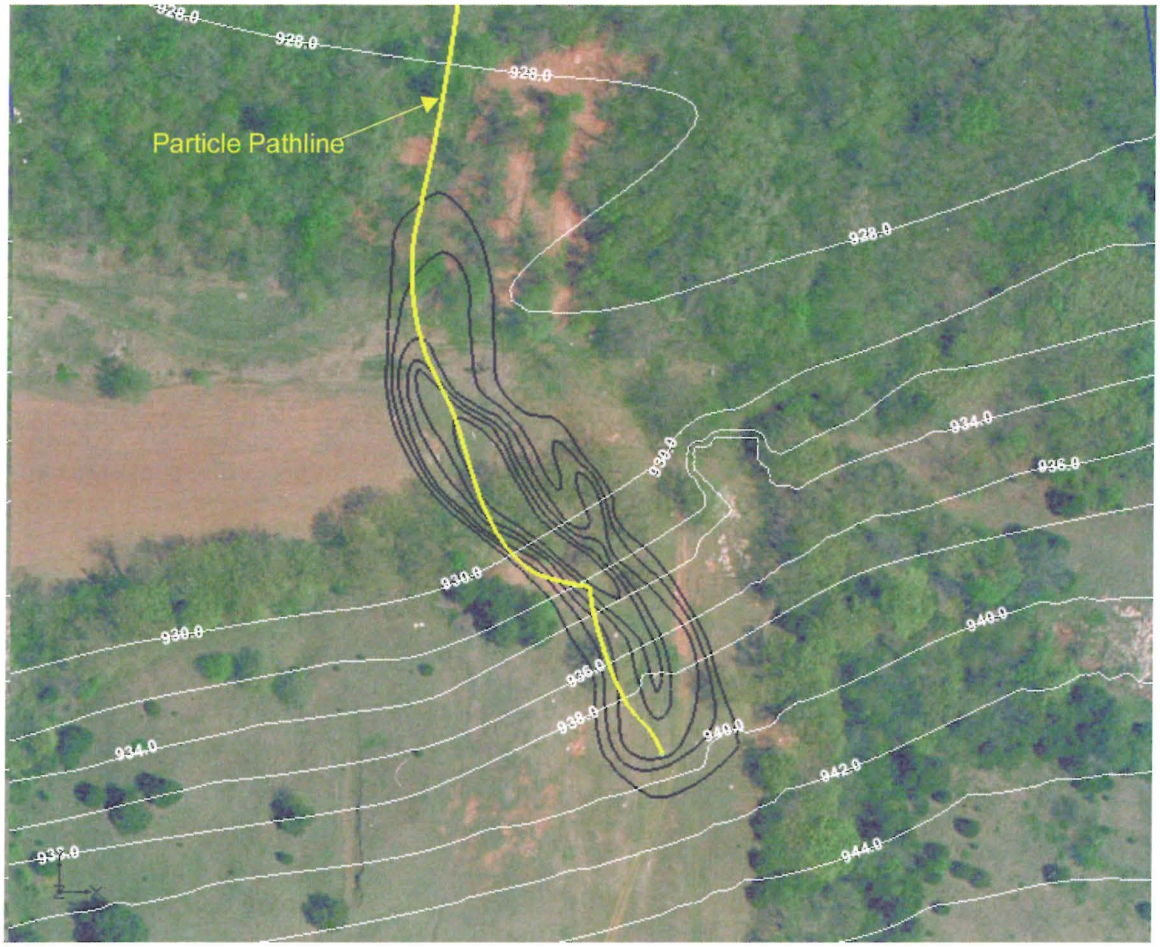
ENSR | AECOM

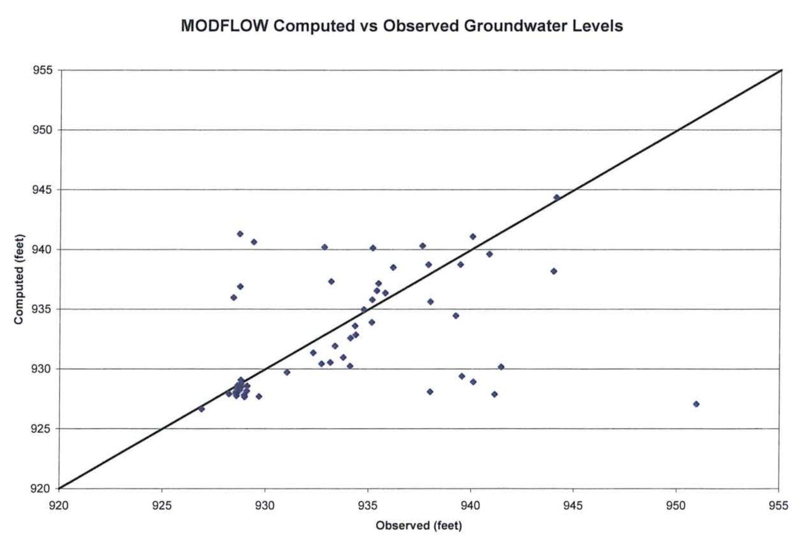
DATE	PROJECT
October 2006	04020-044-300

Figure
12

J:\Water\PROJEC~2\P40\4020\044-CI~1\modeling\MODEL_~1\GIS\figure12.mxd

Predicted Groundwater Contours and Particle Pathlines





N

NOT TO SCALE

Results of Burial Area #1 Model Calibration: Predicted Groundwater Contours with Pathline and Measured vs Predicted Water Levels

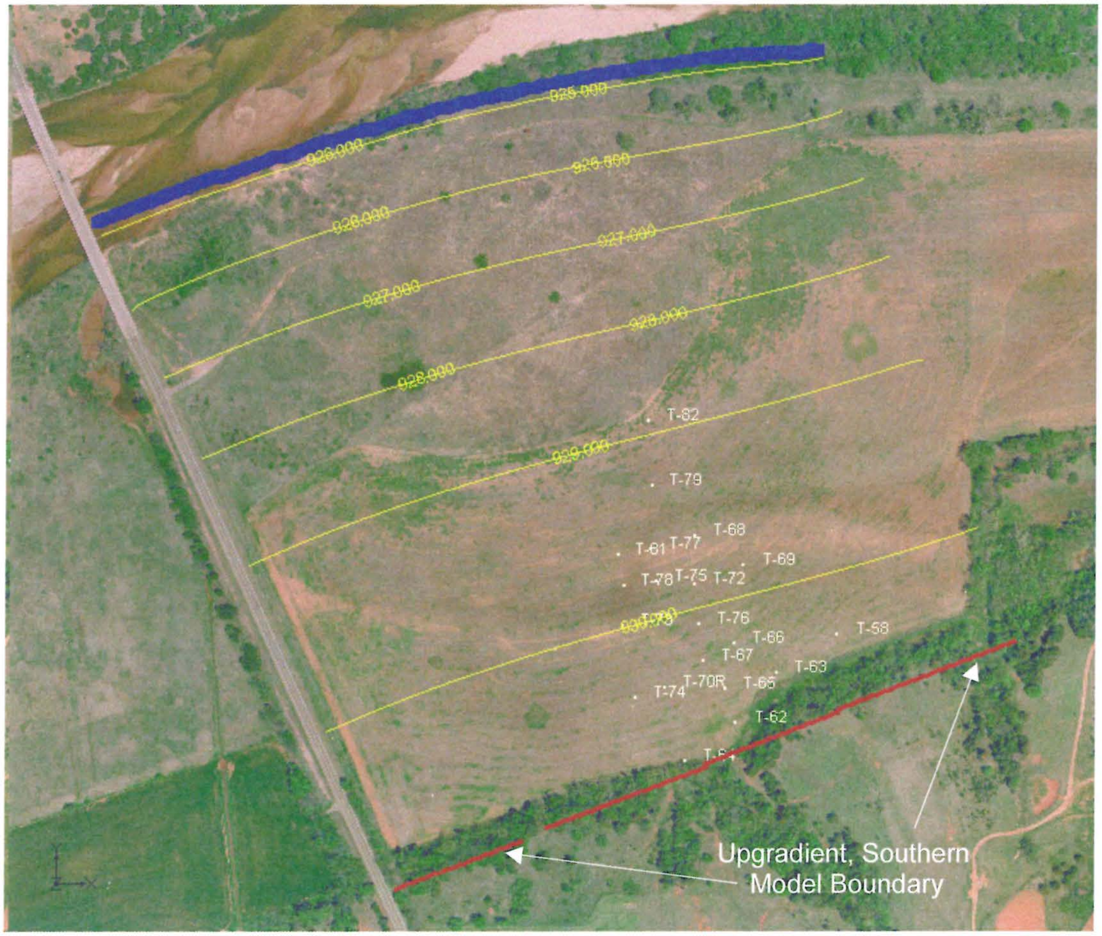
October 2006

ENSR | AECOM

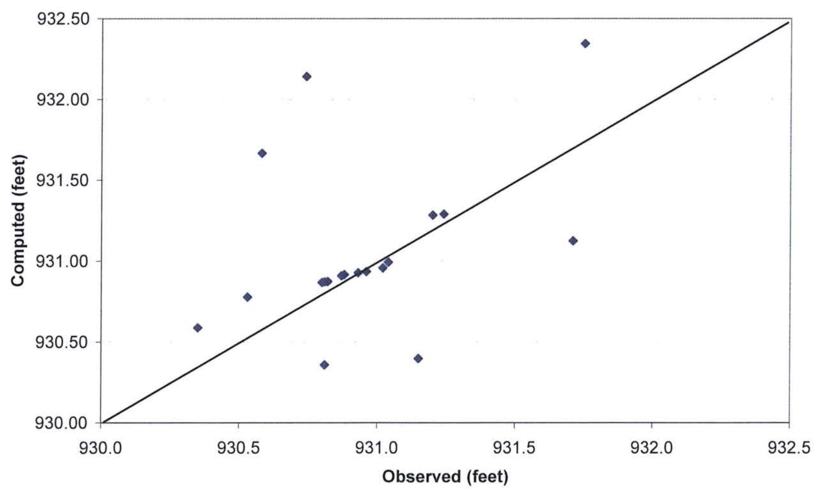
Figure 13

J:\Water\PROJEC~2\P40\4020\044-CI~1\modeling\MODEL_~1\GIS\FIFF2A~1.MXD

Predicted Groundwater Contours



MODFLOW Computed vs Observed Groundwater Levels



N NOT TO SCALE	Results of Western Alluvial Area Model Calibration: Predicted Groundwater Contours and Measured vs Predicted Water Levels October 2006	ENSR | AECOM Figure **14**

APPENDIX B GROUNDWATER FLOW MODEL UPDATE REPORT (BURNS & MCDONNELL, 2014)

GROUNDWATER FLOW MODEL UPDATE
CIMARRON REMEDIATION SITE

Prepared for

CIMARRON ENVIRONMENTAL RESPONSE TRUST

Prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

Project No. 72454

January 2014

GROUNDWATER FLOW MODEL UPDATE
CIMARRON REMEDIATION SITE

Prepared for

CIMARRON ENVIRONMENTAL RESPONSE TRUST

January 2014

Project No. 72454

Prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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* * * * *

LIST OF ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
CSM	Conceptual Site Model
DCGL	Derived Concentration Goal Level
DEQ	Oklahoma Department of Environmental Quality
EPM	Environmental Properties Management LLC
ft	foot/feet
in/yr	inches per year
KMNC	Kerr-McGee Nuclear Corporation
gpm	gallons per minute
MCL	maximum contaminant level
NRC	Nuclear Regulatory Commission
pCi/L	picoCuries per liter
Site	Cimarron Site
Trust	Cimarron Environmental Response Trust
USGS	United States Geological Survey
%	percent
µg/L	micrograms per liter

1.0 INTRODUCTION

Environmental Properties Management LLC (EPM), Trustee for the Cimarron Environmental Response Trust (the Trust), submits this Groundwater Flow Model Update for the Cimarron site (the Site), located at 100 N. Highway 74, Guthrie, Oklahoma.

To evaluate groundwater remediation alternatives at two areas on the Cimarron Site, two existing groundwater flow models were updated. The areas include Burial Area #1 (BA #1) and the Western Alluvial (WA) area. These two models were originally developed as part of the *Groundwater Flow Modeling Report* (ENSR, 2006) included as Appendix A.

The models were updated with new geologic and hydrogeologic data, based on additional assessment performed in 2012 and 2013. The WA model area was expanded to include a larger area. The base of the alluvial aquifer was updated with new geologic information. The porosity was also updated in both models. Both models were recalibrated to a more comprehensive round of groundwater levels collected in November 2013. Calibration was evaluated by comparing measured groundwater elevations, groundwater flow direction, and water budgets, with simulated elevations, flow paths, and budgets. Calibration goals included: 1) a mass balance error less than 1% of the water budget, 2) low residual mean, and 3) a qualitative match of model simulated potentiometric surface and observed potentiometric surface evaluated by comparing contours.

Upon Nuclear Regulatory Commission (NRC) and Oklahoma Department of Environmental Quality (DEQ) approval, the updated models will be used to evaluate alternative remediation scenarios using a particle tracking model (MODPATH). Groundwater extraction with both groundwater recovery trenches and extraction wells will be added to the models, and these will be resubmitted with anticipated groundwater flow rates for both Phase I and Phase II remediation efforts. Upon approval of these revised flow models, a groundwater remediation design will be prepared; this will be included in a comprehensive license amendment request.

1.1 BACKGROUND AND OBECTIVES

The Cimarron facility was formerly operated by Kerr-McGee Nuclear Corporation (KMNC), a wholly owned subsidiary of Kerr-McGee Corporation. The Cimarron facility was utilized for the production of mixed oxide fuel and uranium fuel including enriched uranium reactor fuel pellets, and eventually fuel rods. Enriched uranium fuel was produced at the facility from 1966 through 1975. Process facilities included a main production building; several ancillary buildings, five process related collection ponds, two original sanitary lagoons, one new sanitary lagoon, a waste incinerator, several uncovered storage areas, and three burial grounds.

Licensed material exceeds decommissioning criteria for unrestricted release only in groundwater. The concentration of uranium in groundwater must be reduced to achieve unrestricted release of the site and license termination. The Derived Concentration Goal Level (DCGL) for the site is 180 picoCuries per liter (pCi/L) total uranium, and the DEQ has approved a toxicological concentration release criterion of 110 micrograms per liter (μg/L) for uranium in groundwater. In addition to uranium, groundwater in portions of the Site contains two non-radiological chemicals of concern (COCs): nitrate and fluoride. DEQ has approved site-specific risk-based concentration limits of 52 milligrams per liter (mg/L) for nitrate and 4 mg/L for fluoride.

Uranium exceeds the license release criterion of 180 pCi/L in three areas: BA #1, the Western Upland (WU) Area and the WA Area (ENSR, 2006a and Cimarron, 2007). These areas are illustrated in Figure 1-1. Uranium exceeds the DEQ criterion of 110 μg/L in these same areas, and the extent within those areas roughly matches the extent of uranium exceeding the NRC criterion. The extent of uranium impact to groundwater has been adequately delineated for the development of a groundwater remedy. Years of environmental monitoring have already demonstrated that nitrate and/or fluoride exceed DEQ criteria in the following areas: the WU Area, the WA Area, the Uranium Pond #1 (UP1) Area, the Uranium Pond #2 (UP2) Area, and the uranium plant storage yard (Well 1319 Area). The flow model domain covers all of the areas that exceed the Maximum Contaminant Level (MCL) and that will eventually require remediation. Once the flow models are approved, two phases of groundwater extraction and injection will be evaluated: Phase I will address uranium exceeding NRC's release criteria, and Phase II will address COCs exceeding MCLs.

These groundwater flow models will be used as a tool to assist in the design of groundwater recovery and reinjection systems to reduce the concentrations of COCs in groundwater to less than their release criteria.

* * * * *

2.0 GROUNDWATER MODEL DESCRIPTION AND UPDATES

2.1 CONCEPTUAL MODEL

The Conceptual Site Model (CSM) of the Cimarron River flow system was developed and presented in the *Conceptual Site Model-Rev-01 Report* (ENSR, 2006b) prior to the development of the original groundwater models for the WA area and the BA #1 area. The CSM was then incorporated into the 2006 groundwater models to ensure that the models used existing information and an accepted interpretation of the site-wide geology. Appendix A (*Groundwater Flow Modeling Report* [ENSR, 2006a]) provides a summary of information on the CSM.

2.2 GROUNDWATER FLOW

The Site consists of gently rolling hills, leading northward to the floodplain of the Cimarron River. Ground elevation varies from approximately 925 ft above mean sea level (amsl) at the northeastern property line to approximately 1,045 ft amsl near the southern property line. Three surface water reservoirs are present on the Site. Unnamed ephemeral streams feed these reservoirs, which discharge to the floodplain of the Cimarron River.

Groundwater flow in the WA area is generally northeastward toward the Cimarron River; flow is driven by a relatively flat hydraulic gradient of 0.002 foot/foot. Figure 2-1 presents a potentiometric surface map of the alluvium for the WA area based on groundwater level measurements during November 2013. Additional wells installed in the WA area have provided a more refined understanding of the groundwater flow and direction than was provided in the *2006 Groundwater Flow Modeling Report* (ENSR, 2006a).

Groundwater in the vicinity of BA #1 flows across an escarpment that is an interface for the Sandstone B water-bearing unit and the Cimarron River floodplain alluvium, and finally into and through the floodplain alluvium to the Cimarron River. Figure 2-2 presents a potentiometric surface map of Sandstone B and the alluvium for the BA #1 area based on groundwater level measurements collected during November 2013. Flow in Sandstone B is mostly northward west of the transitional zone and northeastward along the interface with the transitional zone. Flow is driven by a relatively steep hydraulic gradient (0.10 foot/foot) at the interface between Sandstone B and the floodplain alluvium. Once groundwater enters the transition zone of the floodplain alluvium, the hydraulic gradient decreases to around 0.023 foot/foot and flow is refracted to a more northwesterly direction. Once groundwater passes through the transitional zone, it enters an area where the hydraulic gradient is relatively flat and groundwater flow is toward the north. Data indicates that the gradient in the sandy alluvium is approximately 0.0007 ft/ft.

* * * * *

3.0 GROUNDWATER MODEL CONSTRUCTION

A detailed description of the groundwater model construction is provided in Appendix A. The following sections describe the updates or new information in the model update.

3.1 MODEL CONSTRUCTION

MODFLOW-2000 (Harbaugh et al, 2000), a three-dimensional, finite difference groundwater flow computer code, was selected to update the groundwater flow models. Pre- and post-processing was performed using Groundwater Vistas V (Rumbaugh, 2007). Both groundwater models were run using steady state assumptions.

The numerical model domain for the WA area is shown on Figure 3-1; the model was expanded eastward to address remedial alternatives in the entire area of the nitrate plume as defined by the 10-mg/L isoconcentration contour; it therefore covers a larger area than the 2006 groundwater model. The northern boundary of the model domain remains the Cimarron River and the southern boundary of the model is the extent of the transition zone. The grid size remains 10 feet by 10 feet and contains 159,343 active cells. The model origin (left-bottom corner) is located at X = 2090530 and Y = 320886 in Oklahoma State Plane Coordinates. The model grid is rotated (minus) 20 degrees. The WA model domain includes two layers: Layer 1 represents the alluvium and Layer 2 represents the underlying bedrock.

The numerical domain for BA #1 is shown on Figure 3-2 and covers the same area as the 2006 groundwater model. The northern boundary of the model domain is the Cimarron River and the southern boundary of the model is the extent of the transition zone. The grid size is 10 feet by 10 feet and contains 267,440 active cells. The model origin (left-bottom corner) is located at X = 2094550 and Y = 322150 in Oklahoma State Plane Coordinates. There is no rotation of the model grid. There are twelve layers in the model. This complex model layering system setup was described in the *2006 Groundwater Flow Modeling Report* (ENSR, 2006a) and was not modified during the model update.

No adjustments were made to the number of model layers for either model. For the WA area the base of Layer 1 was adjusted with new bedrock depth data. For BA #1 new boring data collected in the alluvium suggested the model layer elevations for the sandstone needed to be adjusted, therefore slight adjustments were made to the bedrock elevation in the model. No additional changes were made to the top or base of layers.

3.2 BOUNDARY CONDITIONS

The model boundary conditions represent the hydrologic interactions between the inside and outside of the model domain. The boundary conditions simulate flow into and out of the groundwater model.

3.2.1 No Flow Boundaries

The active model domains are shown on Figures 3-1 and 3-2. Outside of the active domain are no flow cells that define the western and eastern boundary of both model domains. Within the active model domain all cells are active.

3.2.2 General Head Boundaries

The upgradient boundaries for both the WA area and BA #1 were represented as a General Head Boundary. The upward hydraulic gradient from the underlying bedrock described in the site *Conceptual Site Model Revision 01* (ENSR, 2006b) was represented as a General Head Boundary. Because the Cimarron River is a major discharge area, the discharge of deep groundwater through the alluvium and into the river is an expected phenomenon. To simulate upward flow of deep groundwater through the alluvium a General Head Boundary was used in the lowest layer in both model domains to represent a higher water level at depth than in the alluvial aquifer (ENSR, 2006a). The General Head Boundary along the southern edge of the model for the WA area was updated to account for the water level elevations observed in the wells during the November 2013 water level measurement event and to match the direction of groundwater flow observed with the recently installed wells in the WA area. No changes were made to the groundwater elevations in Sandstone B.

The general head boundaries for BA #1 were updated during model calibration to enable more accurate prediction of groundwater flow direction in the Sandstone and Alluvium. The general head boundary along the southern boundary of the model, which represents the upgradient boundary was adjusted (in some cases the head was higher, and in some cells the head was decreased). The general head boundary in layer 12 (representing an upward gradient from the lowest bedrock layer) was also adjusted slightly as part of model calibration to match the direction of groundwater flow. These adjustments were reasonable and were made to enable a better calibration to the larger data set available for this model update.

3.2.3 River Boundaries

River boundary conditions were updated based on U.S. Geological Survey (USGS) monitoring station data, groundwater level measurements close to the river and as part of model calibration. Data from the

USGS monitoring stations at Dover (30.0 miles upstream to the west) and Guthrie (10.3 miles downstream to the east) were downloaded to determine river elevations at the time of the November water level measurement event. It was determined that the water levels in the area of the Site were on the order of 930 ft amsl to 933 ft amsl, from east to west. Small variations in river boundary heads were made during model calibration. No changes were made to the boundary conductance or the riverbed elevation.

3.3 HYDROGEOLOGIC PROPERTIES

Pneumatic slug tests were performed on select wells in the Western Alluvium to collect data to supplement and verify hydraulic conductivities values used in the 2006 WA model. In addition, conventional slug testing was also performed on select Burial Area #1 wells during the hydrogeologic investigation. After review of new and existing data, no changes were made to the hydraulic conductivity parameters from the 2006 models. The parameters used for each of the areas are provided in Table 3-1. The porosity was updated and is also presented in Table 3-1. These values are based on either site-specific data or (where site data is not available) on values obtained from published literature, as listed in Table 3-1.

3.4 RECHARGE

Based upon a review of precipitation data from 2013, this year appears to have been a higher than normal precipitation year and water levels at the site were higher than in the 2006 model in accordance with the higher recharge. The calendar year 2013 was the 9th wettest year on record for Central Oklahoma, with 41.1 inches of rainfall through October, compared to mean annual precipitation of 37 inches (Oklahoma Climatological Survey, 2013). No changes were made to the recharge values originally presented in the 2006 model because this year does not represent a typical year and the recharge values are meant to represent a long term average condition.

3.5 MODEL CALIBRATION

Table 3-2 and Table 3-3 present the most recent water level measurements available from November 2013 for the WA area and BA #1, respectively. All wells were used as calibration targets except BA #1 wells 02W25 and 02W51, which are screened over multiple zones represented by multiple layers in the BA #1 model.

Both models were recalibrated to water levels collected in November 2013. Calibration was evaluated by comparing measured groundwater elevations, groundwater flow direction, and water budgets, with simulated elevations, flow paths, and budgets. Calibration goals included: 1) a mass balance error less than 1% of the water budget, 2) absolute residual mean error of less than 5% of the range of water level measurements, and 3) a qualitative match of model simulated potentiometric surface and observed potentiometric surface evaluated by comparing contours. Discrepancies between observations and predictions are more pronounced in BA#1 near the transition zone where the groundwater gradient is steep.

3.5.1 Water Budget

The first model calibration goal is to evaluate the mass balance error. A model simulated water budget provides a picture of the flow volumes into and out of the model domain. Water budgets for BA #1 and the WA area for the calibration condition are provided in Table 3-4. General head boundaries account for the highest inflow and the head boundaries and river accounts for the largest outflow. The percent error in the water budget for both models is significantly less than 1%, indicating a stable model.

3.5.2 Comparison of Hydraulic Heads

Comparison of observed heads and simulated heads was conducted in two different ways including a statistical evaluation of the direct measurement of water level versus the simulated water level at the model targets and through a qualitative examination of simulated potentiometric surface and measured potentiometric surface.

For the WA area model, water level measurements were collected from 43 wells. Simulated and observed hydraulic heads for the steady-state model are compared in Table 3-5 and graphed on Figure 3-3. Both the river boundary elevation and the general head boundary condition were adjusted from the 2006 Model to account for the water elevations observed in November 2013. The simulated elevations near the river are influenced by the river and the exact stage of the river near the WA area is unknown, therefore there may be a slight bias to the water levels but the overall direction of groundwater flow matches the observed conditions. The residual mean is less than 0.1 feet.

For the BA #1 model water level measurements were collected from 70 wells. Simulated and observed hydraulic heads for the steady-state model are compared in Table 3-6 and graphed on Figure 3-4. The residual mean is less than 0.1 feet.

The model simulated potentiometric surface and the observed potentiometric surface were compared visually (Figures 3-5 and 3-6). The overall simulated surface is similar to the observed, with some differences to data density especially near the transition zone of BA#1. Discrepancies between observations and predictions are more pronounced in BA#1 near the transition zone where the groundwater gradient is steep.

3.5.3 Sensitivity Analysis

In the 2006 Groundwater Model (Appendix A), a sensitivity analysis was conducted on the flow model. The only parameters adjusted in this update in the WA area model were bedrock elevation (base of Layer 1), general head boundary, and river boundary stage. The only parameters adjusted in the BA#1 model were general head and river boundary stage. Therefore, sensitivity analysis was not repeated for hydraulic conductivity which was addressed in the 2006 Groundwater Model. Modifying the river stage +/- 1 foot changed the model calibration, indicating river stage (elevation) is a sensitive parameter (see Table 3-7). This parameter controls flows out of the groundwater models. In the WA area model modifications to the southern boundary general head changed the model calibration. In BA#1 the southern boundary general head was a relatively insensitive parameter.

3.6 UNCERTAINTY

Site conditions and hydrogeologic properties were estimated through extrapolation of measured or estimated properties or inferences from data measured or estimated based on existing site data and professional judgment. Groundwater models are by definition a simplified version of the aquifer system. Therefore, these simplifications provide some model limitations.

* * * * *

4.0 REFERENCES

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TABLES

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-1
GROUNDWATER MODEL INPUTS

Burial Area #1

Subsurface Units:		Value	Units	Source
Fill	K_H	3.30E+00	ft/day	Average of Silt, Sand & Clay
	K_V	3.30E-01	ft/day	10% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (Kh/Kv)	1	-----	No vertical anisotropy
	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Silt	K_H	2.83E-01	ft/day	ENSR CSM Sec 3.2.1
	K_V	2.83E-02	ft/day	10% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (Kh/Kv)	1	-----	No vertical anisotropy
	Porosity	20	%	Freeze & Cherry, 1979 Table 2.4
Sand	K_H	2.35E+02	ft/day	Average of Pumping Test (ENSR, 2006a)
	K_V	2.53E+01	ft/day	10% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Clay	K_H	5.00E-01	ft/day	ENSR, 2006a (Artificially high to improve model stability)
	K_V	5.00E-02	ft/day	10% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	20	%	Freeze & Cherry, 1979 Table 2.4
Siltstone	K_H	8.43E+00	ft/day	Calibration (ENSR, 2006a)
	K_V	4.22E-01	ft/day	5% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	1	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-A	K_H	4.00E+01	ft/day	Calibrated to high end of range in ENSR CSM Sec-3.2.1 (ENSR, 2006a)
	K_V	2.00E+00	ft/day	5% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-B	K_H	5.00E+00	ft/day	Slug Test, Calibration (ENSR, 2006a)
	K_V	2.50E-01	ft/day	5% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-C	K_H	3.00E+00	ft/day	Slug Test, Calibration (ENSR, 2006a)
	K_V	1.50E-01	ft/day	5% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4

Cimarron River:	Value	Units	Source
Elevation	927.4	feet	Based on Dover and Guthrie gage/Calibration

Notes:

1. All inputs are identical to those in the presented in the ENSR (2006) model report, except the Cimarron River Elevation. However, the actual model files the porosity was 1%.

Western Alluvial Area

Subsurface Units:		Value	Units	Source
Sand (Layer 1)	K_H	2.35E+02	ft/day	Pumping Test (ENSR, 2006a)
	K_V	2.35E+01	ft/day	10% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Specific Storage	0.01	-----	Default, not used in steady state model
	Specific Yield	0.01	-----	Default, not used in steady state model
	Porosity	30	%	Freeze & Cherry, 1979 Table 2.4
Sandstone-C (Layer 2)	K_H	3.00E+00	ft/day	Slug Test, Calibration (ENSR, 2006a)
	K_V	1.50E-01	ft/day	5% of K_H
	Horizontal Anisotropy	1	-----	No horizontal anisotropy
	Vertical Anisotropy (K_H/K_V)	1	-----	No vertical anisotropy
	Specific Storage	0.01	-----	Default, not used in steady state model
	Specific Yield	0.01	-----	Default, not used in steady state model
	Porosity	5	%	Freeze & Cherry, 1979 Table 2.4

Cimarron River:	Value	Units	Source
Upstream Elevation	929.1	feet	Based on Dover and Guthrie gage/Calibration
Downstream Elevation	928.5	feet	Based on Dover and Guthrie gage/Calibration
Riverbed Conductance	20,000	$(ft^2/day)/ft$	ENSR, 2006a

Areal Boundaries:	Value	Units	Source
Recharge	5.40E-04	ft/day	ENSR CSM Sec-3.1.1 & 3.1.4

Notes:

1. All inputs are identical to those in the presented in the ENSR (2006) model report, except the Cimarron River Elevation. However, the actual model files the porosity was 1%.

2. Clay: The ENSR report shows input parameters for clay materials in the WAA model. Although there is a variable-thickness clay layer overlying the sand in the WAA, this is not represented in the model as a layer. Since its effect on recharge should be reflected in the recharge input, any references to clay in the table are omitted, including Longitudinal Dispersivity, which is not needed for purposes of this model as chemical transport modeling will not be performed.

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-2 WESTERN ALLUVIAL AREA WATER LEVEL MEASUREMENTS
NOVEMBER 2013

Well	Easting	Northing	Water Elevation (11/15/2013) (feet amsl)
T-51	2,091,962.33	322,775.31	929.71
T-52	2,092,329.67	322,774.93	929.59
T-53	2,092,658.88	322,773.47	929.46
T-54	2,092,870.50	321,927.51	930.36
T-55	2,093,119.60	322,069.59	930.09
T-56	2,093,377.95	322,211.22	929.89
T-57	2,092,460.78	321,788.03	930.51
T-58	2,092,165.08	321,742.40	930.55
T-59	2,092,954.88	322,773.96	929.43
T-60	2,093,281.82	322,773.99	929.48
T-61	2,093,609.54	322,774.36	929.24
T-62	2,091,852.83	321,470.61	930.76
T-63	2,091,976.65	321,623.17	930.63
T-65	2,091,814.49	321,568.90	930.69
T-66	2,091,841.97	321,712.16	930.6
T-67	2,091,742.89	321,657.32	930.65
T-68	2,091,713.09	322,052.25	930.34
T-69	2,091,871.69	321,961.92	930.4
T-70R	2,091,625.71	321,577.88	930.74
T-72	2,091,716.89	321,899.31	930.47
T-73	2,091,492.01	321,770.59	930.61
T-74	2,091,531.32	321,541.25	930.79
T-75	2,091,598.42	321,910.86	930.46
T-76	2,091,730.57	321,776.39	930.56
T-77	2,091,578.18	322,010.24	930.38
T-78	2,091,493.75	321,897.01	930.44
T-79	2,091,581.67	322,212.51	930.21
T-81	2,091,475.97	321,993.82	930.38
T-82	2,091,568.93	322,413.79	930.09
T-83	2,091,500.85	322,296.59	930.18
T-84	2,091,869.00	322,295.49	930.13
T-85	2,092,242.87	322,346.29	930.02
T-86	2,092,646.71	322,374.17	929.94
T-87	2,092,979.21	322,421.78	929.8
T-88	2,093,383.60	322,464.01	929.53
T-89	2,093,072.37	323,042.18	929.07
T-90	2,092,830.41	323,042.30	929.19
T-91	2,092,965.54	323,228.28	928.97
T-92	2,093,124.95	323,142.63	928.94
T-93	2,093,413.80	323,104.00	928.93
T-94	2,093,266.80	323,409.22	928.7
T-95	2,092,457.65	323,019.00	929.36
T-96	2,091,984.82	322,557.26	929.83

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-3 BURIAL AREA #1 WATER LEVEL MEASUREMENTS
NOVEMBER 15, 2013

Well	New Easting	New Northing	Water Elevation (11/15/2013)	Top of Screened Interval (MSL)	Bottom of Screened Interval (MSL)
02W01	2095439.69	322842.79	933.37	936	926
02W02	2095451.04	322881.61	930.97	934	924
02W03	2095372.73	322882.37	928.93	935	926
02W04	2095333.62	322903.05	928.01	933	924
02W05	2095319.21	322952.00	928.00	932	923
02W06	2095307.98	323007.93	927.99	932	917
02W07	2095343.77	323005.17	927.97	932	917
02W08	2095390.56	323011.59	927.97	931	916
02W09	2095598.18	322763.68	935.67	941	926
02W10	2095579.82	322829.34	934.73	939	924
02W11	2095440.73	323055.82	927.91	934	915
02W12	2095453.66	323035.56	927.84	935	915
02W13	2095478.76	322982.90	928.14	930	916
02W14	2095394.40	323056.26	927.88	934	914
02W15	2095284.14	322896.65	928.03	931	926
02W16	2095269.31	322944.49	928.03	931	921
02W17	2095259.08	323006.59	927.99	931	916
02W18	2095344.50	323094.37	927.89	933	914
02W19	2095328.70	323053.20	927.96	931	917
02W20	2095670.14	322655.42	937.78	942	928
02W21	2095196.20	323055.69	927.97	929	914
02W22	2095217.52	322937.41	928.02	932	922
02W23	2095207.01	323008.48	928.01	930	916
02W24	2095260.88	323055.20	927.93	934	915
02W25	2095463.70	322653.27	947.82	946	926
02W26	2095629.00	322716.17	936.45	942	928
02W27	2095396.97	322825.07	932.37	935	925
02W28	2095535.69	322830.33	934.48	935	923
02W29	2095551.60	322758.33	935.37	939	929
02W30	2095470.17	322767.25	935.15	936	924
02W31	2095501.15	322860.00	933.99	938	923
02W32	2095430.36	322964.35	928.00	933	919
02W33	2095250.57	322916.93	928.06	933	923
02W34	2095184.86	323104.27	927.96	933	914
02W35	2095253.16	323155.84	927.87	932	913
02W36	2095250.07	323107.00	927.92	933	914
02W37	2095324.68	323156.60	927.82	934	914
02W38	2095392.31	323099.02	927.86	934	914
02W39	2095575.12	322735.34	935.76	943	928
02W40	2095529.95	322660.67	939.61	939	925
02W41	2095578.86	322682.92	937.99	940	926
02W42	2095470.24	322724.55	938.96	944	924
02W43	2095321.85	323206.65	927.79	931	912
02W44	2095373.85	323155.44	927.79	932	913
02W45	2095285.68	323197.77	927.81	931	912
02W46	2095469.90	322907.34	929.56	931	922
02W47	2095524.52	322626.66	940.58	947	927
02W48	2095423.83	323407.99	927.49	904	884
02W50	2095525.35	322566.64	941.10	948	928
02W51	2095475.07	322582.30	952.43	953	928
02W52	2095558.69	322568.16	940.34	947	927
02W53	2095381.90	322827.48	932.42	939	924
02W62	2095207.49	323140.54	928.14	933	914
1344	2095776.39	323500.38	927.21	930	915
1314	2095467.35	322412.22	944.61	942	927
TMW-01	2095505.83	322696.66	941.11	942	927
TMW-02	2095508.07	322598.27	941.02	945	930
TMW-05	2095554.17	322882.67	933.27	935	921
TMW-06	2095637.00	322794.74	935.43	942	932
TMW-08	2095537.44	322724.36	935.71	941	926
TMW-09	2095489.80	322825.00	934.11	938	924
TMW-13	2095377.00	322952.48	928.03	931	921
TMW-17	2095498.17	322764.05	932.51	913	903
TMW-18	2095338.37	322866.63	928.69	930	923
TMW-19	2095338.16	322865.04	929.00	936	931
TMW-20	2095612.55	322616.13	939.13	948	934
TMW-21	2095437.57	322700.53	937.88	942	932
TMW-23	2095473.70	323056.46	928.69	910	900
TMW-24	2095432.72	323408.70	927.58	924	914
TMW-25	2095624.78	322654.44	937.87	945	931
1314	2095467.35	322412.22	944.61	942	927
1315R	2095504.06	322756.51	934.94	939	924
1316R	2095438.45	322776.98	933.45	936	922
1361	2095439.83	323265.37	927.69	931	911

CIMARRON ENVIRONMENTAL RESPONSE TRUST

TABLE 3-4 WATER BUDGET

Western Alluvial Area Mass Balance

	Inflow (ft^3/day)	Outflow (ft^3/day)
General Head Boundary	49,182.93	33,896.13
River Boundary	1,257.59	20,675.69
Recharge	4,154.75	-
Total	54,595.27	54,571.82

% Error **0.043**

Burial Area #1 Mass Balance

	Inflow (ft^3/day)	Outflow (ft^3/day)
General Head Boundary	36,086.41	31,638.40
River Boundary	-	5,665.77
Recharge	1,227.78	-
Total	37,314.19	37,304.17

% Error **0.023**

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-5 TARGET RESIDUALS
WESTERN ALLUVIAL AREA

Name	X	Y	Layer	Observed	Computed	Residual
T-51	2091962.326	322775.3141	1	929.71	929.631123	0.078877
T-52	2092329.671	322774.9303	1	929.59	929.571402	0.018598
T-53	2092658.885	322773.4698	1	929.46	929.51156	-0.05156
T-54	2092870.502	321927.5096	1	930.36	930.262255	0.097745
T-55	2093119.602	322069.585	1	930.09	930.10832	-0.01832
T-56	2093377.952	322211.2172	1	929.89	929.843322	0.046678
T-57	2092460.776	321788.0337	1	930.51	930.327332	0.182668
T-58	2092165.082	321742.3981	1	930.55	930.404948	0.145052
T-59	2092954.879	322773.9552	1	929.43	929.457315	-0.027315
T-60	2093281.825	322773.9893	1	929.48	929.409401	0.070599
T-61	2093609.543	322774.3576	1	929.24	929.372255	-0.132255
T-62	2091852.828	321470.6101	1	930.76	930.674002	0.085998
T-63	2091976.647	321623.1691	1	930.63	930.514589	0.115411
T-65	2091814.49	321568.8952	1	930.69	930.581133	0.108867
T-66	2091841.967	321712.1628	1	930.6	930.468861	0.131139
T-67	2091742.89	321657.3189	1	930.65	930.524398	0.125602
T-68	2091713.087	322052.2532	1	930.34	930.225643	0.114357
T-69	2091871.687	321961.92	1	930.4	930.276362	0.123638
T-70R	2091625.712	321577.8812	1	930.74	930.607608	0.132392
T-72	2091716.886	321899.3089	1	930.47	930.345744	0.124256
T-73	2091492.007	321770.5934	1	930.61	930.469952	0.140048
T-74	2091531.319	321541.2476	1	930.79	930.650591	0.139409
T-75	2091598.422	321910.8582	1	930.46	930.348807	0.111193
T-76	2091730.573	321776.3871	1	930.56	930.43871	0.12129
T-77	2091578.181	322010.2388	1	930.38	930.271741	0.108259
T-78	2091493.754	321897.0149	1	930.44	930.368192	0.071808
T-79	2091581.67	322212.5107	1	930.21	930.113355	0.096645
T-81	2091475.972	321993.8212	1	930.38	930.291712	0.088288
T-82	2091568.929	322413.7919	1	930.09	929.956848	0.133152
T-83	2091500.85	322296.589	1	930.18	930.052948	0.127052
T-84	2091868.999	322295.4869	1	930.13	930.014964	0.115036
T-85	2092242.869	322346.2922	1	930.02	929.909285	0.110715
T-86	2092646.711	322374.1651	1	929.94	929.807601	0.132399
T-87	2092979.209	322421.7774	1	929.8	929.702394	0.097606
T-88	2093383.604	322464.0053	1	929.53	929.587511	-0.057511
T-89	2093072.365	323042.1839	1	929.07	929.25402	-0.18402
T-90	2092830.414	323042.2988	1	929.19	929.286906	-0.096906
T-91	2092965.544	323228.2819	1	928.97	929.127403	-0.157403
T-92	2093124.953	323142.6274	1	928.94	929.176394	-0.236394
T-93	2093413.804	323104.0008	1	928.93	929.185053	-0.255053
T-94	2093266.798	323409.2186	1	928.7	928.962405	-0.262405
T-95	2092457.652	323019.0016	1	929.36	929.368038	-0.008038
T-96	2091984.823	322557.2578	1	929.83	929.794245	0.035755

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-5 TARGET RESIDUALS
WESTERN ALLUVIAL AREA

Residual Mean	0.043
Absoluate Residual Mean	0.112
Residual Std. Deviation	0.118
Sum of Squares	0.675
RMS Error	0.125
Min. Residual	-0.262
Max. Residual	0.183
Number of Observations	43
Range in Observations	2.09
Scaled Residual Std. Deviation	0.056
Scaled Absolute Residual Mean	0.054
Scaled RMS Error	0.060
Scaled Residual Mean	0.021

CIMARRON ENVIRONMENTAL RESPONSE TRUST
TABLE 3-6 TARGET RESIDUALS
BURIAL AREA #1

Name	X	Y	Layer	Observed	Computed	Residual
02W02	2095451	322881.6	6	930.97	928.91	2.06
02W03	2095373	322882.4	5	928.93	928.84	0.09
02W04	2095334	322903.1	6	928.01	928.75	-0.74
02W05	2095319	322952	5	928.00	928.58	-0.58
02W06	2095308	323007.9	7	927.99	928.40	-0.41
02W07	2095344	323005.2	7	927.97	928.40	-0.43
02W08	2095391	323011.6	7	927.97	928.37	-0.40
02W09	2095598	322763.7	6	935.67	935.52	0.15
02W10	2095580	322829.3	6	934.73	933.07	1.66
02W11	2095441	323055.8	8	927.91	928.21	-0.30
02W12	2095454	323035.6	8	927.84	928.25	-0.41
02W13	2095479	322982.9	8	928.14	928.41	-0.27
02W14	2095394	323056.3	8	927.88	928.24	-0.36
02W15	2095284	322896.7	5	928.03	928.76	-0.73
02W16	2095269	322944.5	6	928.03	928.60	-0.57
02W17	2095259	323006.6	7	927.99	928.41	-0.42
02W18	2095345	323094.4	8	927.89	928.16	-0.27
02W19	2095329	323053.2	7	927.96	928.27	-0.31
02W20	2095670	322655.4	5	937.78	938.26	-0.48
02W21	2095196	323055.7	8	927.97	928.28	-0.31
02W22	2095218	322937.4	6	928.02	928.62	-0.60
02W23	2095207	323008.5	8	928.01	928.40	-0.39
02W24	2095261	323055.2	8	927.93	928.28	-0.35
02W26	2095629	322716.2	5	936.45	936.95	-0.50
02W27	2095397	322825.1	6	932.37	930.62	1.75
02W28	2095536	322830.3	6	934.48	932.09	2.39
02W29	2095552	322758.3	5	935.37	935.54	-0.17
02W30	2095470	322767.3	7	935.15	934.72	0.43
02W31	2095501	322860	6	933.99	929.70	4.29
02W32	2095430	322964.4	7	928	928.53	-0.53
02W33	2095251	322916.9	6	928.06	928.69	-0.63
02W34	2095185	323104.3	8	927.96	928.17	-0.21
02W35	2095253	323155.8	8	927.87	928.05	-0.18
02W36	2095250	323107	8	927.92	928.15	-0.23
02W37	2095325	323156.6	7	927.82	928.04	-0.22
02W38	2095392	323099	8	927.86	928.13	-0.27
02W39	2095575	322735.3	5	935.76	936.40	-0.64
02W40	2095530	322660.7	7	939.61	939.39	0.22
02W41	2095579	322682.9	6	937.99	938.02	-0.03
02W42	2095470	322724.6	7	938.96	937.06	1.90
02W43	2095322	323206.7	8	927.79	927.95	-0.16
02W44	2095374	323155.4	8	927.79	928.02	-0.23
02W45	2095286	323197.8	8	927.81	927.97	-0.16
02W46	2095470	322907.3	6	929.56	928.81	0.75

CIMARRON ENVIRONMENTAL RESPONSE TRUST

TABLE 3-6 TARGET RESIDUALS

BURIAL AREA #1

Name	X	Y	Layer	Observed	Computed	Residual
02W47	2095525	322626.7	7	940.58	940.68	-0.10
02W50	2095525	322566.6	7	941.10	942.53	-1.43
02W52	2095559	322568.2	7	940.34	941.81	-1.47
02W53	2095382	322827.5	6	932.42	930.50	1.92
02W62	2095207	323140.5	8	928.14	928.09	0.05
1314	2095467	322412.2	8	944.61	947.73	-3.12
1344	2095776	323500.4	7	927.21	927.51	-0.30
1361	2095440	323265.4	8	927.69	927.82	-0.13
1361	2095440	323265.4	8	927.69	927.82	-0.13
1362	2095451	323187	10	927.77	927.61	0.16
1315R	2095504	322756.5	7	934.94	935.43	-0.49
1316R	2095438	322777	7	933.45	933.95	-0.50
TMW-01	2095506	322696.7	7	941.11	938.20	2.91
TMW-02	2095508	322598.3	7	941.02	941.91	-0.89
TMW-05	2095554	322882.7	7	933.27	930.62	2.65
TMW-06	2095637	322794.7	4	935.43	935.15	0.28
TMW-08	2095537	322724.4	6	935.71	936.80	-1.09
TMW-09	2095490	322825	6	934.11	931.23	2.88
TMW-13	2095377	322952.5	6	928.03	928.58	-0.55
TMW-17	2095498	322764.1	12	932.51	934.54	-2.03
TMW-18	2095338	322866.6	6	928.69	928.87	-0.18
TMW-19	2095338	322865	4	929	929.19	-0.19
TMW-20	2095613	322616.1	5	939.13	939.57	-0.44
TMW-21	2095438	322700.5	6	937.88	938.27	-0.39
TMW-24	2095433	323408.7	7	927.58	927.66	-0.08
TMW-25	2095625	322654.4	5	937.87	938.46	-0.59

Residual Mean	-0.00123
Absoluate Residual Mean	0.759309
Residual Std. Deviation	1.156653
Sum of Squares	93.64937
RMS Error	1.156654
Min. Residual	-3.12031
Max. Residual	4.286187
Number of Observations	70
Range in Observations	17.4
Scaled Residual Std. Deviation	0.066474
Scaled Absolute Residual Mean	0.043638
Scaled RMS Error	0.066474
Scaled Residual Mean	-7.1E-05

TABLE 3-7 SENSITIVITY ANALYSIS

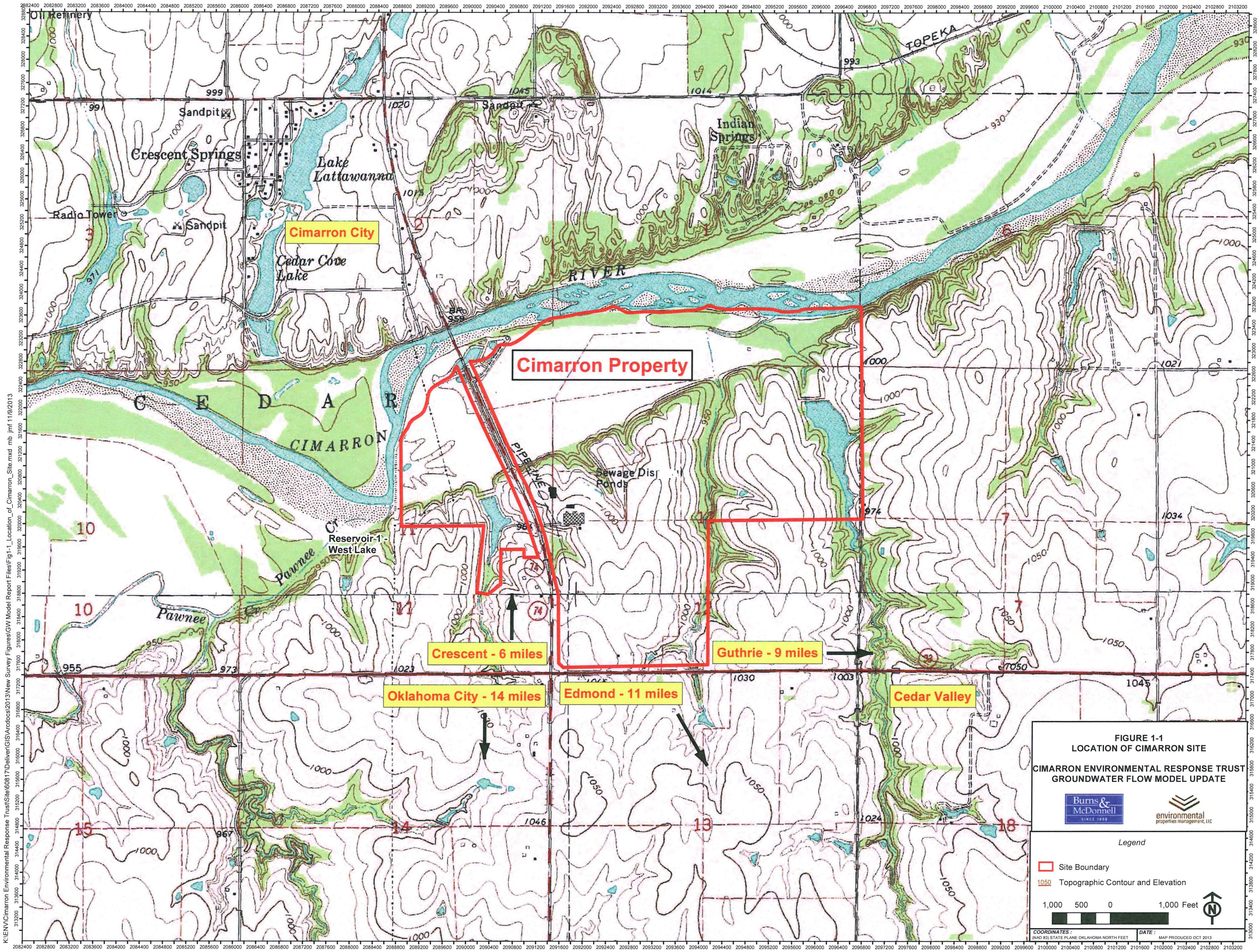
Western Alluvial Area

	Calibrated Result	River Elevation change		Southern General Head Boundary	
		+1 ft	-1 ft	+1 ft	-1 ft*
Residual Mean	0.04	-0.19	0.30	-0.68	0.81
Absolute Residual Mean	0.11	0.21	0.30	0.68	0.81
Residual Std. Deviation	0.12	0.20	0.07	0.07	0.19
Sum of Squares	0.67	3.23	4.16	20.15	29.92
RMS Error	0.13	0.27	0.31	0.68	0.83
Scaled Residual Std. Deviation	0.06	0.11	0.04	0.04	0.11
Scaled Absolute Residual Mean	0.05	0.11	0.17	0.37	0.45
Scaled RMS Error	0.06	0.15	0.17	0.38	0.46
Scaled Residual Mean	0.02	-0.10	0.17	-0.37	0.45

Burial Area #1

	Calibrated Result	River Elevation change		Southern General Head Boundary	
		+1 ft	-1 ft	+1 ft	-1 ft
Residual Mean	0.00	-0.20	0.31	0.05	0.06
Absolute Residual Mean	0.76	0.91	0.84	0.76	0.76
Residual Std. Deviation	1.16	1.20	1.19	1.16	1.16
Sum of Squares	93.65	103.53	106.16	98.58	98.26
RMS Error	1.16	1.22	1.23	1.19	1.18
Scaled Residual Std. Deviation	0.07	0.08	0.08	0.08	0.08
Scaled Absolute Residual Mean	0.04	0.06	0.06	0.06	0.05
Scaled RMS Error	0.07	0.08	0.08	0.08	0.08
Scaled Residual Mean	0.00	-0.01	0.02	0.00	0.00

FIGURES



Cimarron Property
Cimarron City
Crescent Springs
Lake Lattawanna
Cedar Cove Lake
Indian Springs
Sandpit
Radio Tower
Oil Refinery
CEDAR
CIMARRON
RIVER
TOPEKA
PIPELINE
Sewage Disp Ponds
Reservoir 1 - West Lake
Pawnee Cr
Crescent - 6 miles
Guthrie - 9 miles
Oklahoma City - 14 miles
Edmond - 11 miles
Cedar Valley
FIGURE 1-1
LOCATION OF CIMARRON SITE
CIMARRON ENVIRONMENTAL RESPONSE TRUST
GROUNDWATER FLOW MODEL UPDATE
Burns & McDonnell
environmental properties management, LLC
Legend
Site Boundary
1050 Topographic Contour and Elevation
1,000 500 0 1,000 Feet
COORDINATES : (NAD 83) STATE PLANE OKLAHOMA NORTH FEET
DATE : MAP PRODUCED OCT 2013
K:\ENV\Cimarron Environmental Response Trust\Site\60817\Deliver\GIS\Arcdocs\2013\New Survey Figures\GW Model Report Files\Fig1-1_Location_of_Cimarron_Site.mxd mb jmf 11/9/2013

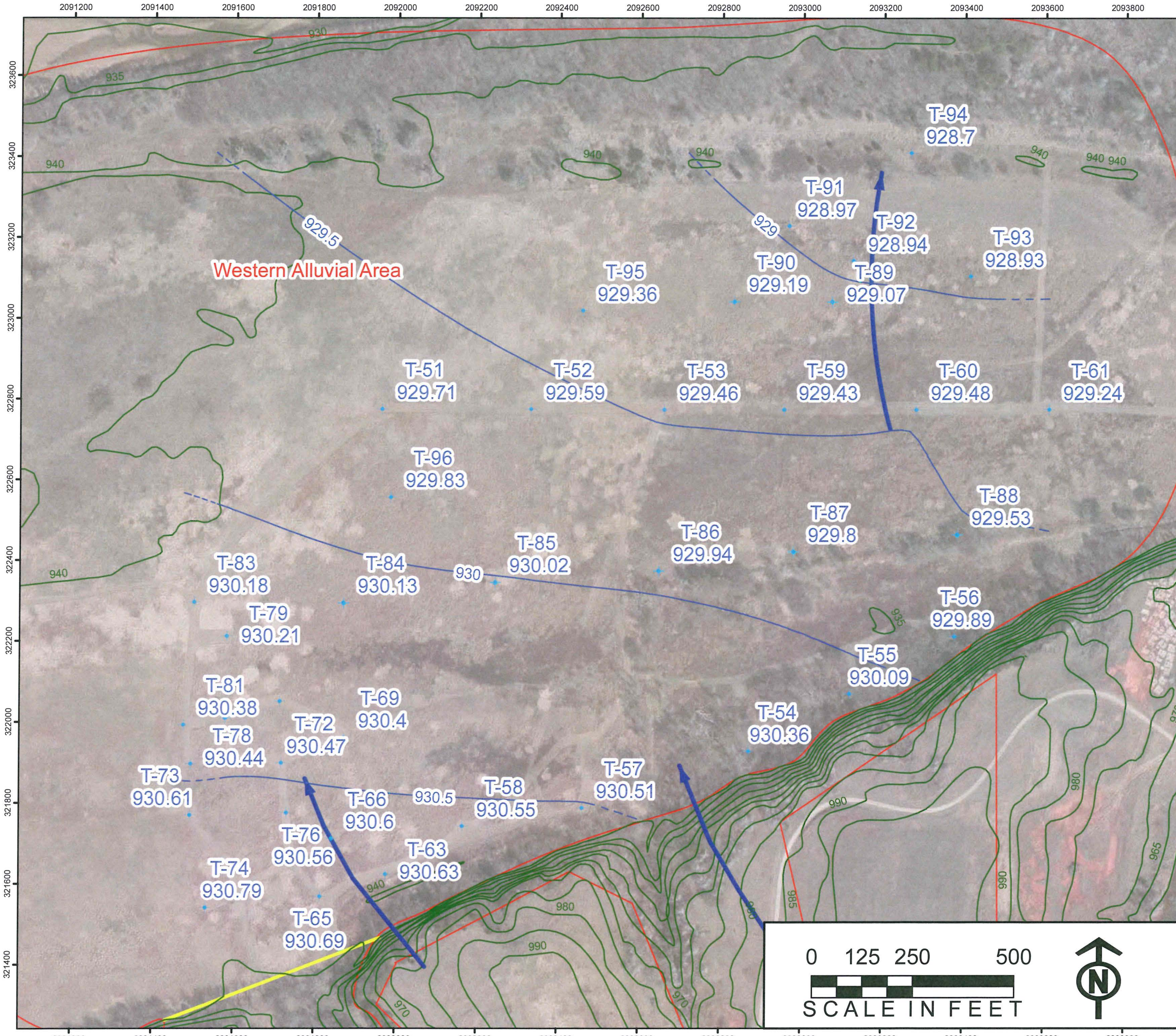


FIGURE 2-1
WESTERN ALLUVIAL AREA NOVEMBER 2013 POTENTIOMETRIC SURFACE MAP

CIMARRON ENVIRONMENTAL RESPONSE TRUST GROUNDWATER FLOW MODEL UPDATE

Burns & McDonnell SINCE 1898

environmental properties management, LLC

Legend

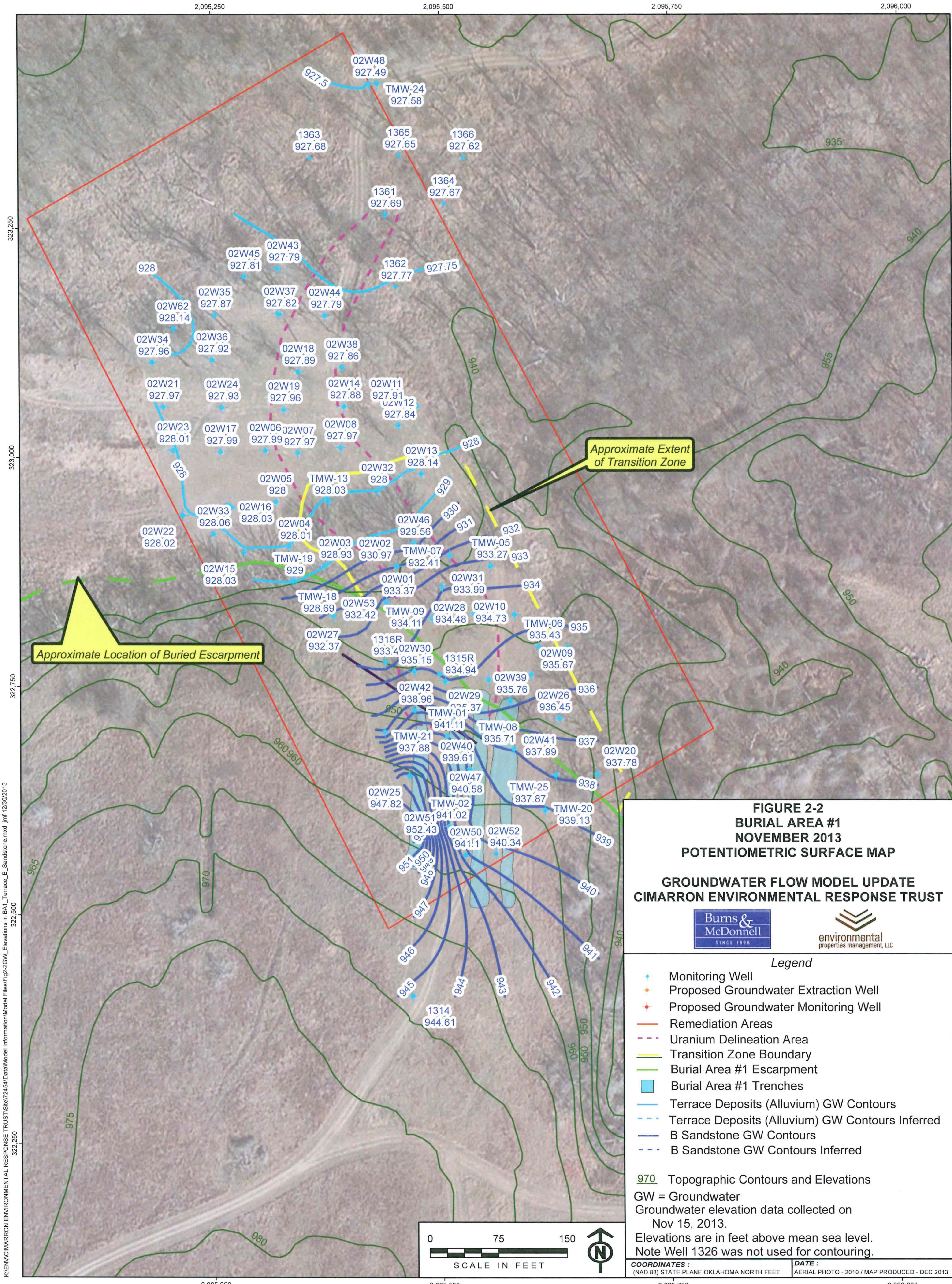
- Monitoring Well
- Transition Zone Boundary
- Remediation Areas
- Groundwater Flow Direction
- 970 Groundwater Elevation
- Groundwater Elevation Contours
- Groundwater Elevation Contours Inferred
- Topographic Contours

Groundwater elevation data collected on November 15, 2013.
Elevations are in feet above mean sea level.

(NAD 83) STATE PLANE OKLAHOMA NORTH FEET

ATE : AERIAL PHOTO - 2010 / MAP PRODUCED - DEC 2013

K:\ENV\Cimarron Environmental Response Trust\Site\72454\Data\Model Information\Model Files\Fig2-1_Western_Alluvial_Area__Nov_2013_Potentiometric_Surface_Map.mxd mb jmf ro 12/30/2013



2,095,250
2,095,500
2,095,750
2,096,000
323,250
323,000
322,750
322,500
322,250
Approximate Extent of Transition Zone
Approximate Location of Buried Escarpment
02W48 927.49
TMW-24 927.58
1363 927.68
1365 927.65
1366 927.62
1364 927.67
1361 927.69
02W45 927.81
02W43 927.79
1362 927.77
02W35 927.87
02W37 927.82
02W44 927.79
02W62 928.14
02W34 927.96
02W36 927.92
02W18 927.89
02W38 927.86
02W21 927.97
02W24 927.93
02W19 927.96
02W14 927.88
02W11 927.91
02W12 927.84
02W23 928.01
02W17 927.99
02W06 927.99
02W07 927.97
02W08 927.97
02W13 928.14
02W32 928
02W05 928
TMW-13 928.03
02W33 928.06
02W16 928.03
02W04 928.01
02W46 929.56
02W22 928.02
02W03 928.93
02W02 930.97
TMW-07 932.41
TMW-05 933.27
TMW-19 929
02W15 928.03
02W01 933.37
02W31 933.99
TMW-18 928.69
02W53 932.42
TMW-09 934.11
02W28 934.48
02W10 934.73
TMW-06 935.43
02W27 932.37
1316R 933.4
02W30 935.15
1315R 934.94
02W09 935.67
02W39 935.76
02W42 938.96
02W29
02W26 936.45
TMW-01 941.11
TMW-08 935.71
TMW-21 937.88
02W40 939.61
02W41 937.99
02W20 937.78
02W47 940.58
TMW-25 937.87
02W25 947.82
TMW-02 941.02
TMW-20 939.13
02W51 952.43
02W50 941.1
02W52 940.34
1314 944.61
FIGURE 2-2
BURIAL AREA #1
NOVEMBER 2013
POTENTIOMETRIC SURFACE MAP
GROUNDWATER FLOW MODEL UPDATE
CIMARRON ENVIRONMENTAL RESPONSE TRUST
Burns & McDonnell SINCE 1898
environmental properties management, LLC
Legend
Monitoring Well
Proposed Groundwater Extraction Well
Proposed Groundwater Monitoring Well
Remediation Areas
Uranium Delineation Area
Transition Zone Boundary
Burial Area #1 Escarpment
Burial Area #1 Trenches
Terrace Deposits (Alluvium) GW Contours
Terrace Deposits (Alluvium) GW Contours Inferred
B Sandstone GW Contours
B Sandstone GW Contours Inferred
970 Topographic Contours and Elevations
GW = Groundwater
Groundwater elevation data collected on Nov 15, 2013.
Elevations are in feet above mean sea level.
Note Well 1326 was not used for contouring.
0 75 150
SCALE IN FEET
N
COORDINATES : (NAD 83) STATE PLANE OKLAHOMA NORTH FEET
DATE : AERIAL PHOTO - 2010 / MAP PRODUCED - DEC 2013
K:\ENV\CIMARRON ENVIRONMENTAL RESPONSE TRUST\Site\72454\Data\Model Information\Model Files\Fig2-2GW_Elevations in BA1_Terrace_B_Sandstone.mxd jmf 12/30/2013

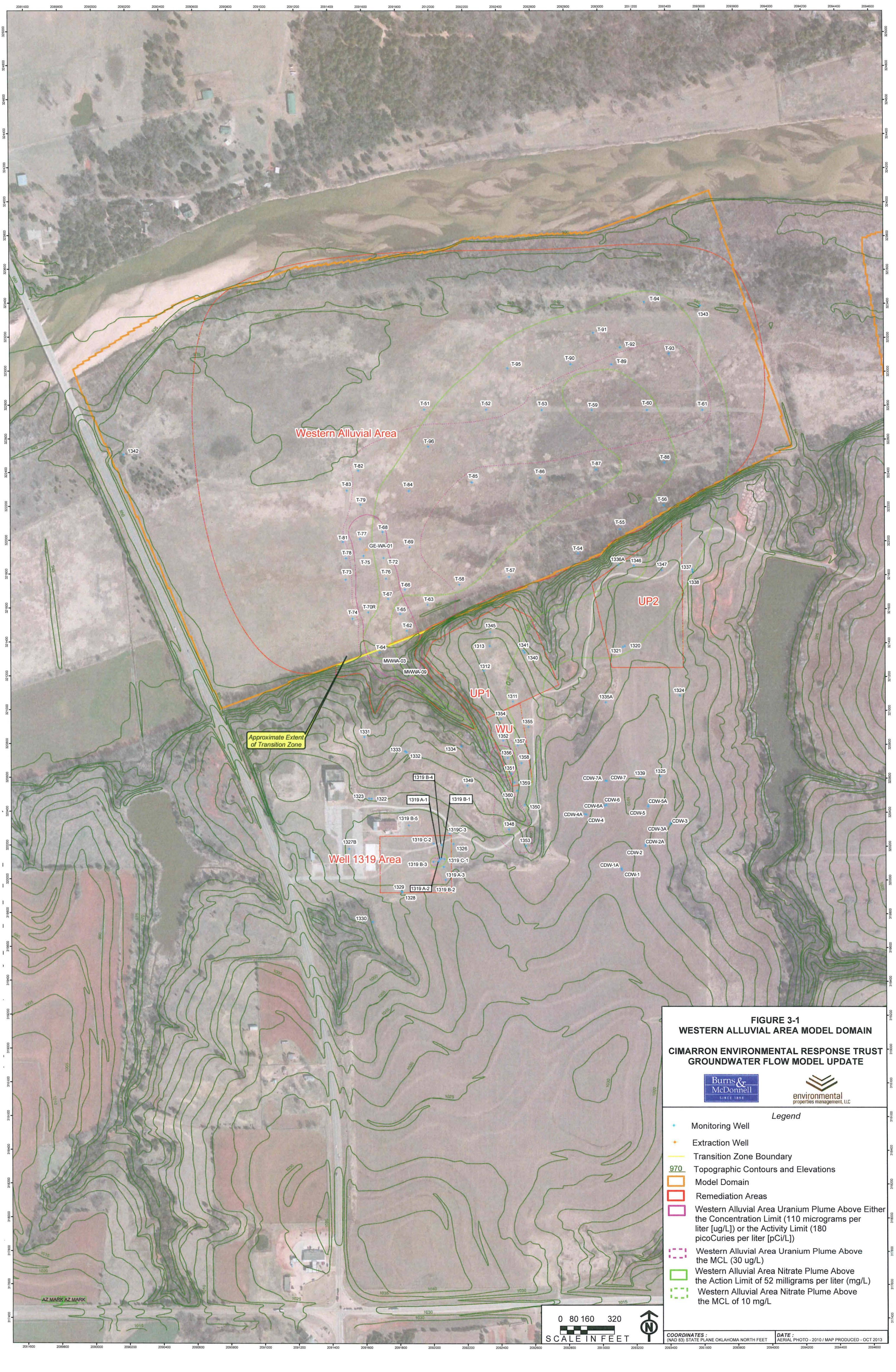


FIGURE 3-1
WESTERN ALLUVIAL AREA MODEL DOMAIN
CIMARRON ENVIRONMENTAL RESPONSE TRUST
GROUNDWATER FLOW MODEL UPDATE
Burns & McDonnell
environmental properties management, LLC
Legend
Monitoring Well
Extraction Well
Transition Zone Boundary
970 Topographic Contours and Elevations
Model Domain
Remediation Areas
Western Alluvial Area Uranium Plume Above Either the Concentration Limit (110 micrograms per liter [ug/L]) or the Activity Limit (180 picoCuries per liter [pCi/L])
Western Alluvial Area Uranium Plume Above the MCL (30 ug/L)
Western Alluvial Area Nitrate Plume Above the Action Limit of 52 milligrams per liter (mg/L)
Western Alluvial Area Nitrate Plume Above the MCL of 10 mg/L
0 80 160 320
SCALE IN FEET
COORDINATES : (NAD 83) STATE PLANE OKLAHOMA NORTH FEET
DATE : AERIAL PHOTO - 2010 / MAP PRODUCED - OCT 2013
Western Alluvial Area
UP1
UP2
WU
Well 1319 Area
Approximate Extent of Transition Zone

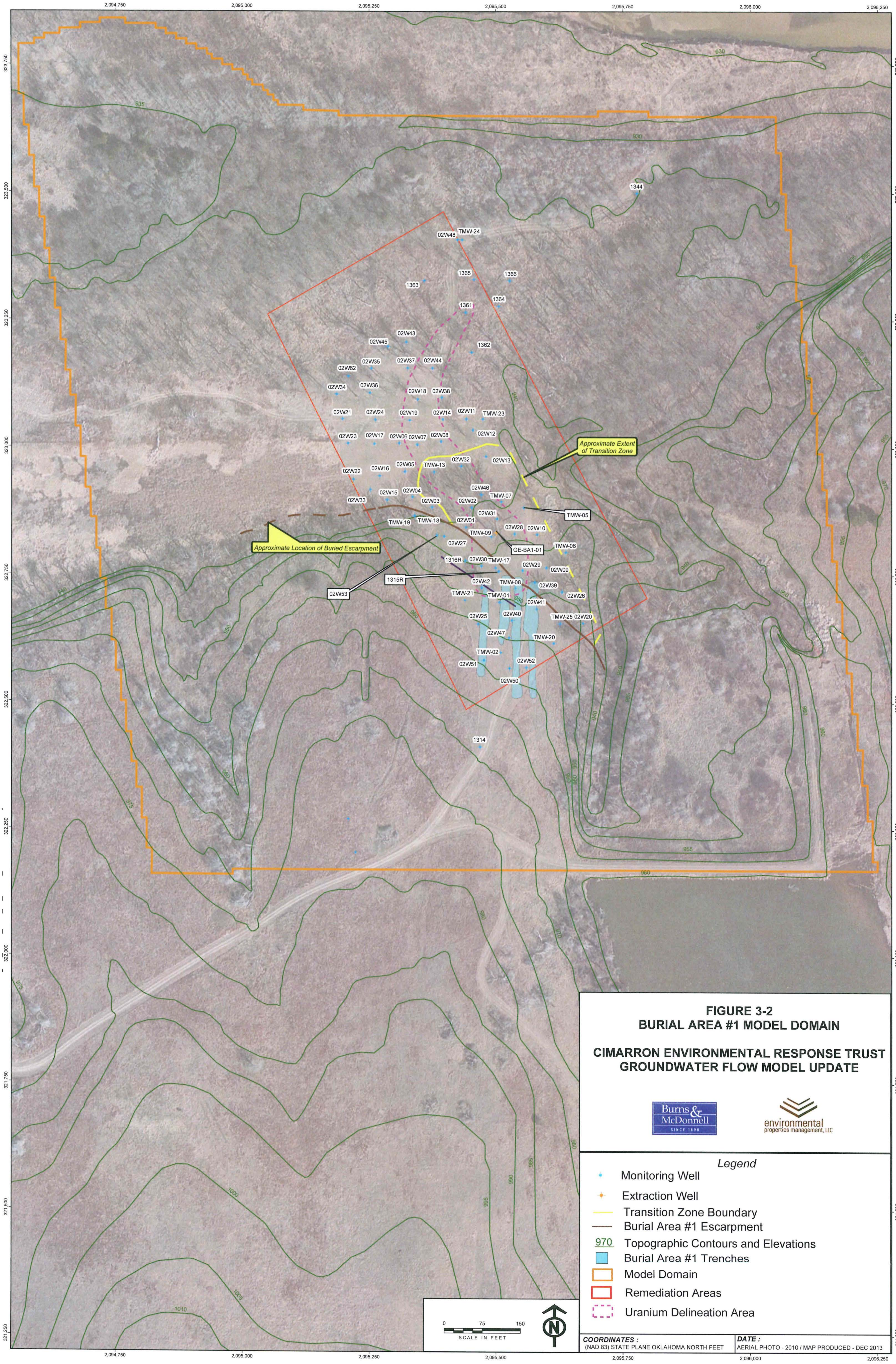


FIGURE 3-2
BURIAL AREA #1 MODEL DOMAIN

CIMARRON ENVIRONMENTAL RESPONSE TRUST
GROUNDWATER FLOW MODEL UPDATE

Figure 3-3
Observed versus Simulated Water Levels
Western Alluvial Area
Cimarron Environmental Response Trust

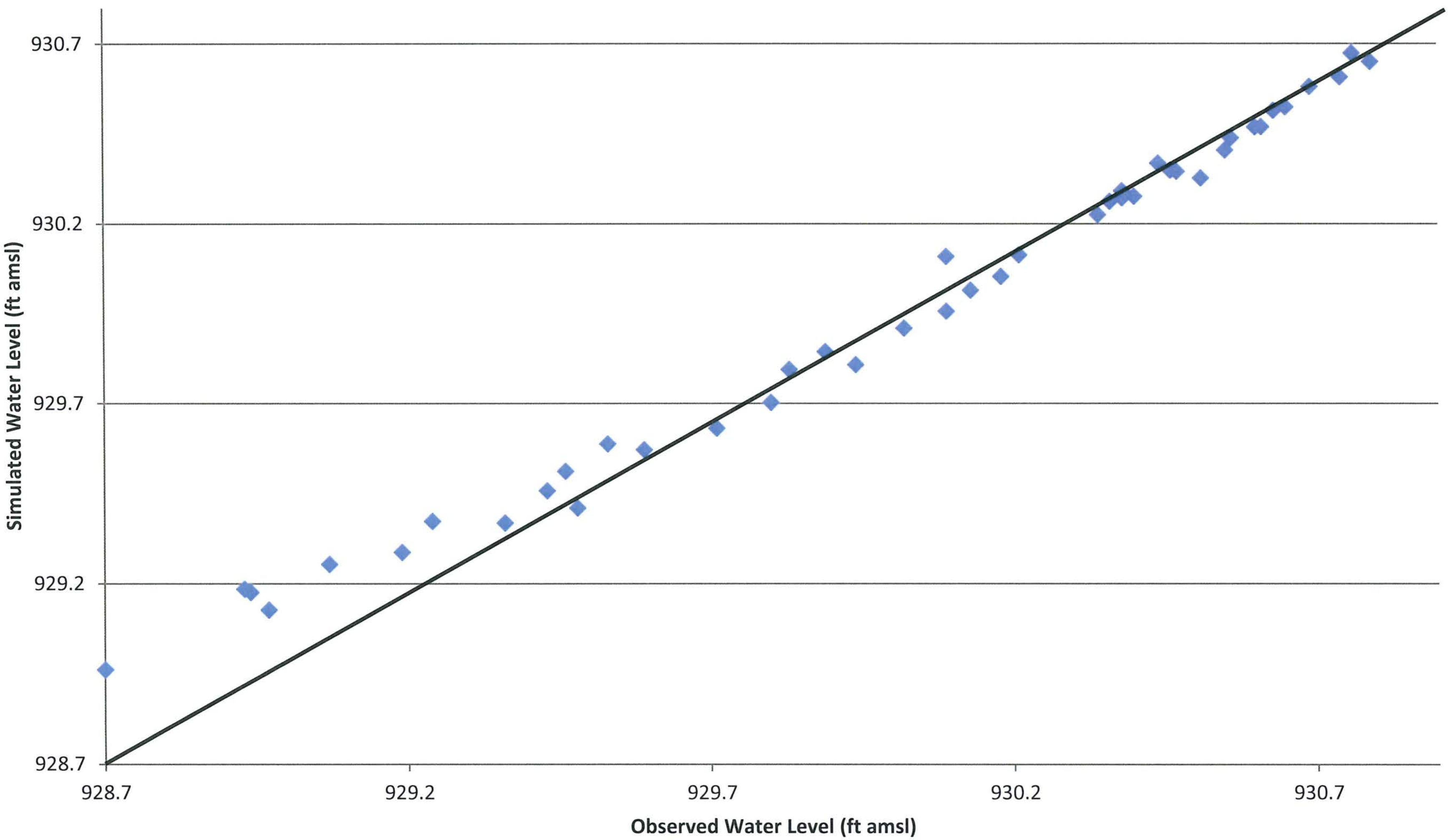
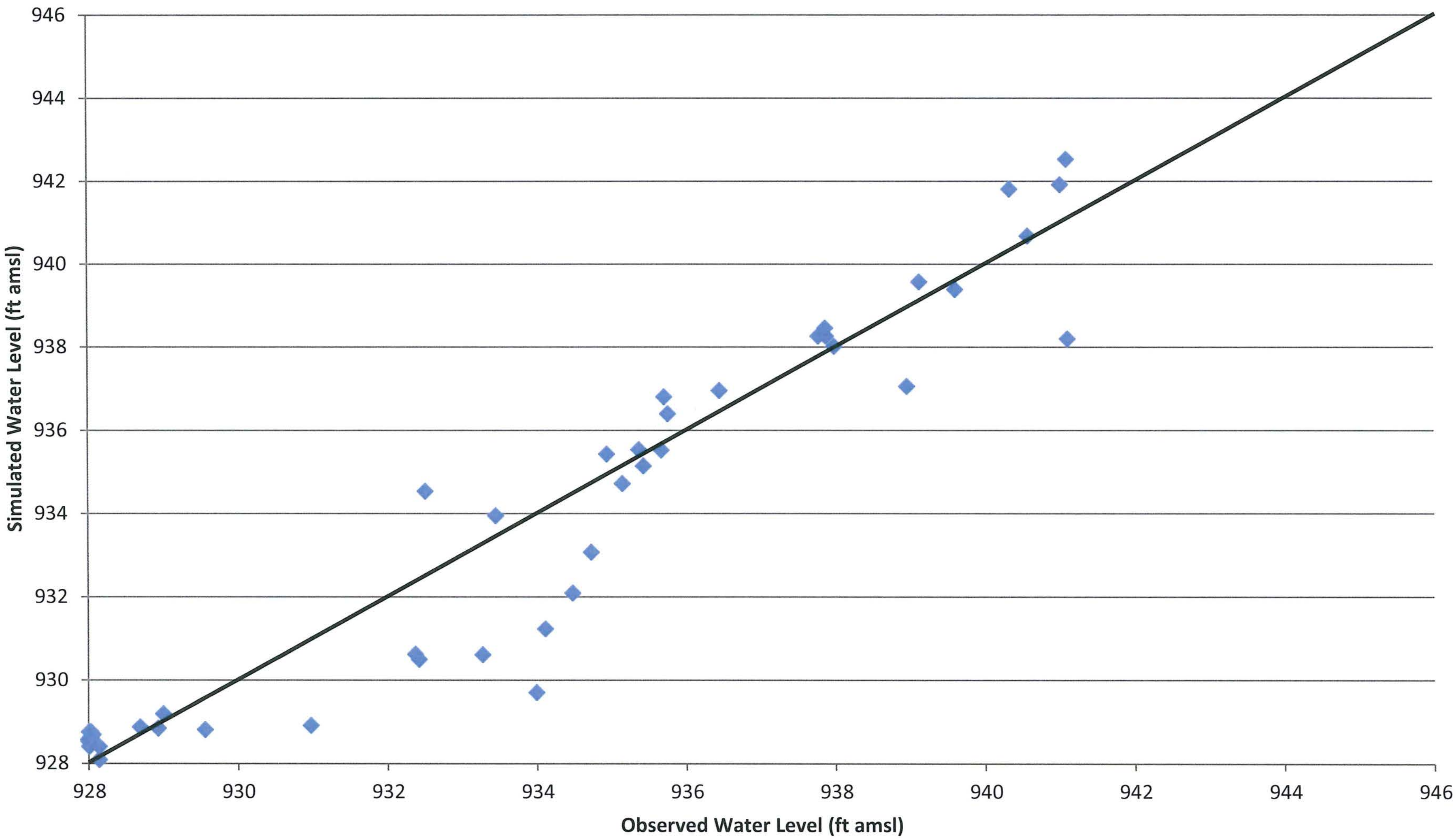
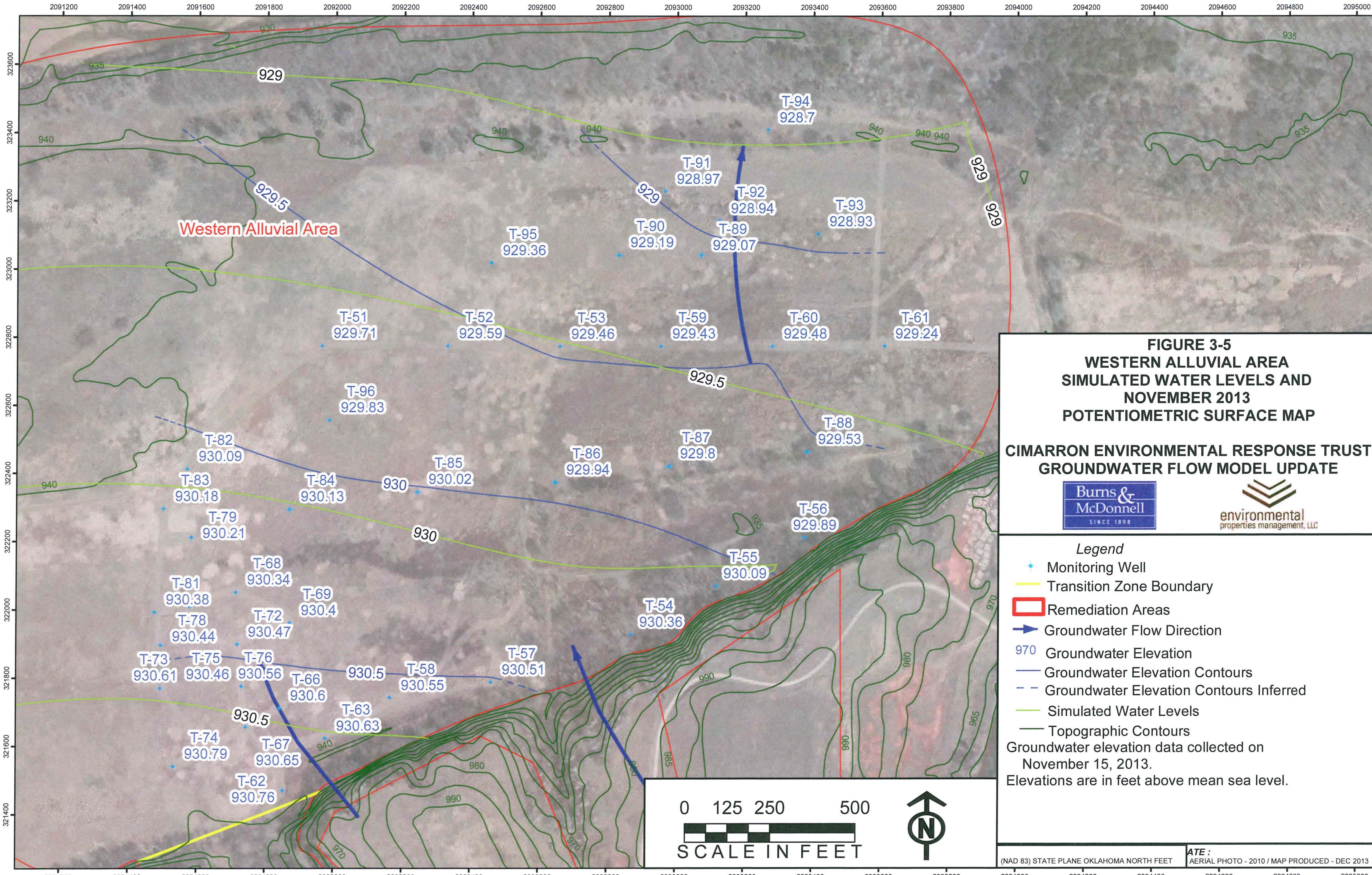


Figure 3-4
Observed versus Simulated Water Levels
Burial Area #1
Cimarron Environmental Response Trust





K:\ENV\Cimarron Environmental Response Trust\Site\72454\Data\Model Information\Model Files\Fig3-5_Western_Alluvial_Area__Simulated_Observed.mxd mb jmf ro 12/30/2013

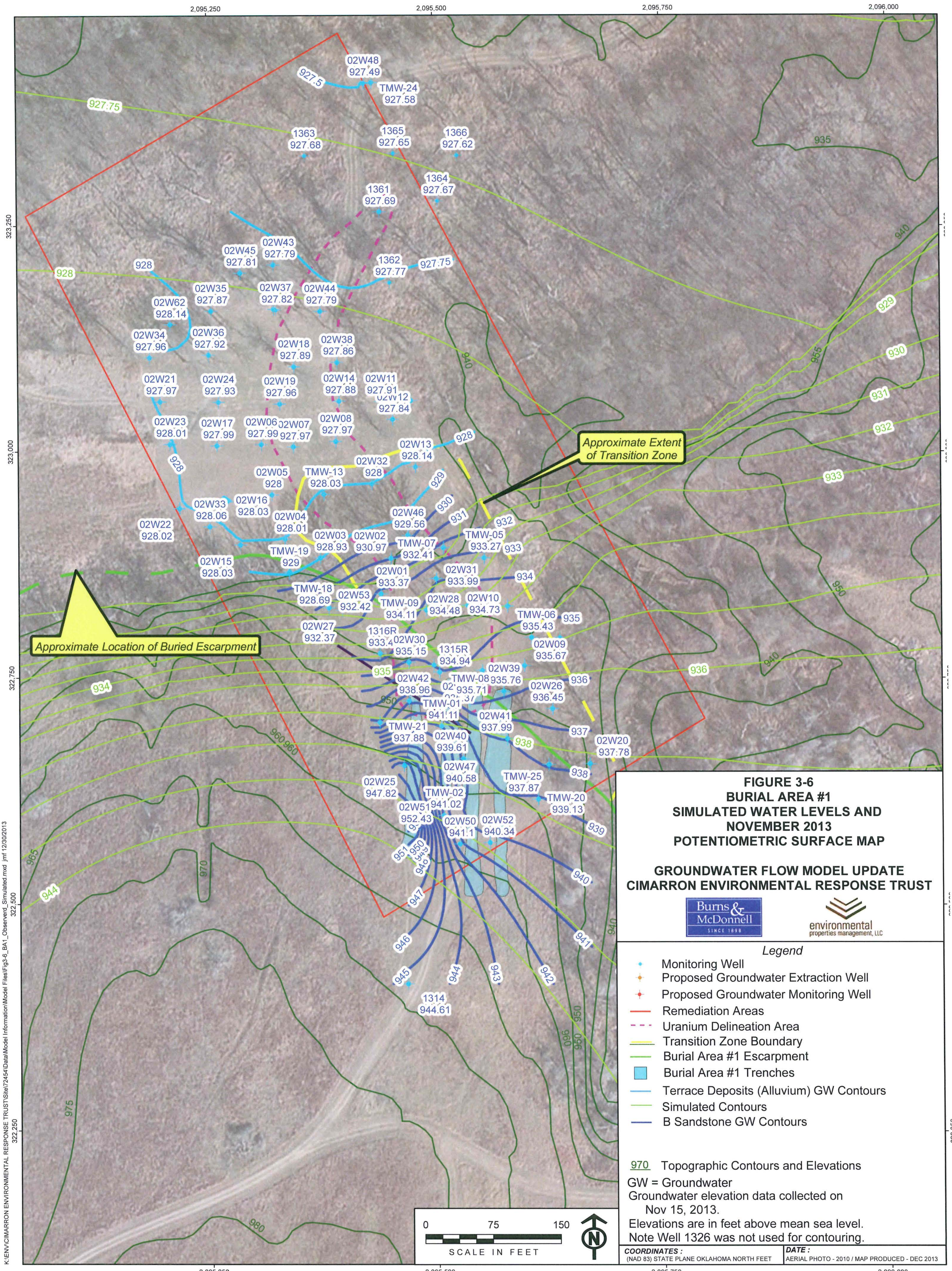


FIGURE 3-6
BURIAL AREA #1
SIMULATED WATER LEVELS AND
NOVEMBER 2013
POTENTIOMETRIC SURFACE MAP
GROUNDWATER FLOW MODEL UPDATE
CIMARRON ENVIRONMENTAL RESPONSE TRUST
Burns & McDonnell
SINCE 1898
environmental properties management, LLC
Approximate Extent of Transition Zone
Approximate Location of Buried Escarpment
Legend
Monitoring Well
Proposed Groundwater Extraction Well
Proposed Groundwater Monitoring Well
Remediation Areas
Uranium Delineation Area
Transition Zone Boundary
Burial Area #1 Escarpment
Burial Area #1 Trenches
Terrace Deposits (Alluvium) GW Contours
Simulated Contours
B Sandstone GW Contours
970 Topographic Contours and Elevations
GW = Groundwater
Groundwater elevation data collected on Nov 15, 2013.
Elevations are in feet above mean sea level.
Note Well 1326 was not used for contouring.
0 75 150
SCALE IN FEET
COORDINATES :
(NAD 83) STATE PLANE OKLAHOMA NORTH FEET
DATE :
AERIAL PHOTO - 2010 / MAP PRODUCED - DEC 2013
2,095,250
2,095,500
2,095,750
2,096,000
323,250
323,000
322,750
322,500
322,250
K:\ENV\CIMARRON ENVIRONMENTAL RESPONSE TRUST\Site\72454\Data\Model Information\Model Files\Fig3-6_BA1_Observerd_Simulated.mxd jmf 12/30/2013

APPENDIX A - GROUNDWATER FLOW MODEL REPORT (ENSR, 2006)
REFERENCE PAGE 42-92

BURNS & McDONNELL

CREATE AMAZING.

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