Prepared for:
Cimarron Corporation
Crescent, Oklahoma

Excerpts and Conclusions from the Hydrology Addendum Cimarron Site, Crescent, Oklahoma

ENSR Corporation
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Excerpts and Conclusions

In December 2006 Cimarron Corporation (Cimarron) submitted a License Amendment Request (LAR) to the NRC for the purposes of amending the Cimarron Site Decommissioning Plan (SDP) and addressing specific changes to the Cimarron license conditions. In March of 2007, having reviewed the LAR, the NRC identified 17 deficiencies related to these submittals. Several of the deficiencies related to transient hydrologic processes associated with the LAR request to use bioremediation on uranium impacts to groundwater at the Cimarron Site. Specifically the NRC expressed concern about the impact of seasonal hydrological events on the potential re-mobilization of uranium after in-situ bioremediation. This impact could be caused by precipitation or flooding. These potential impacts needed to be accounted for in the remediation design.

In response, ENSR is preparing a Hydrology Addendum, which provides a conceptual characterization of site hydrology. Based on this conceptual characterization, ENSR evaluated the impacts transient hydrologic processes have on the water balance in the partially saturated zone and on groundwater. Accordingly, consideration was provided for the following hydrologic transient events: 1) river flood stage events; 2) periods of heavy rainfall; and 3) ponded water vertically infiltrating to the water table.

The Hydrology Addendum will be submitted to NRC in its entirety along with the revised LAR submittal. In the interim, excerpts and conclusions from the Hydrology Addendum are presented here so that the NRC may conduct a preliminary evaluation of responses to outstanding issues prior to submittal of the revised LAR documents.

Document Content

This excerpt includes overviews of the river and groundwater responses to the precipitation data collected over the spring and summer of 2007. These recent precipitation events were divided into four periods: late March/early April 2007, early May 2007, mid-June/late July 2007, and mid-August 2007; each of these periods are discussed individually.

Modeling was completed to estimate recharge volumes to the partially-saturated zone. A summary of that modeling follows the discussion of the recent-past hydrologic events. The discussion of the background and set-up of the model is described as well as preliminary base case runs. Several scenarios were then simulated to address: 1) extreme precipitation events and 2) ponding events.

A summary and conclusions section appears at the end of this document in which key points are highlighted both from the evaluation of the recent-past hydrologic events and the HELP modeling.

Recent Hydrologic Events – Site Response

The rainfall, streamflow, and groundwater elevation data collected over spring / summer 2007 provide a unique opportunity to see how the site responds to individual storm events, individual extreme events, and a series of extreme events.

Overview – Precipitation

Between March 1 and August 21, 2007, 40.48 inches of rain fell in a number of intense storm events in the Oklahoma City and Cimarron Site areas. This total rainfall represents significantly more than the average annual rainfall of around 36 inches per year. A weather website, www.wunderground.com, provides the following summary based on data at the Oklahoma City weather station:

	Actual 2007 Rainfall (inches)	Normal Rainfall (inches)	Deviation from Normal %	Rainfall as measured at site
March	8.02	2.9	177	not available
April	2.57	3	-14	3.0
May	8.49	5.44	56	8.2
June	10.06	4.63	117	12.6
July	6.31	2.94	115	4.2
August (up to the 22nd)	5.39	1.78	203	4
Total	**40.84**	**20.69**	**97**	**32.29**

In these six months almost double the normal rainfall fell. **Figure 1** shows the precipitation data from the Oklahoma City weather station. Based on the precipitation record shown in **Figure 1**, the greatest single precipitation event was 3.82 inches (August 19); this was preceded by 1.56 inches on the August 18. On March 30 3.5 inches fell, preceded by 1.43 inches on March 29. Finally, 2.33 inches and 2.08 inches of rain fell on March 7 and 8. These precipitation events are the most comparable to a statistically based 24-hour, 2-year precipitation event of 3.3 inches (Rea and Tortorelli, 1999). On two occasions, greater than four inches of rain were recorded at the site over 48 and 72 hours.

Overview – Cimarron River Flows

Figures 2 and 3 show the daily average Cimarron River flow data for the Dover and Guthrie gages, respectively, between March 1 and August 21, 2007. Also shown on these graphs is a plot of the median of the daily mean flows calculated based on available historical data. This graph gives a feel for the magnitude of the flow events between March and August relative to daily median flows.

The first large flow events during this time occurred in late March 2007. According to the flow data, peak flows occurred on March 30 in Dover and March 31 in Guthrie. These high flows were largely attributed to the high rainfall measured at Oklahoma City in late March. In response to this event, Cimarron began taking routine measurements of depth to water at a number of monitoring wells in the BA#1 area. Observations were also made especially with respect to the river's elevation relative to the site and to note if there were any areas of ponding water (due to river overtopping or site drainage). The next sections rely heavily on the data collected and observations made by Cimarron staff. Unless otherwise noted, precipitation reported comes from the Oklahoma City weather station.

Overview – Groundwater

Figure 4 depicts the rises and falls of groundwater elevations from early April to August 20, 2007. **Figure 5** shows the locations of these monitoring wells. The response of groundwater was measured routinely in 10 wells located in the BA#1 area. Three of these wells, TMW-02, TMW-08, and TMW-21, are screened in Sandstone B (red lines, red dots). Five wells are screened in alluvium: 02W16, 02W24, 02W36, 02W43, and TMW-13 (green lines, green dots). Two wells are screened in Transition Zone soils: TMW-05 and TMW-09 (blue lines, blue dots).

Overall, compared to the transition zone wells and two of the three Sandstone B wells, groundwater rises and falls indicate that the alluvial wells are the most responsive to hydrologic events. The total head change seen over the period of record ranged from approximately 3.4 feet to just over 8 feet. The smallest overall changes were seen at the wells screened in transition soils and in two (TMW-02 and TMW-08) of the three sandstone wells. Sandstone B well TMW-21 is somewhat anomalous in that its response is more similar to the alluvial wells than to the other two Sandstone B wells.

Groundwater elevation data had been collected previously at these wells and formed the basis of the calibration data set for the groundwater model (ENSR, 2006). The following table summarizes the groundwater changes over the long term and over the spring and summer of 2007.

		Maximum groundwater change (ft) based on data from September 2003, December, 2003, August 2004, and May 2005	Maximum groundwater change (ft) based on data collected from April to August 2007
Sandstone B	TMW-02	0.97	3.82
	TMW-08	3.24	3.6
	TMW-21	7.88	7.91
Transition Zone	TMW-05	3.82	4.44
	TMW-09	3.6	4.38
Alluvial	02W16	2.39	7.03
	02W24	2.43	7.82
	02W36	2.29	7.84
	02W43	2.18	8.08
	TMW-13	2.11	7.81

The data indicates that at two of the Sandstone B wells (TMW-21 and TMW-08) recent fluxes in groundwater changes are consistent with what may be observed based on less frequent measurements. This observation is consistent with observations at the Transition Zone wells. In contrast, water level changes in the alluvial wells (based on long-term measurements) were far smaller than the changes seen over the spring and summer of 2007.

The general consistency in water level changes in the Sandstone B and Transition Zone wells suggests that seasonal, infrequently recorded data tends to be as representative as short-term water level changes, even after the extreme events seen during spring and summer 2007. Alternatively stated, water level rises and falls are no greater whether they are measured frequently or infrequently. This is a significant observation as it implies a fairly stable flow field in the sandstone and transition soils. Water level changes resulting from transient hydrologic events are muted by the relatively low permeability such that they are consistent with longer term (seasonal) hydrologic events. This observation is consistent with what had been stated in the CSM Rev 01 (ENSR, 2006a): "the hydraulic gradients and flow directions do not change significantly over time. Therefore, rates and directions of contaminant transport are also unlikely to change significantly."

In contrast, seasonally recorded and quasi-daily recorded water levels in the alluvial monitoring wells were significantly different. When considering the gradients and fluxes; however, it is the relative elevation differences between the wells that are important. In this case, whether groundwater elevations were low or high, for the most part the elevation differences between the upgradient most alluvial well (TMW-13) and the other alluvial wells were consistent suggesting generally consistent gradients.

The exception to this was between wells TMW-13 and 02W43 where the elevation differences based on seasonal data tended to be a few tenths of feet while the elevation differences based on the quasi-daily data tended to be on average approximately 0.6 feet (three times greater than the average elevation difference of 0.2 feet based on the seasonally collected data). The duration of these changes in head and thus, gradient are short (i.e., approximately one week). In the context of evaluating water balances, the incremental increase in flux during periodic short term increases in gradient is small relative to the total water budget for the site. This exception is described in further detail in the Hydrology Addendum

In summary, in the Sandstone B and Transitions Zone soils, transient hydrologic events as seen during spring and summer 2007 are not expected to result in changes to the groundwater gradients and fluxes that are dramatically different from the changes that might be seen based on seasonally collected water elevations. This suggests that groundwater elevations in Sandstone B and Transitions Zone soils are fairly stable. Groundwater elevations in alluvial zone soils were far more responsive to transient hydrologic events;

however, elevations generally responded uniformly indicating no significant change in groundwater gradients and fluxes. Even noting the exceptions that some data suggest, i.e., between TMW-13 and 02W43, and assuming these gradient changes were real, their short duration (lasting at most 8-days) causes them to be insignificant.

Overview – Groundwater/Cimarron River Interaction

Figure 6 shows the daily water level data collected at 02W48 and TMW-24 using pressure transducers. For reference, the locations of these wells are shown in **Figure 5**; these wells are the most downgradient wells and are approximately 200 feet upgradient from the river bank.

Because of an equipment malfunction, there is an incomplete data record for TMW-24. However it is clear from the available data that the water levels in the two wells closely parallel one another. By comparing the precipitation events to the groundwater response, it is also clear that the water levels respond quickly and in concert with the precipitation events.

In contrast, **Figure 7** shows a plot of the same transducer data compared to surface water flow data collected at the Guthrie station. The groundwater hydrographs and surface water hydrograph are not in concert. Where there are groundwater peaks there are hydrograph troughs and vice versa. This inconsistency indicates that at these wells, groundwater levels are not impacted by river water levels. If there was a direct hydraulic connection between the surface and groundwater at this location, the groundwater conditions would mirror surface water conditions, though with a time lag as the pressure wave of water moved through the porous media. This pattern is not observed. Because there is no relationship between groundwater levels and river flow / stage, there are no anticipated water quality impacts to the groundwater from river water. Note that this conclusion is in agreement with what was presented in the CSM Rev 01 (ENSR, 2006a) wherein a difference between river water quality and groundwater quality was shown to exist through an analysis of stiff diagrams.

Event-Based Discussion

Late March/April 2007

Based on the Oklahoma City weather station data, between March 22 and March 30, 2007, 6.53 inches of rain fell. **Figure 4** shows the groundwater response to these rainfall events. In early April water levels in the wells were either declining or fairly steady. Small water level rises were observed starting on April 13.

The rises in groundwater between April 13 and 18 were at most approximately 2.5 feet and at a minimum 0.13 feet. The highest response was at TMW-21, a well screened in Sandstone B located in the uplands near the BA#1 burial trenches. The lowest response observed was at TMW-02, also located in the uplands in the former burial trench area. Response at TMW-08, a Sandstone B well located downgradient of TMW-02, was also low (0.31 feet). The muted responses of two of the three upland wells are attributable to heterogeneities in the Sandstone B formation. For instance, if TMW-21 is screened across a more fractured and/or porous zone it is expected that it would respond faster to boundary condition changes (i.e., rainfall).

Early May 2007

There were several small rainfall events between mid April and early May. Five days of rainfall began on May 7 (2.33 inches at OKC) and continued through May 11 (2.06, 0.02, 0.29, 0.31 inches, respectively at OKC). According to site precipitation measurements, 5.3 inches of rain fell between May 7 and May 9. According to field notes, water was ponded around well 02W16 on May 9. The ponding occurred after approximately 4 to 5 inches of rain. Observations indicate that ponding was extensive in the lower elevations of BA#1, north of the escarpment in the alluvial plain. Some of this ponding is attributed to river water inundating low-lying areas and flowing to this area.

Groundwater rises were most pronounced in the wells screened in alluvium (**Figure 4**). Over four days the average rise over all five alluvium wells was 6.55 feet and ranged from 6.13 to 6.94 feet. At TMW-21 water levels rose just over 4 feet. Water levels rose 0.17 and 1.22 feet at TMW-02 and TMW-08, respectively (the other Sandstone B wells).

Mid June / Late July 2007

This period represents a protracted period of ongoing rainfall events. The total rainfall over this period (June 10 to July 31) was 16.2 inches, a value approaching nearly half the normal total annual rainfall. **Figure 1** shows that there was no singularly high rainfall event, rather a series of heavy rainfalls day after day.

Similar to early May, the biggest groundwater responses were observed in the alluvial wells and in TMW-21. In the alluvial wells, there was an average increase of 6.33 feet between June 13 and June 29. At TMW-21 the increase was 6.00 feet. Water level increases at TMW-02 and TMW-08 were 1.24 feet and 2.73 feet, respectively. Approximately three feet of water level increase was observed at the transition wells.

Mid August 2007

In Mid August, between August 17 and 19, 5.39 inches of rain fell, with 3.82 inches falling on August 19. Site precipitation was recorded at 4.34 inches with 3.65 inches of that falling on August 19.

In the wells screened in the alluvium, dramatic rises were seen between August 17 and 20 equaling on average 7.89 feet. This event resulted in the largest rise observed during the measurement period to date. Interestingly, the rises at TMW-21 have typically been consistent with alluvial well rises, but for this event, only slightly over a one-foot rise was observed and the peak occurred later than the peak in the alluvial wells. Unlike the previously discussed events where precipitation appeared to be spatially well-distributed, for this event, the precipitation appeared to be spatially variable. Because of this variability, the rises in groundwater during this event are more of a reaction to the quantity of local rainfall as opposed to the accumulated impact of regional increases in groundwater as a result of regionally distributed precipitation. Groundwater rises in the other wells screened in Sandstone B were small, only 0.28 and 0.36 feet. Water level rises in the transition wells were 2.63 feet and 1.20 feet at TMW-05 and TMW-09, respectively. Unlike other events where the water levels in these two wells tended to approximately parallel one another, in this event the response at TMW-05 was more than double that of TMW-09. Similarly the decline of water levels at TMW-05 was rapid.

HELP Modeling

Background and Setup

The use of the HELP model provided a means to evaluate how rainfall is partitioned into evapotranspiration, runoff, storage, and recharge. The HELP model was originally developed by the EPA (Schroeder, et al., 1994) to conduct water balance assessments of landfills, cover systems, and solid waste disposal containment facilities. However, the conceptual and mathematical basis of the model is not exclusive to landfill designs. The model can be used to evaluate water balance for any unsaturated soil system.

The model uses weather and soil data and solution techniques that account for the water balance components, including surface storage, snowmelt, runoff, infiltration, evapotranspiration (ET), vegetation, soil moisture, and vertical drainage. Based on inputs, the model calculates the amounts of runoff, ET, and drainage that may occur through a given soil thickness.

The specific inputs used for HELP are described in detail in the Users Guide. Input and output files for each of the simulations presented in the following sections are available upon request. In general, the two primary classes of inputs include:

- Weather Data, including ET data, precipitation data, temperature data, and solar radiation data. In many instances modeling relied on a database and on model guidance to help select inputs for these values. The HELP model includes a tool to generate synthetic precipitation data based on a database of climatological data; this synthetic precipitation data was used in the simulations as well as measured precipitation data.

- Soil Data, including area and thickness, soil characteristics, and runoff curve information. Site-specific data were used as inputs. Default values were used for some values for which site-specific data are not available.

Output from the model is essentially a water budget for the unsaturated zone. Output can include daily, monthly, and yearly summaries of proportions of ET, runoff, and recharge that make up a precipitation input.

Base Case Simulations

The purpose of the base case was to evaluate how the water balance simulated by the model compared to the understanding provided by literature.

In the first base case, synthetically-generated precipitation data was used. Based on these input parameters, output indicates that precipitation was on average 27.47 inches per year with a range of 20.50 to 35.97. This range seems low compared with what Oklahoma Climatological Survey (OCS) presents for Logan County (i.e., 33 to 36 inches per year), but is considered consistent. Model output indicates that recharge to the water table (percolation/leakage through Layer 2) was on average 1.25 inches or approximately 4.5% of the total precipitation. This rate is low relative to that presented by Adams and Bergmann (1995) who suggested that recharge represents 8% of the total precipitation. However, their estimate may have been based on soils that did not include as much silt and clay as have been simulated here. The ET was simulated to be 95.5% of total precipitation, a rate consistent with expectations.

For comparison purposes a second base case simulation was modeled where actual rainfall observations were used as model input. These rainfall observations were made at the Oklahoma City weather station from 2002 to 2006 (5 years). Note that the Oklahoma Water Resources Board considers these years to be drought years because of the lower than normal precipitation rates (OWRB, 2007). The change to precipitation input data represents the only change in the input values. The model simulation output indicated that the annual average precipitation was 27.47 inches per year with a range of 22.00 to 36.62 inches per year. The simulated recharge rate was 6.9% (range from 1.5-10.1%) and the ET represented on average approximately 93% of the total rainfall. The differences in recharge rates are attributed to different patterns (likely more natural patterns) of rainfall. This recharge rate is consistent with the 8% recharge rate presented by Adams and Bergmann (1995).

Finally, for further comparison, the 2007 (through August 20) precipitation data was added to the 2002-2006 series and the model was re-run to evaluate how the extreme events of this year impact model output. This run indicated that recharge was dramatically higher than other years at a value of 29.2% (approximately 13 inches of the approximately 44 inches of precipitation). This reflects that the plants were obtaining sufficient water such that any additional water could flow vertically past the root zone to the water table. ET was reduced to around 74% compared to a higher percentage in other years.

Model simulations indicate that variable soil type conditions resulted in recharge rates that range from 4.3 to 7.2 % of annual average rainfall. These rates are consistent with what has been observed and reported by others (Adams and Bergman, 1995; Reed, et al., 1952; Belden, 2002).

Heavy Precipitation Simulations

Additional model simulations were run to evaluate the number of recharge inches that would occur given a statistically-based storm. For instance, recharge was simulated to total 0.0155 inches over the 30 days following a 24-hour, 2-year storm event of 3.3 inches (Rea and Tortorelli, 1999). The 24-hour, 500-year storm event of 10 inches yielded a model estimate of 4.24 inches of total recharge over the 30 days following the storm event. The 7-day, 500-year rainfall event (total precipitation of 15.5 inches) yielded almost 8 inches of recharge over 30 days. Given that the BA#1 uranium plume area is 72,300 square feet, 8 inches of recharge equates to 48,000 cubic feet of water (360,000 gallons).

Ponding Simulations

Conceptually, ponding on the land surface occurs because the mechanisms for water removal (i.e., runoff, recharge, ET, and removal to storage) do not cumulatively happen at a rate as fast as water can accumulate. Based on the HELP output, a daily water balance can be calculated in which runoff, recharge and ET are subtracted from precipitation. When the result is negative, it indicates that the water removal mechanisms are greater than the precipitation rate. When the result is positive, it indicates that the there is "residual water" for that day (i.e., precipitation > runoff + recharge + ET). This residual water is defined as the surplus water that includes both water that goes to storage and the water that can be considered ponded water. HELP output does not distinguish between the two. Having said that, when steady state is reached – as demonstrated by a constant recharge rate – storage in will equal storage out and any residual water can be assumed to be all ponded water.

In relation to infiltration of water through the unsaturated zone to the partially-saturated zone and ultimately to the groundwater, the mechanism is the same whether ponding occurs from excessive precipitation or from river bank overtopping. The differences are the depth of ponding and the duration of ponding. The HELP model was used to address each of these scenarios.

Given extreme precipitation, the HELP model was used to evaluate the recharge depth given a scenario where water may pond on the land surface. Ponding in the alluvial area was observed several times during this 2007 period. Observed ponding typically lasted from a day or two to as much as 16 days. Ponding depths were estimated to be on average 1 foot over the days in which ponding occurred. These recent observations were used as a basis for formulating an appropriate scenario and simulating ponding and thus, estimating recharge to the groundwater table using the HELP model.

Uniform daily precipitation depths were input to the HELP model to achieve a variety of ponded depths. In general, steady state ponded depths were reached within a few days of the beginning of rainfall. Recharge rates that result from ponded water were dependent on the depth of ponded water. Based on the observations that ponding depths were on average approximately 1 foot and lasted as much as approximately 14 days, simulations indicated that one foot of ponding (constant head) on each of 14 consecutive days would result in 84 inches of total recharge over that period. Eighty-four inches is 6 inches of recharge per day. The ponded area that also overlays the BA#1 uranium plume area was estimated to be approximately 11,000 square feet yielding a recharge volume of 5,500 cubic feet (41,000 gallons) over 14 days.

HELP was also used to evaluate ponding that resulted from river overtopping. River overtopping that would reach the BA#1 plume area was estimated to occur at an elevation of 940 feet, resulting in a ponding depth of 1 to 2 feet over the plume area. Based on data presented by Tortorelli (1999) the duration of a flooding event was evaluated to be 7 to 10 days. Recharge over the duration of river-generated ponding was calculated to be 60 inches; however, the area over which this might occur would include the entire northern lobe of the BA#1 uranium plume area (at elevations less than approximately 940 feet). This ponded area is estimated to be 39,100 square feet, yielding a recharge volume of 195,500 cubic feet (1.5 million gallons) over 10 days.

Conclusions - Recent Hydrologic Events

- In the BA#1 area, almost all the precipitation events observed in spring and summer of 2007 resulted in some amount of ponding around the low-lying poorly drained areas in the flood plain, for instance around 02W16. Because of the distance from the river and the nature of river bank overtopping observed, the ponding in the BA#1 area over the spring and summer of 2007 is generally attributed to rainfall and runoff. Although, observations did indicate that river water temporarily inundated portions of the BA#1 floodplain during this period.

- Recent extreme hydrologic events were evaluated to gage site response to high precipitation rates and high flows on the Cimarron River. Except for the mid-August hydrologic event, all the other events appear to have been driven by regional (frontal) precipitation events. With these events, there is a fairly uniform response in river levels, recharge rates and groundwater elevations. The sandstone wells are more influenced by regional climatic conditions as opposed to short-duration local precipitation events.
- The water level data collected by transducers at two monitoring wells approximately 200 feet from the Cimarron River showed groundwater hydrographs that are strongly influenced by precipitation and are not influenced by river water levels. It is expected that water quality at the location of these wells would be consistent with Sandstone C and alluvial well waters, respectively, and not influenced by river water quality. It is expected (CSM Rev 01, ENSR 2006a) that high river elevations will not impact groundwater elevations in the currently mapped BA#1 uranium plume area.
- In general, in the Sandstone B and Transition Zone soils, transient hydrologic events such as seen during spring and summer 2007 are not expected to result in changes to the groundwater gradients and fluxes that are dramatically different from the changes that might be seen based on seasonally collected water elevations. This suggests that groundwater elevations in Sandstone B and Transition Zone soils are fairly stable. Groundwater elevations in alluvial zone soils were far more responsive to transient hydrologic events, however elevations generally responded uniformly indicating no net change in groundwater gradients and fluxes. There was one exception in which gradients changed for several days; the short-duration gradient change may result in short-term increases of flux, but relative to the total water balance, these increases are considered insignificant.

Conclusions - HELP Modeling

- Model simulations indicate that variable soil type conditions resulted in recharge rates that range from 4.3 to 7.2 % of annual average rainfall. These rates are consistent with what has been observed and reported by others (Adams and Bergman, 1995; Reed, et al., 1952; Belden, 2002).
- For an extreme statistical rainfall event, 7-day, 500-year rainfall (total precipitation of 15.5 inches), recharge was simulated to be almost 8 inches of recharge over 30 days. Over the BA#1plume area this amounts to 48,200 cubic feet or 361,000 gallons over 30 days.
- The HELP model was used to simulate ponding and consequent recharge that occurred from extreme precipitation and accumulated runoff. The simulations relied on observations made during spring and summer 2007. Ponding of 1 to 2 feet lasting approximately 14 days was estimated to result in a recharge volume over the BA#1 plume area of 5,500 cubic feet or 41,000 gallons over 14 days.
- The HELP model was used to simulate ponding and consequent recharge that occurred from river bank overtopping that would reach elevation 940 feet, thus causing 1 to 2 feet of ponding in the BA#1 plume area. Statistical studies indicated a flooding event of this magnitude may last for 7 to 10 days. Model output estimated a recharge volume of 195,500 cubic feet or 1.5 million gallons over 10 days.

Figure 1
Excerpt - Hydrology Addendum
Precipitation as measured at the OKC weather station
March 1, 2007 to August 21, 2007

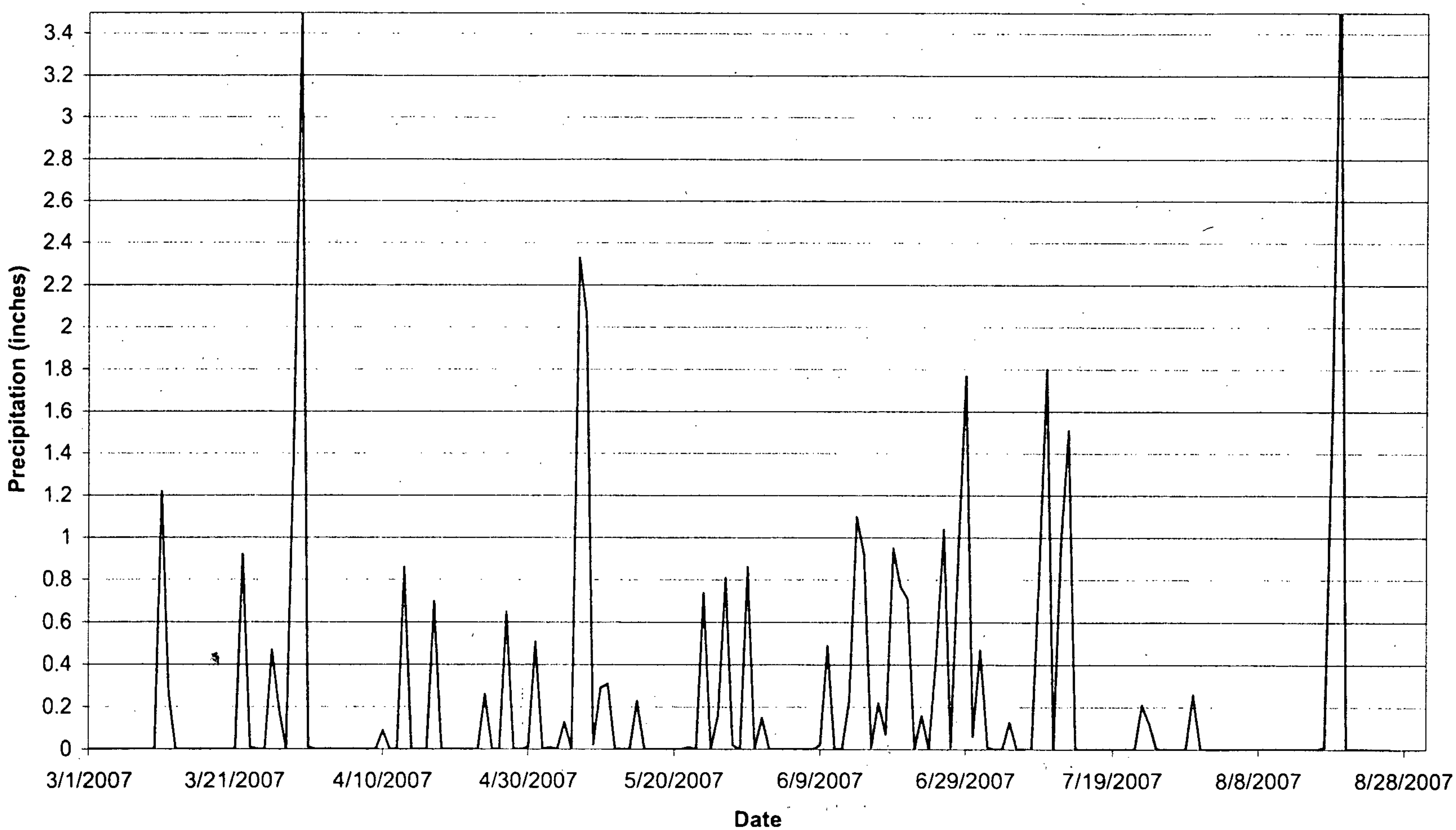


Figure 1
Excerpt - Hydrology Addendum
Precipitation as measured at the OKC weather station
March 1, 2007 to August 21, 2007

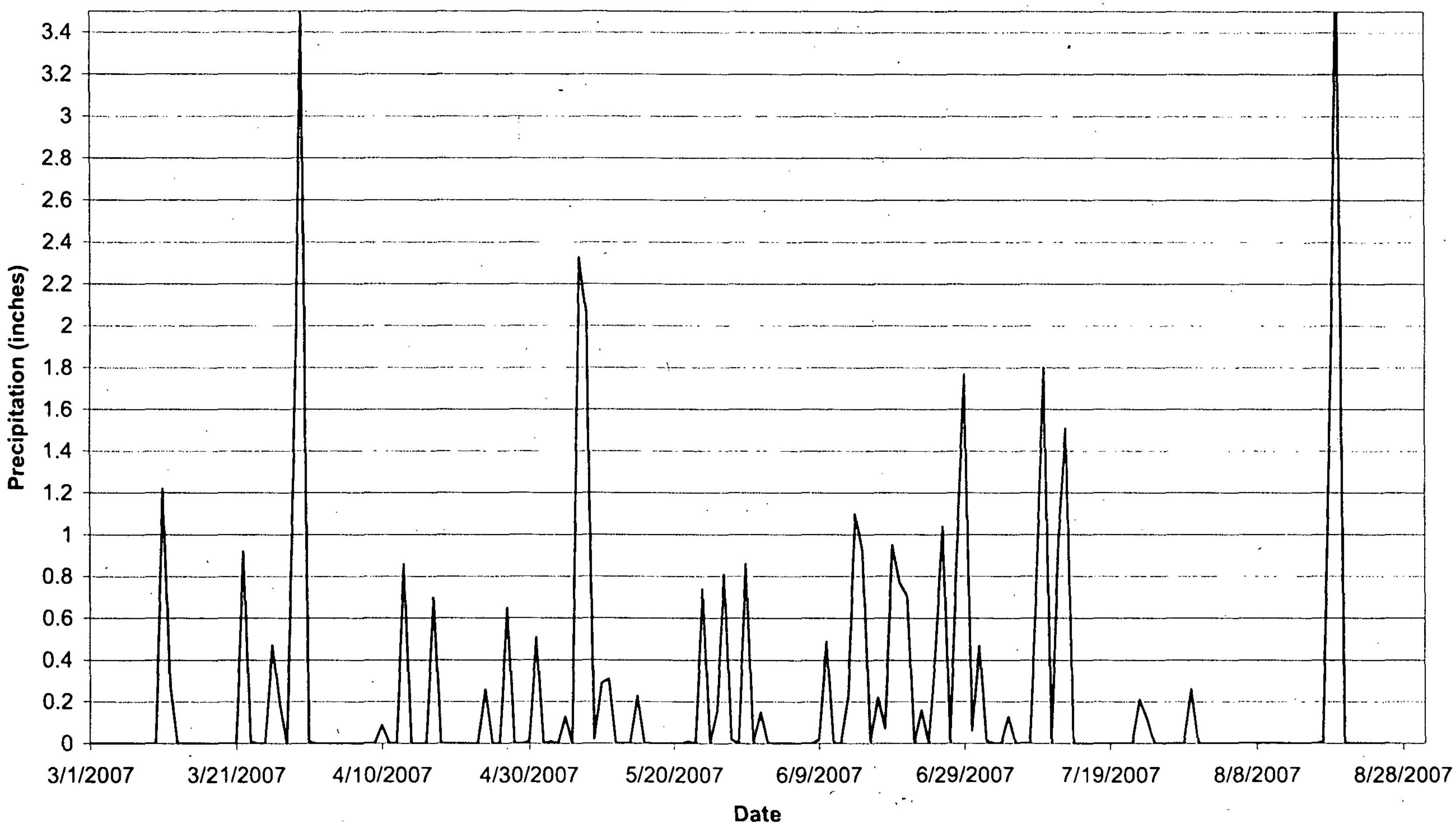


Figure 2
Excerpt - Hydrology Addendum
Flows on the Cimarron River between March 1, 2007 and August 21, 2007 at Dover

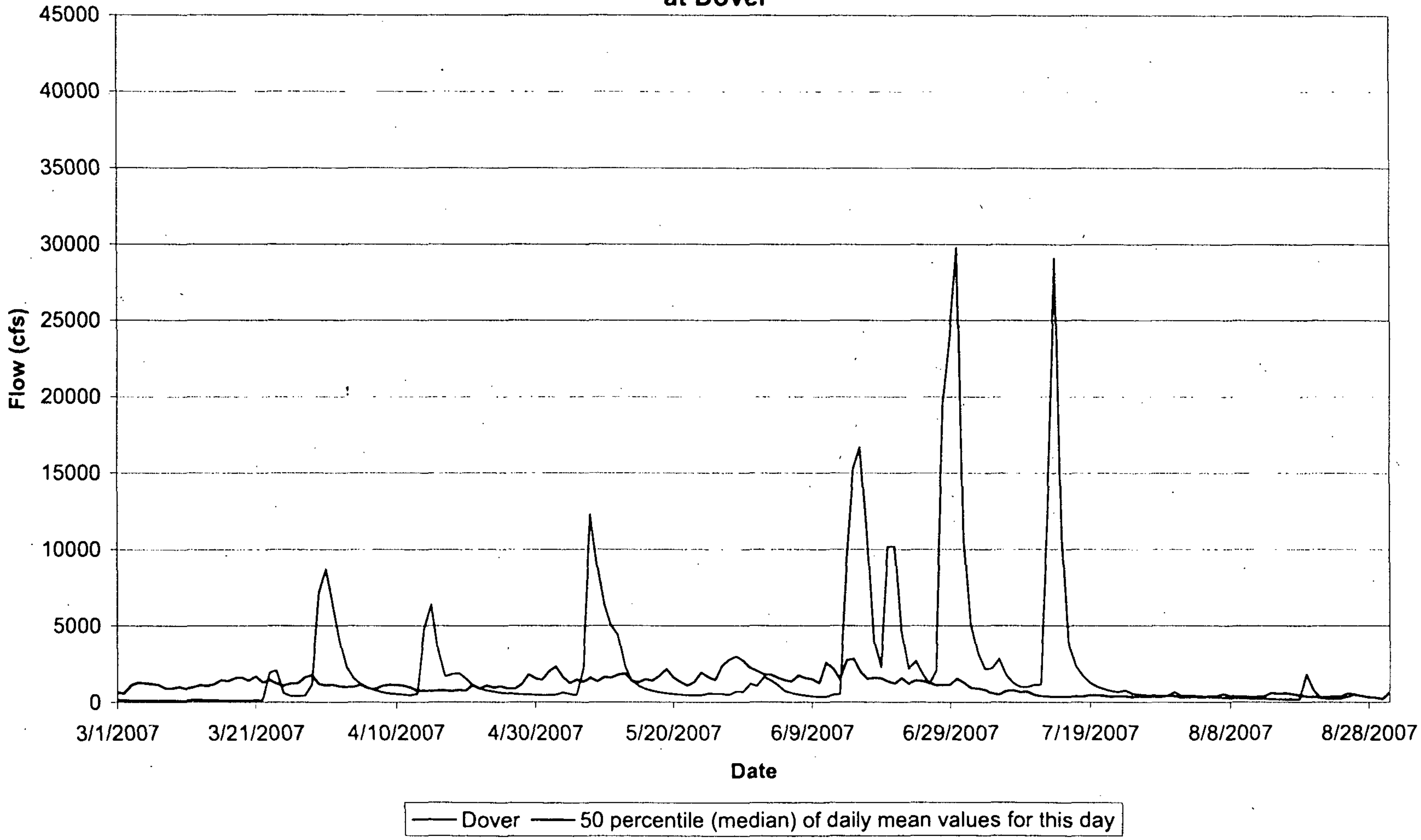


Figure 3
Excerpt - Hydrology Addendum
Flows on the Cimarron River between March 1, 2007 and August 21, 2007
at Guthrie

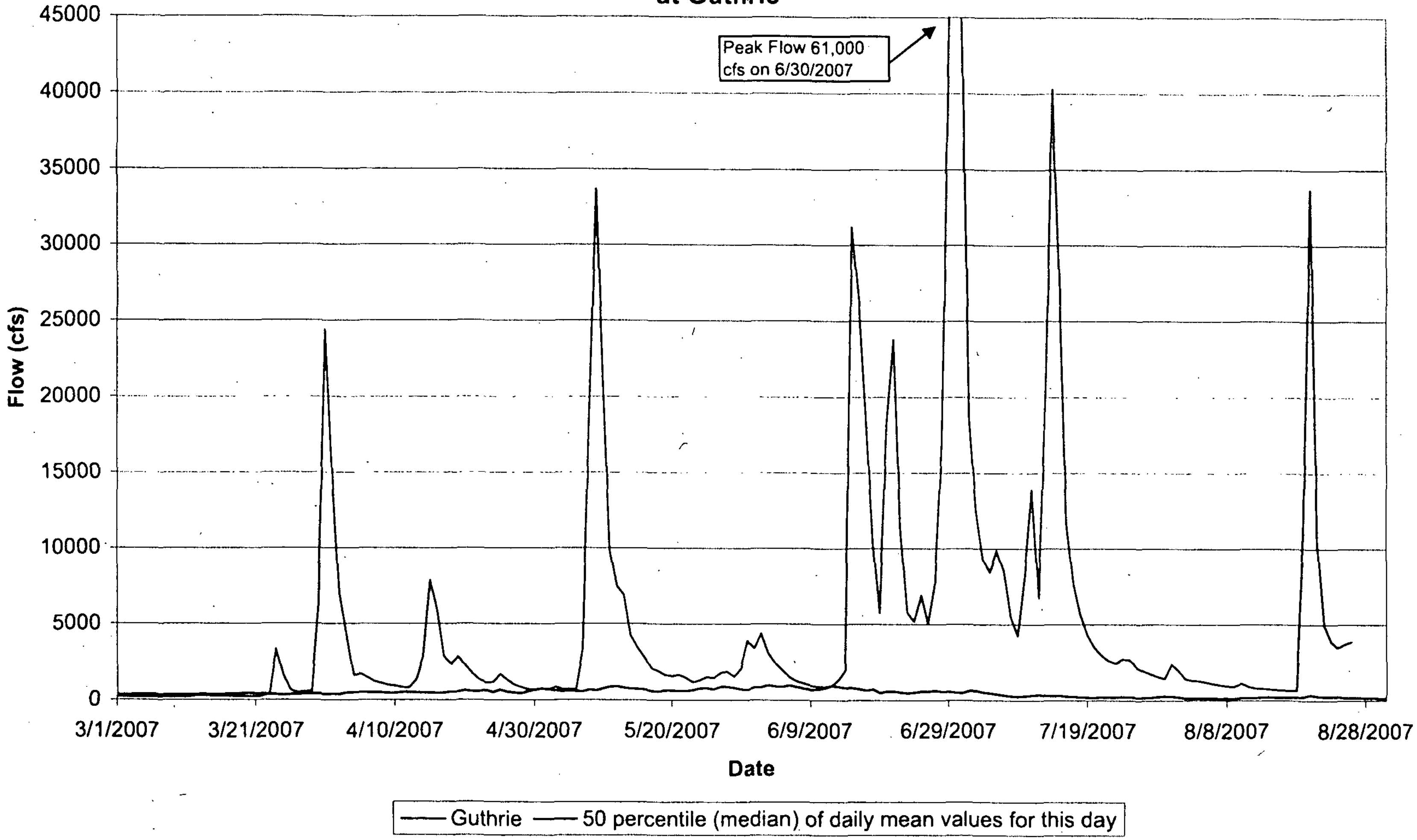
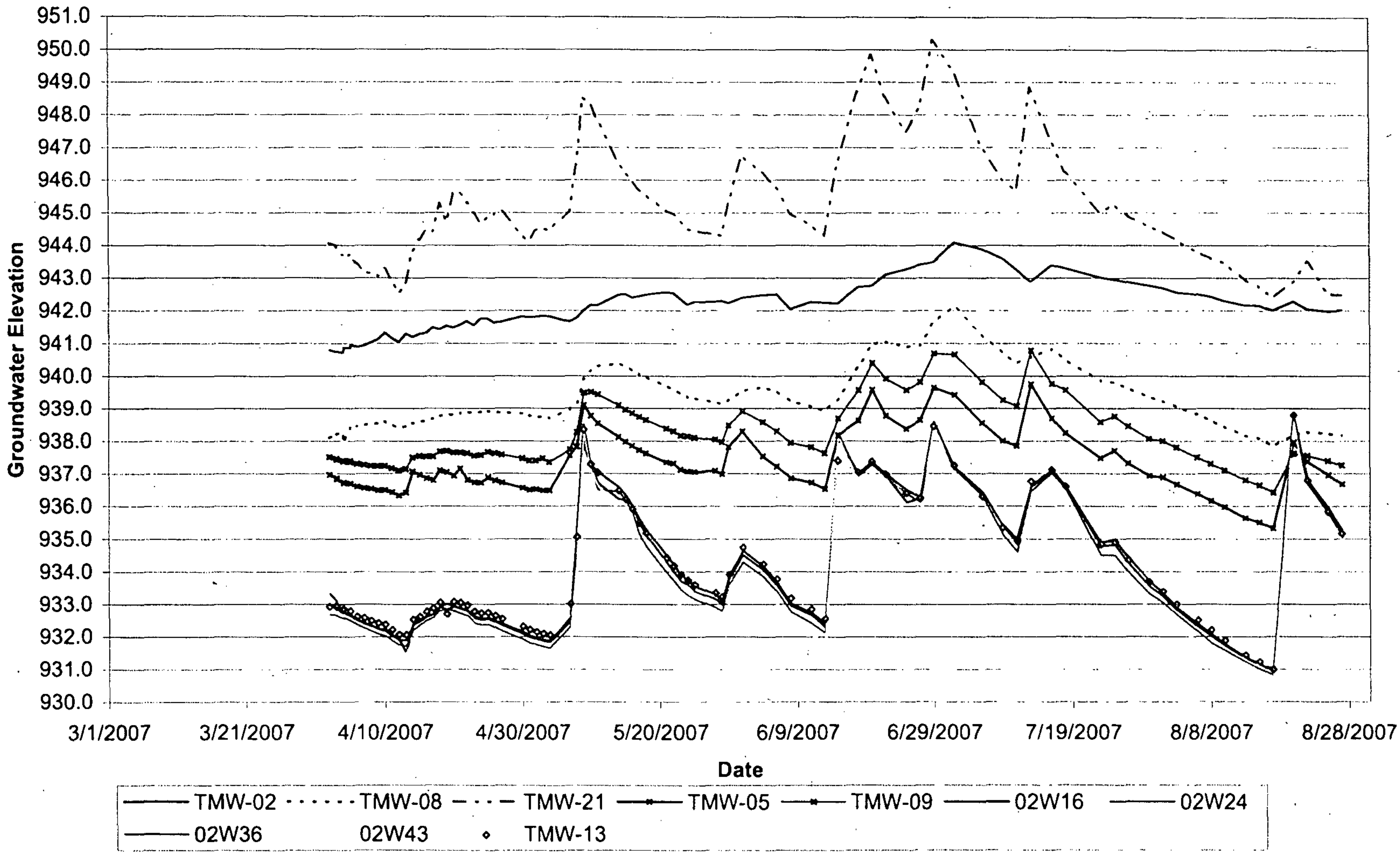
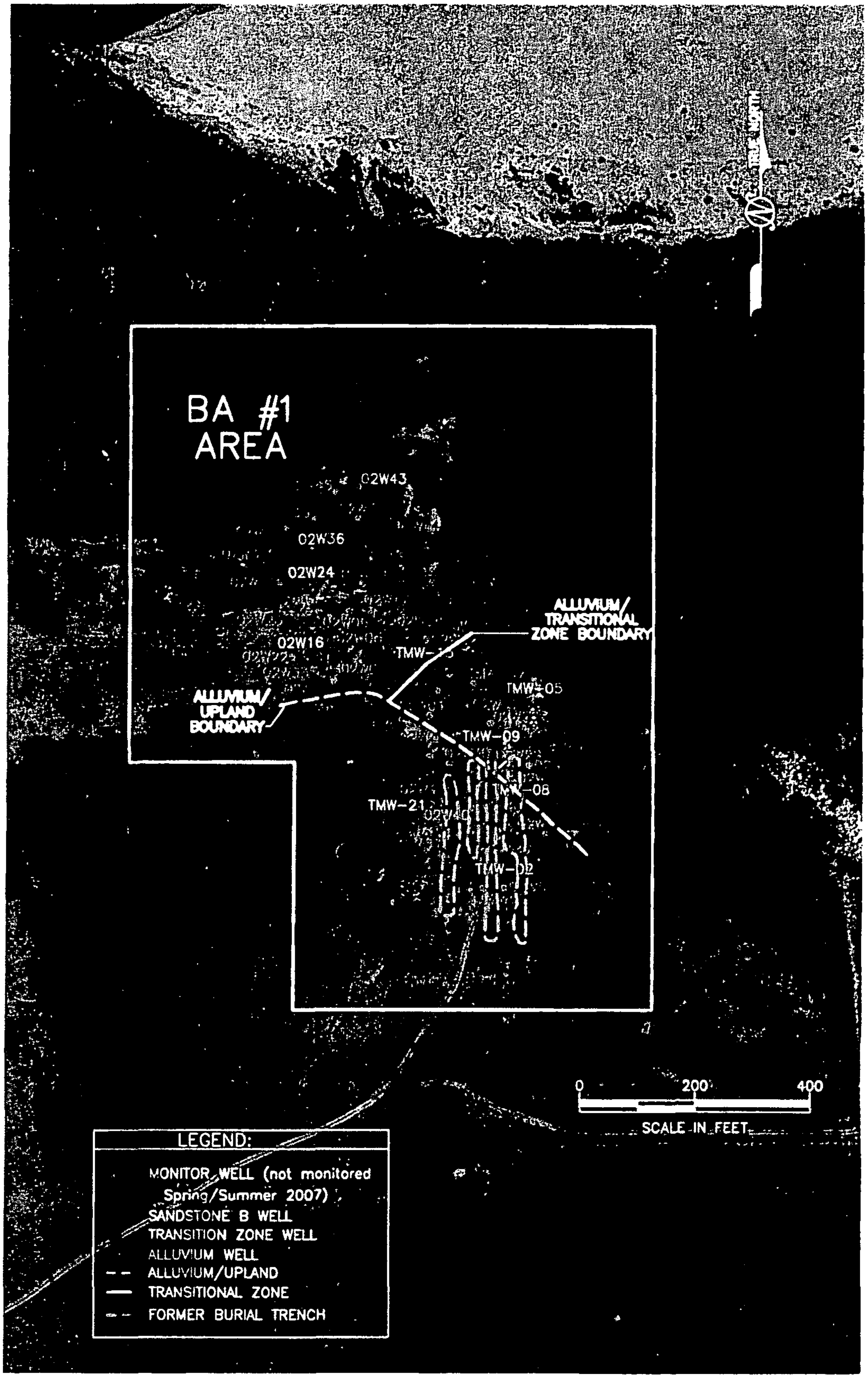


Figure 4
Excerpt - Hydrology Addendum
Groundwater Elevations at BA#1 Wells April 1, 2007 and August 20, 2007





SHEET NUMBER	FIGURE NUMBER
1	5

FIGURE 5
BA #1
LOCATION OF WELLS MONITORED FOR GROUNDWATER ELEVATION APR.–AUG. 2007
CIMARRON CORPORATION
CRESCENT, OKLAHOMA

SCALE:	DATE:	PROJECT NUMBER:
1"= 200'	10-24-07	04020-044-400

ENSR

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

DESIGNED BY:	NO.:	DESCRIPTION:	DATE:	BY:
DRAWN BY:	1		4/01/08	JAS
JAS	2		8/17/08	
CHECKED BY:				
DJF				
APPROVED BY:				
DJF				

Figure 6
Excerpt - Hydrology Addendum
Water level data as measured at the transducers in TMW-24 and 02W48
and site rainfall
March 1, 2007 to August 21, 2007

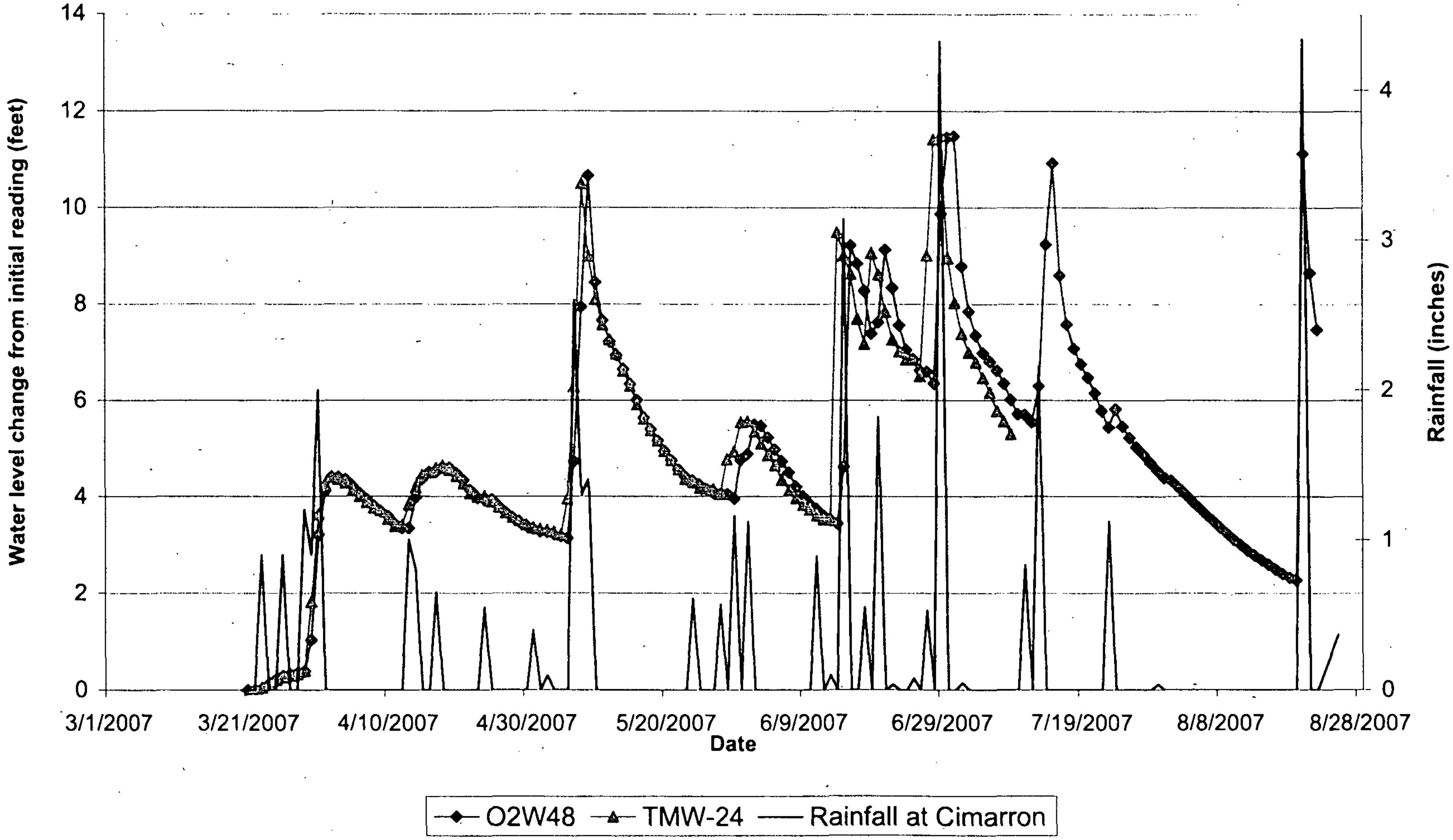
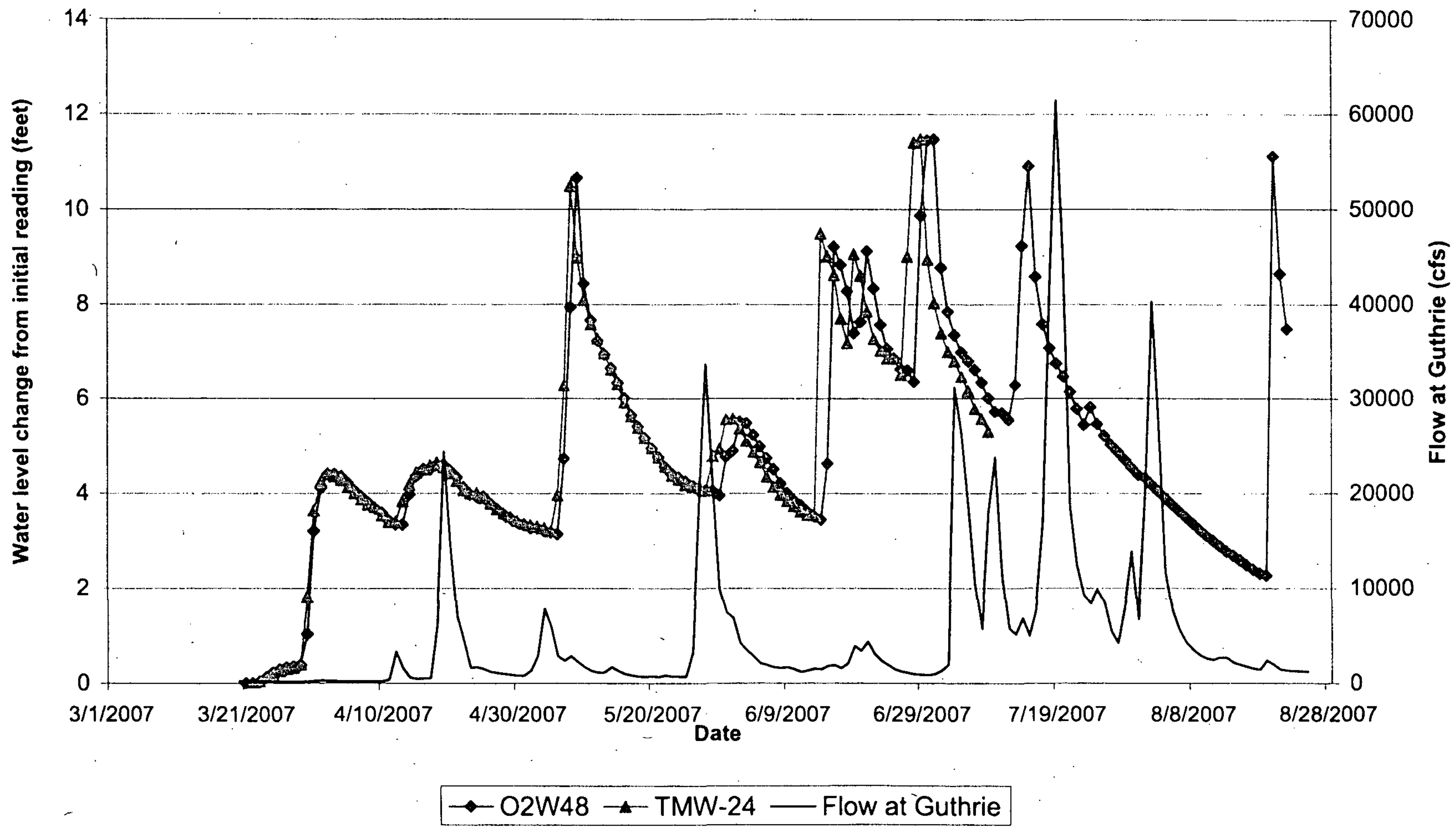
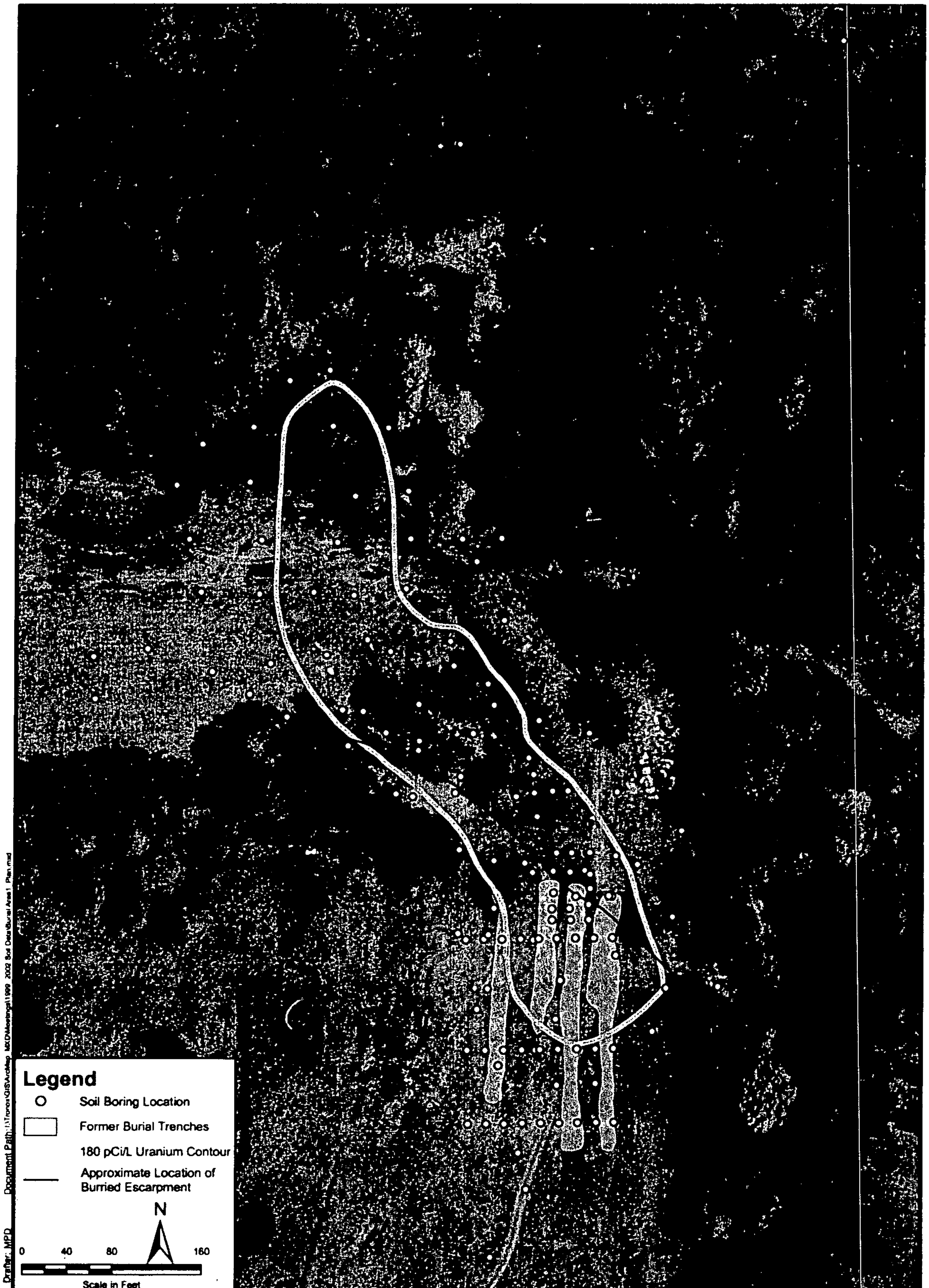


Figure 7
Excerpt - Hydrology Addendum
Water level data as measured at the transducers in TMW-24 and 02W48
and Guthrie flow data
March 1, 2007 to August 21, 2007

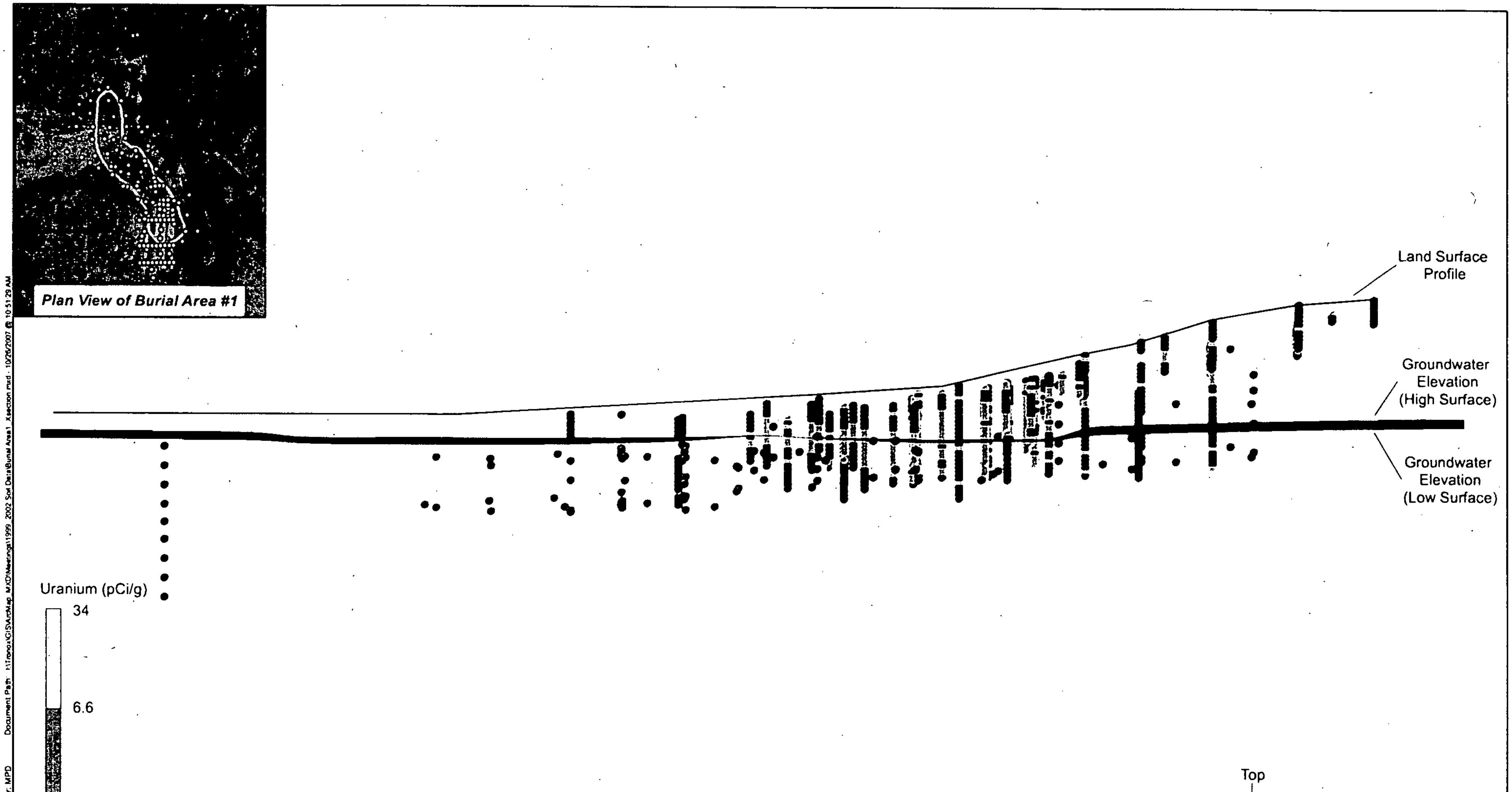




Drafter: MPD

Date: 10/24/2007

Program Manager Erhardt Werth Project Manager Sara Handy Task Manager Janis Lutrick Technical Review Paul Barnes	ARCADIS 630 Plaza Drive, Suite 100 Highlands Ranch, Colorado 80129 Tel: 720-344-3500 Fax: 720-344-3535 www.arcadis-us.com	Burial Area #1 Soil Boring Locations TRONOX Crescent, Oklahoma	Date: 10/24/2007 FIGURE 1



Note: A total of 134 soil boring locations and 1,082 sample intervals were used in the Uranium soil data representation.

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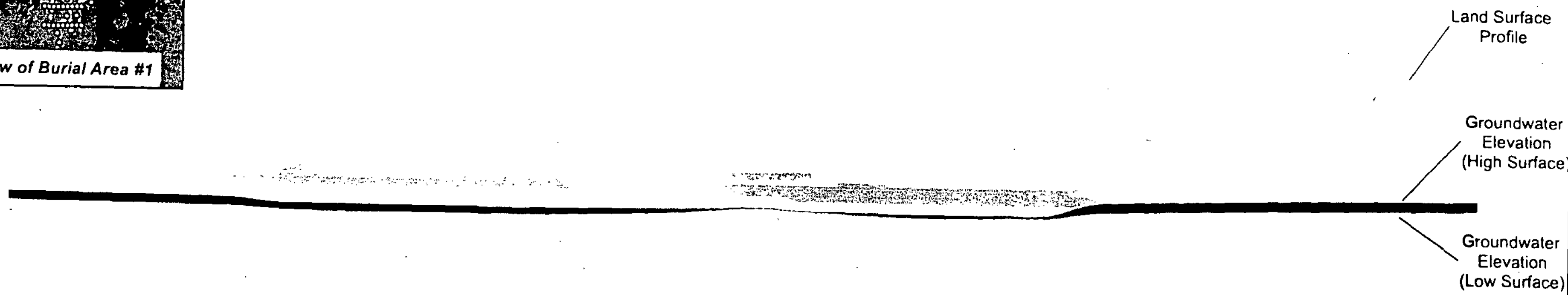
Plan View of Burial Area #1



Lithology

- Clay
- Fill
- Mudstone
- Sand
- Sandstone
- Silt

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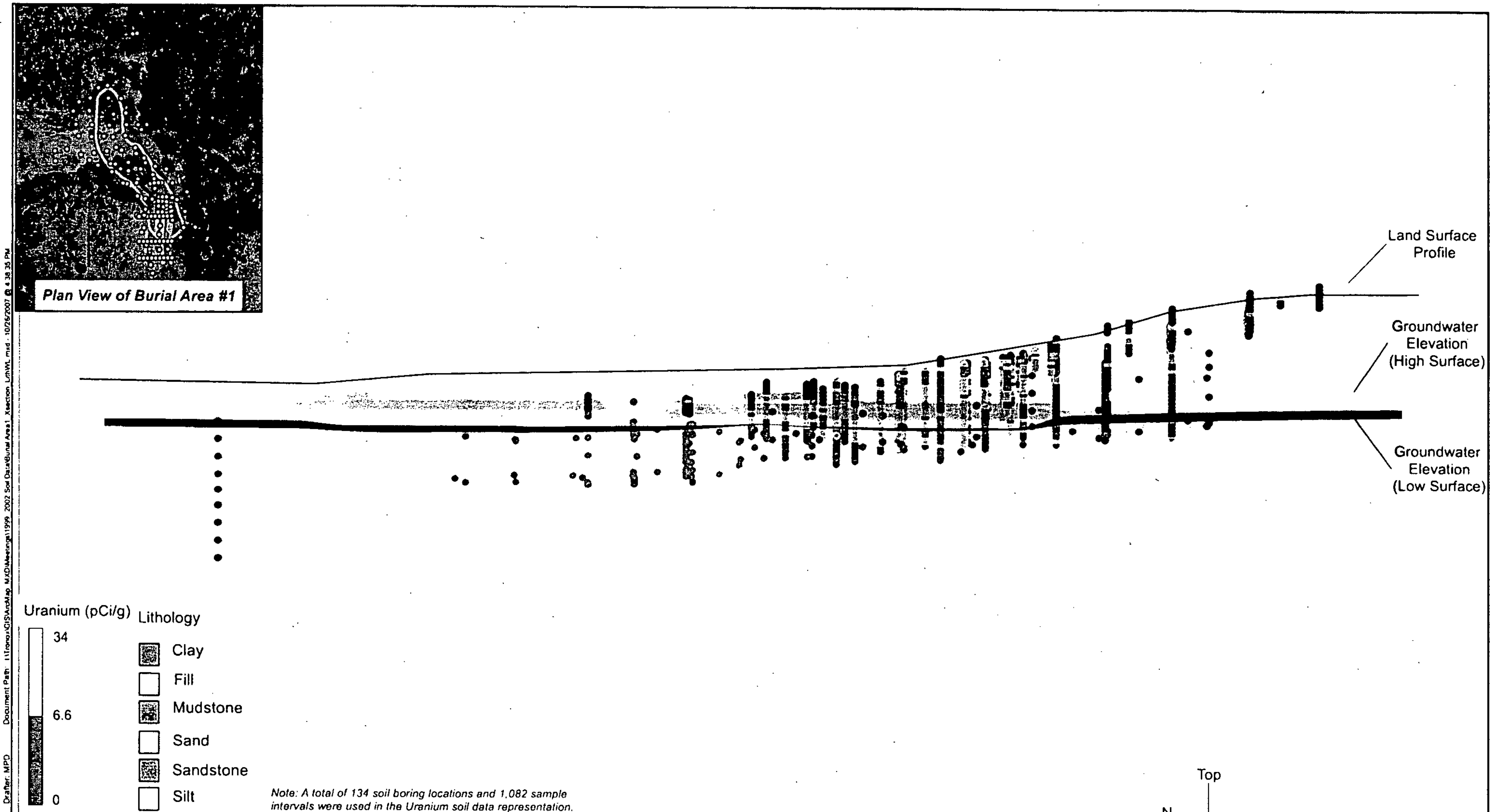
West View of Groundwater Table and Lithology

TRONOX
Crescent, Oklahoma

Date: 10/24/2007

FIGURE 3



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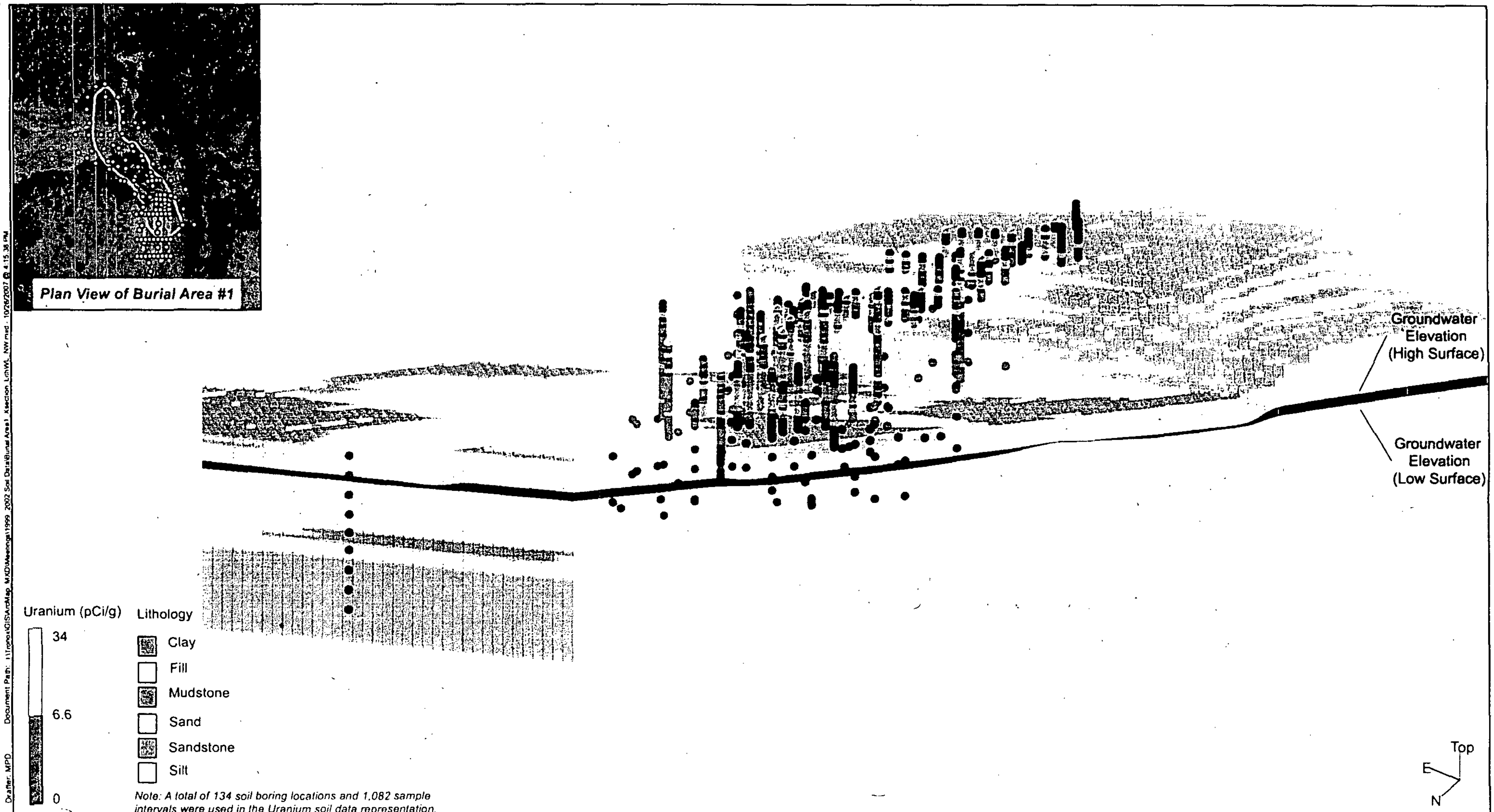
West View of Groundwater Table, Lithology, and Soil Locations

TRONOX
Crescent, Oklahoma

Date: 10/24/2007

FIGURE
4

Drafter: MPD



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Northwest View of Groundwater Table, Lithology, and Soil Locations

TRONOX
Crescent, Oklahoma

Date: 10/24/2007

FIGURE
5

Proposed Approach for Installation Design / Optimization /"Shake-Down"

Work Plan Approval (by the NRC and ODEQ)

Year 1

- Additional field characterization as needed in each of the three areas to advance the 30% design to the 60% design; establish soils mineralogy baseline
- Adjust geochemical model and utilize outputs in 60% design considerations
- Complete 60% design for all 3 remediation systems
- Share new information[1] with the NRC and ODEQ (estimated at 6 months from WP approval)

Install and operate initial treatment system components in the forward, middle and rear portions of the alluvial groundwater plumes in **Burial Area #1 (BA #1) and the Western Alluvium (WAA).**

Utilize initial systems installation efforts to collect:

- Groundwater water quality and flow information
- Soils - iron mineralogy information

Update / adjust CSM as appropriate

Install and operate initial elements of the amendment recycling systems in the **Western Upland Area (WUA)**

Collect water quality and flow information to support final design considerations

Complete 100% design and share new information[1] with the NRC and ODEQ

Year 2

- Expand systems to complete functionality
- Initiate treatment throughout all plume areas

Continue to collect systems operations and impacts data

Monthly Groundwater Data Collection (Table 1)
- water quality sampling (full suite)
- flow information

Complete groundwater treatment system (if and as necessary) to full functionality

Continue to collect systems operations and impacts data

Monthly Groundwater Data Collection (Table 1)
- water quality sampling (full suite)
- flow information

Update / adjust CSM as appropriate and share new information[1] with the NRC and ODEQ

Make basic remediation system adjustments

Upland groundwater systems operations adjustments

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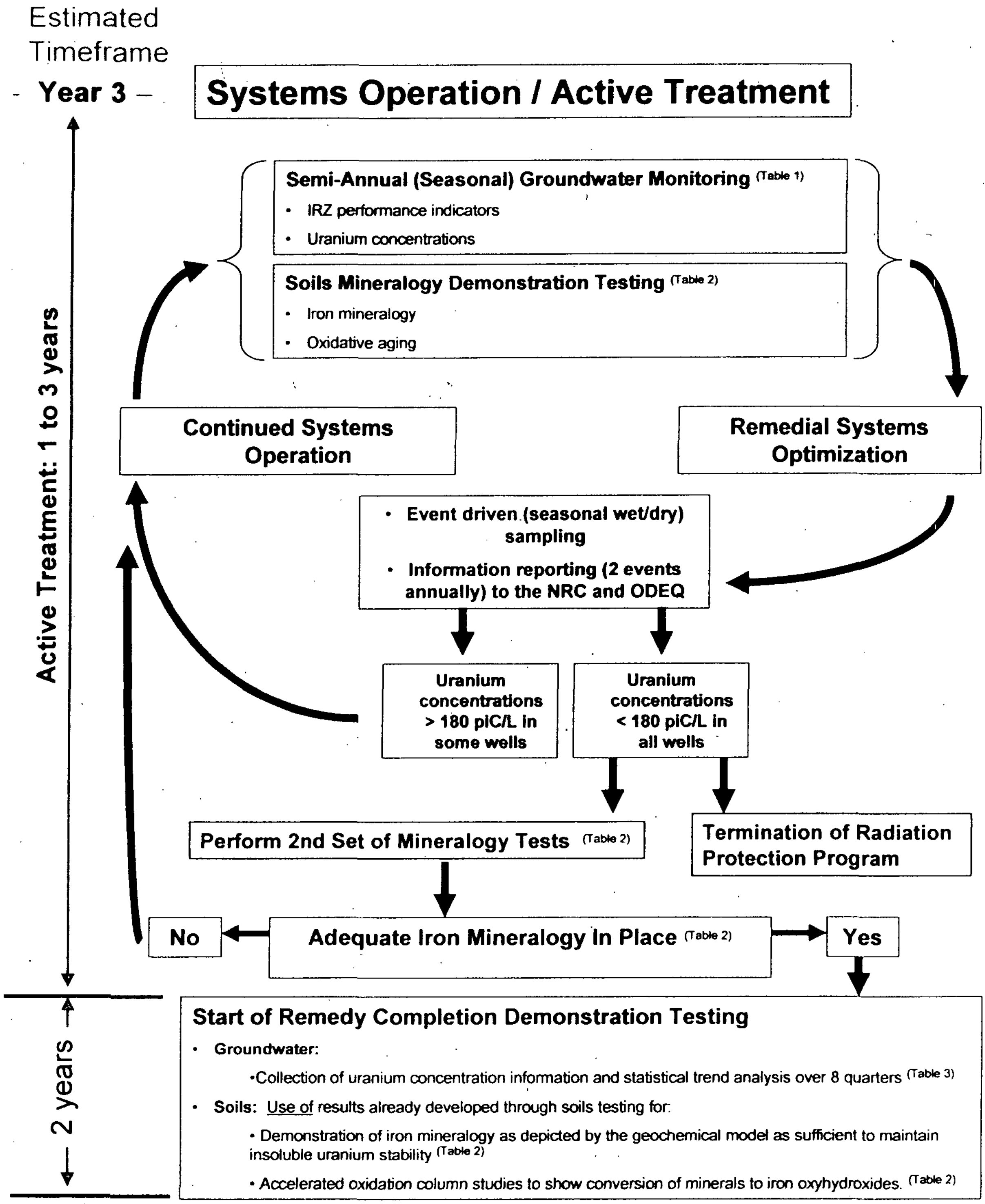
(1) Submission of an information addendum to the NRC and ODEQ directly followed by a teleconference call to discuss significance.



Successful Remediation Demonstrations = License Termination

License termination shall be granted upon the successful demonstration that:

• Results of soil analyses for iron mineralogy and oxidative aging demonstrate that the presence of soil mineral conditions necessary to ensure the stability of precipitated uranium as identified through the geochemical modeling work has been achieved.

• Groundwater samples collected from 32 wells located in Burial Area #1, the WAA and the WUA consistently show uranium concentrations below 180 piC/L.

• 16 demonstration wells across BA#1, WAA and the WUA do not show statistically significant positive trend in uranium concentrations in 8 quarters of data using USEPA approved statistical methods.

License Termination Process:

• Submit license termination request (estimated submission at the start of year 7 or earlier based upon remedial performance)

• Achieve license termination (no later than start of year 8)

Table 1. Groundwater Performance Monitoring

# of Sampling Locations	Sampling Frequency	Analytical Work
32 wells (across all three areas: BA#1 / WAA / WUA)	Monthly for first 6 months of IRZ operation	pH, temp, DO, TOC, TDS, sulfate, sulfide, Fe^{+2}, dissolved Fe, alkalinity, uranium
	Semi-annually starting 12 months after IRZ operation and continuing until the start of groundwater completion demonstration testing.	

Table 2. Mineralogy Demonstration Testing

Testing Focus	# of Sampling Locations	Sampling Frequency	Analytical Work
Iron Mineralogy	3 locations (borings) / alluvial plume 2 soil samples from different depth intervals / boring 6 samples / alluvial plume	No less than 2X based upon developing results	•Bulk iron mineralogy – selective chemical extraction – x-ray diffraction • Iron sulfide content quantification • Induced mineralogy changes – Microprobe methods will be used to examine soil mineralogy changes induced by organic carbon addition and anaerobic microbial processes; using • SEM • micro-XRF • micro-XANES
Oxidative Aging	3 locations (borings) / alluvial plume 2 soil samples from different depth intervals / boring 6 samples / alluvial plume	Twice • 1st - near beginning of year 3 • 2nd – upon determination of adequate mineralogy	Column Testing to assess: • Oxygen consumption • Iron oxidation
Adequate Iron Mineralogy in Place		Establish a ratio of total iron to total uranium (determined through nitric acid digestion) of 80:1.	

Table 3. Groundwater Completion Demonstration Testing

# of Sampling Locations	Sampling Frequency	Analytical Work	Demonstration Analyses
16 wells (across all three areas: BA#1 / WAA / WUA)	Quarterly for 8 quarters	Uranium concentrations in groundwater	Perform rigorous statistical analysis to demonstrate no significant positive trends in the concentration of uranium in groundwater over 8 quarters of continuous monitoring. The analysis will be performed using the USEPA approved Sen's Slope Estimator approach.

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