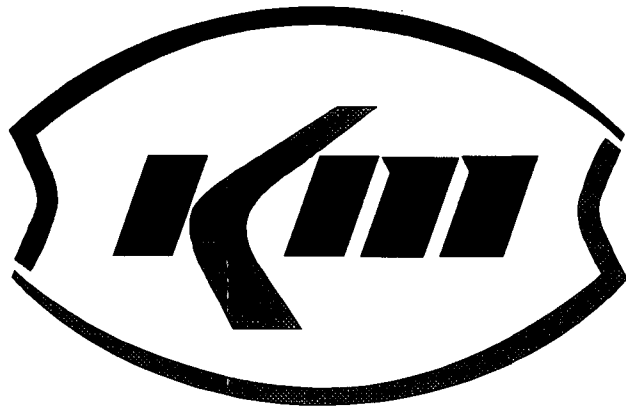


# KERR-McGEE CORPORATION



## DECOMMISSIONING PLAN GROUND WATER EVALUATION REPORT

for  
Cimarron Corporation's Former  
Nuclear Fuel Fabrication Facility  
Crescent, Oklahoma

July, 1998

License Number: SNM-928  
Docket No. 70-0925

CIMARRON CORPORATION  
CRESCENT, OKLAHOMA

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**CIMARRON DECOMMISSIONING PLAN  
GROUNDWATER EVALUATION REPORT  
July, 1998**

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## 1.0 INTRODUCTION

The purpose of this report is to provide information regarding groundwater at the Cimarron Facility for inclusion in the Cimarron Decommissioning Plan. This report addresses vicinity and site geology/hydrology, a summary of closure activities for facility areas with groundwater contamination, background and affected area groundwater quality, the trending of environmental data for affected areas and a proposal for additional work at Burial Area #1. The attached Appendix #1 contains the Cimarron Environmental Data for the period June, 1985 through March, 1998. This data was utilized to analyze exposure pathways, a radiological dose assessment for groundwater, the chemical toxicity of the contaminant of concern, a derivation of appropriate groundwater criteria, and a program to address any lingering groundwater levels above the criteria. With the submission of this report, Cimarron believes that it is now appropriate to approve the Cimarron Decommissioning Plan.

Comprehensive background reports previously submitted to the NRC staff addressing groundwater at the Cimarron Facility are cited extensively throughout this document and include:

- Hydrological Information in the Vicinity of the Kerr-McGee Facility, Logan County, Oklahoma, 1973.
- Hydrologic Water Balance, Option Two Burial Site and Vicinity, Cimarron Corporation Facility, Crescent, Oklahoma, 1989.
- Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September, 1989.
- Cimarron Facility Closure Responses to NRC Questions, 1990.
- Cimarron Facility Closure Responses to OSDH Comments, Cimarron Site Investigation Report, 1990.
- Environmental Assessment of a Proposed Disposal of Uranium – Contamination Soil at the Cimarron Uranium Plant, March, 1994.

- Cimarron Radiological Characterization Report, October, 1994.
- Cimarron Decommissioning Plan, April, 1995
- Groundwater and Surface Water Assessment for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.
- Recharge and Groundwater Quality Study for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.
- Cimarron Corporation Responses to NRC Staff Comments Dated March 13, 1997, on "Groundwater and Surface Water Assessment" and "Recharge and Groundwater Quality Study", May, 1997.

Cimarron Corporation believes that applicable conditions and criteria for releasing the Cimarron site for unrestricted release can be met as proposed in the Cimarron Decommissioning Plan and in this report. As a result, Cimarron Corporation is requesting that this report become the groundwater assessment part of the Cimarron Decommissioning Plan and be approved so that all remaining activities and final status surveys can be completed, leading ultimately to the termination of License SNM-928.

The Cimarron Facility, located near Crescent, Oklahoma, was operated by Kerr-McGee Corporation (Kerr-McGee) from 1966 to 1975 for the manufacture of enriched uranium and mixed-oxide fuels. Cimarron Corporation is a wholly owned subsidiary Kerr-McGee Corporation (Kerr-McGee).

The Cimarron site was originally licensed under two separate Special Nuclear Material Licenses. Cimarron operated a production facility for the fabrication of mixed oxide (plutonium and uranium) and enriched uranium fuel elements. License SNM-928 was issued in 1965 for the Uranium Plant and License SNM-1174 was issued in 1970 for the Mixed Oxide Fuel Fabrication (MOFF) Plant.

Both facilities operated through 1975, at which time operations were terminated and commencement of characterization/decommissioning efforts began. Since 1976, Cimarron has continued to decontaminate and remove equipment from the facility, dismantle the buildings, and excavate soils under NRC Licenses SNM-928 and SNM-1174. The facility grounds, originally 840 acres, were managed for decommissioning under License SNM-928.

Decommissioning efforts for the MOFF Plant were completed in 1990, at which time Cimarron applied to the NRC for termination of License SNM-1174 (August 20, 1990). The NRC terminated License SNM-1174 for the MOFF Plant on February 5, 1993.

Based upon knowledge of site operations and the characterization and decommissioning work completed at the time, Cimarron prepared and submitted the Cimarron Radiological Characterization Report to the NRC in October of 1994. Cimarron also prepared and submitted the Cimarron Decommissioning Plan to the NRC in April, 1995. As described in these documents, the entire 840-acre site was divided into affected and unaffected areas. The Final Status Survey Plan for the entire Cimarron 840-acre site has been divided into three major areas, which contain both affected and unaffected areas. Each of these three major areas were designated as Phases I, II, and III. These three Phases were then each further subdivided into 5 smaller "Sub-Areas" (i.e. A through E, F through J, and K through O). (See drawing 95MOST-RF3, page 1-7.)

As discussed above, decommissioning efforts involving characterization, decontamination and remediation for the 840-acres, licensed under SNM-928, were initiated in 1976 and are nearing completion. The goal of the Cimarron decommissioning effort is to release the entire 840-acre site for unrestricted use. A small portion of the site will remain active and under the control of Kerr-McGee Chemical LLC, which operates a small-scale Titanium Dioxide pilot plant. The

status of Radiological Decommissioning for Phases I, II, and III is discussed further below:

### **Phase I**

The Final Status Survey Plan for Phase I was submitted to the NRC on October 15, 1994 and was approved by the NRC via letter dated May 1, 1995. The Final Status Survey Report for Phase I was submitted to the NRC on August 1, 1995 and confirmatory sampling was performed by ORISE. The Phase I Area, consisting of unaffected Sub-Areas A, B, C, D, and E, was released for unrestricted use via license amendment #13 on April 23, 1996. License Amendment #13 reduced the licensed acreage from approximately 840 acres to approximately 152 acres. The released acreage was never utilized for any licensed activities.

### **Phase II**

The Phase II area contains both affected and some contiguous adjoining areas and represents approximately 122 of the 152 acres remaining under License SNM-928. The Final Status Survey Plan for Phase II was submitted to the NRC on July 11, 1995 and was approved by the NRC on March 14, 1997. Phase II includes Sub-Areas F, G, H, I and J and includes former Burial Area #1, which was released for backfill and seeding by the NRC in December, 1992. Also included in Phase II are the East and West Sanitary Lagoons, the Emergency Building, the Warehouse Building (Uranium Building #4) and surrounding yard area, as well as numerous natural drainage pathways. Cimarron has substantially completed the remediation of each of the Phase II Sub-Areas and the final status surveys have either been completed or are currently underway. The Final Status Survey Report of Sub-Area "J" was submitted to the NRC in September, 1997, and represents the first Sub-Area of Phase II to



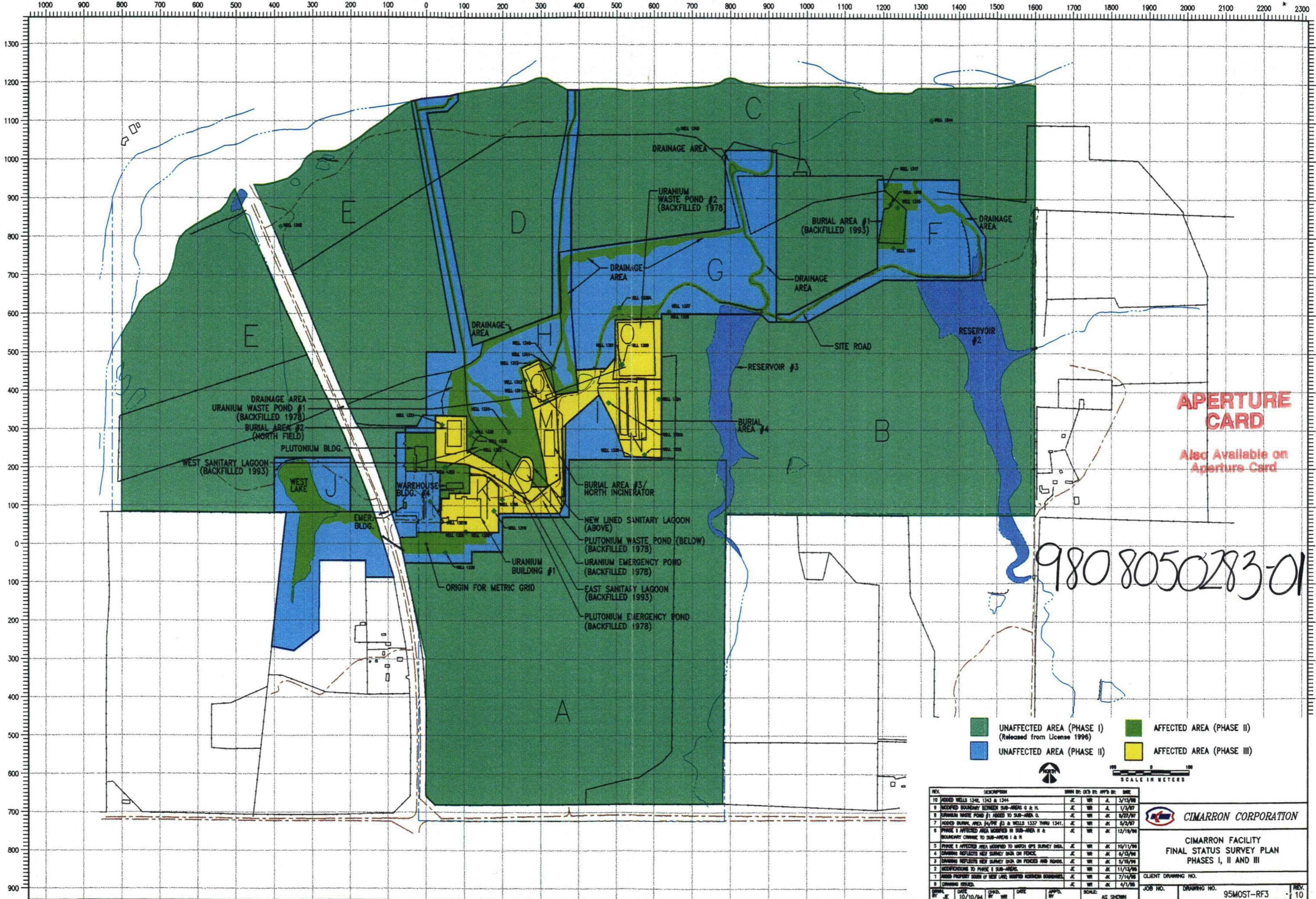
be submitted to the NRC. The NRC provided comments on Sub-Area "J" to Cimarron via letter dated January 9, 1998 and Cimarron responded on May 13, 1998.

### **Phase III**

The Phase III area consists of affected areas only, and represents approximately 30 acres. Phase III includes Sub-areas K, L, M, N, and O. The Final Status Survey Plan for Phase III was submitted to the NRC in June, 1997. The NRC provided comments to Cimarron on the Phase III Final Status Survey Plan via letter dated October 3, 1997 and Cimarron responded to the NRC comments via letter dated December 5, 1997. The NRC provided additional comments to Cimarron on the Phase III Final Status Survey Plan via letter dated February 9, 1998 and Cimarron responded to these comments on June 26, 1998. The Phase III area includes the Uranium Processing Buildings and yard area, Burial Areas #2 and #3, the New Sanitary Lagoon, the BTP Option #2 Disposal Cell (Burial Area #4), and the five former Waste Water Treatment Ponds. These five former ponds consist of Uranium Waste Ponds #1 and #2, the Plutonium Waste Pond, the Plutonium Emergency Pond and the Uranium Emergency Pond.

These five former ponds had been previously released by the NRC in 1978. Waste Ponds #1 and #2 were revisited by the NRC in 1993. As a result, Cimarron Corporation performed further remediation on Waste Ponds #1 and #2 in accordance with the BTP Option #1 criteria and the NRC volumetric averaging guidance. Cimarron is currently awaiting NRC final review and release of Waste Ponds #1 and #2, as detailed in the Sub-Area "O" Final Status Survey Report (Sub-surface).

With the submittal of this Groundwater Evaluation Report, Cimarron has now addressed all of the issues associated with the Cimarron Decommissioning Plan. This report therefore addresses this last remaining issue (i.e., groundwater) required for approval of the Cimarron Decommissioning Plan and eventual license termination.



**APERTURE CARD**  
 Also Available on Aperture Card

UNAFECTED AREA (PHASE I)  
 (Released from License 1996)  
 AFFECTED AREA (PHASE II)  
 UNAFECTED AREA (PHASE II)  
 AFFECTED AREA (PHASE III)



REV.	DESCRIPTION	DRWN BY:	CHKD BY:	APP'D BY:	DATE
10	ADDED WELLS 1342, 1343 & 1344	J.E.	W.R.	A.	3/13/98
9	MODIFIED BOUNDARY BETWEEN SUB-AREAS G & H.	J.E.	W.R.	A.	1/3/97
8	URANIUM WASTE POND #1 ADDED TO SUB-AREA G.	J.E.	W.R.	A.K.	6/27/97
7	ADDED BURIAL AREA #4/PHE #3 & WELLS 1337 THRU 1341.	J.E.	W.R.	A.K.	5/2/97
6	PHASE I AFFECTED AREA MODIFIED IN SUB-AREA H & BOUNDARY CHANGE TO SUB-AREAS I & H.	J.E.	W.R.	A.K.	12/18/94
5	PHASE I AFFECTED AREA MODIFIED TO MATCH GPS SURVEY DATA.	J.E.	W.R.	A.K.	10/11/94
4	DRAWING REFLECTS NEW SURVEY DATA ON FENCE.	J.E.	W.R.	A.K.	6/12/94
3	DRAWING REFLECTS NEW SURVEY DATA ON FENCES AND ROADS.	J.E.	W.R.	A.K.	5/16/94
2	MODIFICATIONS TO PHASE II SUB-AREAS.	J.E.	W.R.	A.K.	11/12/93
1	ADDED PROPERTY BOUNDARY OF WEST LAKE; ADDED BOUNDARY BOUNDARY.	J.E.	W.R.	A.K.	7/14/93
0	DRAWING ISSUED.	J.E.	W.R.	A.K.	4/1/93

**CIMARRON CORPORATION**

CIMARRON FACILITY  
 FINAL STATUS SURVEY PLAN  
 PHASES I, II AND III

CLIENT DRAWING NO. \_\_\_\_\_  
 JOB NO. \_\_\_\_\_ DRAWING NO. 95MOST-RF3 REV. 10

## **2.0 GEOLOGY**

The Cimarron facility lies in the Central Lowlands portion of the Great Plains physiographic province. The local and regional topography is characterized by low, rolling hills and incised rivers, streams, and floodplains. The site elevation ranges from about 940 to 1010 feet above mean sea level. A principal geomorphic feature at the site is the Cimarron River floodplain which is approximately one-half mile in width and trends east-west. The river and floodplain are bordered by a system of low lying cliffs and bluffs that overlook the river. The facility is located in an upland area south adjoining the river and includes portions of the floodplain and the adjoining cliffs and bluffs. The upland elevation of the facility in former operations areas is approximately 980 to 1,000 feet above mean sea level. The elevation of the floodplain is approximately 940 feet. Total relief across the site is approximately 50 to 70 feet. Local drainage is toward the Cimarron River and its floodplain.

Regional and local hydrogeologic features have been described through numerous characterization reports assembled for the Cimarron Facility. (See Introduction). Regional and site geology are described in detail in the Comprehensive Site Characterization Report (Grant, 1989) completed for the application for on-site disposal of Option #2 materials. The Grant report presented results of an extensive site hydrogeologic and geotechnical characterization completed in 1989. Pertinent details from this report and more recent additional investigations are summarized in this section.

### **2.1 Regional Geology**

The regional geology is characterized as a gentle, west-southwest dipping homocline of Permian bedrock. The sediments forming the Permian bedrock were deposited in shallow marine and non-marine deltaic environments. Quaternary-age alluvial and terrace deposits unconformably overlie the erosional surface of the bedrock.

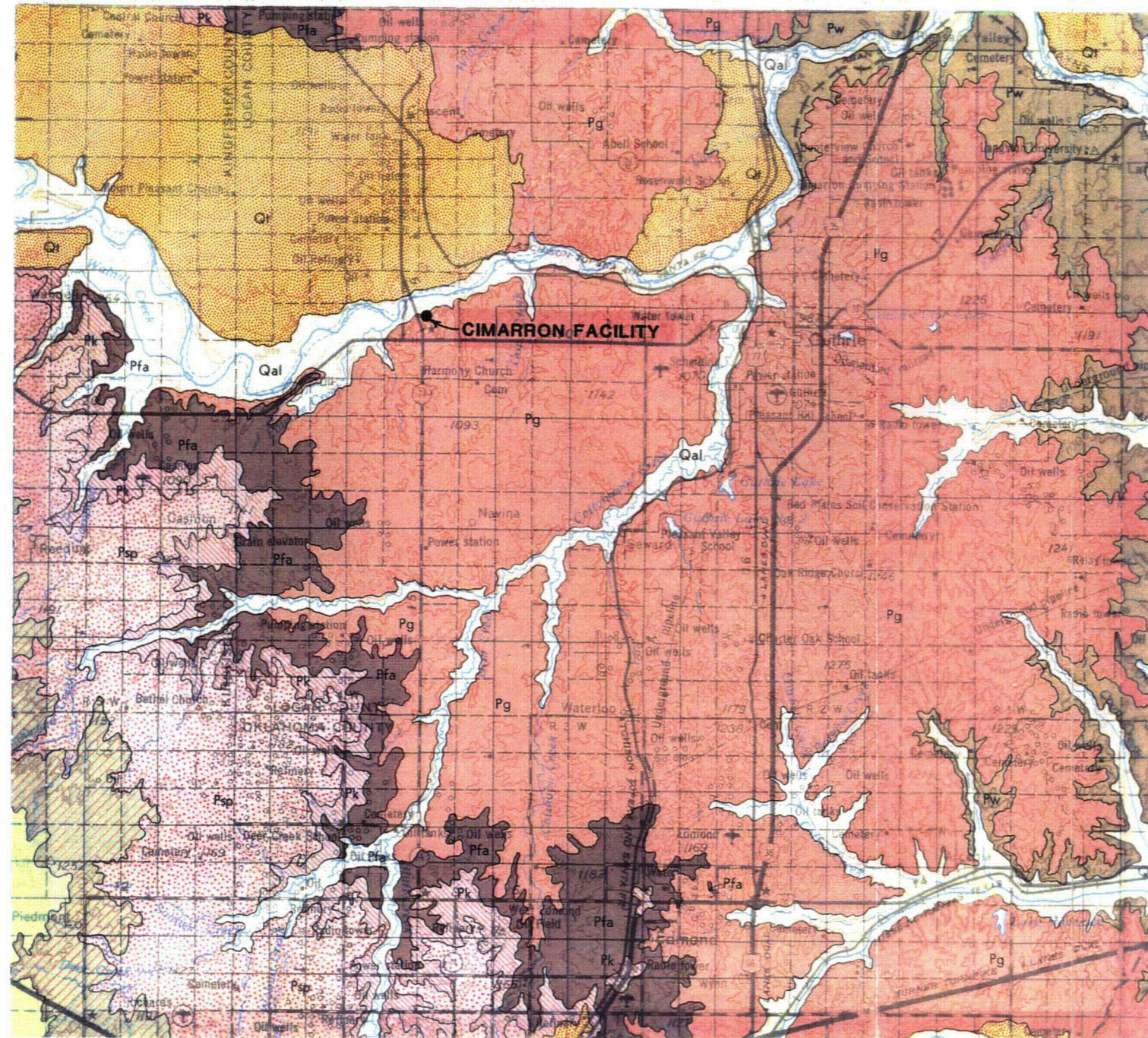
Permian bedrock in the area includes (from younger to older) the Hennessey Shale Formation, the Garber Sandstone and the Wellington Formation. The Hennessey Formation is absent beneath the site, but is present about four miles west of the facility. Regional dip of the Permian beds at the surface is about 20 to 40 feet per mile to the west. A map showing regional geology is included as Figure 2.1.

The Permian-age Garber Sandstone and underlying Wellington Formation include lenticular sandstones interbedded within shales and mudstones. The combined thickness of the Garber Sandstone and the Wellington Formation is about 800 to 1,000 feet. The lithology of both units is similar, consisting of interbedded sandstones, shales and mudstones with an absence of fossils. The water-bearing characteristics of each formation (e.g., hydraulic conductivity and water quality) also are similar. Since the two formations are reportedly not readily distinguishable, they often are considered as a single hydrostratigraphic unit, the Garber-Wellington Aquifer (Wood and Burton, 1968).

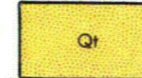
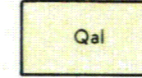
The Quaternary deposits overlying the Garber Sandstone include terrace deposits from earlier river channels and alluvium in the modern river channels. The terrace deposits are located on the northern side of the Cimarron River. The alluvium in the river channel floodplain on the south side is unconformably deposited on the Garber Sandstone (Engineering Enterprises, 1973).

## **2.2 Site Geology**

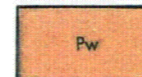
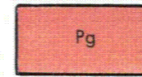
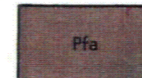
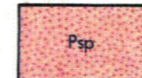
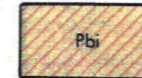
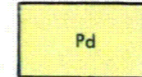
A soil veneer, one to eight feet thick, covers most of the site. The shallow bedrock at the site consists of sandstones and siltstones of the Garber formation (Garber Sandstone). The Garber Sandstone is relatively thick in the facility area and no other formations have been penetrated by drilling conducted during the most recent investigations.



QUATERNARY



PERMIAN



**ALLUVIUM**

Sand, silt, clay, and lenticular beds of gravel. Thickness ranges from about 30 to 100 feet and probably averages about 50 feet along major streams. Along minor streams, thickness ranges from a few feet to about 50 feet and probably averages about 25 feet. Alluvium is a major aquifer in parts of quadrangle.

**TERRACE DEPOSITS**

Lenticular beds of sand, silt, clay, and gravel. Thickness ranges from a few feet to about 100 feet and probably averages about 50 feet along major streams. These deposits are major aquifers along Cimarron, Canadian, and North Canadian Rivers.

**DUNCAN SANDSTONE**

Mainly red-brown to orange-brown fine-grained sandstone, with some mudstone conglomerate and shale; grades northward into Cedar Hills Sandstone and Chickasha Formation. Thickness, 450 feet near Chickasha, 300 feet near Oklahoma City, and 100 feet or more near Okarche.

**BISON FORMATION**

Mostly red-brown shale; grades northward into many thin greenish-gray calcitic siltstones and some orange-brown fine-grained sandstones and siltstones. *Reeding Sandstone Bed* at base. Thickness ranges from 95 feet in south to 120 feet in north.

**SALT PLAINS FORMATION**

Red-brown blocky shale and orange-brown siltstone, grades southward into Purcell Sandstone in Norman area. Thickness, 200 feet.

**FAIRMONT SHALE**

Red-brown blocky shale; grades into Garber Sandstone at base. Thickness, 30 feet at Oklahoma City, 110 feet near Purcell, and 120 feet near Kingfisher.

**GARBER SANDSTONE**

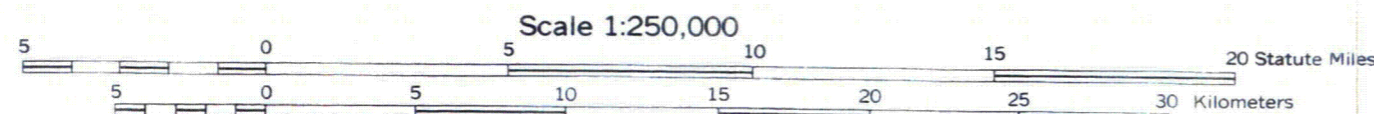
Mostly orange-brown to red-brown fine-grained sandstone, irregularly bedded with red-brown shale and some chert and mudstone conglomerate. Thickness ranges from 150 feet in south to 400 feet or more in north. The Garber and underlying Wellington are major aquifers in Cleveland and Oklahoma Counties.

**WELLINGTON FORMATION**

Red-brown shale and orange-brown fine-grained sandstone, containing much maroon mudstone conglomerate and chert conglomerate to south. Thickness ranges from about 150 feet in south to 500 feet in north.

**APERTURE CARD**

*Also Available on Aperture Card*

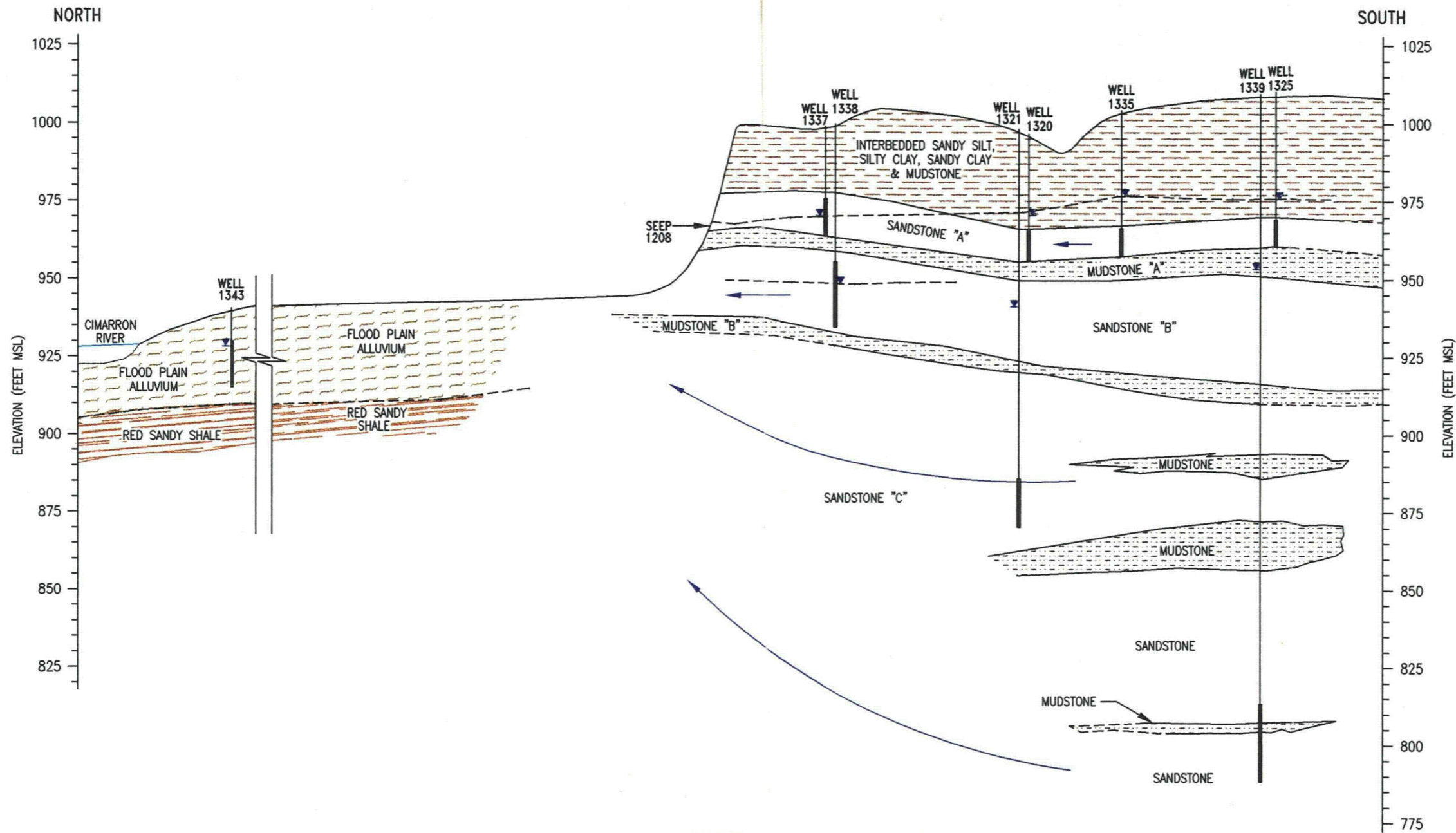


Scale 1:250,000  
 CONTOUR INTERVAL 100 FEET  
 WITH SUPPLEMENTARY CONTOURS AT 50-FOOT INTERVALS  
 DATUM: MEAN SEA LEVEL

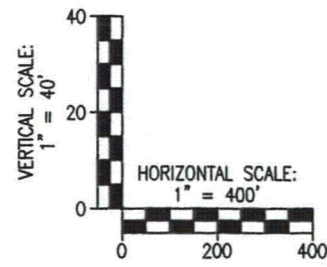
SOURCE: BINGHAM AND MOORE, 1975

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**FIGURE 2.1**  
**GEOLOGIC MAP**



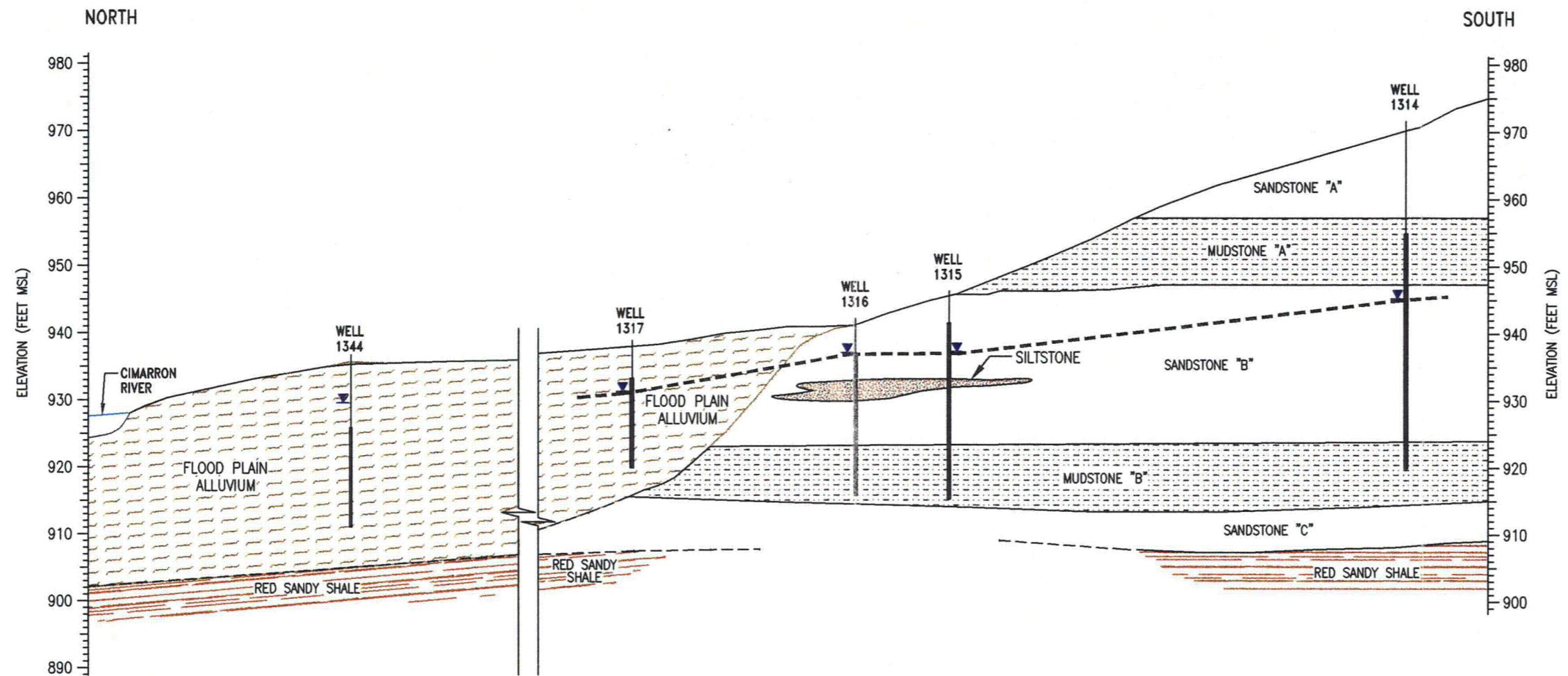
**APERTURE CARD**  
 Also Available on Aperture Card



9808050283-03

**CIMARRON CORPORATION**  
 CIMARRON FACILITY  
 NORTH-SOUTH CROSS SECTION THROUGH  
 WELLS 1337, 1338, 1321, 1320,  
 1335, 1339, 1325 & 1343

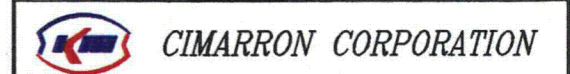
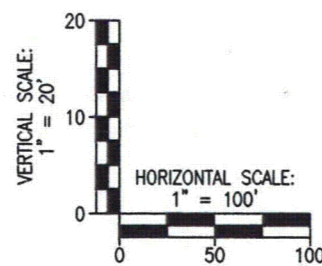
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1	WELL 1343 ADDED.	JE	RS	JL	6/18/98	JE	3/27/97	AS SHOWN
0	DRAWING ISSUED.	JE	RS	JK	3/27/97			



**APERTURE CARD**

Also Available on Aperture Card

9808050283-04



CIMARRON FACILITY  
NORTH-SOUTH CROSS SECTION THROUGH  
WELLS 1314, 1315, 1316, 1317 & 1344

REV.	DESCRIPTION	DRWN BY:	CK'D BY:	APP'D BY:	DATE	DRWN BY:	DATE	SCALE
1	WELL 1344 ADDED.	JE	RS	JL	6/18/98	JE	4/17/97	AS SHOWN
0	DRAWING ISSUED.	JE	SL	JK	4/18/97			



The Quaternary alluvium in the Cimarron River channel consists of sand, silt, clay, and lenticular gravel beds. The alluvium is estimated to range between 30 and 100 feet in thickness along major rivers such as the Cimarron River, with an average thickness of about 50 feet. The depth of alluvium in the vicinity of the site is important because of the extent (vertical) to which the river has cut into the underlying sandstone layers. The intersection of the alluvium with the underlying sandstones creates discharge zones for the sandstones, and controls the lateral movement of groundwater from beneath the site. The intersection of the alluvium with the Garber Sandstone is discussed in more detail in Section 3.0, Site Hydrogeology. Drawing No. 98-XSEC-1 (next page ) is a geologic cross section showing the shallow subsurface stratigraphy underlying the center of the site, and schematically extends north to the Cimarron River.

The deeper stratigraphic units in the area were penetrated by a proposed deep test well that was completed in 1969. This well represents the deepest borehole known to have been drilled in the immediate vicinity of the site. The deep well which was located on the Cimarron facility property near the former uranium plant has been plugged. The depth of the well was 2,078 feet. The well was never permitted or used for injection purposes or other site uses. The top of the geologic unit immediately underlying the Garber Formation, the Wellington Formation, was identified at 200 feet below the ground surface. The Wellington Formation consists of 960 feet of red shale with several thin siltstone beds. The top of the Wolfcampian age Stratford Formation was found at 1,160 feet. It is 870 feet thick and consists of red and gray shale with thin anhydrite beds in the upper part. The lower part of the Stratford Formation is predominately red and gray sandy shale with three porous sandstone members.

### **2.2.1 Geologic Description of the Garber Sandstones/Mudstones Across the site**

The Cimarron Facility is directly underlain by the Garber Sandstone and Wellington Formation. These geologic units collectively form the Garber-Wellington Aquifer.

Three major sandstone units and two mudstone units have been identified in borings drilled at the site. These sandstones have been informally classified (from shallow to deep) as the A, B, and C sandstones (and in some site reports as the 1, 2, and 3 sandstones respectively). Thicknesses range from 30 to 55 feet for each of the sandstones.

The two predominant mudstones (the A and B mudstones) are each about six to 14 feet thick, and separate the A sandstone from the B sandstone, and the B sandstone from the C sandstone, respectively. The mudstones generally are massive, with some zones of thin laminations in the upper portions. The mudstones are less permeable than the sandstones, and retard the vertical movement of groundwater. The sandstone and mudstone units are discussed below.

- Sandstone A: As shown by Drawing No. 98-XSEC-1, the first water bearing sandstone encountered at the site is referred to as Sandstone A. This sandstone consists of up to 25 feet of red-to-tan colored sandstone and silty sandstone on the western half of the site. This sandstone may be well or poorly cemented, and is locally cross bedded. Water level data collected from monitor wells show that the sandstone is fully saturated at the southern boundary (upgradient) of the site. The saturated thickness decreases to the north where groundwater discharges as base flow into small, north-flowing tributaries to the Cimarron River, and at seeps where the

sandstone outcrops along the bluff. Well yield data collected during aquifer tests and well development work indicates that Sandstone A will not support a sustained pumping rate greater than approximately one to two gallons per minute. Areas of this horizon that are impacted by past facility operations are near the extreme north of the facility (e.g., around Uranium Waste Ponds No. 1 and No. 2).

- Mudstone A: As shown by Drawing No. 98-XSEC-1, this sequence of mudstone and silty mudstone ranges in thickness from six feet to nearly 20 feet between Sandstone A from the underlying Sandstone B. Water level data from monitor wells show that this mudstone unit hydrologically separates the two sandstones.
- Sandstone B: As shown by Drawing No. 98-XSEC-1, the second, or intermediate, water bearing sandstone encountered at the site is referred to as Sandstone B. This sandstone, which is similar in lithology to Sandstone A, can be up to 30 feet in thickness on the site. At the eastern edge of the site, Sandstone A has been eroded to the extent that Sandstone B is the first water bearing sandstone encountered. The sequences of sandstones and mudstones in this area are shown by Drawing No. 98-XSEC-2 (next page); which represents the shallow subsurface stratigraphy through the area formally occupied by Burial Area #1.

Water level data collected from monitor wells in this sandstone located at the central and western parts of the site show that the saturated thickness decreases to the north where groundwater discharges to both the alluvium of the Cimarron River and to seeps in cliffs overlooking the river flood plain. At the eastern portion (Burial Area # 1) of the site, Sandstone B generally discharges to

the north to the alluvium. Well yield data collected during development work indicates that Sandstone B will not support a sustained pumping greater than approximately one to two gallons per minute. Areas of this horizon that are impacted by past facility operations are near the extreme north of the formation (i.e., around Burial Area No. 1).

- Mudstone B: As shown by Drawing No. 98-XSEC-1, this sequence of mudstones ranges in thickness from six feet to 14 feet between Sandstone B and Sandstone C. Water level and water quality data from monitor wells show that this unit hydrologically separates Sandstone B from Sandstone C.
- Sandstone C: As shown by Drawing No. 98-XSEC-1, all sandstones underlying the Mudstone B confining layer are collectively referred to as Sandstone C. This sequence of interlayered sandstones and mudstones is at least 100 feet in thickness beneath the Cimarron site. The base of the fresh water zone as defined by the USGS, is found within the shallow-most strata of Sandstone C. Water-level data collected from monitor wells constructed at various depths in this horizon show that the sandstone is fully saturated, with pressure heads that increase with increasing depth. Given the elevations of the potentiometric surface, Sandstone C is discharging into the Cimarron River as base flow. The base of the high salinity interface was found in the deeper strata of Sandstone C at a depth of 190 feet below grade.

### **2.2.2. Description of Sandstones**

All three sandstones encountered during the numerous investigations can be described as generally fine to very fine grained with well sorted subangular to rounded grains. Variable silt content was observed in the

sandstones. The estimated silt content ranges from less than 10 up to 50 percent. Where the silt content is high, distinction between sandstone and siltstone is difficult. The sand grains are virtually all quartz, with minor amounts of potassium feldspar and occasional mafic grains such as magnetite. Micas are minor constituents. Intergranular porosity is generally good, though obviously varies with silt content.

The sandstones typically are weakly cemented and friable. The cementing agents appear to be calcite and hematite; however, silt and clay-sized fractions in the matrix may also contribute to cementation. Thin intervals are present occasionally that are well cemented and hard. These intervals are frequently conglomeratic with gypsum and possibly barite providing additional intergranular cement. The sandstones often are cross-stratified with thin, silty laminae. The cross-stratification is planar and is indicative of deposition in a fluvial/deltaic system. Cross stratification was usually found near the middle of the sandstone intervals.

### **2.2.3 Description of Mudstone**

Separating the sandstones are fine-grained, silty and shaley beds. These beds were identified in the field as mudstones, a generic description inferring their origin. Stratification within the mudstones is largely absent and they lack the fissile nature characteristic of shales.

The mudstone units typically are poorly consolidated as indicated by the tendency for core samples to deteriorate rapidly. The mudstone cores have a consistency more like a very stiff to hard sandy silt or clay than rock, even at depths greater than 100 feet below ground.

Encapsulating the mudstone layers were thin, bluish-gray zones or layers that ranged from less than 0.1 inches to over 4 inches in thickness. These layers tentatively were identified in the field as "reduction zones."

Reduction spots were also observed. This phenomenon is common in red bed formations and therefore is not considered unique to the site. In the subsurface at the facility, the thickness of the bluish-gray layers is directly proportional to the thickness of the silt and clay-rich layers they bound.

The reduction zones may represent intervals where ferric compounds have been reduced to ferrous compounds. Ferrous iron is much more soluble and more easily removed or transported by ground water. Al-Shaieb (1977), attributed the reduction of ferric iron to a reaction with hydrogen sulfide produced either by the contact of sulfate with hydrocarbons, or hydrogen sulfide released directly from naturally occurring hydrocarbons.

#### **2.2.4 Chemical Environments**

The chemical environment underlying the site is characterized by the chemistry of the unsaturated and saturated zones of the A, B, and C sandstones. The unsaturated zone environment will be dominated by the chemistry of the soils and rock strata. The saturated zone will be dominated by the chemistry of the ground water.

Groundwater at the site is oxygenated and slightly alkaline. The strata appear oxidized and have a relatively low cation exchange capacity. The organic content of the strata is negligible.

### **2.3 References**

Al-Shaieb, 1977. Uranium Potential of Permian and Pennsylvania Sandstones in Oklahoma: American Association of Petroleum Geologists Bulletin, Volume 61, 1997.

Engineering Enterprises, 1973. Hydrological Information in the Vicinity of the Kerr-McGee Facility, Logan County, OK.

Grant, James L., 1989. Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September 12, 1989.

Wood and Burton, 1968. Groundwater Resources in Cleveland and Oklahoma Counties, Oklahoma: Oklahoma Geological Survey Circular, 71.

### **3.0 HYDROLOGY**

Exploitable groundwater in the central Oklahoma region occurs principally in the Permian-aged Garber/Wellington Aquifer. The Oklahoma Geological Survey groups the Garber and Wellington formations together as a single hydrologic unit on the basis of similar lithologies and water-bearing characteristics (Bingham and Moore, 1975).

The EPA (40 CFR 270) and the NRC (10 CFR 40, Appendix A) both define an aquifer as "a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs." This definition, unfortunately, makes no specific reference to water quality, nor does it define the term "significant." Therefore, in areas where a widely used and recognized aquifer is present, other water-bearing zones that may yield lesser amounts of water, or water of poorer quality, become less important, although they may still meet the regulatory definition of aquifer. In such instances where lesser yields are present, important considerations become those of locations of impacts, availability of better sources of water, and potential for habitation. As indicated by a wide range of data, Cimarron believes the shallow and deeper groundwater at the site does not represent a potentially useful, viable or sustainable source of potable water – particularly with regard to consideration of higher quality alternate local sources of water (reservoirs and local water district). Data that supports this position, including information regarding regional and local hydrology, well yields, groundwater and surface water quality, and other sources of water are discussed in the following sections.

#### **3.1 Regional Hydrogeology**

The water-bearing sandstones in the region are fine-grained and friable, with interbedded siltstones, mudstones and shales. North of Oklahoma County and into Logan County (where the site resides), the Garber-Wellington Aquifer thins and becomes more fine-grained. This

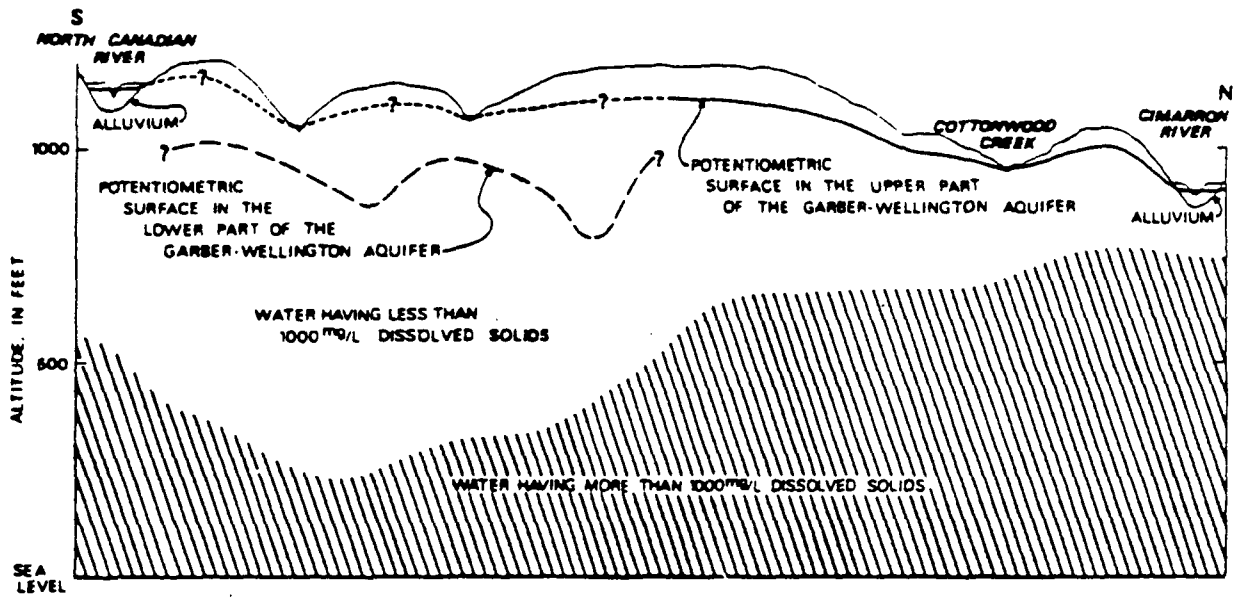


characteristic results in low aquifer permeability, resulting in a low amount of water that can be produced from the aquifer.

Generally, the sandstones in the Garber-Wellington are lenticular and thin. Their lenticular nature creates an environment within which water quality and quantity can differ greatly from one location to another (Engineering Enterprises, 1973). For example, yields from six Garber Sandstone wells near the site ranged from 20 to 90 gallons per minute (gpm), with hardness ranging from 212 to 2,240 parts per million (ppm) and chloride ranging from 26 to 3,155 ppm (Engineering Enterprises, 1973). Monitoring wells on the site show similar ranges of constituent concentrations, but less yield, and are discussed in greater detail in Section 3.2.

### **3.1.1 Regional Groundwater Movement**

The regional groundwater movement in the Garber-Wellington Aquifer depends on the depth of the groundwater. There are two major changes in the groundwater with depth. First, water-table (unconfined to semi-confined) conditions generally exist in the upper 200 feet in the area where the Garber-Wellington Aquifer crops out. Below 200 feet, and where the aquifer is saturated, the groundwater is typically under confined conditions. Second, there is a fresh-water/salt-water interface within the Garber-Wellington Aquifer. The elevation of this interface ranges from about 250 feet above mean sea level (fmsl) in the south to 850 fmsl in the north (near the site). The fresh/saline interface is about 190 feet below the ground surface in the vicinity of the site. This interface is shown on Figure 3.1.



SOURCE CARR AND MARCHER, 1977

FIGURE 3.1  
 CONTACT DEPTH OF WATER CONTAINING  
 IN EXCESS OF 1,000 PPM TDS

Groundwater in the shallow portions of the aquifer predominantly flows laterally and discharges to surface drainage pathways formed by the major rivers and streams. Upward flow near the discharge locations has been interpreted from potentiometric surface measurements of shallow groundwater (Carr and Marcher, 1977). This discharge maintains flows in the major rivers and some larger streams, even during dry periods. The movement of groundwater in the terrace and alluvial deposits is toward the surface drainages followed by rivers and streams. At the site, this flow is toward the north, culminating in the Cimarron River.

There are few potentiometric measurements in the lower part of the aquifer; some water-level data are available in the Oklahoma City area, several miles south of the site. Based on these measurements, deep groundwater (e.g., groundwater below that whose flow is influenced by the river channels, or below about 200 feet) movement is believed to be generally down-dip in a west- southwesterly direction.

### **3.1.2 Regional Groundwater Recharge/Discharge**

Groundwater movement is controlled by local and regional recharge and discharge locations. The movement of groundwater in regional and local systems has been examined by Toth (1963) and Freeze and Witherspoon (1967). The local system overlays the regional groundwater system. The large river systems form the regional discharge locations, while local discharges may occur at smaller streams, as well as at the regional discharge locations. One characteristic of a recharge location is that the hydraulic head decreases with depth (downward flow), while in a discharge area, the hydraulic head increases with depth (upward flow).

Regional recharge to the Garber-Wellington Aquifer is primarily by the lateral movement of groundwater from outcrop areas located upgradient and to the east and south of the site. The principal recharge area for

precipitation and infiltration in the outcrop area for the Garber-Wellington has been identified as being north of the Canadian River, south of Guthrie, east of the Canadian County line and west of Shawnee (Johnson, 1983).

Johnson (1983) determined that surrounding the known recharge area is an area termed a "potential recharge area". The potential recharge area is a buffer surrounding the known recharge area, and includes any regions that may recharge to the aquifer that are unknown or not mapped. Johnson indicated that the potential recharge area extends about four miles beyond the recognized recharge area. The Cimarron site is located at the edge of the potential recharge area, and quite possibly beyond the limit of this potential recharge area.

Groundwater recharge has been estimated to be between five and ten percent of annual precipitation (annual precipitation is about 30 to 33 inches per year (in/yr) in the immediate vicinity of the site) (Carr and Marcher, 1977). Annual precipitation in the Oklahoma City quadrangle, which includes the site, ranges between about 28 and 41 in/yr. Actual evapotranspiration is on the order of 24 to 30 in/yr, with runoff ranging between 2.5 and 8 in/yr. Thus, an estimated 1.5 to 3.5 in/yr of precipitation is available for recharge (Bingham and Moore, 1975).

Natural regional discharge from the shallow portions of the Garber-Wellington Aquifer (as defined earlier) in the site area is to the Cimarron River and feeding stream drainages, as indicated by troughs in the potentiometric surface along the valleys of the Deep Fork, Bear Creek, Cottonwood Creek and the Cimarron River. Carr and Marcher (1977) indicate that upward flow occurs in areas where major streams, such as the North Canadian River, are entrenched into the aquifer, and where groundwater discharges to the alluvium. They also indicate that this situation is analogously occurring in the vicinity of the Cimarron River.

The locations of points or areas of discharge from the deeper portions of the Garber Wellington Aquifer are unknown, but are presumed to be outside of the central Oklahoma region (Carr and Marcher, 1977). Discharge from the shallower portions of the aquifer are to the rivers and streams that form the local discharge locations. This difference in discharge characteristics demonstrates a separation of the shallower and deeper flow zones in the Garber-Wellington Aquifer.

### **3.2 Site Hydrology**

Groundwater is found in two types of geologic deposits found at the site including the Quaternary aged alluvial deposits found beneath the river and floodplain of the Cimarron River and in sandstone bedrock units of the Permian-aged Garber Sandstone. The Garber Sandstone contains interbedded sandstones, mudstones, and shales. The Garber Sandstone forms the bedrock formation that outcrops in upland areas bordering the Cimarron River. The alluvium was deposited in a deep channel that was cut into the Permian bedrock.

Groundwater in the Garber Sandstone can be divided into two water bearing zones including a shallow zone which includes groundwater found in Sandstones A and B and a deeper zone associated with Sandstone C. Groundwater in the shallow zone at the site is recharged from upland sources, and from on-site reservoirs and from infiltration from precipitation. Groundwater in the deeper zone is recharged regionally at upland outcrops areas found in areas east of the site.

Shallow groundwater in Sandstones A and B discharges to a series of seeps found in the cliffs and bluffs that are found adjacent to the floodplain of the Cimarron River. Deeper groundwater found in Sandstone C discharges to the alluvium deposits associated with the Cimarron River.

Groundwater found in the lower portions of Sandstones B also discharges to the river alluvium.

These groundwater flow systems are discussed in greater detail in the following sections.

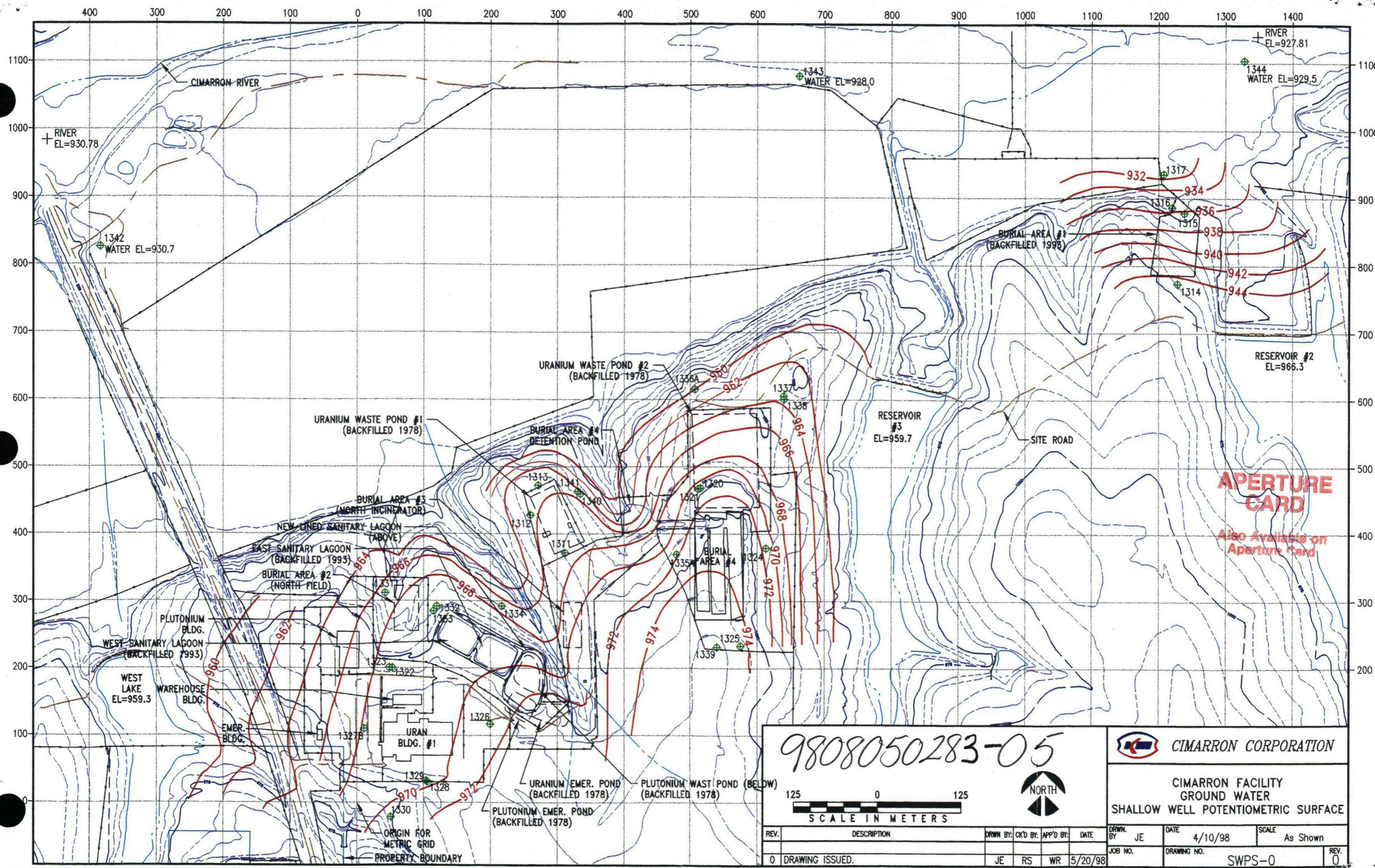
### **3.2.1 Site Groundwater**

Shallow groundwater under the site occurs under water table and partially confined conditions. The depth to water in the shallow wells ranges from about 10 to 40 feet below ground level. Drawing No. SWPS-0 (next page) is a map of the potentiometric surface for the shallow groundwater, and illustrates the general elevations of the groundwater within this zone. The groundwater contours shown for the western portion of the site represent groundwater located within Sandstone A; the contours shown for the eastern area of the site represent groundwater located within Sandstone B.

All the rocks below the shallow water table are saturated. The deep wells were screened in a confined sandstone (Sandstone C) that occurs approximately 100 feet below the ground surface. Drawing No. DWPS-0 (page 3-9) is a map of the potentiometric surface defined by the deep wells, and also illustrates the general elevation of groundwater within this deeper zone.

#### **3.2.1.1 Site Groundwater Movement**

Shallow groundwater flow (Sandstones A and B) is influenced by local topography and surface water bodies. Seepage faces are present along the eroded slope found along the south side of the Cimarron River floodplain. In the vicinity of Well 1334 (see Drawing No. SWPS-0), seepage occurs at an elevation of about 964 feet with standing water occurring in a marshy area at an elevation of about 960 feet. The incised

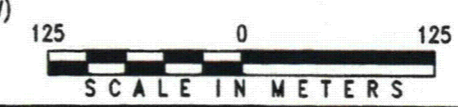


**APERTURE CARD**  
 Also Available on Aperture Card

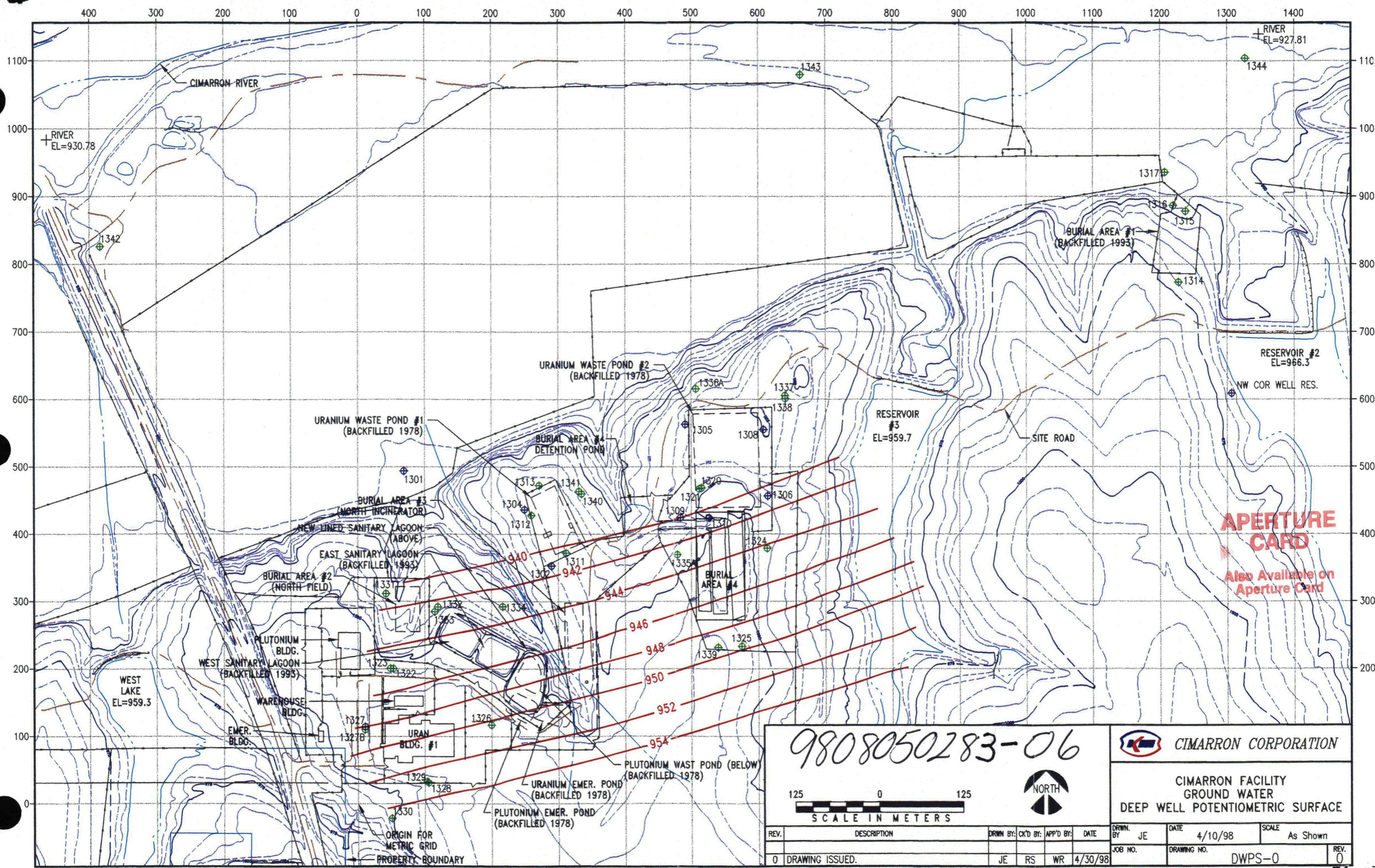
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**CIMARRON CORPORATION**


**CIMARRON FACILITY  
 GROUND WATER  
 SHALLOW WELL POTENTIOMETRIC SURFACE**



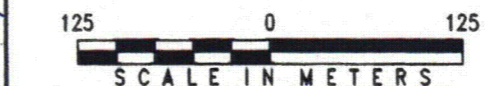
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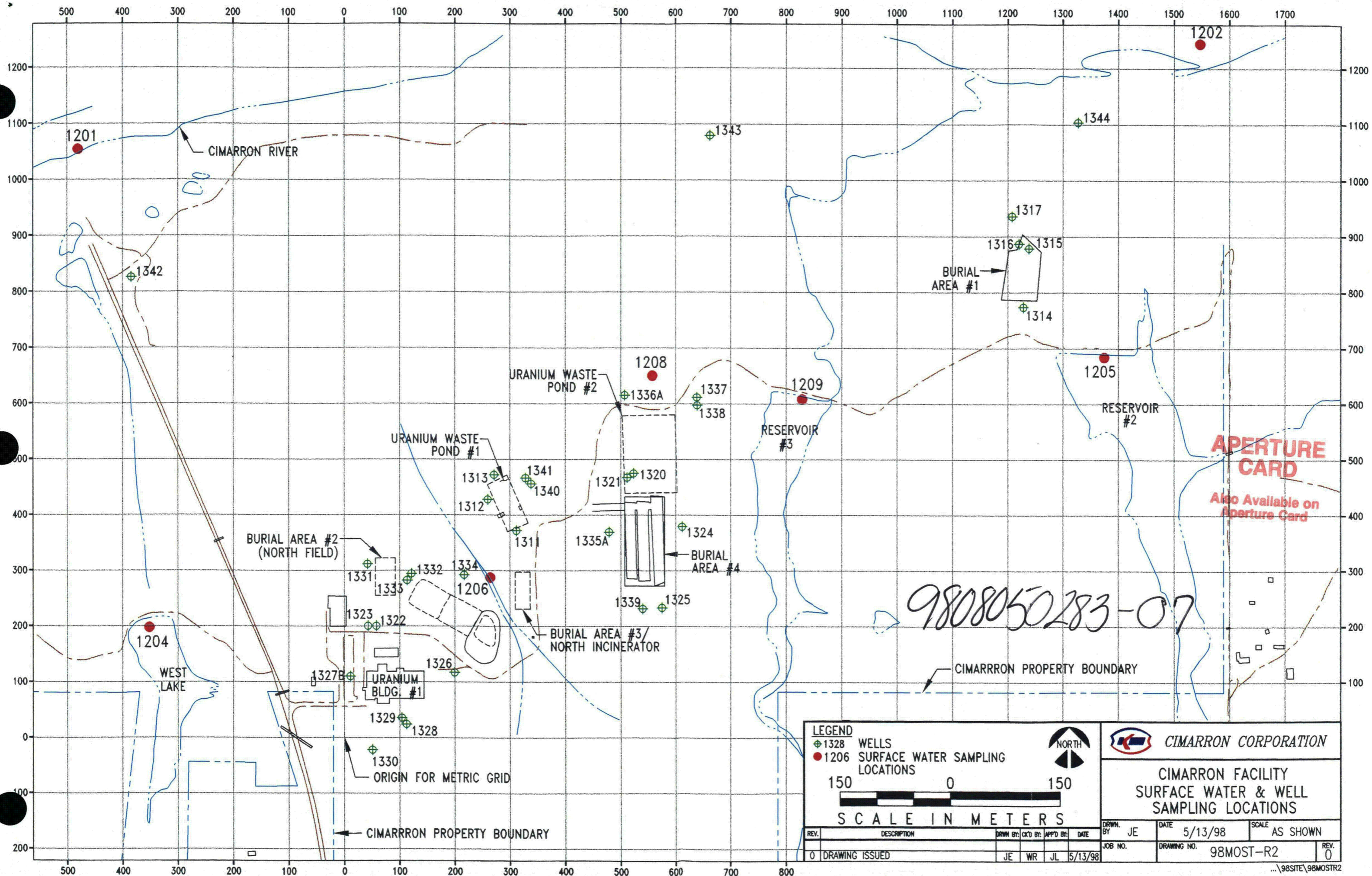
 CIMARRON CORPORATION

CIMARRON FACILITY  
GROUND WATER  
DEEP WELL POTENTIOMETRIC SURFACE



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**LEGEND**  
 ◆ 1328 WELLS  
 ● 1206 SURFACE WATER SAMPLING LOCATIONS

**SCALE IN METERS**  
 150 0 150

**CIMARRON CORPORATION**  
**CIMARRON FACILITY**  
**SURFACE WATER & WELL SAMPLING LOCATIONS**

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drainages and bluff overlooking the river's floodplain exert local influences on shallow groundwater flow.

The piezometric surface determined from shallow monitoring wells (represented by Drawing No. SWPS-0) and deep monitoring wells (represented by Drawing No. DWPS-0) indicates groundwater flow in the Garber Sandstone is generally north-northwest toward the Cimarron River. This local condition is contrary to the general regional westward flow direction in the Garber-Wellington Aquifer (as discussed in Section 3.1.1 above). The movement of groundwater from both the shallow (Sandstones A and B) and deeper (Sandstone C) monitored zones beneath the site is toward the Cimarron River. This indicates that both zones monitored at the site are part of a shallow (near-ground surface) groundwater flow regime, and discharge is to the bluffs or to the alluvium north of the site (Cimarron River).

The groundwater gradient for the shallow groundwater zone averages approximately 0.025 (unitless) except where it steepens as a result of proximity to discharge areas. Groundwater from the confined aquifer screened by the deep wells (Sandstone C) flows at a gradient of approximately 0.014. This deeper groundwater interval is at an elevation that indicates it recharges directly to the Cimarron alluvium and contributes to the base flow of the Cimarron River.

Each of the sandstone units discussed above in Section 2.2.1 contains discontinuous mudstone or siltstone layers that may affect the movement of groundwater through the aquifer. The mudstones typically have a consistency of very stiff to hard sandy silt or clay even at depths greater than 100 feet. As illustrated by the piezometric surface (Drawing No. SWPS-0), there is a net downward vertical potential between the upper water table aquifer and the lower confined units. However, based upon

extensive site borings and investigations, there are significant confining mudstone layers separating the lower confined groundwater zones from the more shallow stratum. These mudstone layers promote lateral flow north toward the seeps and river alluvium. The intersection of the alluvium with the underlying sandstones creates discharge zones for the sandstones and this further influences and controls lateral movement of the groundwater.

Four wells completed in the shallow sandstones confirm that a confining layer exists between Sandstones A and B. Well #1337 (Sandstone A) was installed adjacent to Well #1338 (Sandstone B). For well locations see Drawing No. 98MOST-R2 (next page). Groundwater elevations of 965 MSL verses 942 MSL were noted respectively between the two wells. Similarly, Well #1340 (Sandstone A) and Well #1341 (Sandstone B) show elevations of 961 MSL and 936 MSL respectively. These elevation differences indicate a downward component of flow, but also suggest that Mudstone A acts as a hydrological barrier layer between Sandstones A and B. Also, these elevations provide additional data indicating that groundwater in Sandstone A is unconfined and flows laterally northward, discharging to the bluffs overlooking the south bank of the Cimarron River; and that groundwater in Sandstone B also discharges north to both the bluffs and the Cimarron River alluvium (see Drawing No. 98-XSEC-1, page 2-5).

Groundwater in Sandstone C is confined throughout the site. In addition to the increasing pressure heads with increasing depth, analytical data illustrates that the intervening mudstones act as confining layers. This analytical data is discussed in Section 3.4.2.3.

During installation it was noted that the groundwater level for Well #1339 (completed to a depth of 218 feet in the deeper part of Sandstone C), was

higher than that recorded in the upper Sandstone C strata. This increased pressure head indicates an upward component of flow, and supports the projections that the Cimarron River is a discharge location for the deeper groundwater. Also, these data show that the discharge pathway of the deeper groundwater (Sandstones C and below) forms a hydraulic barrier to the potential downward migration of the near surface groundwater.

Groundwater quality data for Well #1339 shows that the base of the freshwater interface occurs at a depth of 190 feet below grade surface. Groundwater in this zone (>11,000 mg/L TDS) contributes to the already poor quality of the Cimarron River.

In summary, there are effective confining mudstone strata between each of the groundwater zones of Sandstones A, B, and C. These mudstones influence the lateral flow of groundwater and act to limit the potential downward migration of shallow groundwater found in the A and B sandstone units. Shallow groundwater in the A and B sandstones units generally discharges to the incised drainage pathways and seeps found in the low-lying bluffs and cliffs that border the floodplain of the Cimarron River. Deeper groundwater in both Sandstone B and C discharges to the alluvium deposits that underlie the Cimarron River and the adjoining floodplain. As reported in Section 3.4.2.2, deeper groundwater is of poor quality as a result of high TDS. The water of the Cimarron River is also of poor quality as a result of generally higher TDS.

#### **3.2.1.2 Hydraulic Properties of Water Bearing Strata**

Hydraulic conductivities of the Garber Formation sandstones generally are moderate. The sandstones are poorly cemented and show few diagenetic effects. The primary porosity and permeability restrictions are the variable amounts of fines present in the sandstones. Inspection of outcrops at the

site and core samples revealed minimal jointing indicating that the effect of fractures on hydraulic conductivities is expected to be low.

The hydraulic conductivity of the shallow aquifer (Sandstones A and B) ranges from  $2.3 \times 10^{-4}$  cm/sec to  $3.0 \times 10^{-3}$  cm/sec. The mean of the measured values is  $1.01 \times 10^{-3}$  cm/sec. The transmissivity of this aquifer ranges from 9.9 ft sq/day to 108 ft sq/day.

The hydraulic conductivity of the deep aquifer (Sandstones C) ranges from  $2.0 \times 10^{-5}$  cm/sec to  $1.0 \times 10^{-3}$  cm/sec, with a mean of  $4.4 \times 10^{-4}$  cm/sec. The transmissivity ranges from 4.6 ft sq/day to 254 ft sq/day.

### **3.2.2 Site Groundwater Recharge/Discharge**

Aquifer tests indicate that there is no significant hydraulic connection between Garber sandstone layers that are separated by shale layers (Wood and Burton, 1968). This hydraulic separation between water-bearing sandstones has been confirmed at the site as described earlier. During unusually heavy precipitation in 1985, there was no noticeable impact upon water levels in site monitoring wells completed in shallow sandstones separated by mudstones (Sequoyah, 1985). Bingham and Moore (1975) attribute the poor response to precipitation changes shown by well hydrographs to the poor communication of the sandstones with the surface or the recharge areas being a considerable distance from the well.

The site is located upgradient of a system of low-lying bluffs located adjacent to the Cimarron River. As discussed in Section 3.2.1.1, the bluff that borders the river floodplain influences the movement of shallow groundwater at the site. An evaluation of the shallow and deeper potentiometric surface maps for the site indicates that the groundwater flow direction for both is toward the Cimarron River. The lowest potentiometric elevation in the shallow monitoring well (Sandstone A)

nearest to the river is about 960 fmsl (see Drawing No. SWPS-0). The lowest potentiometric elevation in the deeper monitoring wells nearest to the river is about 940 fmsl (see Drawing No. DWPS-0). The elevation of the Cimarron River at normal flow is 927 to 930 fmsl near the site. The elevation of the floodplain is about 940 fmsl (Engineering Enterprises, 1973). Seepage faces are present along the bluffs just above the Cimarron River floodplain (NRC, 1994). Seeps and standing water similarly are reported at elevations between 960 and 964 fmsl (NRC, 1994). The river stage is lower than the potentiometric surface for the shallow and deep monitoring wells at the site. This finding suggests that groundwater in both Sandstones B and C are hydraulically linked to the river and groundwater in these units discharges to the floodplain alluvium and the river. Whereas, groundwater in Sandstone A and the upper portion of Sandstone B discharges to a series of seeps found along the bluff just south of the river.

A hydrologic water balance has been performed for the site. The analysis followed the procedures presented in EPA/530/SW-168. The study focused on the soil types that comprise the surface at the site, and whether those soils contributed to rapid runoff or allowed percolation. Three soil types were identified at the site, the compositions of which typically generate high runoff and preclude rapid infiltration. Water availability was represented by total precipitation, while water loss was represented by evapotranspiration, surface runoff, and soil moisture storage. The average recharge of shallow groundwater to underlying strata is estimated to be low (5 to 10 percent of annual precipitation). Significantly, evaluation of potential recharge at the site suggests that no significant seepage occurs in years of average precipitation, but seepage could occur in years of above-average precipitation (Lower, 1989).

Additionally, the analyses by Toth (1963), Freeze and Witherspoon (1967), support the interpretation of local discharge to seeps and to the Cimarron River. Groundwater in the shallow Garber sandstones underlying the site, and surface water that infiltrates through the site moves laterally toward the Cimarron River, and does not become part of the recharge to the deeper Garber-Wellington Aquifer.

### **3.3 Surface Water Hydrology**

The principal surface-water bodies at the site are the three reservoirs indicated on the site map and the Cimarron River (see Drawing No. SWPS-0).

#### **3.3.1 Local Surface-Water Bodies – Reservoirs**

The water elevation of the three reservoirs was determined at the time the monitoring wells were surveyed in 1989. The water elevations (i.e., spill way elevations) for Reservoirs 1, 2, and 3 at that time were 959.3, 966.3, and 959.7 feet above mean sea level, respectively.

The three reservoirs appear to influence shallow groundwater flow at the site. Reservoirs 1 and 3 have water levels significantly below the water table in the nearest wells indicating that shallow groundwater maintains the water level of these reservoirs and hence provides the base flow for the streams that exit the reservoirs.

#### **3.3.2 Cimarron River**

As discussed in Section 3.2.1.1, groundwater contained in the confined Sandstones located under the site (i.e., Sandstone B and C) and the deeper high salinity groundwater discharges to the Cimarron River as base flow. The groundwater elevations show that the discharge pathways of the deeper groundwater (Sandstone C and below) forms a hydraulic

barrier to the potential downward migration of the near surface groundwater.

The movement of groundwater through the Garber-Wellington Aquifer is dependent upon depth and location. As shown on Figure 3.1 (page 3-3), the principle component of groundwater movement in the shallow sand-bearing units of the Garber-Wellington Aquifer is lateral from recharge areas along surface outcrops to points of discharge along exposures in stream valleys. Figure 3.1 shows that the ultimate point of discharge for the shallow groundwater in the vicinity of the Cimarron Facility is the Cimarron River. The movement of groundwater in the deepest portions of the Garber-Wellington Aquifer is thought to be down dip toward the southwest.

### **3.4 Background Groundwater Quality**

As discussed in the previous sections, there are two main occurrences of groundwater in the area of this site south of the Cimarron River. Groundwater is present both in the Garber sandstone and the floodplain alluvium adjacent to the Cimarron River. These occurrences are discussed separately.

#### **3.4.1 Regional Groundwater Quality**

The primary groundwater occurrence in the vicinity of the Cimarron facility is within the Garber Sandstone and Wellington Formation. The water-bearing portions of these formations are collectively known as the Garber-Wellington Aquifer. These formations were deposited by streams in a delta that occupied central Oklahoma during the Permian Age.

Figure 3.1 (page 3-3) shows the base of fresh water/salt water interface in the Garber-Wellington Aquifer, which is defined by the U. S. Geological Survey as groundwater having a total dissolved solids (TDS) of more than



1,000 mg/L. The source of the fresh water is meteoric water derived from the infiltration of precipitation, while the salt water is derived from connate water trapped in deeper sediments deposited in a marine environment. The base of the fresh water/salt water interface is deepest beneath Oklahoma County, where much of the recharge occurs, rising to a more shallow depth (about 190 ft below grade) to the north where recharge is less and the Garber-Wellington Aquifer discharges into the Cimarron River.

### **3.4.2 Site Groundwater Quality**

Background groundwater quality has been addressed by two reports (Chase, 1996 and Cimarron 1997) previously submitted to the NRC; these reports demonstrate that water quality varies substantially across the site and with depths on site. Historical groundwater analytical data are discussed in the following sections.

#### **3.4.2.1 Shallow Groundwater Quality**

The shallow groundwater zones, identified as Sandstones A and B, contain groundwater from local recharge that flows predominantly laterally north toward the Cimarron River and to the sandstone outcrops located along the northern bluffs. The water quality within these zones is generally fair because they have been influenced by local precipitation and surface water recharge. The ranges of onsite background groundwater quality data for Sandstones A and B are shown in Table 3.1. Wells #1314 (Sandstone B) and #1325 (Sandstone A) are located upgradient from past site operations, and are considered background wells.

Although not included in Table 3.1, background isotopic total uranium concentrations can be determined from historic data. Total isotopic uranium for Well #1314 has ranged from 1.4 pCi/L to 2.3 pCi/L with an

average of 2.0 pCi/L. Total isotopic uranium for Well #1325 has ranged from 1.7 pCi/L to 2.5 pCi/L with an average of 2.3 pCi/L. These average values would indicate that background uranium is similar for both Sandstone A and B.

TABLE 3.1  
RANGE OF VALUES FOR SELECT  
CONSTITUENTS FOR BACKGROUND WATER QUALITY  
SANDSTONES A AND B

Background Water Quality	Shallow Wells #1314 and #1325	
	Grant Data 1989	1996 Data
Hardness (mg/L)	253 - 284	228 - 522
Calcium (mg/L)	65 - 74	55 - 120
Magnesium (mg/L)	22 - 24	22 - 54
Sodium (mg/L)	16 - 22	21 - 44
Bicarbonate (mg/L)	336 - 402	200 - 230
Chloride (mg/L)	8 - 16	7 - 16
Sulfate (mg/L)	8 - 10	8 - 11
Fluoride (mg/L)	1.0	0.31 - 0.64
Nitrate/Nitrite (mg/L)	9 - 14	1.80 - 9.30
Specific Conductance (µmho/cm)	900	500-600

Additionally, Sandstone A Wells #1324 and #1335 can be included in the background water quality data set because, historically, they have been upgradient of the BTP Option #2 cell established in early 1995. Total isotopic uranium for Wells #1324 and #1335 have averaged 1.5 pCi/L and 2.3 pCi/L respectively (with a range of 0.7 pCi/L to 3.7 pCi/L), which are indicative of background uranium concentrations noted in the other Sandstone A and B wells.

#### 3.4.2.2 Deeper Groundwater Quality

Well #1328, which is completed in Sandstone C, can be considered an upgradient well; it monitors the deeper groundwater zones which are not

considered impacted by prior site operations. Background water quality data for this well is shown in Table 3.2. Analytical results from three other deep wells completed in Sandstone C also are included in Table 3.2.

Although not included in Table 3.2, the historical total isotopic uranium concentrations have remained fairly constant. Total isotopic uranium for Well #1328 has averaged 34.0 pCi/L during the period of 1989 to 1997 with a range of 27 to 44 pCi/L.

TABLE 3.2  
GROUNDWATER ANALYTICAL RESULTS FOR  
SELECTED CONSTITUENTS SANDSTONE C WELLS

	Well Numbers			
	MW1321	MW 1323	MW 1328	MW 1332
Depth (ft.)	122	127	135	116
Hardness (mg/L)	1,698	1,641	1,634	1,751
Calcium (mg/L)	550	530	500	550
Magnesium (mg/L)	78.9	77.1	93.5	91.8
Sodium (mg/L)	65.2	244	127	300
Bicarbonate (mg/L)	223	149	149	137
Chloride (mg/L)	42.0	180	135	400
Sulfate (mg/L)	1,920	2,480	2,310	2,500
Fluoride (mg/L)	0.2	0.2	0.2	0.2
Nitrate/Nitrite (mg/L)	1.01	1.77	2.14	1.82
Spec. Cond. (mho/cm)	2550	3,700	3,440	44,260
TDS (mg/L)	2,660	3,490	3,270	4,090

Well #1321 has averaged 18 pCi/L, and Well #1320 (adjacent to Well #1321 and completed in Sandstone A) has remained fairly constant at an average of 3.7 pCi/L. Likewise, fluorides in Well #1321 have remained, in general, fairly constant at background levels (<1 mg/L) further indicating that this deeper zone has not been impacted by prior site operations and that the intervening mudstones act as confining layers.

Total isotopic uranium for both wells (i.e., #1321 and #1328) has ranged from 11 pCi/L to 44 pCi/L, which is considered within background variances for this deeper sandstone layer.

### 3.4.2.3 Water Quality Varies With Depth

As discussed in the previous sections, the shallow groundwater zones represent the part of the aquifer that carries modern recharge, while the deeper zones contains saltier formation (connate) water remaining from the original depositional environment. Changes in water quality with depth are discussed in this section.

The total isotopic uranium concentrations for the two shallow Sandstone A and B background wells, and the five deeper Sandstone C wells, are summarized in Table 3.3. The monitoring well data indicates that background groundwater total uranium concentrations increase with depth.

TABLE 3.3  
TOTAL ISOTOPIC URANIUM CONCENTRATIONS

Well Location	Total Uranium Concentrations (pCi/L)
Sandstone A	
Well #1325	1.7 – 2.5
Sandstone B	
Well #1314	1.4 – 2.3
Sandstone C	
Well #1321	10.5 – 23.7
Well #1323	27.2 – 40.7
Well #1328	27.7 – 43.7
Well #1332	17.6 – 38.4
Well #1339	14.9

Additionally, analytical data shows that background groundwater quality for certain other constituents, other than uranium, becomes poor with

depth indicating a hydraulic disconnect between the sandstone layers (i.e., A/B and C). For example, sulfates in Well #1325 (Sandstone A) are 11 mg/L, whereas in #1321 (Sandstone C) it is 1,900 mg/L. Well #1339 (depth 218 feet), shows sulfates at 3,560 mg/L. Well #1339 is located upgradient to former Uranium Waste Pond #2 (U-Pond #2).

The four wells completed in shallow Sandstone C, in general, showed elevated dissolved solids concentrations (TDS) greater than 1,000 mg/L. The TDS ranged from 2,660 mg/L to 4,090 mg/L. Concentrations of sulfates for the four shallow Sandstone C wells ranged from 1,920 mg/L to 2,500 mg/L. The hardness of the water calculated from the sum of the magnesium and calcium ranged from 1,641 mg/L to 1,751 mg/L. These results indicate very hard water. For these four wells, chloride ranged from 43 mg/L to 400 mg/L. The deeper Sandstone C well, Well #1339, which was completed to a depth of 218 feet below grade, has a TDS exceeding 11,000 mg/L, with chlorides exceeding 3,700 mg/L. The elevated concentration of TDS, chlorides, and sulfates in these wells attest to the low infiltration rate of fresh water into Sandstone C from the upper sandstone layers.

Nitrates also demonstrate that constituents in Sandstone C are at background levels. Since June 1989, nitrates in Well #1321 have historically been approximately 1 mg/L; whereas in Well #1320 concentrations have ranged from 15 to 30 mg/L. Low nitrate concentrations are also found in deep Wells #1323, #1328 and #1332, averaging 1.5, 1.7, and 1.9 mg/L respectively similar to the value found in Well #1321. This is not true for the shallower horizon where nitrates have shown substantial variances across the site and adjacent to the site in the shallowest groundwater zones. The greatest impact to nitrates in the upper zones is attributed to the agricultural activities that have occurred for several years uninterrupted as noted in the next section .

#### **3.4.2.4 Quality of Groundwater Adjacent to Site**

Several wells located adjacent to and upgradient of the site have shown influence from local farming. Wells #1307 and #1303, which are located south (i.e., upgradient) of the operational areas, both near Highway #33, were sampled during the 1970's, 1980's and early 1990's as part of the Cimarron environmental monitoring program. For Well #1307, nitrates/nitrites ranged from 0.3 ppm (0.3 mg/L) to 270 ppm (270 mg/L) from 1971 through 1977. From 1978 through 1991, the results were reported in units of mg/L and varied from 1.0 to 104 mg/L. Well #1303 had concentrations of nitrate/nitrite of 0.98 ppm (0.98 mg/L) to 430 ppm (430 mg/L) from 1971 through 1977. From 1978 through 1986, the results were reported at <1 mg/L to 53 mg/L. The elevated nitrates are believed to be a result of nitrogen fertilizers being used on agricultural fields. Extensive site acreage were used for farming, most typically wheat crops.

The nitrate concentration in Well #1330 has ranged from 172 mg/L down to 35 mg/L (the analytical result of <0.5 mg/L in 1993 was considered erroneous data). This well is located near the edge of a cultivated wheat field and upgradient of any prior production facility operations.

#### **3.4.3 Water Quality of the Cimarron River and Floodplain**

The Cimarron River located north of the Cimarron site, flows toward the east. A considerable thickness of alluvium has accumulated within the flood plain. These alluvial sediments generally consist of sand, silt and gravel.

The Cimarron River, carries large amounts of chlorides from the Big Salt plains area approximately 100 miles upstream from the site. A USGS study (Blaz, 1995) completed for the Cimarron River near Guthrie over a fourteen year period from 1949 to 1963 showed chlorides varying from 136 mg/L to 16,500 mg/L. Another USGS study reviewed all data

collected from the Guthrie sample station up through 1978. For the samples analyzed, 98% of the hardness values were greater than 180 mg/L and the average hardness concentration was 710 mg/L. These concentrations result in a hardness classification for the river water as very hard.

The Cimarron Facility environmental monitoring program includes collecting and analyzing samples from upstream and downstream locations. The river was last sampled in June 1997 and showed total uranium concentrations of 8.1 pCi/L for the upstream location (i.e., sample location #1201) and 7.3 pCi/L for the downstream location (i.e., sample location #1202).

#### **3.4.4 Justification for Well Locations On-Site**

The Cimarron facility established an extensive and continuous environmental monitoring program to determine the impact of facility activities on the environment. This program consists of routinely collecting and analyzing air, surface water, ground water, soil and vegetation samples from the site and adjacent areas.

The environmental program includes many monitoring wells installed throughout the facility area for collection of groundwater samples from the shallow, unconfined aquifer which occurs at depths less than 50 feet below ground surface. Well #1311 through #1317 shown by Drawing No. 98MOST-R2 were installed during a site investigation in 1985. Boring logs and well completion information for these wells, hydrologic and geologic data, and analyses of groundwater collection from these wells were utilized by Grant (1989) for planning the 1989 characterization investigation.

Grant's 1989 investigation was conducted to supplement the previous site characterization. A total of eighteen (18) Wells (#1320 through #1336) were installed during the 1989 field investigation. Wells were completed in Sandstone A, Sandstone B, and Sandstone C groundwater zones. Data gathered during this 1989 characterization was utilized to:

- characterize the stratigraphy and lithology of the soils and bedrock strata at the site;
- characterize the aquifer properties including hydraulic conductivity, groundwater flow direction and gradient;
- characterize the groundwater quality and determination of the effects that facility operations may have had on groundwater quality; and
- determine the mobility of radionuclides, particularly uranium, in the subsurface and the ability of subsurface materials to retard migration.

The 1989 Characterization Report (Grant, 1989) was completed as part of Cimarron's application for on-site disposal of NRC Branch Technical Position (NRC, 1981) Option #2 soils. The Report included a presentation of groundwater flow direction for both the shallow and deep groundwater zones.

With the completion of the 1989 well installations, groundwater monitoring wells located upgradient, near, or downgradient to former waste management areas and the uranium plant were in place. This system of wells constitutes the facility's groundwater monitoring program.

In early 1997, five additional wells were installed at the site to further characterize the three designated sandstone layers. Four of the wells completed in Sandstones A and B confirmed that a confining layer exists



between Sandstones A and B. Well #1337 (Sandstone A) was installed adjacent to Well #1338 (Sandstone B), with groundwater elevations of 965 MSL versus 942 MSL respectively. Similarly, Well #1340 (Sandstone A) and Well #1341 (Sandstone B) show elevations of 961 MSL and 936 MSL respectively. These elevations confirm that Mudstone A acts as a confining layer between Sandstones A and B. Also, these well elevations provide further evidence that groundwater in Sandstone A discharges to the cliff north of the site and groundwater in Sandstone B discharges to both the cliff and the Cimarron River alluvium. Groundwater discharging from the cliff north of Uranium Waste Pond #2 is monitored by surface water location #1208.

The fifth Well #1339, completed at a depth of 218 feet, confirmed the thickness of Sandstone C, the depth of the freshwater-saltwater interface, and showed that pressure heads increase with increasing depth. Groundwater in this zone, starting at a depth of 190 feet, shows very high salinity (>11,000 mg/L TDS). Groundwater in this zone contributes to the poor quality of the Cimarron River.

Finally, in late 1997, three shallow wells were installed in the river alluvium next to the Cimarron River. These Wells #1342, #1343, and #1344 were installed to a depth of approximately 25 feet. Data from a separate boring was used to locate the depth of the alluvium deposits.

A review of the potentiometric surface drawings (i.e., Drawing Nos. SWPS-0 and DWPS-0) for the shallow and deep groundwater zones demonstrates the direction of groundwater flow. Based upon the numerous wells installed at the Cimarron site, shallow groundwater was verified to move downgradient in a northerly direction and discharge to the surface as seeps or in the subsurface to the Cimarron River alluvium. Monitoring wells located downgradient from all former waste management

areas are monitoring any shallow groundwater zones that may have been impacted by prior site operations. This system is adequate for continued tracking of the overall progress of site decommissioning and evaluation of residual remaining impacts.

As discussed in Section 3.4.2.2 and 3.4.2.3, environmental monitoring data verifies that groundwater within the deeper sandstone (Sandstone C) has not been impacted by prior site operations. Continued monitoring of this zone is not necessary.

### **3.5 Groundwater Quantity**

At the site, three major sandstone units and two mudstone units have been identified in borings drilled at the site. These sandstones have different hydrologic properties, including the thickness of the saturated material penetrated (see Drawing No. 98-XSEC-1 for illustration).

As discussed in Section 2.0, the mudstones generally are massive, with some zones of thin laminations in the upper portions. The mudstones are less permeable than the sandstones, retard the vertical movement of groundwater, and promote lateral movement toward the sandstone outcrops in the bluffs north of the site (Sandstones A and B), and towards the alluvium of the Cimarron River (Sandstones B and C). The location and thickness of these mudstones have been confirmed by several investigations completed on site.

All three sandstones encountered during the numerous site investigations can be described as generally fine-to very-fine grained with well sorted subangular to rounded grains. Variable silt content was observed in the sandstones. The estimated silt content ranges from less than 10 to up to 50 percent. The sandstones are poorly to well cemented. The primary porosity restrictions are the variable amounts of fines present in the

sandstones. Inspections of outcrops at the site and core samples revealed minimal jointing indicating that the effect of fractures on hydraulic conductivities is expected to be low.

Water generally moves very slowly through fine-grained rocks such as siltstone and mudstone because the openings between the particles are too small to transmit water freely; thus, yields of wells penetrating these lithologic units are small. The substantial silt in the shallow sandstones on-site are reflected by the low transmissivities and low yields measured in the on-site wells.

Sandstone layers in the Garber-Wellington Aquifer to the east and south of the site are fine-to medium-grained, and wells completed in this formation produce greater amounts of water.

### **3.5.1 Potential Groundwater Withdrawal Rate from Wells On Site**

A 24-hour pumping test was performed at the site in 1996 on Well #1325. This well is an upgradient, Sandstone A well. Pre-test analysis of available hydrogeologic data (e.g., hydraulic conductivity, saturated thickness, and lithology) was used to estimate a maximum sustainable pumping rate that could be maintained during the test. Well #1325 was selected for the test because it was expected to be able to sustain a test of 24-hour duration. The predicted pumping rate was on the order of one to two gpm. A Theis analysis (Grant, 1996) predicted a drawdown of about 6.3 feet within 24-hours.

The field results matched postulated results. A sustained pumping rate of 1.2 gpm yielded 6.5 feet of drawdown during the 24-hour test. The data were analyzed using the Jacobs straight-line approximation to the Theis solution. The recovery data from the test also were analyzed using the

Theis recovery solution. These analyses yield similar results, with transmissivity values of about 42 ft<sup>2</sup>/day.

A reduction in transmissivity was observed in the data after 480 minutes of recovery, and yielded a transmissivity value of about 28 ft<sup>2</sup>/day. This reduction in transmissivity is believed to be a result of the lenticular structure in the Garber Sandstone. This suggests that long-term sustainable pumping rates would be less than the 1.2 gpm rate used in the pumping test.

Two additional wells (Wells # 1338 and #1341), which were completed in Sandstone B, indicated from their development that this sandstone also yields relatively little groundwater. Both wells were pumped in an attempt to establish a sustained pumping rate. Well #1338 yielded a rate of approximately 1 gpm, whereas Well #1341 yielded a slightly higher rate of 2-3 gpm. These rates indicate a low transmissivity formation that would probably yield very little water under long-term sustained pumping.

The bluffs overlooking the Cimarron River represents a large discharge zone that continually drains Sandstones A and B. The upper sandstones are no longer saturated as they approach the bluffs. Any water supply wells located in these areas would experience a declining water level because they would be pumping from an already partially dewatered zone.

### **3.6 Alternate Source of Water**

Cimarron believes that an individual (intruder or even a potential resident) would not likely incur the cost to drill a shallow well (or multiple wells) and install a treatment system (to reduce hardness) when there are numerous alternate sources of better quality water and greater volumes readily available. Alternate sources are (1) the established rural water system that presently supplies water to the site and (2) the two large unaffected

reservoirs located on site. The unaffected reservoirs are recharged from shallow groundwater which is upgradient from impacted areas on site. The two reservoirs (Reservoirs #2 and #3) were originally constructed as sources of process/drinking water during site operations in lieu of groundwater which did not provide an adequate supply. The reservoirs were used as the site water supply until the rural water system became available. Of further importance is the belief on Kerr-McGee's part that the governmental system and its associated infrastructure will not fail for any foreseeable future.

### **3.7 References**

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## **4.0 HISTORY OF REMEDIAL ACTIONS/CLOSURES FOR BURIAL AREAS #1 AND #2, AND WASTE PONDS #1 AND #2**

These areas are discussed below in detail due to the fact that groundwater in these distinct areas has been impacted from previous site operations.

### **4.1 Burial Area #1**

Burial Area #1 was constructed in 1965 and was opened in 1966 for disposal of radioactive material in accordance with 10 CFR 20.302. Radioactive waste material buried in this area included drummed thorium contaminated waste from the Kerr-McGee Cushing, Oklahoma Facility in addition to materials from the Cimarron facility operations. Burial Area #1 was closed and capped in 1970. The site burial records reveal that approximately 1,303 kg of depleted uranium, 148 kg of enriched uranium, and 5,555 kg of natural thorium were buried in Burial Area #1 (Cimarron Corporation, October, 1994). Due to soil settling over the Burial Area #1 trenches, an investigation was initiated in 1984 to establish an appropriate remedial action.

In February of 1985, several monitoring wells were installed in the vicinity of Burial Area #1 (i.e. Monitoring Wells #1314 through #1317). In May of 1985, a number of soil samples from nine boreholes around the perimeter of this area were obtained to a maximum depth of twelve feet. In 1986, a borehole gamma scan was completed on the four trenches contained within Burial Area #1 and the immediate area surrounding Burial Area #1. Based upon the sample/survey data and the continued slumping within Burial Area #1, the decision was made to excavate Burial Area #1 and ship the materials to an off-site low-level radioactive waste disposal facility.

From 1986 through 1988, the Burial Area #1 trenches were excavated and all excavated waste was packaged and shipped off-site to a commercial low-level radioactive waste disposal facility. Waste shipment records indicated that approximately 65,000 ft<sup>3</sup> of drummed waste was shipped off-site. Approximately 16,000 ft<sup>3</sup> of contaminated soil (Option #2 concentrations) was also removed and stockpiled in the East U-Yard Area. These contaminated soils were subsequently placed in the NRC approved on-site BTP Option #2 Disposal Cell (ORISE, November 1, 1994).

ORAU performed interim confirmatory surveying and sampling of remediated Burial Area #1 in August of 1988 and highlighted eight (8) locations that required further remediation (ORISE, January 31, 1989). Cimarron Corporation performed additional remediation in these locations. After this additional excavation of Burial Area #1, soil samples were taken from 0 to 4 feet below the excavated depth of Burial Area #1 on a 10-meter by 10-meter grid. This grid sampling/surveying revealed several areas requiring further remediation. An additional 14,000 ft<sup>3</sup> of contaminated soil (Option #2 concentrations) was removed and added to the previously stockpiled contaminated soil (i.e. 16,000 ft<sup>3</sup>) located in the East U-Yard Area. After this remediation was completed, additional soil samples were taken from 0 to 4 feet below the re-excavated depth of Burial Area #1 on a 10-meter by 10-meter grid. These sample results confirmed that Burial Area #1 had been remediated and that any remaining contaminated soils met the BTP Option #1 criteria.

ORAU again performed confirmatory surveying and sampling for Burial Area #1 in December of 1991 and confirmed that Burial Area #1 had been remediated in accordance with the BTP Option #1 criteria (ORISE, January 7, 1991 and ORISE, November 18, 1991). The ORAU Final Report for Burial Area #1 was issued in July of 1992 (ORISE, July 22,



1992). Based upon the ORAU Final Report, the NRC released Burial Area #1 for backfilling with clean soil via License Amendment #9 to SNM-928 (December 28, 1992).

During the period March through July 1993, clean soil was transported and placed in the excavated Burial Area #1. Final grading of Burial Area #1 was completed in July of 1993. Random surface soil sampling of the final graded surface was completed in August of 1993. Detailed information regarding the remediation and closure of Burial Area #1 can be found in Section 7.0 of the Cimarron Radiological Characterization Report (Cimarron Corporation, October, 1994).

#### **4.2 Burial Area #2**

Burial Area #2 was utilized in the early 1970's for the disposal of on-site generated industrial solid waste from Cimarron site activities. During an investigation of this area in 1990, there were indications that radioactive waste materials were present in the waste materials in Burial Area #2. Remediation of Burial Area #2 was initiated in 1991.

Remediation and characterization efforts for Burial Area #2 resulted in the identification and excavation of all BTP Option #2 and Option #4 soils from Burial Area #2. Excavated Option #2 soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. All Option #4 soils were packaged and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Industrial waste removed from Burial Area #2 was also packaged and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed. Additional information regarding Burial Area #2 can be found in Section 8.0 of the Cimarron Characterization

Report (Cimarron Corporation, October, 1994) and in the FSSR for Sub-Area "L" - Subsurface (Cimarron Corporation, May, 1996).

Soil samples were collected in May of 1990 on a 10-meter by 10-meter grid at depths from 0 to 4 feet, in one-foot intervals. Additional soil sampling was performed in 1991, 1994 and 1995 to increase the frequency of sampling to correspond to a 5-meter by 5-meter grid. In addition, samples were also obtained in some areas to depths of up to 6 feet, in one-foot increments, and composited.

Approximately 20,000 cubic feet of Option #4 waste, with an average activity of 300 pCi/g uranium, was excavated and shipped off-site for disposal to a commercial low-level radioactive waste disposal facility. Burial Area #2 was remediated such that all remaining soils were at or below the BTP Option #1 criteria.

The NRC Staff supervised a confirmatory sub-surface sampling effort for Burial Area #2 on October 30, 1996. Based upon the results of this confirmatory sampling effort, the NRC staff approved of backfilling Burial Area #2. During the period January 7-14, 1997, Burial Area #2 was backfilled with clean soil and final grading was completed. Burial Area #2 was remediated such that all remaining soils were at or below the BTP Option #1 criteria.

#### **4.3 Uranium Waste Pond #1**

Uranium Waste Pond #1 was built in September of 1970 and was an asphalt pitch, felt-paper and pea-gravel-lined evaporation pond that was rectangular in shape. Axis measurements along the centerline to the top of the dike were approximately 300 feet by 110 feet. The bottom area was approximately 23,000 ft<sup>3</sup> in size and the capacity was approximately

1,152,000 gallons at a maximum depth of 8 feet (Cimarron Corporation, October, 1994).

The decommissioning of Uranium Waste Pond #1 was initiated in March of 1976 with the construction and installation of a dike across the south half of Waste Pond #1. This constructed dike consisted of a four-foot plywood barrier that was covered with an EPDM liner. This dike was weighted and staked to the bottom and sidewalls of Uranium Waste Pond #1. The installation of this dike enabled the sediments in Uranium Waste Pond #1 to be consolidated into a much smaller area.

Excess water from Uranium Waste Pond #1 was decanted and pumped to Uranium Waste Pond #2 beginning on April 13, 1976 and continuing through April 22, 1976. In April of 1976, water from the Plutonium Emergency Pond and the Uranium Emergency Pond was also pumped to Uranium Waste Pond #1 to facilitate their closure. No visible sludge remained in either the Plutonium Emergency Pond and the Uranium Emergency Pond after all water was pumped to Uranium Waste Pond #1.

The solidification of the sludge remaining in Uranium Waste Pond #1 commenced on July 30, 1976. The solidification process was accomplished by using a pump to fill 55-gallon drums with the contaminated sludges, which were then placed on conveyors adjacent to the mixing operation. After filling the 55-gallon drums with contaminated sludges (approximately 80-85%), a mixer was inserted and Portland cement was gradually added to produce a solidified waste form. Waste solidification operations were completed on October 27, 1976 for Uranium Waste Pond #1.

A total of 865 55-gallon drums (approximately 6,500 cubic feet) of solidified waste sludges from Uranium Waste Pond #1 were generated

which contained approximately 3,000 grams of U-235. This solidified waste from Uranium Waste Pond #1 was shipped off-site to a commercial low-level radioactive waste disposal facility.

Uranium Waste Pond #1 was sampled by Cimarron Corporation, the Oklahoma Department of Health (predecessor agency of the Oklahoma Department of Environmental Quality) and the NRC after completion of the water treatment project and the subsequent sludge solidification. The Oklahoma Department of Health sampled Uranium Waste Pond #1 in October of 1977 and the NRC sampled Uranium Waste Pond #1 in November of 1977. The analysis results from these sampling events were then compared for consistency.

Cimarron Corporation received written permission from the Oklahoma Department of Health to backfill and cover Uranium Waste Pond #1 on March 2, 1978. Cimarron Corporation received written permission from the NRC to backfill and cover Uranium Waste Pond #1 on July 10, 1978. Uranium Waste Pond #1 was subsequently backfilled and covered between August 3, 1978 and November 1, 1978. Uranium Waste Pond #1 was closed by crushing the asphalt liner into the pond. The clay dike material and clean soil was utilized to fill in the depression of approximately four feet.

A December 14, 1978 NRC Inspection Report stated that the burial of the "five liquid effluent retention ponds was completed during the inspection." Initial seeding and fencing were performed between November 2, 1978 and March 20, 1979. Sprigging and fertilization of Uranium Waste Pond #1 was performed from July 18, 1979 to October 30, 1979.

On January 8, 1993, the NRC sent a letter to Cimarron Corporation stating the following: "... the five former wastewater ponds that were

closed in 1978 must be addressed in detail. A thorough characterization of these ponds must be included, and the Decommissioning Plan must describe how you plan to address any contamination in excess of levels acceptable for release for unrestricted use." As a result of this letter from the NRC, Cimarron Corporation initiated an extensive characterization program for Uranium Waste Pond #1.

In March of 1993, a 10-meter by 10-meter grid was established for Uranium Waste Pond #1 and 1-foot composited soil samples were obtained via coring down to a depth of 6 feet. Several samples revealed concentrations exceeding the Option #1 level (i.e. 30 pCi/g) in several locations. Additional samples were collected in these locations down to a depth of 9 feet. In addition, random sampling was also performed on Uranium Waste Pond #1 down to a depth of 12 feet, which demonstrated that total uranium concentrations were below 30 pCi/g below 10 feet in depth. This information is discussed in detail Section 12.0 of the Cimarron Characterization Report.

Additional characterization work was initiated in 1996 to supplement the characterization work performed in 1993. The characterization work initiated in 1996 on Uranium Waste Pond #1 was performed to supplement the original 10-meter by 10-meter grid sampling size, such that the sampling frequency was reduced to a maximum of a 5-meter by 5-meter grid size. The additional composite samples obtained in 1996 were collected in one-foot intervals to a depth of 6 feet. Approximately 1,600 soil samples were collected during these characterization efforts. Offset sampling was also performed in numerous locations to determine the aerial extent of residual concentrations of total uranium.

Based upon reviews of the 5-meter by 5-meter grid sample results, Cimarron Corporation performed additional characterization work.

Twenty-one (21) locations with elevated concentrations of total uranium at the 5-6 foot depth interval were selected for additional offset sampling. These samples were obtained in one-foot intervals to a depth of 10 feet unless rock was encountered and resulted in 780 additional samples being obtained. In 1997, additional 5-meter by 5-meter grid locations were also selected for sampling below 6 feet in depth.

In response to the NRC staff's comments on the Cimarron Decommissioning Plan (Cimarron Corporation, April, 1995) dated July 1, 1997, Cimarron Corporation committed to re-enter and decommission Uranium Waste Pond #1 under the BTP Option #1 criteria as applied through the NRC's guidance on "Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil". The derivation of the enriched uranium guideline values based upon this NRC guidance is discussed in detail in the Cimarron FSSR for Phase III, Sub-Area "O" - Subsurface (Cimarron Corporation, March, 1998) which is currently being reviewed by NRC staff.

A comprehensive review of all the characterization data identified 14 locations with composite sample results exceeding the guideline value developed under the NRC guidance documents (i.e. 220-pCi/g total uranium). Remediation of Waste Pond #1 was performed with a trackhoe excavator. Surface soils were removed to gain access to the contaminated soils with concentrations above the guideline value. Excavation of contaminated soils exceeding the guideline value continued as necessary down to a depth of approximately 12 feet unless rock was encountered. Excavated contaminated soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. Approximately 23,000 cubic feet of BTP Option #2 soils were removed from these 14

locations. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed.

Utilization of the NRC guidance, coupled with Cimarron's desire to assure full compliance, resulted in an additional excavation of soil volumes from Uranium Waste Pond #1 (Uranium Waste Pond #1 was previously excavated in 1976). Additional soil sampling and confirmatory surveys were also performed after these areas were excavated. The complete set of all characterization data for Uranium Waste Pond #1 was evaluated under the NRC's guidance ("Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil") to demonstrate that the soils within Uranium Waste Pond #1 were in compliance with the BTP Option #1 criteria.

#### **4.4 Uranium Waste Pond #2**

Uranium Waste Pond #2 was built in January of 1971. Uranium Waste Pond #2 had a compacted clay bottom liner with EPDM poly-rubber sidewalls anchored at the bottom and the top of the dike. Axis measurements along the centerline to the top of the dike were approximately 405 feet by 270 feet. The bottom area was approximately 90,000 ft<sup>3</sup> in size and the capacity was approximately 3,025,000 gallons at a maximum depth of 4 feet (Cimarron Corporation, October, 1994).

The decommissioning of Uranium Waste Pond #2 was initiated in March of 1976. Excess water from Uranium Waste Pond #1 was decanted and pumped to Uranium Waste Pond #2 beginning on April 13, 1976 and continued through April 22, 1976. Uranium Waste Pond #2 was closed and decommissioned without the removal or solidification of sludge due to the fact that sludge was never generated in Uranium Waste Pond #2.

Uranium Waste Pond #2 was sampled by Cimarron Corporation, the Oklahoma Department of Health (predecessor agency of the Oklahoma Department of Environmental Quality) and the NRC after completion of the water treatment project. The Oklahoma Department of Health sampled Uranium Waste Pond #2 in October of 1977 and the NRC sampled Uranium Waste Pond #2 in November of 1977. The analysis results from these sampling events were then compared for consistency. Cimarron Corporation received written permission from the Oklahoma Department of Health to backfill and cover Uranium Waste Pond #2 on March 2, 1978. Cimarron Corporation received written permission from the NRC to backfill and cover Uranium Waste Pond #2 on July 10, 1978. Uranium Waste Pond #2 was subsequently backfilled and covered between August 3, 1978 and November 1, 1978. Uranium Waste Pond #2 was closed by removing the EPDM poly rubber sidewalls, and the underlying clay dike material and clean soil was utilized to partially fill in the depression of approximately four feet.

A December 14, 1978 NRC Inspection Report stated that the burial of the "five liquid effluent retention ponds was completed during the inspection." Initial seeding and fencing were performed between November 2, 1978 and March 20, 1979. Sprigging and fertilization of Uranium Waste Pond #2 was performed from July 18, 1979 to October 30, 1979.

On January 8, 1993, the NRC sent a letter to Cimarron Corporation stating the following: "... the five former wastewater ponds that were closed in 1978 must be addressed in detail. A thorough characterization of these ponds must be included, and the Decommissioning Plan must describe how you plan to address any contamination in excess of levels acceptable for release for unrestricted use." As a result of this letter from the NRC, Cimarron Corporation initiated an extensive characterization program for Uranium Waste Pond #2.



In early 1993, a 10-meter by 10-meter grid was established for Uranium Waste Pond #2 and 1-foot composited soil samples were obtained via coring down to a depth of 6 feet. Several samples revealed concentrations exceeding the Option #1 level (i.e. 30 pCi/g) in several locations. Additional sampling, including random sampling, was also performed on Uranium Waste Pond #2 down to a depth of 12 feet, which demonstrated that total uranium concentrations were below 30 pCi/g below 9 feet in depth. This information is discussed in detail in Section 12.0 of the Cimarron Characterization Report.

Additional characterization work was initiated in 1996 to supplement the characterization work performed in 1993. The characterization work initiated in 1996 on Uranium Waste Pond #2 was performed to supplement the original 10-meter by 10-meter grid sampling size, such that the sampling frequency was reduced to a maximum of a 5-meter by 5-meter grid size. The additional composite samples obtained in 1996 were collected in one-foot intervals to a depth of 5 feet. Approximately 3,300 soil samples were collected during these characterization efforts. Offset sampling was also performed in numerous locations to determine the aerial extent of residual concentrations of total uranium.

Based upon reviews of the 5-meter by 5-meter grid sample results, Cimarron Corporation performed additional characterization work. Twenty-nine (29) locations with elevated concentrations of total uranium were selected for additional offset sampling. These samples were obtained in one-foot intervals to a depth of 5 feet and resulted in approximately 400 additional samples being obtained.

In response to the NRC staff's comments on the Cimarron Decommissioning Plan (Cimarron Corporation, April, 1995) dated July 1,

1997, Cimarron Corporation agreed to re-enter and decommission Uranium Waste Pond #2 under the BTP Option #1 criteria as applied through the NRC's guidance on "Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil". The derivation of the enriched uranium guideline values based upon this NRC guidance is discussed in detail in the Cimarron FSSR for Phase III, Sub-Area "O" - Subsurface (Cimarron Corporation, March, 1998) which is currently being reviewed by NRC staff.

A comprehensive review of all the characterization data identified 29 locations with composite sample results exceeding the guideline value developed under the NRC guidance documents (i.e. 220-pCi/g total uranium). Remediation of Waste Pond #2 was performed with a trackhoe excavator. Surface soils were removed to gain access to the contaminated soils with concentrations above the guideline value. Excavation of contaminated soils exceeding the guideline value continued as necessary down to a depth of approximately 9 feet. Excavated contaminated soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. Approximately 7,000 cubic feet of BTP Option #2 soils were removed from these 29 locations. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed.

Utilization of the NRC guidance, coupled with Cimarron's desire to assure full compliance, resulted in an additional excavation of soil volumes from Uranium Waste Pond #2 (Uranium Waste Pond #2 was previously excavated in 1976). Additional soil sampling and confirmatory surveys were also performed after these areas were excavated. The complete set of all characterization data for Uranium Waste Pond #2 was evaluated under the NRC's guidance ("Methods for Surveying and Averaging

Concentrations of Thorium in Contaminated Sub-surface Soil") to demonstrate that the soils within Uranium Waste Pond #2 were in compliance with the BTP Option #1 criteria.

#### **4.5 Summary**

As discussed above in sections 4.1 through 4.4, Burial Areas #1 and #2 and Uranium Waste Ponds #1 and #2 have been remediated such that all materials exceeding the BTP Option #1 criteria have been removed. These materials have either been shipped off-site for disposal to a commercial Low-level Radioactive Waste Disposal Facility or placed in the NRC approved BTP Option #2 Disposal Cell.

The remediation of Burial Area #1 was completed and this area was backfilled in 1993, the remediation of Burial Area #2 was completed and this area was backfilled in 1997, and the remediation of Waste Ponds #1 and #2 were also completed and the areas were backfilled in 1997.

Significant volumes of BTP Option #2 and #4 materials were removed from Burial Areas #1 and #2 and Waste Ponds #1 and #2. The majority of this remediation work was completed recently, between 1993 and 1997. As a result, the source terms from these four areas that were available for potential contamination of the groundwater have recently been removed.

A review of historical groundwater data reveals that groundwater in the four areas described above (Burial Areas #1 and #2 and Waste Ponds #1 and #2) has been impacted by previous site operations. The trending analysis which is included in Section 5.0 demonstrates that the groundwater monitoring results are continuing a downward trend (i.e. confirming that maximum site concentrations in groundwater have already occurred). This also coincides with the recent removal of the sources of

potential groundwater contamination from Burial Areas #1 and #2 and Waste Ponds #1 and #2.

#### **4.6 References**

ORISE, January 31, 1989, "Interim Report of the Confirmatory Survey of portions of the Sequoyah Fuels, Cimarron Corporation Plant (Pu-Plant and Burial Ground #1)."

ORISE, January 7, 1991, "Confirmatory Survey of Cimarron Corporation Mixed Oxide Fuel Fabrication Plant."

ORISE, November 18, 1991, "Confirmatory Radiological Survey of the Sanitary Lagoons at the Cimarron Corporation Facility, Crescent, Oklahoma."

ORISE, July 22, 1992, "Confirmatory Radiological Survey of the Former Burial Ground. Cimarron Corporation Facility at Crescent, Oklahoma."

Cimarron Corporation, October, 1994, "Radiological Characterization Report for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility."

ORISE, November 1, 1994, "Confirmatory Survey of 2 Soil Piles proposed for on-site storage. Kerr-McGee Corporation, Crescent, Oklahoma."

Cimarron Corporation, April, 1995, "Decommissioning Plan for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility."

ORISE, November 13, 1995, "Confirmatory Survey of South U-Yard Remediation, Kerr-McGee Corporation, Crescent, Oklahoma."

Cimarron Corporation, May, 1996, "Final Status Survey Report for Phase III, Sub-Area "L" (Sub-surface)."

Cimarron Corporation, March, 1998, "Final Status Survey Report Phase III – Sub-Area "O" (Sub-surface)."

## 5.0 GROUNDWATER QUALITY IN IMPACTED AREAS

Several groundwater/surface water characterization and assessment studies have been performed for the Cimarron Facility to determine whether or not groundwater has been impacted by previous site operations and, if so, the extent of that impact. Results of those studies have been discussed in previous sections of this Report and are further summarized in this Section. Also, the anticipated behavior of operations derived species in the shallow subsurface is discussed briefly in this Section. The Cimarron facility implemented an extensive and continuous environmental monitoring program for determining the impacts of facility operations and subsequent remediation on the environment. This Section reviews historic and current groundwater data to determine impacts from past operations; and discusses changes to groundwater quality since issuance of the Grant Report (1989). These historic data are provided in Appendix attached to this Report.

The facility's annual environmental reports submitted to the NRC over the last twenty (20) years have revealed that groundwater has been impacted in localized areas by previous site operations. Additionally, the Grant (1989) report, submitted in support of the BTP Option #2 On-Site Disposal Cell application, concluded that groundwater near or downgradient of former waste management areas has been impacted by previously managed waste materials. Grant also explained the mechanisms by which uranium entered the groundwater at these affected areas and discussed those mechanisms that would further mitigate the impacts as closure progressed. A decreasing concentration trend is to be expected and should continue with the removal of the source of contamination (e.g., source term) during the decommissioning process. Grant predicted "that separation of the uranium and the production salts would lead to decreasing mobility." This means that without a continuing recharge of complexing ions such as fluoride or nitrate, the uranium remaining would become less and less mobile.

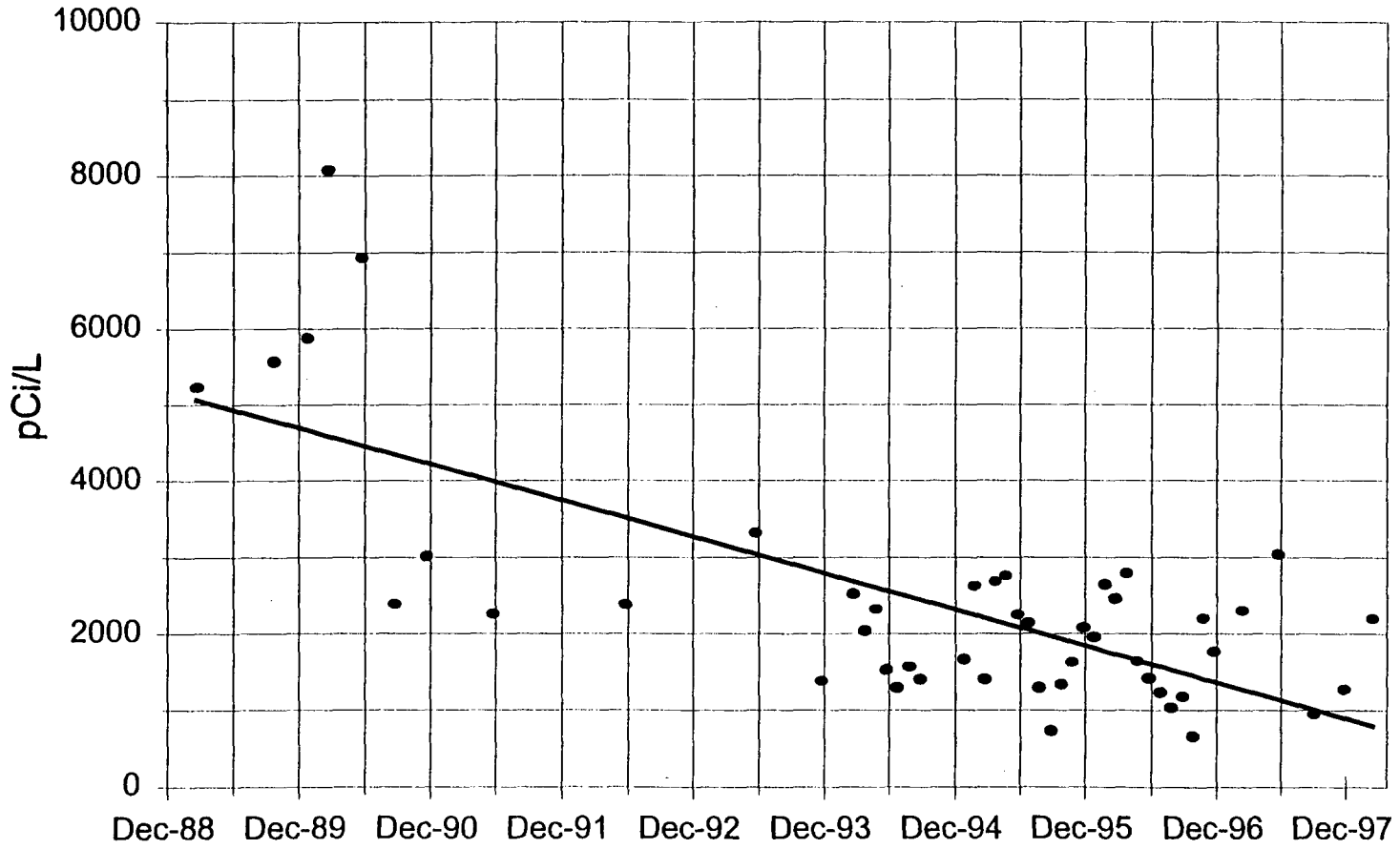
As discussed in Section 4.0, the Uranium Waste Ponds (U-Ponds), process building areas, and former waste (302 burials) burial areas have been remediated per BTP Option #1 criteria. With source removal complete, the detection of constituents above background at the monitoring wells reflect residual amounts of constituents remaining either in the soil, in the unsaturated zone, or in the water-bearing stratum.

To briefly discuss the impact to the groundwater and trending associated with affected areas onsite, environmental data is presented in this Section. The 1996 "Groundwater and Surface Water Assessment" (Chase 1996) included a comprehensive evaluation of the entire sitewide environmental monitoring data base. The evaluation concluded that the analytical data for the shallow groundwater near or downgradient from the four former waste management areas discussed below should be included in trend analyses for illustrating the downward concentration trend for residual contamination in groundwater at the site.

### **5.1 Burial Area #1**

Well #1315 was installed between trenches into the shallow groundwater monitoring area formerly occupied by Burial Area #1. A cross section showing the location of this well in relation to the groundwater is provided by Drawing No. 98-XSEC-2 (Ref. To Section 2.0, page 2-8). When Burial Area #1 was excavated the trenches remained open for several years resulting in some residual activity (Option #1 concentrations) leaching from the vadose zone into the shallow groundwater. Cimarron believes that with the sources removed, and the area backfilled with clean unaffected soil, and vegetated, the general decreasing groundwater concentration trends noted since 1988 will continue. This decreasing trend is shown by Figure 5.1. Well #1315 peaked in March 1990 at 8,080 pCi/L with the most recent analysis (March 1998) showing a total uranium

**Figure 5.1-- Well 1315 Total Uranium  
Linear Curve Fit**



of 2,200 pCi/L. The last four quarters have averaged 1,866 pCi/L total uranium.

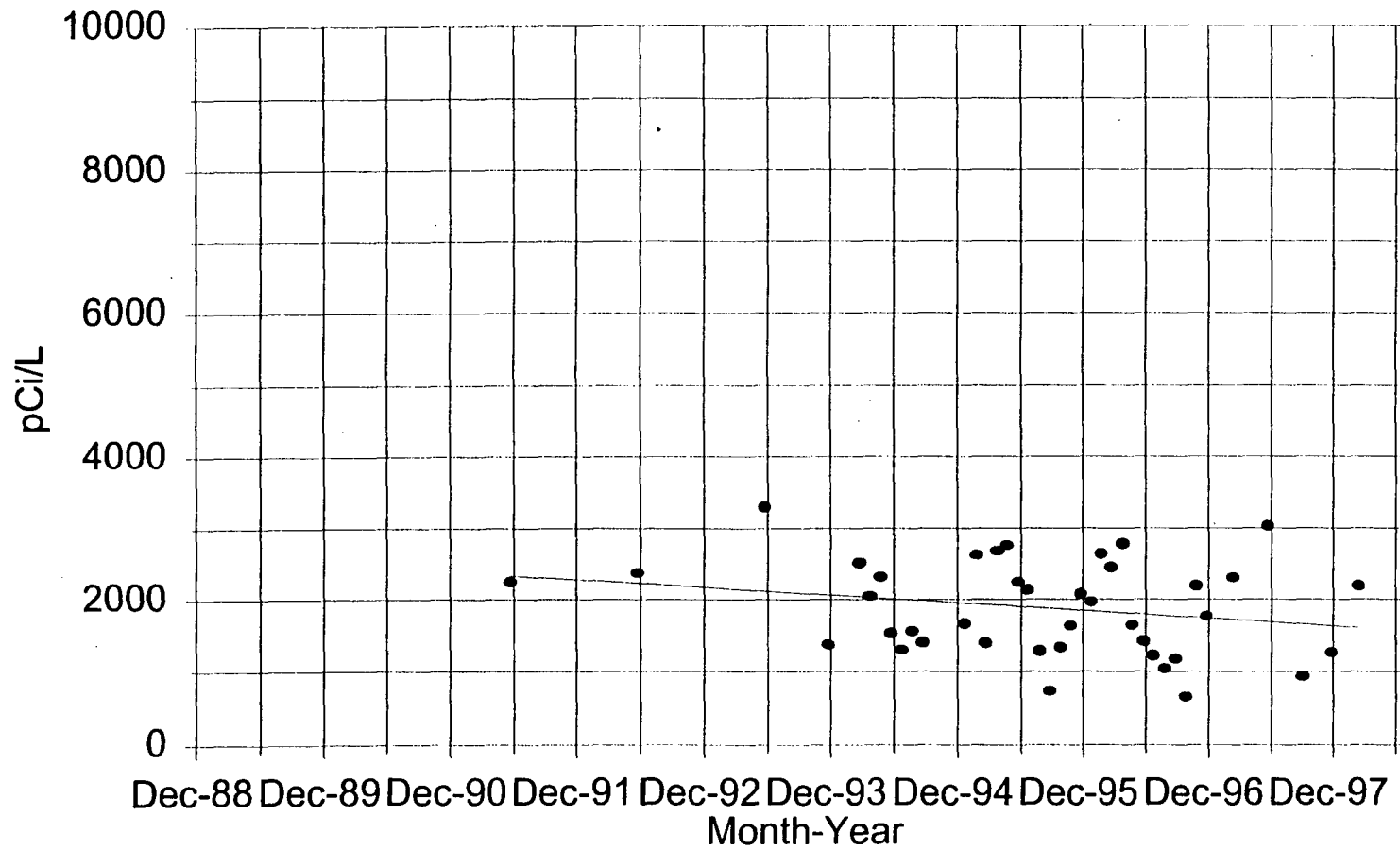
As noted by Figure 5.1, the concentration of total uranium in Well #1315 decreased rapidly from its peak in March 1990 to September 1990 (i.e., from 8,070 pCi/L to 2,386 pCi/L, respectively). In order to determine if continued decreases in groundwater concentrations were occurring from September 1990 forward, a plot of these concentrations for total uranium was completed. Figure 5.2 shows total uranium data for the monitoring period for Well #1315 from September 1990 forward. The computer generated linear curve fit function (i.e., Corel Quattro Pro Version 6) shows an average decrease in total uranium concentration of 5.3% per year for this data set.

Downgradient from Well #1315, two additional wells were installed (Wells #1316, and #1317). The total uranium concentration trending for Well #1316 is shown by Figures 5.3. Well #1316 shows continued decreasing trending; with Well #1316 peaking at 1,880 pCi/L in 1991 and decreasing to 109 pCi/L for the latest analysis. Trending for Well #1317 is shown by Figure 5.4; this figure shows a slightly increasing total uranium concentration. However, Well #1317's latest analytical result (March 1998) shows total uranium at 62.7 pCi/L; this well peaked at 499 pCi/L in 1990. The June 1997 result of 408 pCi/L total uranium may be an anomalous result because it does not fit the data set. With this data point treated as an outlier, the concentrations show a continually decreasing trend.

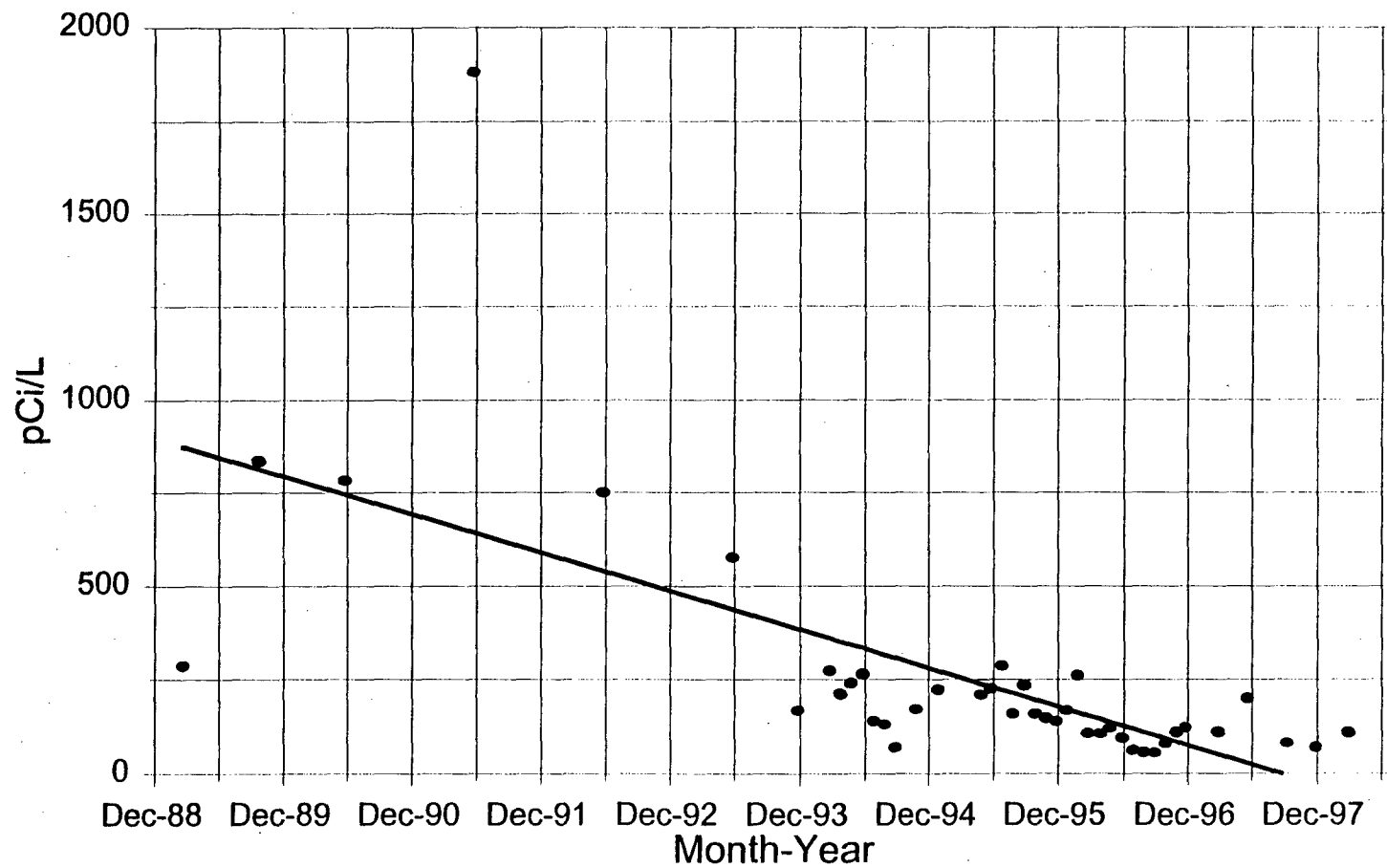
Site water quality data for these wells monitoring former Burial Area # 1 reflect removal of the source and the immobility of uranium in the subsurface. Wastes were buried in this management area and later exhumed and disposed off-site. Upgradient Well #1314 shows



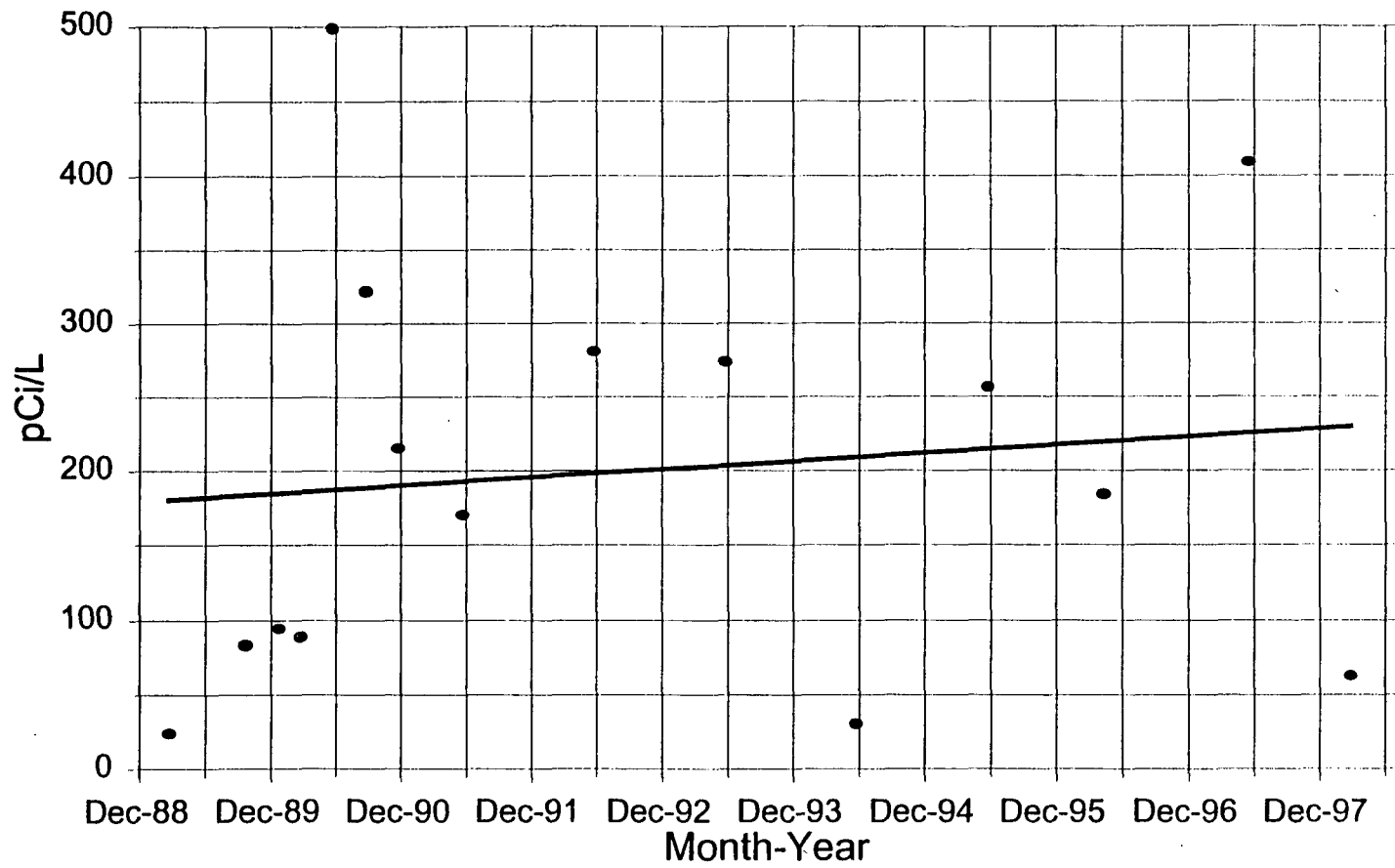
Figure 5.2--Well 1315 Total Uranium  
Linear Curve Fit



**Figure 5.3--Well 1316 Total Uranium  
Linear Curve Fit**



**Figure 5.4--Well 1317 Total Uranium  
Linear Curve Fit**



background U-238 concentrations of about 2 pCi/L. Concentrations have increased across the former burial area, and decreased rapidly with distance downgradient of the area. Migration around this area reflects the influence of the leachate chemistry upon uranium Kd's. Within the former burial area, Kd's probably are much smaller than in the natural system. The Kd's increase with distance from the facility as the groundwater chemistry approaches that of the native groundwater.

As discussed, the concentrations of total uranium in Well #1315, located within the former burial ground, and Well #1316, located near Well #1315, peaked in years 1990 and 1991 respectively and are subsequently decreasing in concentration. The temporary increase is believed to be related to rainfall retention and percolation during the time the trench was open and being excavated. The area remained open waiting NRC approval to backfill. This former burial area was excavated between 1986 and 1988 and the excavation remained open until early 1993. The area was backfilled and contoured to promote drainage.

A recently installed well (Well #1344) adjacent to the Cimarron River, downgradient former Burial Area #1, shows a total uranium concentration of 4.5 pCi/L. This concentration is considered equivalent to the 7 to 8 pCi/L average total uranium concentrations recorded for the Cimarron River.

The change in total uranium concentrations with distance from the former burial ground reflects the influence of the changing groundwater chemistry upon uranium with distance from the source and the influence from surface water infiltration and subsurface dispersion. The mobility of uranium in the groundwater is further discussed in Section 6.2.

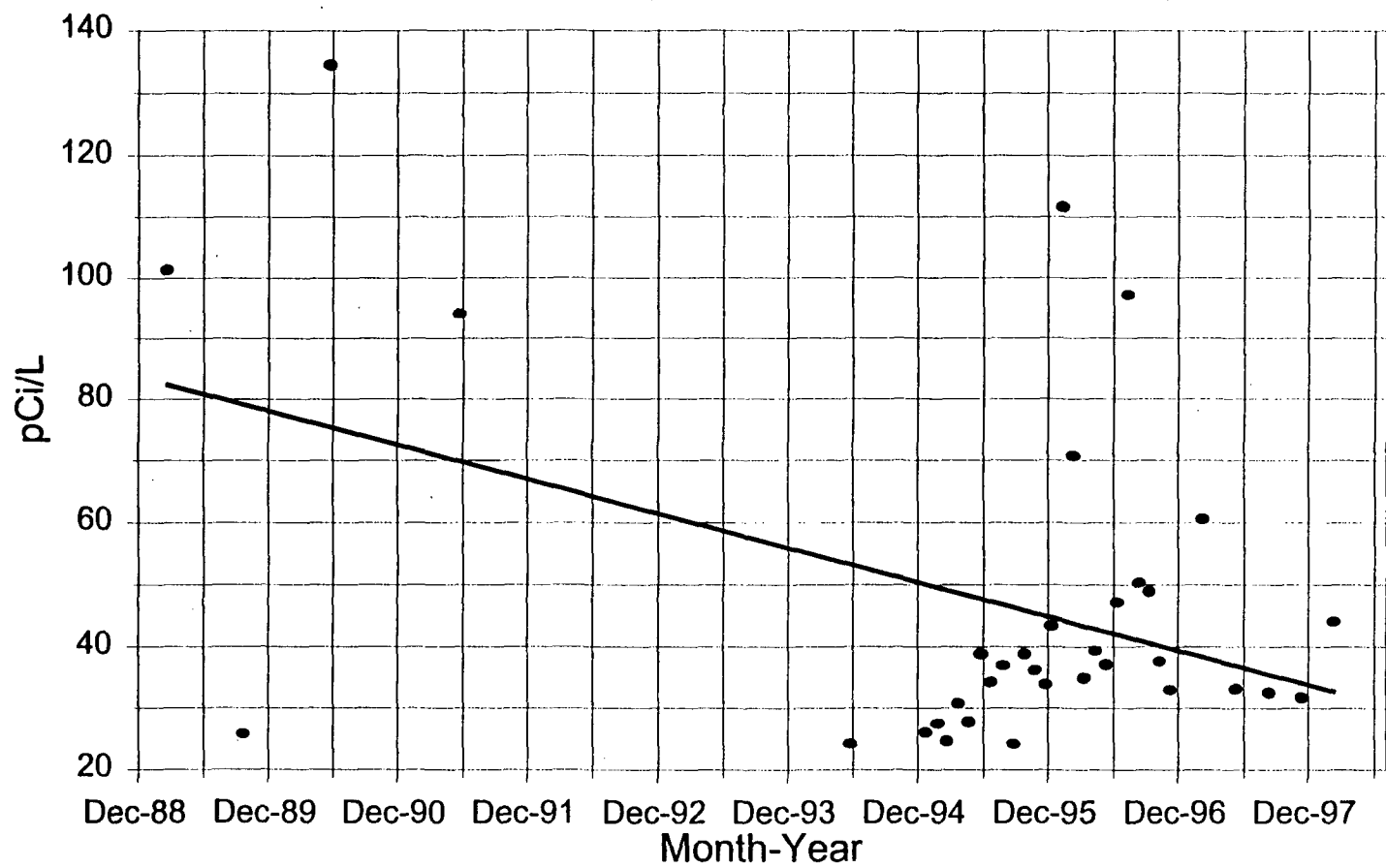
## 5.2 Uranium Waste Pond #2

Well #1336 and surface water seep location #1208 monitor the groundwater impacted from former U-Pond #2. A cross section showing the location of the wells and seeps relative to the groundwater is provided by Drawing 98-XSEC-1 (Ref. To Section 2.0). The total uranium and gross beta trending for Well #1336 are included with this section and are shown on Figures 5.5 and 5.6. The location (Well #1336) shows a continued downward trending in residual concentrations of total uranium. Also, starting in 1997, Tc-99 has been monitored and also has shown a continued decreasing trend from 2,590 to 1,600 pCi/L in the most recent analysis. The decrease in Tc-99 also is reflected by the gross-beta downward trend for Well #1336 (Figure 5.6).

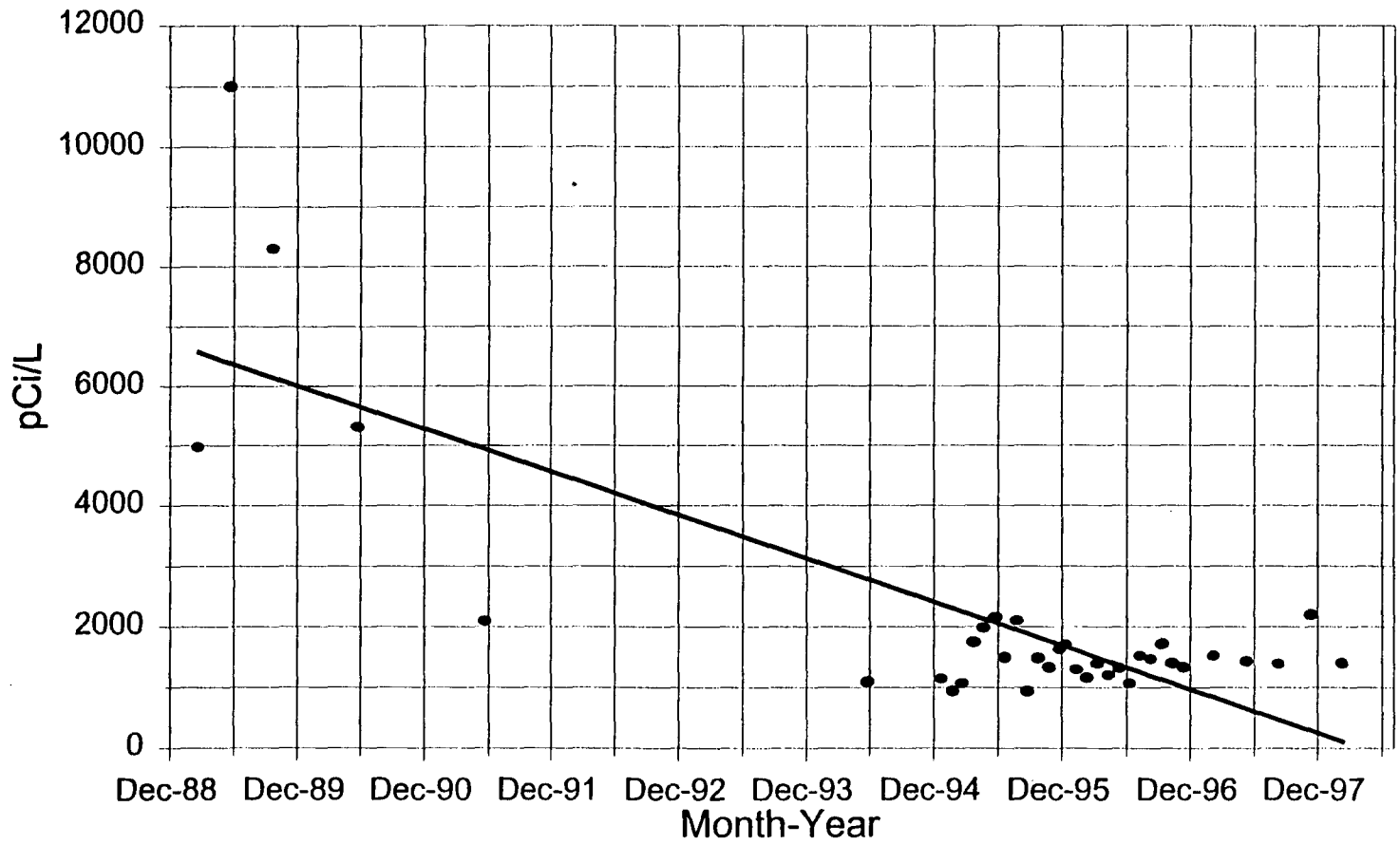
The Seep, #1208, also was monitored for Tc-99 and showed a decreasing trend in activity from 3,960 to 2,306 pCi/L for the most recent analysis completed in March 1998. Total uranium monitored at Seep #1208 has shown a decreasing trend from 303 pCi/L in 1993 to 48.4 pCi/L in the most recent analysis in March 1998. Cimarron believes, in general, that the decreasing trends in groundwater constituents will continue and will be further mitigated now that former U-Pond #2 was further remediated and then capped, crowned and vegetated.

As discussed in Section 3.2.1.1, two wells were installed recently northeast and downgradient of former U-Pond #2 for the purpose of verifying that a semi-confining layer (Mudstone A) exists between Sandstones A and B under this area. The groundwater elevations verified that an aquitard was present between the two sandstones. Total uranium analytical results from June 1997 were 11.7 pCi/L for Well #1337 (Sandstone A) and 1.2 pCi/L for Well #1338 (Sandstone B). The analytical results demonstrate that the underlying Sandstone B located below this U-Pond has not been impacted by previous site operations.

**Figure 5.5--Well 1336 Total Uranium  
Linear Curve Fit**



### Figure 5.6--Well 1336 Gross Beta Linear Curve Fit



Finally, Sandstone A below and downgradient of Waste Pond #2 is unsaturated due to the proximity of the seeps along the bluffs.

### **5.3 Uranium Waste Pond #1**

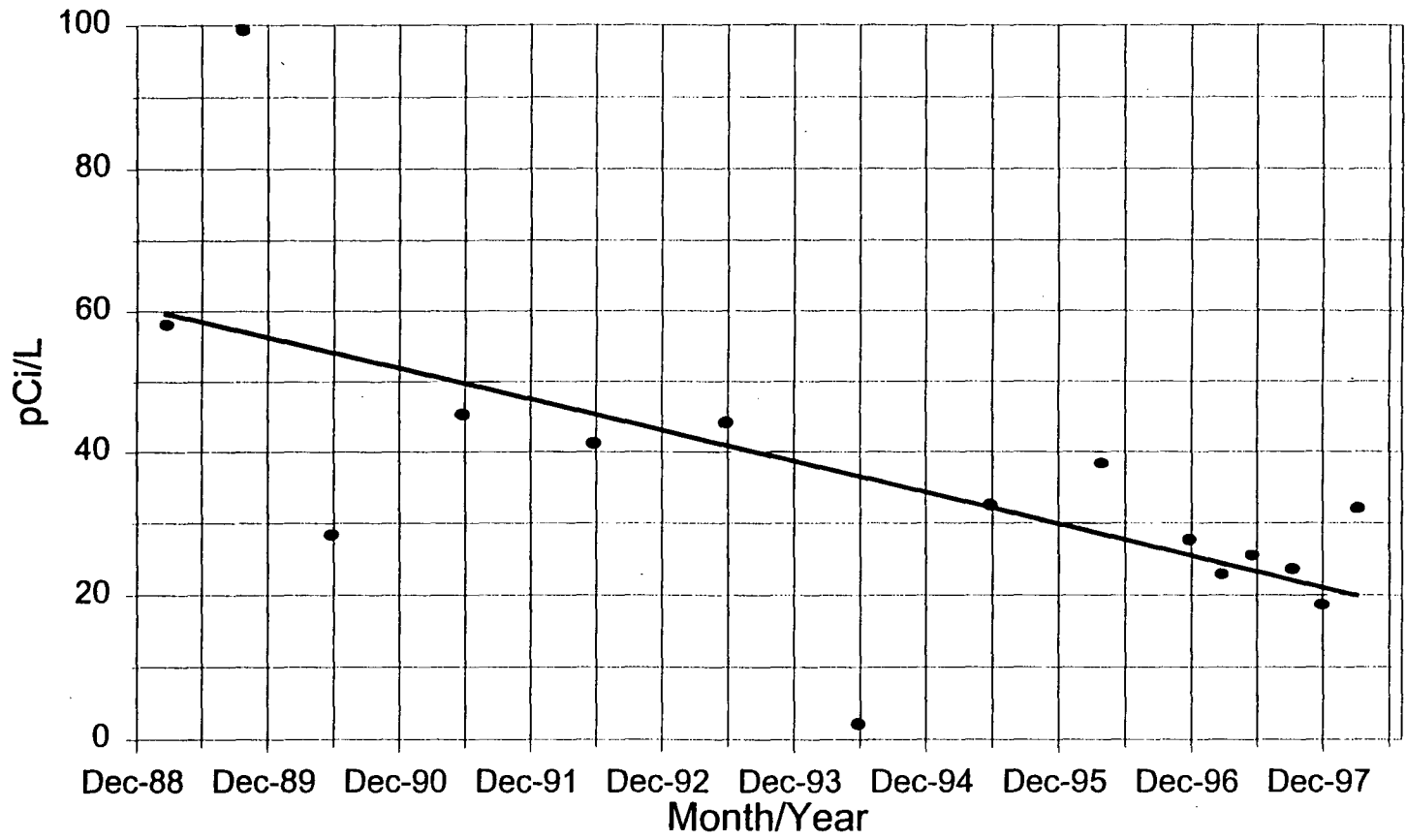
This former U-pond area contains two well locations which show that groundwater has been impacted by prior site operations. Those locations are monitored by Wells #1312 and #1313. Trending for these wells for total uranium and gross beta are included with this section and are shown in Figures 5.7 through 5.10. These locations show a continued decreasing trend in residual concentrations of total uranium. Since 1997, Tc-99 has been monitored for both wells and also has shown decreases in concentration. Tc-99 for Well #1312 has decreased from a high of 3,680 to 1,856 pCi/L for the most recent analysis. Well #1313's most recent analysis for Tc-99 was 562 pCi/L. The decrease in Tc-99 also is reflected by the gross-beta downward trending for Wells #1312 and #1313 shown by Figures 5.8 and 5.10.

For Well #1312, gross alpha has decreased from a high of 2,220 pCi/L in 1985 to the most recent analysis in March of 15.8 pCi/L; total uranium for the March sample was 32.1 pCi/L. Similarly, for Well #1313, gross alpha has decreased from a high of 1,510 pCi/L in 1992 to the most recent analysis in 1998 of 30 pCi/L; total uranium for the March sample was 39.3 pCi/L. Cimarron believes that the decreasing trends in groundwater constituents will continue since additional source removal has been completed. Final backfilling and contouring of U-Pond #1 has been completed.

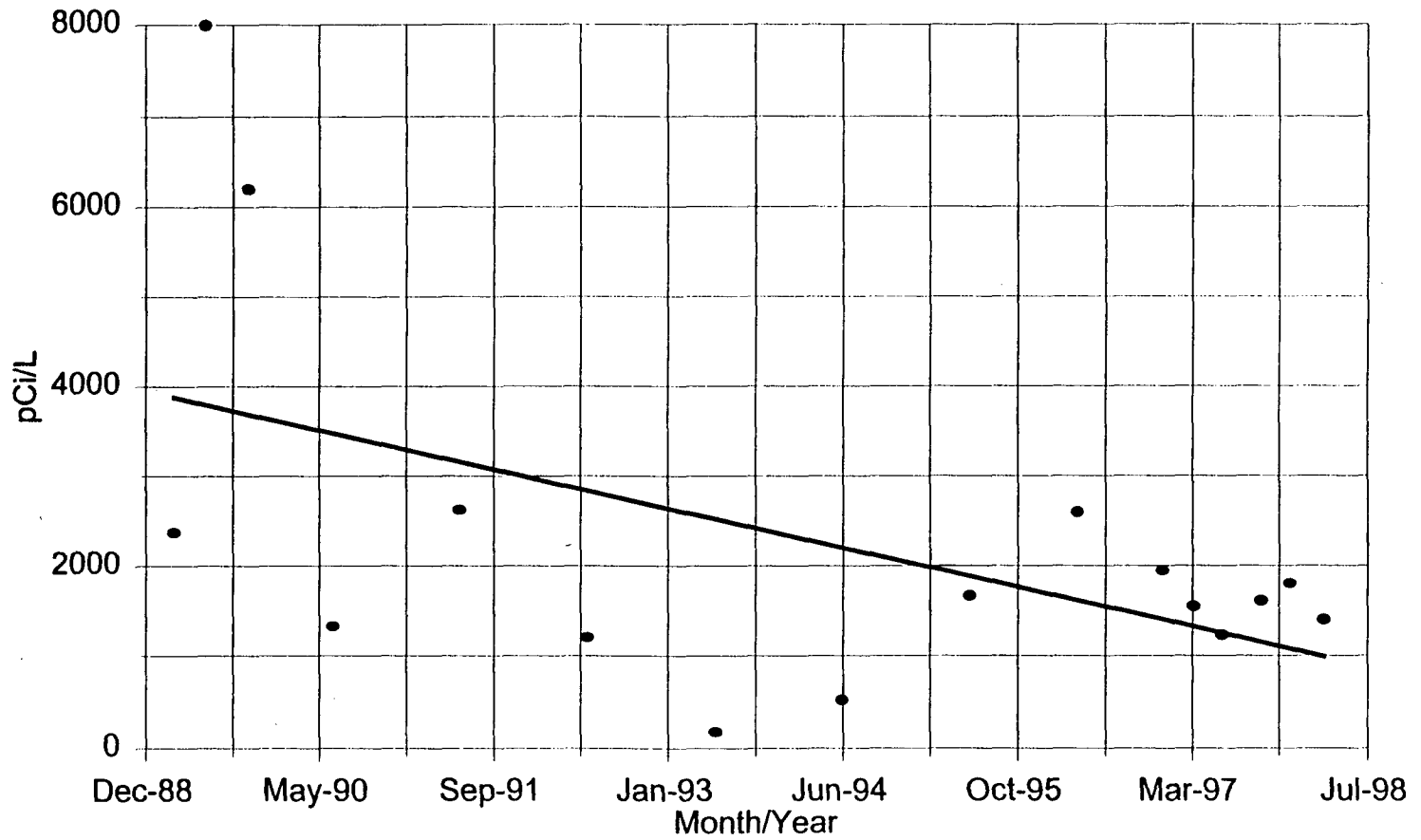
When the two additional wells (Nos. 1337 and 1338) were installed near U-Pond #2, two wells (Nos. 1340 and 1341) also were installed east and downgradient of former U-Pond #1. Well #1340 was completed in Sandstone A and Well #1341 in Sandstone B. Analytical results for total



**Figure 5.7--Well 1312 Total Uranium  
Linear Curve Fit**



**Figure 5.8--Well 1312 Total Beta  
Linear Curve Fit**



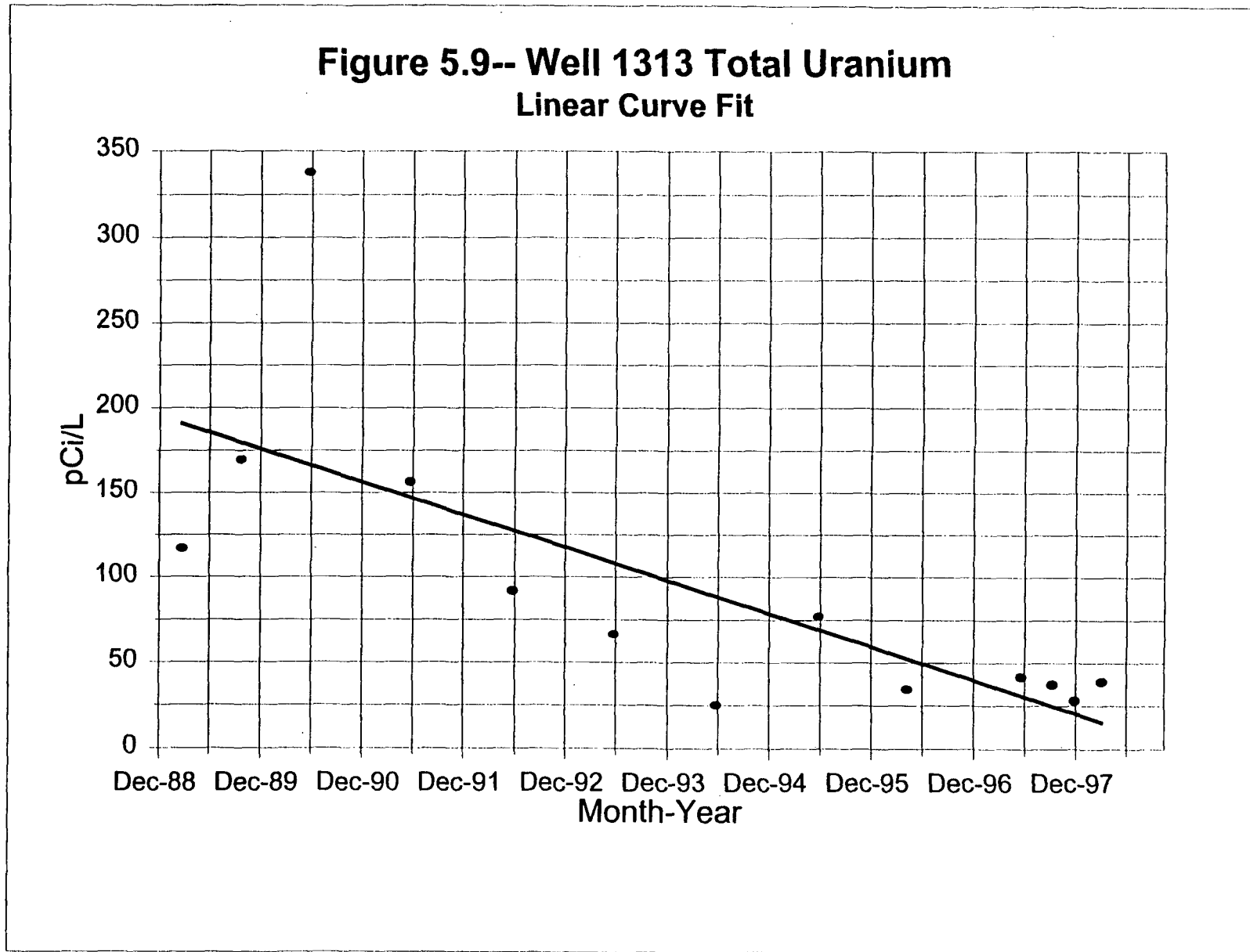
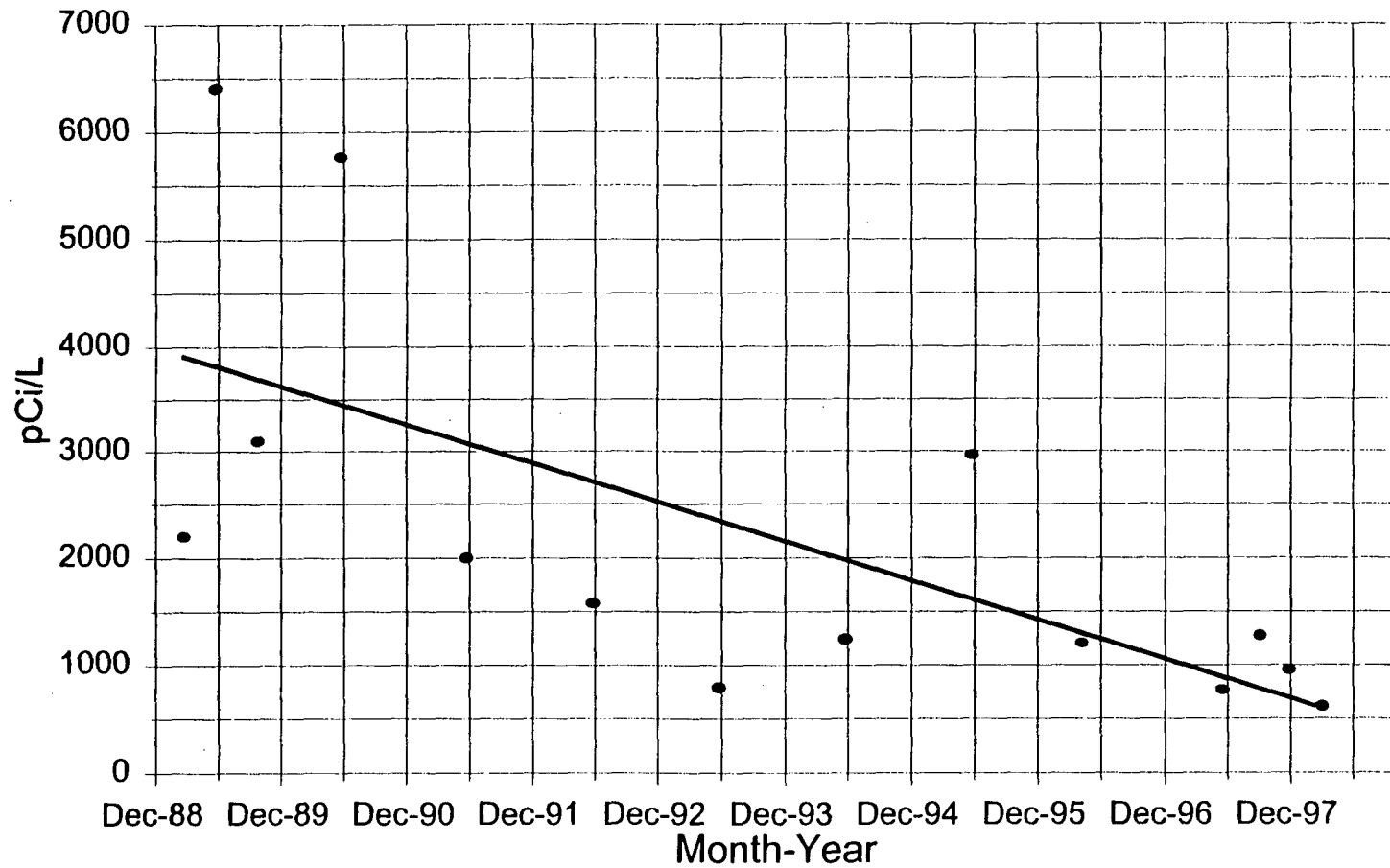


Figure 5.10-- Well 1313 Gross Beta  
Linear Curve Fit



uranium from the latest sampling event, June 1997, show 3.9 pCi/L for Well #1340 and 2.2 pCi/L for Well #1341. The total uranium concentration in Well #1341 is indicative of background meaning that this zone has not been impacted by prior site operations.

#### **5.4 Burial Area #2**

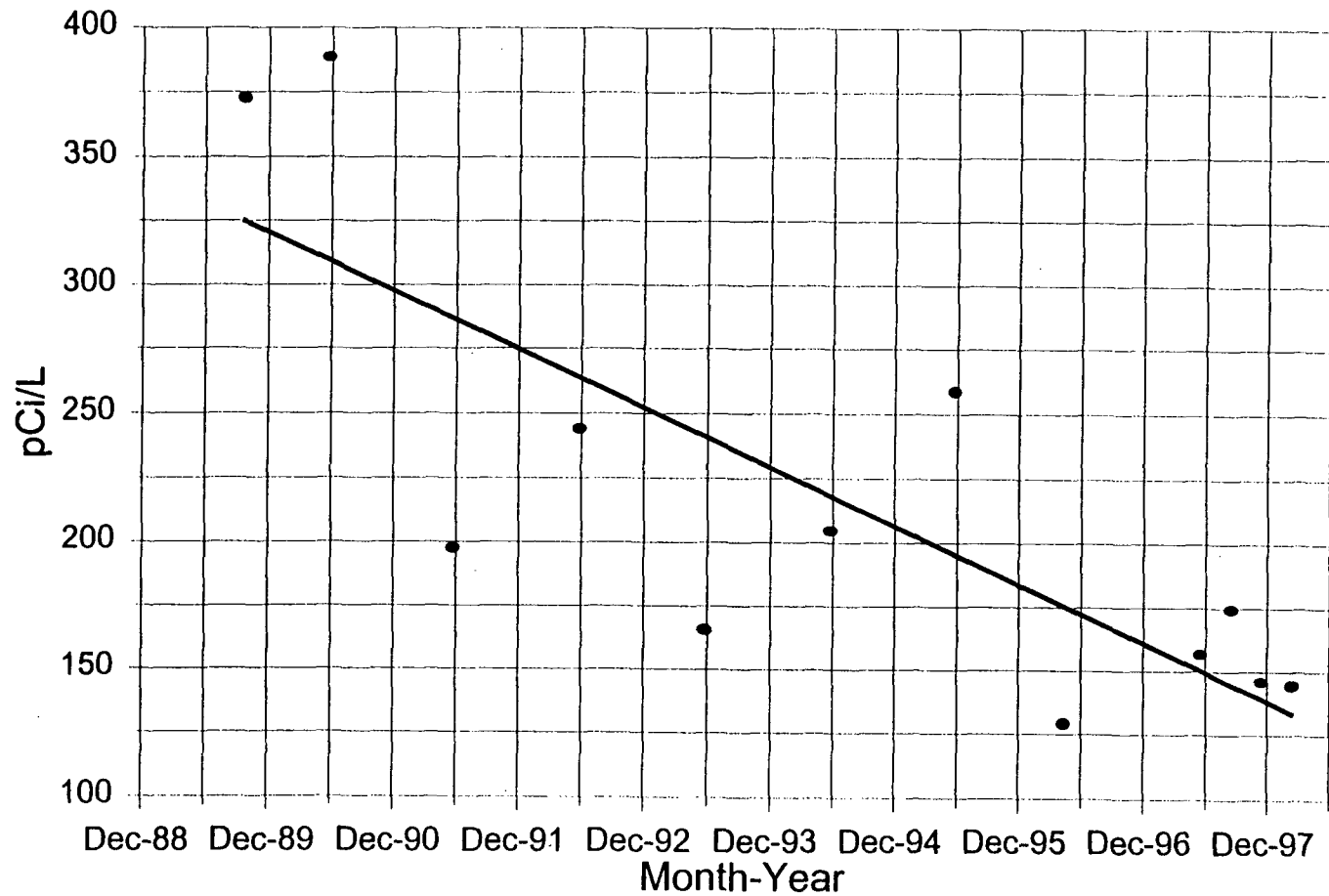
This area contains one monitoring well, Well #1331, located downgradient from former Burial Area #2 which indicates that constituents in groundwater are elevated, but are also decreasing in concentration. Figure 5.11 represents the trending for groundwater monitored for total uranium.

Recent remediation at Burial Area #2 may be influencing the constituents in this well. Cimarron has completed the removal of the buried waste and the grading, backfilling, and contouring of Burial Area #2. This remediation should mitigate any further affects upon groundwater in this area. The highest concentration of total uranium for Well #1331 was 388 pCi/L recorded in June 1990; the latest sampling results shows 145 pCi/L. This recent concentration is slightly elevated above the 129 pCi/L recorded in April 1996, but still reflects an overall decreasing trend in total uranium concentration.

#### **5.5 All Other Monitored Locations for Shallow Groundwater**

The other Sandstone A monitoring wells on-site that are located downgradient from previously closed process areas have shown minimal, if any, impact from prior site operations. The eleven monitoring wells sampled in June 1997 showed total uranium concentrations ranging from 1.2 pCi/L to 13.2 pCi/L, with the highest concentration representing Well #1333. The average total uranium concentration for these eleven wells was 6.2 pCi/L.

Figure 5.11-- Well 1331 Total Uranium  
Linear Curve Fit



Three monitoring wells were installed recently adjacent to the Cimarron River for determining the thickness of the alluvium and for sampling the groundwater within this zone. Well #1342 was installed near Highway #74 as an upgradient alluvium well; and Wells #1343 and #1344 were installed north of U-Pond #2 and former Burial Area #1 (see Drawing No. 98MOST-R2 included in Section 3.0). These wells were sampled in March 1998 and show total uranium of 6.5 pCi/L for Well #1342, 18.7 pCi/L for Well #1343 and 4.5 pCi/L for Well #1344. Also, as noted in Section 3.4.3, total uranium measured for the Cimarron River was 8.1 pCi/L upstream and 7.3 pCi/L downstream. These data reflect background conditions for the Cimarron River.

#### **5.6 Other Monitored Locations for Surface Water / Seeps**

Monitored location surface drainage/seep #1206 includes a combination of collection points for both surface run-off and shallow seeps. This monitored location is shown on Drawing No. 98MOST-R2. The water monitored collects from a combination of prior waste management areas including seeps and surface runoff. These areas have subsequently been remediated, and include a former pipe line area, a surface storage area, waste ponds, and a burial area. During extreme dry periods there may be no water available for sampling this location. Also, during wet periods surface run-off affects the analytical results.

Analytical data for this location shows the downward trend for total uranium expected as a result of continued remediation and source removal. The total uranium peaked in 1994 at 517 pCi/L; the first quarter 1998 data shows a total uranium concentration decreasing to 189 pCi/L. The average concentration for total uranium is 161 pCi/L for the last four quarters when data is available; for the December 1997 sampling event, the location was dry.

The three reservoirs located on site are monitored under the sitewide environmental monitoring program. These reservoirs are recharged by a combination of surface run-off and shallow groundwater. Surface water location #1204 monitors Reservoir #1 which also is designated the West Lake. Monitoring location #1205 is for Reservoir #2, and location #1209 is for Reservoir #3. The 1997 analytical data for total uranium was 4.0 pCi/L for #1204; 0.8 pCi/L for #1205; and 2.9 pCi/L for #1209. These results show no effects from prior site operations.

### **5.7 Deep Monitoring Well**

As discussed in Section 3.2.1, the monitoring wells located on site that monitor the deeper groundwater zones have shown total uranium concentrations ranging from 11 to 44 pCi/L. These concentrations are considered within background variances for these deeper sandstone layers. Historical data for uranium and other constituents monitored indicated that these deeper zones have not been impacted by prior site operations.

### **5.8 Summary**

The historical and more recent groundwater and surface water investigations clearly show that groundwater radionuclide impacts have continued their decreasing trends from the levels presented in the 1989 Grant report. With additional sources removed in these areas and the site in the final phase of decommissioning, these recorded decreasing trends will continue.

### **5.9 References**

Chase Environmental Group, Inc, 1996. Groundwater and Surface Water Assessment for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.



Grant, James L., 1989. Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September 12, 1989.

## **6.0 DISCUSSION OF PREVIOUS PATHWAY EVALUATIONS**

This section discusses previous human exposure pathway evaluations performed by the NRC and Cimarron. In addition, Cimarron performs routine monitoring of radiation workers and monitors the environment to ensure that operations are performed in a manner that conforms with all regulatory requirements and exposures are ALARA. The results of actual measurements are presented as these are generally considered to be the best data for assessment of operational impacts.

### **6.1 NRC Safety Evaluation Report (SER) and Environmental Assessment (EA) for Disposal of On-site BTP Option #2 Soils**

This subsection provides an overview of the Safety Evaluation Report (SER) (USNRC, 1994) and Environmental Assessment (EA) (USNRC, 1994a) performed by the NRC to address health, safety, and environmental effects from an authorization for the on-site disposal of low-enriched uranium in the NRC Branch Technical Position (BTP) (USNRC, 1981) Option #2 concentration range. Although the intent of this Groundwater Report is primarily to address current groundwater issues, the SER is also relevant as it provides additional information related to the potential impacts associated with the on-site disposal of the BTP Option #2 material. The analysis is important as it evaluates conditions that present the highest soil concentrations to remain at the site. Any other remediated areas will have impacts that are significantly lower than the Option #2 disposal cell.

The SER and EA provide a significant amount of information that is directly applicable to the assessment of any other affected areas at the facility. This section lays the groundwork for determination of the relative impacts associated with former Burial Areas #1 and #2, and Uranium

Waste Ponds #1 and #2, in comparison with the impacts projected for the approved BTP Option #2 Disposal Area.

#### **6.1.1 Discussion/Description of the NRC's SER and EA**

In 1987, Cimarron requested an amendment to License No. SNM-928 to dispose on-site soils containing low concentrations of enriched uranium (i.e., BTP Option #2 materials). The original request was made in accordance with the requirements of 10 CFR 20.302 (currently 10 CFR 20.2002) (USNRC, 1998) using NRC's BTP criteria. The proposed method for disposal was to bury those soils on-site.

Pursuant to this request, the NRC prepared a SER and an EA which evaluated the health, safety, and environmental issues related to Cimarron's proposal. Based upon these evaluations, the NRC issued License Amendment No. 10 to License No. SNM-928, authorizing the burial of up to 500,000 cubic feet of soil contaminated with low-enriched uranium in the BTP Option #2 concentration range. License Condition No. 23 was issued by the NRC on November 4, 1994 and limited the maximum concentrations allowable for disposal based upon the solubility of the material. Importantly, the NRC's maximums were based upon 100 percent solubility of the uranium, which would result in the highest projected concentrations in groundwater.

The EA prepared by NRC staff provided a general description of the site and proposed BTP Option #2 Disposal Area, and presented information regarding the climate, meteorology, demographics, land and water usage, wetlands, biology, surface water hydrology, geology and hydrogeology, site geochemistry, and radiological background for the facility. This information was used to determine the expected environmental impacts

from the BTP Option #2 disposal. The environmental impacts considered included the potential for groundwater contamination, intrusion into the disposed material, direct radiation exposure, and inhalation or ingestion. The EA also considered the potential radiological doses and addressed State of Oklahoma concerns regarding non-radiological chemical impacts from the disposal of the BTP Option #2 materials. As such, the NRC analysis represents the highest exposure scenario for any soils residing at the Cimarron site.

#### **6.1.1.1 Pathways Considered in the SER and EA**

The stated purpose of the SER was "to consider the potential radiological impacts on worker health and safety associated with the movement and disposal of uranium-contaminated soil on the Cimarron site". The SER considered doses to workers from the direct exposure pathway and from the inhalation pathway. In its conclusion, the SER states that "The samples in the 0-30 picocuries/gram range (BTP Option 1) have acceptably low concentration so that the enriched uranium may be buried without restriction."

The purpose of the EA was to determine the impact of the BTP Option #2 burial on the public and the environment. The EA states that "NRC policy on on-site disposal of uranium contaminated soil pursuant to 10 CFR 20.2002 (formerly 10 CFR 20.302) is described in the 'Branch Technical Position on Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations (46 FR 52061, October, 23, 1981)."

The primary pathway considered in the EA was the groundwater pathway, as doses from this pathway were not previously considered in the NRC BTP. In the BTP, NRC staff considered the radiation doses that members

of the public could conceivably be expected to receive from direct radiation, ingestion of food raised on the site, and gamma and inhalation dose due to physical intrusion into the contaminated soil. The results of the generic calculations are used in the EA and are corrected for the average activity in the BTP Option #2 Disposal Area to present estimates of the potential dose from the disposal activity. Doses to the nearest off-site resident from earthmoving activities are also calculated in the EA. These calculated doses are presented in Section 6.1.1.4.

Based upon the results of the EA, the NRC concluded that the impact on the public and the environment would be minimal, and made a Finding of No Significant Impact (FONSI).

#### **6.1.1.2 Assumptions/Parameters**

The SER applied only to workers at the Cimarron facility, and estimated exposures that would occur during the movement of contaminated soil into the disposal cell. The activities considered in the SER also included the placement and compaction of contaminated soils in the disposal cell. The SER assumed that the soil was contaminated at 70 pCi/g, total uranium, and that workers were exposed to inhalation Class Y. The particle size chosen was 1 micron. The duration of the exposure was 6 months, and the average air concentration utilized was  $2.7 \text{ E-}12 \text{ } \mu\text{Ci/mL}$ . As discussed in Section 6.3, this assumed concentration has been shown to be very conservative, based upon the results of actual measurements performed in the field.

The SER also calculated the effective dose equivalent from exposure of radiation workers to direct radiation. The RESRAD code was used for this evaluation. For this estimate, it was assumed that workers would be

exposed continuously for one year during earthmoving and other activities. The exposure geometry used was a planar field contaminated with 70 pCi/g uranium.

The EA assumed that 500,000 cubic feet of low-enriched (3%) uranium at 70 pCi/g was buried, and that the cell would have a 4 foot cover. The source term assumed was 1.9 Ci total uranium. The solubility for the uranium was assumed to be 100 percent. In addition, the Kd value used was 339 mL/g. The solubility and Kd values used in the EA are considered to be conservative, and will result in projected estimates of exposure that are higher than reality. These parameters are addressed in more detail in Section 6.2. The well that supplied drinking water, irrigation water, and livestock water was placed at a distance of one foot from the downgradient edge of the disposal area, resulting in a travel time of 0.1 year. The groundwater flow velocity used was 10 feet/y. The porosity of the soil was assumed to be 0.33, and the soil density was 1.9 g/cm<sup>3</sup>.

The nearest residence was chosen at the current distance of 0.8 kilometers. Uses of land in the vicinity were assumed to be row crop cultivation, grazing, or construction.

#### **6.1.1.3 Methods**

The methods used in the SER for calculation of inhalation dose involve standard health physics calculations equating the concentration of uranium contaminant in the air to the dose received. The concentration of uranium in air is multiplied by the total volume of air breathed by the worker. This result is then multiplied by a dose conversion factor to obtain the committed effective dose equivalent.

The SER also addressed the potential for exposure from direct radiation. The effective dose equivalent was determined using the RESRAD code, assuming a planar source with a uranium concentration of 70 pCi/g.

The EA used several methods to calculate doses. The leaching and subsurface migration of uranium from the BTP Option #2 Disposal Area was modeled using the simplified one-dimensional contaminant transport code TRANSS (Simmons, 1986). The TRANSS model is a convective-dispersive transport program that has been modified to allow for radioactive decay of the source and to simulate adsorption ( $K_d$ ), solubility in water, and concentration or diffusion barrier controlled releases.

There were no calculations performed for direct radiation from exposure to the buried materials, since the NRC concluded in the BTP that contaminated soil buried under Option #2 conditions (i.e., at least 1.2 meters (4 feet) below the surface) would not expose any member of the public. The same 1.2 meters of cover would essentially eliminate the uptake of uranium by food or pasture crops and correspondingly reduce the amount of uranium that could be ingested by consuming food produced on-site.

The EA did consider the possibility of physical intrusion into buried contaminated soil, for the site that is released for unrestricted use. The EA made use of calculations performed for the BTP which showed that even an extreme intrusion into the buried Option #2 soil would result in an annual organ dose of no more than 170 mrem, which is equivalent to a total effective dose equivalent (TEDE) of 5 mrem for uranium soluble in lung fluid to 20 mrem for insoluble uranium.

Calculations of the potential annual dose to the nearest resident (0.8 kilometers southeast) due to blowing dust was calculated using the GENeration II (Napier, 1988) radiological pathways and dosimetry model (GENII). In addition, the toxic effects (non-radiological) due to the residual uranium activity were addressed in the EA.

#### **6.1.1.4 Results**

The SER concluded that the major radiological impact to workers would be from the inhalation of dust during earth movement activities. The calculated maximum annual exposure was 408 mrem, with 405 mrem due to dust inhalation and 3 mrem due to external occupational exposure. This projection can be compared to the actual dose received by the workers who placed the Option #2 soils into the on-site disposal cell. As of this date (through June, 1998), facility monitoring records (personnel dosimeter and lapel air monitors) show there has not been any dose assigned due to external exposures and that a single radiation worker has been assigned a dose due to intake of 0.32 mrem. The placement of materials into the BTP Option #2 disposal cell was an extensive relocation effort, with work done in close proximity or contact with the Option #2 material. Any future intruder into on-site soils containing residual activity would not create levels of airborne radioactivity as high as those produced during the placement of the soils into the Disposal Area. Therefore, based upon actual monitoring results, it is unlikely that any future intruder would receive any exposure due to the inhalation of residual Option #1 soils located within former Burial Areas #1 and #2, or from Uranium Waste Ponds #1 and #2.

The TRANSS code, which was run to determine the potential impacts due to groundwater contamination, showed that there was no calculated



impact (i.e., no measurable increase) due to the leaching of uranium from the BTP Option #2 Disposal Area for many thousands of years. The net downward movement of uranium will be much slower than the downward movement of infiltrating water because of the adsorption of uranium onto soil and rock. The TRANSS code predicted that after 1,000 years, the uranium concentration in the intruder well would still be at natural background levels. This prediction held even when the most conservative Kd value (339 mL/g at Well #1336) was input into the code. This signifies that chemical constituents, at levels such as those found in soils near the waste ponds, would not produce measurable increases in uranium concentration. All of these assumptions apply to any remaining on-site residual activity, e.g., Waste Ponds #1 and #2 and former Burial Areas #1 and #2.

As stated in Section 6.1.2.3, there were no calculations performed for direct radiation from exposure to the buried materials, due to the shielding effect of the cover materials. The same cover would essentially eliminate the uptake of uranium by food or pasture crops and correspondingly reduce the amount of uranium that could be ingested by consuming food produced on-site. Residual Option #1 materials in Uranium Waste Ponds #1 and #2 are below four feet of cover. Residual materials are present in other areas of the facility at Option #1 levels (i.e., 0 to 30 pCi/g total uranium).

The physical intrusion scenario evaluated in the EA showed that even an extreme intrusion into the buried Option #2 soil would result in an annual total effective dose equivalent (TEDE) of less than 7 mrem, without regard to solubility. The EA further states that "Such a dose is considered to be quite small compared to doses from natural background radiation..."

The potential annual TEDE to the nearest resident (0.8 kilometers southeast) due to blowing dust was calculated to be 0.67 mrem for the BTP Option #2 Disposal Area. This dose was calculated using conservative assumptions and is also insignificant in relation to background.

The EA states that "The current NRC standard for uranium exposure of occupational workers is based on a nephrotoxicity standard of 3 micrograms of uranium per gram of kidney continuously maintained for a lifetime." The EA also concluded that toxic effects from the ingestion of uranium would require groundwater concentrations in the hundreds of picocuries per liter, while the TRANSS code analysis showed that the uranium concentration will not exceed 1 pCi/L over a time period of 100,000 years. The toxicity of uranium is addressed in more detail in Section 8.0.

## **6.2 Adequacy of Previous Cimarron Environmental Assessments**

The EA that was discussed in Section 6.1 was performed by the NRC in March 1994 and was based upon site characterization data developed by James L. Grant and Associates (Grant, 1989 and 1990) in support of Cimarron's application for on-site disposal of Option 2 soils. The pathways analysis and dose model performed by the NRC verified the earlier dose evaluation completed by Grant. The Grant evaluation can be considered a conservative representation any maximum of future exposure from residual uranium contained in media remaining at the Cimarron site.

### **6.2.1 Grant Analysis (1989/1990)**

In the 1989 Report, Grant completed a computer simulation of the potential for leaking and migrating of contaminants from the Option #2 landfill. The simulation used the TRANSS model (Simmons, 1986). As noted in Section 6.1.2.3, the TRANSS model is a one-dimensional, convective, dispersive transport program based on Van Genuchten analytical solutions, modified to include the simultaneous decay of the source and released radionuclides. The program can model concentration or solubility limited releases, adsorption ( $K_d$ ) limited releases, or diffusion beneath a barrier to the water table.

Simulations of distribution coefficient-limited releases were performed to predict uranium migration through the unsaturated zone to the water table, and through the saturated zone to the Cimarron River alluvium. For the release model, five samples of site soils, rock and groundwater were analyzed by the Kerr-McGee Technical Center to determine equilibrium distribution coefficients ( $K_d$ ) for uranium. This test provides a measure of the affinity of the selected elements for soil and rock and the solubility of the material in the rock/groundwater system. The experimentally derived  $K_d$  values for the uranium range from 339 mL/g to 2,829 mL/g. This range of  $K_d$ 's is representative of different conditions found on-site in groundwater due to influence from prior site operations, and for the natural background groundwater. For example, the derived  $K_d$  values of 339 mL/g was measured from aquifer matrix material collected from the installation of Well #1336 which is located within an impacted area. The higher  $K_d$ 's (i.e., 2,829 mL/g) were derived from matrix material collected from upgradient non-impacted wells.

Two simulations of uranium leaching and migration to the water table directly below the proposed landfill were performed using Kd values representative of the range of aquifer matrix materials. Kd values of 2,000 mL/g and 300 mL/g were used. With a Kd of 2,000 mL/g, a maximum leachate concentration of about 4 pCi/L was seen at the end of the flowtube in approximately 237,000 years. A Kd of 300 mL/g produces a maximum leachate concentration of about 27 pCi/L at the end of the flowtube in approximately 36,000 years.

The results of the TRANSS model simulation support interpretations that leaching and migration of uranium in the subsurface of the Cimarron facility will be limited. The simulations show that the combined effects of precipitation, adsorption and dilution of uranyl complexes will prevent significant migration of uranium from the on-site disposal cell and other areas on-site when residual uranium is present.

### **6.2.2 Discussion of Existing Impacted Areas**

The mobility of uranium at the site depends upon the chemistry of the groundwater, soils, and rocks. The stability and mobility of particular species in the subsurface depends primarily on active matrix adsorption sites, ligands available for complexation, and pH and Eh of the groundwater. Uranium has limited solubility in the slightly alkaline and oxidizing groundwater typical of the site. As demonstrated by the derived Kd's, the solubility is higher near the ponds because of the altered groundwater chemistry in these areas and the presence of complexing agents, e.g., fluoride and nitrate.

The dominant uranium species in the natural environment are uranyl complexes. Uranium exists in the hexavalent state as the uranyl ion  $\text{UO}_2^{+2}$

in this environment (Grant, 1989). The solubility of uranium is limited by precipitation and adsorption on the aquifer matrix. Uranyl hydroxide and uranium trioxide will precipitate from slightly alkaline and oxidizing groundwater. These compounds are relatively insoluble. Uranyl ions in solution also will be sorbed onto the aquifer matrix.

The distribution coefficient ( $K_d$ ) tests demonstrate that uranium will have limited solubility in the subsurface groundwater (Grant, 1989). Final concentrations of uranium in the  $K_d$  test solutions ranged from 1.2 to 9.9 pCi/L. These concentrations are consistent with naturally occurring uranium concentrations in the shallow groundwater samples from most of the monitoring wells. The combined effects of uranium precipitation and absorption on the shallow aquifer matrix materials appear to produce equilibrium concentration of uranium in Cimarron groundwater that are less than 10 pCi/L.

Concentrations of uranium above the typical equilibrium level have been detected in some on-site monitoring wells. These wells are located down-gradient from the closed uranium waste ponds and former Burial Areas #1 and #2. Materials stored in these areas have caused changes in the chemistry of the groundwater. The process wastewater discharged to the U-ponds contained dissolved uranium and was significantly different chemically from the natural groundwater, resulting in the higher uranium concentrations near the ponds. Likewise, leaching of materials stored at the former burial locations would alter the groundwater chemistry in those areas.

Uranium concentrations in the groundwater decreases rapidly with distance from the source (e.g., Uranium Waste Ponds). Uranium

complexes of fluoride, nitrate and sulfate may be more soluble than uranium carbonate salts, and the complexes often are not sorbed as strongly. Increased competition between uranium and other cations for a limited number of sorption sites increases the concentration of uranium in solution relative to the uranium sorbed on the soils. As anions are stripped from the ligands to react with matrix material (e.g.,  $F^-$  with  $Ca^{++}$ ), the uranium ion becomes susceptible to formation of more insoluble species and eventually sorbs on clays where it is tightly bound. The competition for exchange sites and the complexing of the uranium by other ions diminishes in importance downgradient of the former waste management areas as dilution and chemical reactions cause the modified groundwater to become more akin to the native groundwater than to the leachate.

With the closure of the former Uranium Waste Ponds and excavation of the former Burial Areas, the residual concentrations of uranium and solubilizing ligands remaining in soil will no longer possess the solubility-enhancing factors present within these former sources. Since the uranium concentrations in soil left in place will be far less than that placed into the Option #2 on-site disposal cell, the potential concentration of uranium in groundwater that leaches from the in-situ soils will be less than that predicted for the On-Site Disposal Cell. Under the remediation process, the highest concentrations of uranium and ligands in the soil went to the Option #2 On-Site Burial Area, thus making it the "worst case" scenario for the site.

### **6.2.3 Uranium Solubility in Soil**

The previously discussed groundwater pathway models, including the EA, assumed that in-situ uranium was 100 percent soluble. This turns out to

have been a very conservative assumption. In 1997, Cimarron employed the services of an outside laboratory to perform solubility tests on representative soil samples collected from the two uranium waste pond areas and from the on-site Option 2 disposal cell. These tests were approved by the NRC via letter dated December 10, 1996 (USNRC, 1996). A total of six sample locations were included in the study, two from each location. The "yearly" solubilities were determined to range from 26.7 percent to 33.3 percent, with an average of 28.9 percent. Additionally, the average solubilities measured for the three locations were essentially the same (29.9 for Uranium Waste Pond #1, 27.7 for Uranium Waste Pond #2, and 29.2 for the On-Site Disposal Cell). Since the solubilities are similar, the three areas will perform in a similar fashion in the future with respect to constituent migration. Migration from the closed waste management areas will be much less pronounced than from the former Uranium Waste Ponds and burial grounds because the remaining impacted in-situ soils will not influence groundwater chemistry, and because only soils with low levels of uranium will be present at license termination. Leaching of the uranium will be limited by solubility and by sorptive processes in the soil. Migration of uranium that does leach will be limited by the sorption of the material in the subsurface.

Finally, since the total uranium activity permitted to be placed into the on-site disposal cell (i.e., 1.9 curies) far exceeds the residual activity estimated to be present in the two former Uranium Waste Pond areas (i.e., 0.17 Ci for Uranium Waste Pond #1 and 0.44 curies for Uranium Waste Pond #2), the pathway analysis and dose model performed for the On-site Disposal Cell represents a conservative upper boundary evaluation. Additionally, the assessment completed for the On-Site Disposal Cell assumed (Grant, 1989) a conservative solubility (i.e., 100

percent vs. 29.2 percent) and evaluated Kd's as low as 300 mL/g. These assumptions added additional conservatism to the overall evaluation.

### **6.3 Field Measurements**

Field measurements of exposure provide a more accurate assessment of the actual exposures that may have occurred. During operations involving the movement and/or placement of BTP Option #2 materials into the disposal cell, Cimarron performed ambient environmental air monitoring, area monitoring upwind and downwind of operations, and breathing zone monitoring of radiation workers. In addition, Cimarron has a system of TLD monitors to monitor environmental exposure to direct radiation. Radiation workers are also required to wear direct radiation monitoring badges.

Results of these measurements showed that no worker received an annual exposure greater than the facility ALARA goals. The ALARA goals are set by the site ALARA Committee and are 100 mrem TEDE (individual) and 300 mrem TEDE (collective, all radiation workers) annually. The ALARA goals include doses from all operations, including the movement and placement of BTP Option #2 soils. The cumulative dose assigned to radiation workers was 3.2 mrem during the BTP Option #2 soil relocation activities. This dose was assigned to a single individual and was based upon a lapel sampler that had very low air volume. In addition, environmental monitoring results have not indicated any measurable impacts above background associated with the disposal of the BTP Option #2 materials in the on-site disposal cell (i.e., Burial Area #4).



These field results indicate that the modeling and assessments performed by the NRC were conservative. The actual doses to workers and the general public were substantially overestimated, based upon the field results.

#### **6.4 References**

Grant, J. L. and Associates, 1989, "Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma," September 12, 1989.

Grant, J. L. and Associates, 1990, "Cimarron Facility Closure Responses to NRC Questions," May 10, 1990.

Napier, B. A., 1988, PNL-6584, 1988, "Hanford Environmental Dosimetry Upgrade Project; GENII – Hanford Environmental Radiation Dosimetry Software System," Batelle Pacific Northwest Laboratory, Richland, WA.

Simmons, C. S., Kincaid, C. T., and Reisenauer, A. E., 1986, "A Simplified Model for Radioactive Contaminant Transport; the TRANSS Code, Batelle Pacific Northwest Laboratory, PNL-6029.

USNRC, 1981, "Branch Technical Position for Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations, Federal Register, Vol. 46, No. 205, pp. 52061-52063, October 23, 1981.

USNRC, 1994, "Safety Evaluation Report: Application Dated September 4, 1987, 20.2002 Burial," Docket No. 70-925, Cimarron Corporation, Crescent, OK, June 21, 1994.

USNRC, 1994a, Environmental Assessment of a Proposed Disposal of Uranium-Contaminated Soil at the Cimarron Uranium Plant," Docket No. 70-925, License No. SNM-928, March, 1994.

USNRC, 1996, letter from Mr. Kenneth L. Kalman, Project Manager, Low-Level Waste and Decommissioning Projects Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, to Mr. Jess Larsen, Vice President, Cimarron Corporation, December 10, 1996.

USNRC, 1998, Code of Federal Regulations, Title 10, Part 20, "Standards for Protection Against Radiation," 1998.

## **7.0 DOSE ASSESSMENT FOR ALL SIGNIFICANT SOURCE AREAS ONSITE**

This section discusses the impacted areas at the facility where concentrations of total uranium or Tc-99 in groundwater significantly exceed background concentrations. The BTP Option #2 Disposal Cell is not addressed in this section as it has been previously discussed in Section 6 and has not been determined to contribute to concentrations of radioactive contaminants in the groundwater. The four areas specifically addressed in this section include former Burial Areas #1 and #2, and Uranium Waste Ponds #1 and #2. In those areas the sources have been excavated and only some residual soils meeting Option #1 criteria remain.

As discussed in Section 6, the soil pathway in any affected area will not significantly influence groundwater concentrations as the concentrations are significantly below BTP Option #2 conditions which have been previously modeled. Cimarron believes that the only pathway of concern for those areas is groundwater and that any projected doses will continue to decrease with time. This section evaluates the dose from the groundwater pathway as the only significant exposure concern.

The dose conversion factors for total uranium and Tc-99 are also discussed in this section. In addition, doses are calculated for each of the wells monitored at the facility, assuming consumption of 2 liters per day by reference man.

### **7.1 ICRP-69 Ingestion Model for Uranium**

The ICRP-69 (ICRP, 1995) Ingestion Model presents current scientific knowledge pertaining to uptake and distribution of uranium in the human

body. The uranium model is based upon biokinetic models for gastrointestinal absorption and transfer compartments within the body. A full discussion of the ICRP Gastrointestinal Model is provided in ICRP Publication 56 (ICRP, 1989). ICRP Publication 69 presents age-dependent doses to members of the public, and gives ingestion dose coefficients for uranium.

ICRP Publication 69 reviewed recent gastrointestinal absorption data for dietary forms of uranium. Based upon the data reviewed, the ICRP Committee adopted a value for gastrointestinal absorption ( $f_1$ ) of 0.02. This absorption factor is consistent with the value utilized in the chemical toxicity evaluation in Section 8.0. The ICRP models also incorporate tissue weighting factors to "represent the factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contributions of that tissue or organ to the total detriment resulting from uniform irradiation of the body" (ICRP, 1991).

#### **7.1.1 Dose Conversion Factors (DCFs) for Uranium and Tc-99**

ICRP Publication 69 (Part 3) presents age dependent doses to members of the public from intake of uranium. The adult DCFs for uranium are summarized in Table 7.1.

The DCF for Tc-99 is taken from EPA Federal Guidance Report No. 11 (EPA, 1988). The committed dose per unit intake is  $3.95\text{E-}10$  Sv/Bq ( $1.46\text{E-}06$  mrem/pCi). The gastrointestinal absorption fraction ( $f_1$ ) for Tc-99 given in the EPA guidance is 0.8. The NRC stated in a letter from Mr. Kenneth Kalman to Mr. Jess Larsen dated March 13, 1997 (USNRC, 1997) that a Tc-99 concentration of 3,790 pCi/L would result in an effective dose of 4 mrem/y (assuming consumption of 730 liters/y by

reference man). The Tc-99 DCF used by Cimarron is consistent with this value.

**TABLE 7.1**  
**DOSE CONVERSION FACTORS FOR URANIUM**

	<b>Sv/Bq Ingested</b>	<b>mrem/pCi Ingested</b>
Uranium-234	5.0E-08	1.85E-04
Uranium-235	4.7E-08	1.74E-04
Uranium-238	4.5E-08	1.67E-04

- Notes: 1) Values in the table represent effective dose for an adult.  
2) To convert Sv/Bq to mrem/pCi, multiply Sv/Bq by 3700.

### **7.1.2 Calculation of an Overall DCF for the Total U Isotopic Ratios at Cimarron**

The previous section presented DCFs for the individual uranium isotopes of concern at Cimarron. The DCFs for the individual isotopes range from 1.67E-04 mrem/pCi for Uranium-238 to 1.85E-04 mrem/pCi for Uranium-234. Thus, the isotopic mixture, or activity percentage of each of the three uranium isotopes will not significantly affect the hypothetical dose to a person drinking water from a well established at the Cimarron facility.

The isotopic ratios for soils at Cimarron have been previously established in the NRC's "Environmental Assessment Associated with the BTP Option #2 Onsite Disposal Cell at Cimarron" (NRC, 1994). The Environmental Assessment used activity percentages of 79% for Uranium-234, 1.7% for U-235, and 20% for Uranium-238. As stated above, the DCFs for each of the three uranium isotopes are similar. The activity percentages for soil

were used as weighting factors to determine the total uranium DCF, as shown below.

$$1.85\text{E-}04 \text{ mrem/pCi (0.79)} + 1.74\text{E-}04 \text{ mrem/pCi (0.017)} + 1.67\text{E-}04 \text{ mrem/pCi (0.20)}$$

$$= 1.83\text{E-}04 \text{ mrem/pCi of total uranium.}$$

The DCFs for Uranium-234, Uranium-235, Uranium-238, total uranium, and Tc-99 are summarized in Table 7.2 and Table 7.3 along with the concentrations that would result in an effective dose of 4 mrem/y and 100 mrem/y (Tc-99), or 25 mrem/y and 100 mrem/y (Uranium). These concentration values were selected for comparison purposes.

## 7.2 Dose Calculations Based Upon Well Sample Results

This section presents the hypothetical effective annual dose that could be received by a reference man drinking 2 liters every day from each of the ground water monitoring wells and surface water monitoring locations at the Cimarron facility. Of course, as discussed in Section 3.6 of this report, it is highly unlikely that an individual would use any of the on-site wells as a drinking water supply. The data presented are for calendar year 1997 and the first quarter of 1998. Tc-99 analyses were performed only when indicated based upon gross beta to gross alpha activity ratios exceeding 3:1 and gross beta activity exceeding 30 pCi/L. Those areas were around Uranium Waste Ponds #1 and #2. Total uranium is calculated by summing the isotopic uranium data for each date and location. The effective annual dose is calculated through application of the DCF to the total activity taken into the reference man. Table 7.4 presents the isotopic uranium and Technetium-99 laboratory results for each location by sampling date.

### **7.2.1 Burial Area #1 Dose Calculation**

Burial Area #1 is surrounded by four wells. Well #1314 is upgradient of the burial area, while Wells #1315, #1316, and #1317 are within or downgradient of the burial area. As shown in Table 7.4, the total uranium concentration in Well #1314 averaged 2 pCi/L, resulting in an effective dose to the hypothetical individual of approximately 0.3 mrem/y from ingestion of uranium. There is no Tc-99 associated with Burial Area #1. (Note: As stated above, the use of a DCF for enriched uranium will not have a significant effect upon the dose calculation when naturally occurring uranium isotopic activity ratios are present).

Well #1315 (located in former Burial Area #1) had the highest concentrations of uranium for this area, and also for all monitoring wells within the Cimarron site boundary. This well averaged 1,993 pCi/L, with a resultant annual effective dose of 269 mrem calculated for the hypothetical individual.

Wells #1316 and #1317 are downgradient of former Burial Area #1. The calculated annual effective doses for the hypothetical individual were 16 mrem and 32 mrem, respectively, for the two wells.

### **7.2.2 Uranium Waste Pond #1 Dose Calculation**

Wells #1311, #1312, and #1313, #1340, and #1341 have been used to monitor Uranium Waste Pond #1. Well #1311 is upgradient of the Pond, while Well #1312 is West of the Pond and Well #1313 is downgradient. Wells #1340 (Sandstone A) and #1341 (Sandstone B) are located side by side in an area east of the Pond.

Upgradient Well #1311 showed low levels of total uranium and Tc-99. The reported concentration for Tc-99 (March, 1997) is near the reported laboratory detection limit. The annual effective dose to the hypothetical individual for this well was calculated to be 0.53 mrem due to uranium and 0.02 mrem due to Tc-99, and is within the range of other upgradient and background wells.

Well #1312 continued to show a low level of impact from past operations. The total uranium and Tc-99 concentrations in this well averaged 26 pCi/L and 2,152 pCi/L, respectively. The concentration of Tc-99 dropped from 3,680 pCi/L in March, 1997, to 1,850 pCi/L in March, 1998. The calculated average annual effective dose for this well was 3.5 mrem (uranium) and 2.3 mrem (Tc-99).

Well #1313 had average total uranium and Tc-99 concentrations of 38 pCi/L and 1,047 pCi/L. The calculated annual effective dose to the hypothetical individual was 5.1 mrem (uranium), and 1.1 mrem (Tc-99) for this well.

The concentration of total uranium in Wells #1340 and #1341 was 3.9 pCi/L and 2.2 pCi/L, respectively, for the single sampling event in June, 1997. These concentrations correspond to annual effective doses of 0.5 mrem and 0.3 mrem for the two wells (hypothetical individual).

### **7.2.3 Uranium Waste Pond #2 Dose Calculation**

Uranium Waste Pond #2 is monitored by one seep (#1208), four shallow groundwater wells (#1320, #1336A, #1337, and #1338), and one Sandstone C deep well (#1321). The seep is located on the bluff Northeast of the Pond. Wells #1320 and #1321 are located within the



former Pond area near the Southwest corner. Well #1336A is located downgradient of the Pond, just north of the Northwest corner. Wells #1337 (Sandstone A) and #1338 (Sandstone B) are located side by side at a location Northeast of the Pond.

Seep #1208 averaged 40 pCi/L total uranium and 2,836 pCi/L Tc-99 during 1997 and the first quarter of 1998. Tc-99 concentrations dropped from 3,960 pCi/L in March, 1997, to 2,300 pCi/L in March, 1998. It is unlikely that this seep would be used as a drinking water source on a consistent basis due to the low volumes of water available. Even so, the average annual effective dose to the hypothetical individual was calculated to be only 5.4 mrem (uranium) and 3 mrem (Tc-99).

Wells #1320 and #1321 were monitored in June, 1997. The calculated effective doses for these wells due to uranium were 0.3 mrem and 2.2 mrem, respectively. The average total uranium concentration in Well #1336A was 41 pCi/L, while the average Tc-99 concentration was 1,840 pCi/L. Tc-99 concentrations decreased from 2,590 pCi/L during March, 1997, to 1,600 pCi/L in March, 1998. The annual effective dose for this well was calculated to be 5.5 mrem (uranium), and 2 mrem (Tc-99).

Wells #1337 and #1338 had total uranium concentrations of 11.7 pCi/L and 1.2 pCi/L, respectively in June, 1997. The annual effective dose for these wells is calculated to be 1.6 mrem and 0.2 mrem, respectively.

#### **7.2.4 Burial Area #2 Dose Calculation**

Wells #1332 and #1333 are located to the east of Burial Area #2. These wells are somewhat upgradient to the Burial Area, but are also downgradient of the West Sanitary Lagoon. Well #1333 is a Sandstone C

deep well. Well #1331 is located in a draw to the northwest of the Burial Area.

Wells #1332 and #1333 had total uranium concentrations of 29 pCi/L and 13 pCi/L, respectively, during 1997. These concentrations correspond to annual effective doses of 3.9 mrem for Well #1332, and 1.8 mrem for Well #1333. The average total uranium concentration at Well #1331 was 160 pCi/L, which equates to an annual effective dose of 22 mrem to the hypothetical individual.

#### **7.2.5 Summary of Annual Doses for Burial Area #1, Uranium Waste Ponds #1 and #2, and Burial Area #2**

Table 7.5 provides a summary of the calculated annual average doses for the four operationally affected areas discussed in this section. As discussed above, the doses are hypothetical in nature and assume that reference man consumes 2 liters from the same affected well each day of the year. In all cases, the Tc-99 dose is less than 2.5 mrem, and the total uranium dose is less than 22 mrem, except at former Burial Area #1.

#### **7.2.6 Other Areas**

Well data and dose calculations for other surface water and ground water monitoring locations is presented in Table 7.4. The calculations performed for other wells at the facility do not indicate that there is the potential for any individual to receive greater than 4 mrem per year from Tc-99 or 5 mrem/y from total uranium. These calculations are very conservative and assume that an individual (i.e., reference man) continuously drinks 2 liters of water each day from the selected well.

### 7.3 References

- EPA, 1988, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Federal Guidance Report No. 11, EPA-520/1-88-020, September, 1988.
- ICRP, 1989, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1," ICRP Publication 56, Volume 20, No. 2, 1989.
- ICRP, 1991, "1990 Recommendations of the International Commission on Radiological Protection," ICRP Publication 60, Volume 21, No 1-3, 1991.
- ICRP, 1995, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients," ICRP Publication 69, Volume 25, No.1, 1995.
- USNRC, 1994, Environmental Assessment of a Proposed Disposal of Uranium-Contaminated Soil at the Cimarron Uranium Plant," Docket No. 70-925, License No. SNM-928, March, 1994.
- USNRC, 1997, letter from Mr. Kenneth L. Kalman, Project Manager, Low-Level Waste and Decommissioning Projects Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, to Mr. Jess Larsen, Vice President, Cimarron Corporation, March 13, 1997.

**TABLE 7.2**  
**DOSE CONVERSION FACTORS FOR INGESTION AND CONCENTRATIONS**  
**EQUIVALENT TO 25 and 100 mrem/year (effective dose) - URANIUM**

f1	Dose Conversion Factor CDE (Sv/Bq)	Dose Conversion Factor CDE (mrem/pCi)	Organ	Concentration equal to 25 mrem/y (pCi/L)	Concentration equal to 100 mrem/y (pCi/L)
0.02	5.00E-08	1.85E-04	effective	185	740
0.02	4.70E-08	1.74E-04	effective	197	788
0.02	4.50E-08	1.67E-04	effective	206	823
0.02	4.93E-08	1.82E-04	effective	188	751

- 1) Doses are calculated for reference man.
- 2) Total U DCF (based on the activity fractions used for U-234 (79%), U-235 (1.7%), and U-238 (20%) in the NRC's Option #2 Onsite Disposal Environmental Assessment), in Sv/Bq = 4.93E-08
- 3) Uranium data are based on ICRP Publication 69, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients", 1995.

**TABLE 7.3**  
**DOSE CONVERSION FACTORS FOR INGESTION AND CONCENTRATIONS**  
**EQUIVALENT TO 4 and 100 mrem/year (effective dose) - Tc-99**

f1	Dose Conversion Factor CDE (Sv/Bq)	Dose Conversion Factor CDE (mrem/pCi)	Organ	Concentration equal to 4 mrem/y (pCi/L)	Concentration equal to 100 mrem/y (pCi/L)
0.8	3.95E-10	1.46E-06	effective	3749	93730

- 1) Tc-99 data are based on EPA Federal Guidance Report #11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1/88-020, Sept., 1988.
- 2) Doses are calculated for reference man.

**TABLE 7.4**  
**CALCULATION OF ANNUAL DOSE FROM DRINKING SURFACE WATER AND/OR**  
**WELL WATER AT CIMARRON**  
**CALENDAR YEAR 1997 AND 1st QUARTER 1998**

Assumptions/Notes:  
 person drinks 2 liters per day  
 Federal Radiation Guidance Report No. 11 DCF's for Tc-99  
 ICRP Publication 69 DCFs for Uranium-234, 235, and 238  
 Annual dose in mrem/y is effective dose (i.e. whole body equivalent)  
 No background subtraction performed  
 Tc-99 data available at selected locations only  
 EPA MCL for Tc-99 (equivalent to 4 mrem/y effective dose) = 3750 pCi/l  
 WP = Waste Pond, BA = Burial Area  
 ND = Not Detected (i.e., <MDA)  
 NM = Measurement not required (gross beta less than 30 pCi/L and/or beta/alpha ratio < 3 to 1)

Location	Sample Date (U)	U-234 (pCi/l)	U-235 (pCi/l)	U-238 (pCi/l)	Isotopic U, total (pCi/l)	mrem/y from uranium	Tc-99 (pCi/l)	mrem/y from Tc-99	Comments
<b>SURFACE WATER</b>									
1201	6/97	5.5	0.1	2.5	8.1	1.09	NM	NM	Cimarron River, upstream
1202	6/97	4.1	0.1	3.1	7.3	0.99	NM	NM	Cimarron River, downstream
1204	6/97	1.6	ND	0.5	2.1	0.28	NM	NM	Reservoir #1 (West Lake)
1205	6/97	0.5	ND	0.2	0.7	0.09	NM	NM	Reservoir #2 (East Lake)
1206	3/97	125.0	5.3	33.2	163.5	22.08	12.2	0.01	East of Sanitary Lagoons
1206	6/97	117.0	3.7	42.4	163.1	22.03	25.4	0.03	East of Sanitary Lagoons
1206	9/97	97.2	5.2	25.6	128.0	17.29	54.4	0.06	East of Sanitary Lagoons
1206	12/97	No Sample-Dry							East of Sanitary Lagoons
1206	3/98	115.0	9.6	64.5	189.1	25.54	NM	NM	East of Sanitary Lagoons
1206 Average		113.6	6.0	41.4	161.0	21.74	30.7	0.03	East of Sanitary Lagoons
1208	3/97	37.0	1.8	11.7	50.5	6.82	3960.0	4.22	Seep on bluff NE of WP#2
1208	6/97	8.3	0.6	3.5	12.4	1.67	2800.0	2.98	Seep on bluff NE of WP#2
1208	9/97	24.7	1.3	8.0	34.0	4.59	3040.0	3.24	Seep on bluff NE of WP#2
1208	12/97	40.1	1.8	13.6	55.5	7.50	2080.0	2.22	Seep on bluff NE of WP#2
1208	3/98	29.0	1.8	17.6	48.4	6.54	2300.0	2.45	Seep on bluff NE of WP#2
1208 Average		27.8	1.5	10.9	40.2	5.42	2836.0	3.02	Seep on bluff NE of WP#2
1209	6/97	1.7	0.1	1.1	2.9	0.39	NM	NM	Reservoir #3
<b>WELLS</b>									
1307	6/97	3.4	0.1	1.5	5.0	0.68	NM	NM	Junction Hwys 33/74
1311	3/97	1.3	0.1	0.9	2.3	0.31	18.1	0.02	Waste Pond #1, upgradient
1311	6/97	3.0	0.4	2.1	5.5	0.74	NM	NM	Waste Pond #1, upgradient
1311 Average		2.2	0.3	1.5	3.9	0.53	18.1	0.02	Waste Pond #1, West side
1312	3/97	18.5	0.7	5.8	25.0	3.38	3680.0	3.92	Waste Pond #1, West side
1312	6/97	18.7	0.9	6.0	25.6	3.46	1470.0	1.57	Waste Pond #1, West side
1312	9/97	17.2	0.8	5.7	23.7	3.20	2190.0	2.33	Waste Pond #1, West side
1312	12/97	14.8	2.2	6.0	23.0	3.11	1570.0	1.67	Waste Pond #1, West side
1312	3/98	21.0	1.1	10.0	32.1	4.34	1850.0	1.97	Waste Pond #1, West side
1312 Average		18.0	1.1	6.7	25.9	3.50	2152.0	2.29	Waste Pond #1, West side
1313	6/97	31.0	1.0	10.0	42.0	5.67	1190.0	1.27	Waste Pond #1, downgradient
1313	9/97	28.2	1.0	8.4	37.6	5.08	1560.0	1.66	Waste Pond #1, downgradient
1313	12/97	22.5	1.2	7.2	30.9	4.17	874.0	0.93	Waste Pond #1, downgradient
1313	3/98	27.7	1.3	10.3	39.3	5.31	562.0	0.60	Waste Pond #1, downgradient
1313 Average		27.4	1.1	9.0	37.5	5.06	1046.5	1.12	Waste Pond #1, downgradient
1314	6/97	1.3	0.1	0.6	2.0	0.27	NM	NM	Burial Area #1, upgradient
1315	3/97	1410.0	76.0	819.0	2305.0	311.29	NM	NM	Burial Area #1, downgradient
1315	6/97	1770.0	74.2	1200.0	3044.2	411.12	NM	NM	Burial Area #1, downgradient
1315	9/97	546.0	24.9	374.0	944.9	127.61	NM	NM	Burial Area #1, downgradient
1315	12/97	822.0	68.3	579.0	1469.3	198.43	NM	NM	Burial Area #1, downgradient
1315	3/98	1320.0	25.0	855.0	2200.0	297.11	NM	NM	Burial Area #1, downgradient
1315 Average		1173.6	53.7	765.4	1992.7	269.11	NM	NM	Burial Area #1, downgradient
1316	3/97	73.9	3.7	33.4	111.0	14.99	NM	NM	Burial Area #1, downgradient
1316	6/97	136.0	5.0	59.5	200.5	27.08	NM	NM	Burial Area #1, downgradient
1316	9/97	53.5	2.4	24.2	80.1	10.82	NM	NM	Burial Area #1, downgradient
1316	12/97	53.2	4.0	22.8	80.0	10.80	NM	NM	Burial Area #1, downgradient
1316	3/98	65.6	3.1	40.7	109.4	14.77	NM	NM	Burial Area #1, downgradient
1316 Average		76.4	3.6	36.1	116.2	15.69	NM	NM	Burial Area #1, downgradient
1317	6/97	247.0	11.7	150.0	408.7	55.19	NM	NM	Burial Area #1, NNW
1317	3/98	39.5	2.8	20.4	62.7	8.47	NM	NM	Burial Area #1, NNW
1317 Average		143.3	7.3	85.2	235.7	31.83	NM	NM	Burial Area #1, NNW
1319	6/97	27.9	1.7	4.8	34.4	4.65	NM	NM	East U Plant Yard

Location	Sample Date (U)	U-234 (pCi/l)	U-235 (pCi/l)	U-238 (pCi/l)	isotopic U, total (pCi/l)	mrem/y from uranium	Tc-99 (pCi/l)	mrem/y from Tc-99	Comments
1320	6/97	1.2	ND	1.0	2.2	0.30	34.0	0.04	Waste Pond #2
1321	6/97	11.1	0.2	5.3	16.6	2.24	NM	NM	Waste Pond #2 (deep)
1322	6/97	7.5	0.1	3.8	11.4	1.54	NM	NM	N of Bldg. #4 @ flamm. stor. pad
1323	6/97	20.0	0.6	9.7	30.3	4.09	NM	NM	N of Bldg. #4 @ flamm. stor. pad (deep)
1324	6/97	0.9	ND	0.4	1.3	0.18	NM	NM	BTP Opt. #2 disp. area, East
1325	6/97	0.9	0.1	0.3	1.3	0.18	NM	NM	BTP Opt. #2 disp. area, upgradient
1326	3/97	5.0	0.7	1.6	7.3	0.99	21.9	0.02	East of U Plant Yard
1326	6/97	4.8	0.1	2.2	7.1	0.96	13.1	0.01	East of U Plant Yard
1326	9/97	4.0	0.1	1.1	5.2	0.70	41.3	0.04	East of U Plant Yard
1326	12/97	2.9	0.1	1.7	4.7	0.63	NM	NM	East of U Plant Yard
1326 Average		4.2	0.2	1.7	6.1	0.82	25.4	0.03	East of U Plant Yard
1327B	6/97	3.1	ND	1.2	4.3	0.58	NM	NM	West of Bldg. #1
1328	6/97	20.7	0.5	10.5	31.7	4.28	NM	NM	South of Bldg. #1 (deep)
1329	6/97	4.5	0.2	2.0	6.7	0.90	NM	NM	South of Bldg. #1
1330	6/97	7.4	0.2	2.8	10.4	1.40	NM	NM	South of Bldg. #1
1331	6/97	127.0	4.7	25.0	156.7	21.16	NM	NM	West of Burial Area #2
1331	9/97	137.0	6.7	31.0	174.7	23.59	NM	NM	West of Burial Area #2
1331	12/97	126.0	11.4	27.4	164.8	22.26	NM	NM	West of Burial Area #2
1331	3/98	110.0	3.2	31.5	144.7	19.54	NM	NM	West of Burial Area #2
1331 Average		125.0	6.5	28.7	160.2	21.64	NM	NM	West of Burial Area #2
1332	6/97	18.9	0.3	9.3	28.5	3.85	NM	NM	NW of West Sanitary Lagoon (deep)
1333	6/97	9.1	0.3	3.8	13.2	1.78	NM	NM	NW of West Sanitary Lagoon
1334	6/97	7.4	0.3	3.2	10.9	1.47	NM	NM	Sanitary Laggons, downgradient
1335A	6/97	1.6	ND	0.7	2.3	0.31	NM	NM	West of BTP Option #2 Disposal Area
1336A	3/97	37.5	8.1	15.0	60.6	8.18	2590.0	2.76	Waste Pond #2, downgradient
1336A	6/97	23.2	1.1	9.1	33.4	4.51	1930.0	2.06	Waste Pond #2, downgradient
1336A	9/97	23.6	1.8	7.2	32.6	4.40	1880.0	2.00	Waste Pond #2, downgradient
1336A	12/97	22.9	0.8	8.1	31.8	4.29	1200.0	1.28	Waste Pond #2, downgradient
1336A	3/98	28.7	3.1	12.3	44.1	5.96	1600.0	1.71	Waste Pond #2, downgradient
Well 1336A Average		27.2	3.0	10.3	40.5	5.47	1840.0	1.96	Waste Pond #2, downgradient
1337	6/97	8.0	0.6	3.1	11.7	1.58	NM	NM	Waste Pond #2, NE
1338	6/97	0.7	0.1	0.4	1.2	0.16	NM	NM	Waste Pond #2, NE
1340	6/97	2.7	0.2	1.0	3.9	0.53	NM	NM	Waste Pond #1, East
1341	6/97	1.5	0.1	0.6	2.2	0.30	NM	NM	Waste Pond #1, East
1342	10/97	3.7	0.3	1.7	5.7	0.77	11.4	0.01	NW of facility near site boundary
1342	12/97	4.9	0.3	3.1	8.3	1.12	NM	NM	NW of facility near site boundary
1342	3/98	3.7	0.3	2.5	6.5	0.88	NM	NM	NW of facility near site boundary
1342 Average		4.1	0.30	2.43	6.83	0.92	11.4	0.01	NW of facility near site boundary
1343	10/97	20.9	0.9	13.8	35.6	4.81	12.5	0.01	N of Waste Pond #2 near site boundary
1343	12/97	14.0	1.0	9.5	24.5	3.31	NM	NM	N of Waste Pond #2 near site boundary
1343	3/98	10.5	0.6	7.6	18.7	2.53	NM	NM	N of Waste Pond #2 near site boundary
1343 Average		15.1	0.8	10.3	26.3	3.55	12.5	0.01	N of Waste Pond #2 near site boundary
1344	10/97	5.0	0.1	3.5	8.6	1.16	9.0	0.01	N of Burial Area #2 near site boundary
1344	12/97	1.7	0.2	1.0	2.9	0.39	NM	NM	N of Burial Area #2 near site boundary
1344	3/98	2.5	0.1	1.9	4.5	0.61	NM	NM	N of Burial Area #2 near site boundary
1344 Average		3.1	0.1	2.1	5.3	0.72	9.0	0.01	N of Burial Area #2 near site boundary

**TABLE 7.5**  
**SUMMARY OF AVERAGE ANNUAL DOSE AT FOUR AREAS**  
**CALENDAR YEAR 1997 AND 1st QUARTER 1998**

Area	Well #	Average Annual Dose Total Uranium (mrem)	Average Annual Dose Technetium-99 (mrem)	Comment
<b>Burial Area #1</b>	1314	0.27	Not Measured*	Upgradient
	1315	269	Not Measured*	Downgradient
	1316	15.7	Not Measured*	Downgradient
	1317	31.8	Not Measured*	Downgradient
<b>Uranium Waste Pond #1</b>	1311	0.53	0.02	Upgradient
	1312	3.5	2.3	West Side
	1313	5.1	1.1	Downgradient
<b>Uranium Waste Pond #2</b>	1325	0.18	Not Measured*	Upgradient
	1320	0.3	0.04	Near Southwest Corner
	1321	2.2	Not Measured*	Near Southwest Corner (deep)
	1336A	5.5	2.0	Downgradient
	1337	1.6	Not Measured*	Northeast of Pond
	1338	0.16	Not Measured*	Northeast of Pond
<b>Burial Area #2</b>	1331	21.6	Not Measured*	West of Burial Area in Draw
	1332	3.9	Not Measured*	NW of West Sanitary Lagoon (deep)
	1333	1.8	Not Measured*	NW of West Sanitary Lagoon

Not Measured\* = Measurement of Tc-99 is performed only when gross beta concentration exceeds 30 pCi/L and beta/alpha ratio is equal to or exceeds 3 to 1.

## **8.0 DISCUSSION OF CHEMICAL TOXICITY EVALUATION**

In addition to radiogenic properties, uranium is considered to have chemical toxicity. The ICRP and others have indicated that risk evaluation of uranium in drinking water is more properly based on chemical toxicity rather than on hypothetical radiological toxicity, which has not been observed in either humans or animals (Wrenn, 1985; ATSDR, 1997). Therefore, the potential chemical toxicity associated with the highest concentration of uranium in groundwater at the Cimarron site, i.e., Burial Area #1, is discussed in this section. It should be noted that chemical toxicity risk is not additive with hypothetical radiological toxicity. Further, uranium is not considered to have chemical carcinogenic effects.

Technetium-99 was not evaluated for chemical toxicity, since its chemical toxicity, if any, is not well documented and the dose was within the EPA dose standard of 4 mrem for man-made radionuclides. The highest annual radiological dose from drinking water with Tc-99 present at the site is approximately 3 mrem/year (TEDE), as described in Section 7.0.

### **8.1 Uranium Chemical Toxicity**

#### **8.1.1 Comparative Chemical and Radiogenic Toxicities**

Uranium is a chemical substance which has biological effects related to its radioactivity and its chemical interaction with body tissues, namely the kidney. Although uranium may present a radiological health hazard, uranium-associated cancers have not been seen in humans. At this time, the US Environmental Protection Agency (EPA) has not classified uranium for carcinogenicity (EPA, 1998). The results of studies in both humans and animals are consistent with this conclusion that uranium does not present a



chemical carcinogenic risk (ATSDR, 1997). Therefore, carcinogenic risk is not considered in the chemical toxicity assessment.

Non-cancerous adverse effects to the lung and cardiovascular systems have been noted in animal species. The potential for these adverse non-cancerous radiological health effects is dependent on several factors, including the distribution in the various body organs, the biological retention time in the tissues, the energy and intensity of the radiation, and the half-life; the potential for such effects is independent of the chemical toxicity. However, because the specific activities of natural and depleted uranium are low, no radiological health hazard is expected from exposure to natural and depleted uranium (ATSDR, 1997).

Uranium forms compounds and complexes of different solubilities. The chemical toxicity of the compound or complex is related only to chemical properties and is unrelated to the specific activity or isotopic number. The chemical toxicity of natural, depleted, and enriched uranium is identical because chemical action depends only on chemical properties which are identical (ATSDR, 1997).

Current toxicological evidence is suggestive that the toxicity of uranium is largely due to its chemical properties rather than its radiogenic properties. In terms of chemical toxicity, renal toxicity is the major adverse effect of uranium. Exposure of the general public to natural uranium is unlikely to pose an immediate lethal threat to humans. No human deaths have been reported that are definitely attributable to uranium ingestion; therefore, no lethal dose has been reported for humans. One study reported renal effects in humans following exposure to uranium, while several other studies have found no increased deaths in uranium workers due to kidney disease (ATSDR, 1997).

Animal studies have reported renal effects associated with chronic inhalation and oral exposure to uranium. Lethal doses of uranium in animals (dog) have been reported to be as low as 14 mg/kg-day following 23-day oral exposures. Uranium chemical toxicity depends on the solubility of the uranium compound tested (higher solubility compounds having greater toxicity, especially in the kidney), route of exposure, and animal species (Elless et al, 1997). However, the available data in both humans and animals is sufficient to conclude that even for soluble compounds, uranium has a low order of metallotoxicity in humans (ATSDR, 1997).

### **8.1.2 Gastrointestinal and Dermal Absorption Rates**

Uranium is absorbed from the intestine or the lungs, enters the bloodstream, and is rapidly deposited in the tissues, predominantly kidney and bone, or excreted in the urine. In the bloodstream, uranium is associated with red cells, and its clearance is relatively rapid (Taylor, 1997). The fractional absorption of uranium compounds following oral exposure is generally considered to be quite low and mostly dependent upon chemical form and length of time since the last intake of food. Human drinking water studies indicate that absorption of ingested uranium is 0.006 to 0.015 (mean fraction absorption). Wrenn et al (1985) reviewed the literature regarding gastrointestinal absorption and concluded that fractional absorption is most likely 0.01 to 0.02 and is reasonably independent of age or the mass of uranium ingested. Leggett and Harrison (1995) reported that average gastrointestinal uptake of uranium in adult humans appears to be about 0.01 to 0.015. Differences with age in uranium uptake were not noted; therefore, it would appear that fractional absorption is in the same range for children. EPA has also indicated no differences in fractional absorption of children aged one and older (Eckerman, et al, 1998). Based on this information, ATSDR (1997), USEPA (1998) and Karpas et al (1998) have reported that the reference fraction for gastrointestinal absorption of

relatively soluble ingestion uranium should be less than 0.02. This absorption factor has been utilized in the intake calculations for the Cimarron site.

There is suggestive evidence in animals that certain uranium compounds in pure form may be absorbed through intact skin; however, there is a paucity of data with regard to potential absorption of uranium in water through skin (ATSDR, 1997). Therefore, the default dermal absorption rate for inorganics of  $1 \times 10^{-3}$  cm/hr has been utilized in Cimarron's risk evaluation (EPA, 1992).

### **8.1.3 Chemical Toxicity Values**

No chronic effects have been reported in humans following oral exposure to uranium (ATSDR, 1997). Data available from populations occupationally exposed to high concentrations of uranium compounds through inhalation and information studies in experimental animals indicate that the critical organ for chronic uranium toxicity is the proximal tubule of the kidney (EPA, 1997d). In humans, chemical injury reveals itself by increased catalase excretion in urine and proteinuria. The lowest dose of uranyl nitrate that caused body weight loss and moderate nephrotoxicity in rabbits was 2.8 mg/kg-day (EPA, 1997d). This value was modified by an uncertainty factor of 1000 to provide the current Reference Dose (RfD) of 3E-03 mg/kg-day. The RfD is an estimate of a chemical dose at which consumption over a lifetime would not be likely to result in the occurrence of chronic, noncancer effects (EPA, 1997d).

## **8.2 Chemical Exposure Evaluation**

Groundwater represents the primary media of concern for the Cimarron site. Soils and deposited Option #2 materials at the site have previously been determined not to present any potential threats to human health or

the environment (NRC, 1994). Due to the nature of the site, exposures associated with re-entrained particulate materials in air are unlikely to occur. Reservoirs and the Cimarron River have been monitored for over a decade and no exceedences of MCLs have been noted and therefore, these surface waters do not constitute a potential exposure media.

## **8.2.1 Potential Exposure Scenarios for Groundwater**

### **8.2.1.1 Vicinity Groundwater Use**

The Garber-Wellington Aquifer is a primary water supply for Logan County. In the County, municipal (to a limited extent) and irrigation waters are drawn from groundwater; however, domestic water usage from wells in the vicinity of the site is minor due to the high naturally occurring hardness. The area is served by a rural water district (Grant, 1989). In general, groundwater in the alluvium is not used because of its salinity. Area investigations have shown there are four (4) domestic water supply wells screened in the Garber-Wellington Aquifer and located within a three-mile radius of the Site, on the south side of the Cimarron River (Grant, 1990). All of these wells are in an upgradient direction of the Facility. The average depth of these wells is 116.5 feet. Evaluation of these wells has demonstrated no impacts to off-site groundwater quality from the Cimarron site. The downgradient receptor for groundwater from the site is the Cimarron River. These data may also reflect these off-site wells have been completed in a more permeable part of the Garber-Wellington Aquifer which is located east of the site and runs north-south across the State (Chase, 1997).

### **8.2.1.2 Current Use Exposure Scenario (Trespasser)**

The site is under the control of Cimarron such that potential receptors are limited to a trespasser or agricultural worker who may be exposed to

“seeps” resulting from the discharge of shallow groundwater in the areas of the bluffs at the site. The assumptions used in evaluating each of the scenarios are conservative to ensure that the estimated risks are greater than any actual exposure will likely be.

Other activities presently occurring within the Cimarron site are work involved with the overall decommissioning of the site, periodic ground maintenance (i.e., cutting the native grass), periodic environmental assessment activities, and non-radiation related research involving titanium dioxide pigment. Groundwater is not utilized by Cimarron personnel for any purpose; therefore, it does not constitute an exposure pathway for on-site workers.

There are significant portions of the site surroundings under agricultural use, therefore, cultivation activities as required are performed by an agricultural lease holder. Groundwater is not utilized at the site for irrigation purposes in these unrestricted use areas; therefore, it does not constitute an exposure pathway for agricultural workers.

The former processing area site is controlled with regards to the potential for unauthorized persons being on site by the presence of a security fence, and currently also by security guards. Potential receptors, such as trespassers, are not likely to be drawn to this area for any type of recreational activity due to the fencing and overall nature of the site. The Cimarron River is not used for recreation activities in this vicinity. The only potential exposure to impacted groundwater, therefore, is limited to a few localized “seeps” along the bluffs. The limited volume of groundwater discharging at these seeps and their location make it highly unlikely that water could be consumed as a drinking water supply by agricultural

workers or trespassers. If a trespasser should happen upon the site, the exposure to groundwater would be highly unlikely.

It is possible, although not highly probable, that a trespasser could have limited dermal contact with water from the "seeps", using it to wash dirt from hands and forearms. Therefore, as a worst case scenario, a situation which assumes contact with the water from the "seeps" on the hands and forearms of an adult trespasser was determined to be the most likely completed exposure scenario for evaluation. This scenario was also used in the non-radiological constituent risk assessment performed for the Oklahoma DEQ. The potentially complete pathway for current exposure considered for evaluation is:

- dermal contact with shallow groundwater.

#### **8.2.1.3 Future Use Exposure Scenario (Groundwater Consumer)**

Due to the nature of the groundwater underlying the Cimarron Site and the availability of surface and supplied water systems, the development of the groundwater resources for drinking, irrigation and livestock watering purposes is unlikely to occur. Studies (Grant, 1996; Chase, 1997) have revealed that, in general, the shallow aquifer would not yield the long-term sustainable pumping rate for groundwater at the site greater than approximately one to two gallons per minute. Further, groundwater near the site is hard to very hard, and naturally high in dissolved solids, chloride, and nitrates which further limit its usage. Most importantly and as described above, the ready access to other higher quality water supplies and the generally less-than-acceptable quality and quantity of the groundwater underlying the site, make the use of groundwater unlikely to occur, even if there are no controls on use of the Site. Moreover, governmental institutions and their associated support infrastructure will

remain in place, further limiting the possibility of any use of such a limited water source by a future resident.

Although the groundwater at the site would not typically be utilized for a drinking water supply because of its poor quality and marginal yield, the risk evaluation conservatively assumes that the waters could be utilized on an individual basis for domestic consumption. Therefore, a future exposure scenario which assumes consumption of groundwater and dermal exposure associated with domestic use was evaluated. Direct ingestion of groundwater is anticipated to represent the majority of the exposure potential due to the poor dermal absorption of uranium (see Section 8.1.2). The potentially completed pathways considered for evaluation for this scenario are:

- ingestion of water;
- dermal contact with water.

#### **8.2.1.4 Exposure Point Concentrations for Groundwater**

Table 8.1 summarizes the shallow groundwater data for the site for 1997 and first quarter 1998. The 95 upper confidence limit (95th UCL) of the arithmetic mean was calculated for the shallow groundwater system and the water surfacing at the “seeps” as shown in Table 8.1. Collectively, these concentrations are considered the exposure point concentrations used to evaluate the potential risk associated with the site. The use of 95UCL values to evaluate chemical toxicity is standard practice for chemical risk assessment in order to estimate reasonable maximum exposure levels. This is in contrast to the standard use of average concentrations when evaluating radiogenic risk as in Section 7.0. Both the shallow groundwater system data and the “seeps” data were utilized to evaluate the current trespasser scenario. The maximum concentration

in the shallow groundwater was utilized for the future-use groundwater consumer scenario.

### **8.2.2 Calculated Potential Daily Intake Values for Uranium**

Chemical intake estimates are based on EPA methodology (EPA, 1989). All exposure equations used to calculate dose and intake from the ingestion of chemicals in soil and from dermal contact are presented in Table 8.2.

#### **8.2.2.1 Current Use Exposure Scenario**

The trespasser scenario assumed that a trespasser will have contact with the water from the "seep" for 1.5 hours per trespass event; this value is the EPA default value for adult time spent out of doors. It was assumed that 12 trespass events occurred per year. This value is consistent with the EPA default value for frequency of recreational water contact of 1 event per month (i.e., 12 per year). Since such contact is unlikely to occur over the colder months, this estimate is extremely conservative. The surface area of the hands and forearms of the adult trespasser was assumed to be 1,980 cm<sup>2</sup> which is the mean surface area as reported by EPA (EPA, 1997).

#### **8.2.2.2 Future Use Exposure Scenario**

The analysis of the future groundwater consumer scenario for domestic consumption of groundwater assumes that these waters serve as the sole source of drinking water for a user. It will be assumed that the water user will potentially consume water (2 L/day) and have dermal contact (full-body) with water from the shallow groundwater system 365 days/year for a 30 year period. Chemical intake estimates utilized were drawn from NRC and USEPA default exposure parameters (Kennedy, 1992; EPA, 1989; EPA, 1991; EPA, 1992a; EPA 1997a). The exposure factors



utilized in the risk evaluation and their source are summarized in Table 8.3.

### **8.2.3 Human Health Risk Characterization**

#### **8.2.3.1 Chemical Noncarcinogenic Dose-Response**

Compounds with known or potential noncarcinogenic effects are assumed to have a dose below which no adverse effect occurs or, conversely, above which an adverse effect may be seen. This dose is the threshold dose. The threshold dose is called a No Observed Adverse Effect Level (NOAEL). The lowest dose at which an adverse effect occurs is called a Lowest Observed Adverse Effect Level (LOAEL). By applying uncertainty factors to the NOAEL or the LOAEL, RfDs for chronic exposures to chemicals with noncarcinogenic effects have been developed by EPA. The uncertainty factors account for uncertainties associated with the dose-response relationship such as the effects of using an animal study to derive a human dose-response value, extrapolating from high to low doses, and evaluating sensitive subpopulations. The source of the published dose-response value used in this evaluation was EPA's Integrated Risk Information System (IRIS) (EPA, 1997a).

For chemicals with noncarcinogenic effects, an RfD provides reasonable certainty that no noncarcinogenic health effects are expected to occur even if daily exposures were to occur at the RfD level for a lifetime. The RfD and exposure doses are expressed in units of milligrams of chemical per kilogram body weight per day (mg/kg-day). The oral RfD for uranium is  $3.0E-03$  mg/kg-day, as discussed in Section 8.1.3.

### 8.2.3.2 Human Health Risk Characterization

Risk characterization combines toxicity and exposure information to arrive at qualitative and quantitative evaluation of any potential human health hazards. The potential noncarcinogenic risk to each potential human receptor from ingestion of contaminants in groundwater was quantitatively evaluated.

For the chemical assessment, risk is defined as the estimate of exceeding toxic effect thresholds for noncarcinogens. A probabilistic approach is not used to estimate the potential for noncarcinogenic health effects. Instead, the potential for noncarcinogenic effects is evaluated by comparing the average daily exposure (intake) over a specified time period (exposure duration) with a RfD derived for similar exposure periods for each chemical. This ratio of exposure is called a hazard quotient (HQ) calculated as:

$$HQ = \frac{\text{intake (mg / kg - day)}}{\text{RfD (mg / kg - day)}}$$

HQ's may be summed to obtain a hazard index (HI) for each chemical and specific pathway. An HQ or HI greater than one has been defined as the level of concern for potential adverse noncarcinogenic health effects (EPA, 1989).

### 8.2.3.3 Risk Estimates for the Cimarron Facility

The noncarcinogenic risk estimates calculated are presented in Tables 8.4 through 8.9. The results are discussed in the following subsections.

### **On-Site Current Use Trespasser**

The noncarcinogenic HQ/HI for dermal contact with shallow groundwater at the 95th UCL concentration of  $1.07E-04$  for the trespasser scenario is considerably less than the target level of 1.0 (Table 8.4). The dermal contact HQ/HI of  $3.53E-05$  for waters at the seeps where exposure is more likely to occur is also well below the target level of 1.0 (Table 8.5). If average concentrations had been utilized, the calculated HQ/HI would have been considerably lower. Therefore, the uranium compounds in groundwater at the site do not pose a hazard to a trespasser.

### **On-site Future Use Groundwater Consumer**

The total noncarcinogenic HQ/HI associated with uranium for an on-site groundwater consumer was evaluated at both the 95th UCL concentration for the site and the maximum concentration at Well 1315 (3.1 mg/L) [3,044 pCi/L] which is located at Burial Area #1. The total noncarcinogenic HQ associated with dermal contact with uranium at the maximum concentration was an order of magnitude below the target level of 1.0 (Table 8.6). For ingestion, when fractional absorption of 2 percent is utilized, the HQ for ingestion of groundwater at the maximum concentration by a resident farmer is  $5.90E-01$  which is less than the target level of 1.0 (Table 8-7). The total HI ( $7.34E-01$ ) for uranium considering both the dermal and ingestion pathways for the groundwater consumer exposed at the site maximum concentration is below the target level of 1.0. If the average concentration had been utilized as the basis of the risk calculation, the calculated HQ/HI would have been even lower. As can be noted from these data, direct ingestion of groundwater constitutes the major component of exposures and the HQ.

The 95th UCL concentrations were also evaluated (Tables 8.8 and 8.9). As with the maximum concentrations, the dermal contact and ingestion

when gastrointestinal absorption of 2 percent is utilized, the total HI of 5.44E-02 is well below the target level of 1.0. The evaluation demonstrates that it is unlikely that adverse health effects would occur if a groundwater consumer utilized groundwater at the Cimarron site at the highest impacted well for domestic purposes. Again, it can be noted that direct ingestion of groundwater contributes the majority of the HQ. Further, if the average concentration had been utilized as the basis of the risk calculation, the calculated HQ/HI would have been even lower. Use of groundwater at any other location on-site would result in exposure levels which would be significantly less than that evaluated at the highest concentration well.

#### **8.2.4 Uncertainties In The Chemical Toxicity Evaluation**

The risks calculated in this assessment are single point estimates of risk rather than probabilistic estimates. Therefore, it is important to discuss uncertainties inherent in the risk assessment in order to place the risk estimates in proper perspective. Uncertainties can be associated with sampling data adequacy, exposure assessment variables, and toxicity values.

Uncertainty is inherent in selection of data to represent the exposure point concentrations for the Site. Considerable data on uranium concentrations in groundwater, which had been collected since 1985, was available for use in the evaluation. The data collection program at the Cimarron Site has been comprehensive and hence, the uncertainty associated with the identification of exposure point concentrations for analysis is low.

Selection of the future use exposure scenario at the Facility may result in an overestimation of potential risk. Due to the water quality and the availability of rural water, it is unlikely that site groundwater would be utilized for

domestic consumption. The conservative nature of the scenario selected for analysis ensures that the potential risks are not underestimated, and are, in fact, likely to be greatly overstated.

The variables used for the exposure assessment were extremely conservative and would lead to an overestimation of risk. The exposure intake assumptions were those determined by the NRC and/or the EPA. The conservative nature of the assessment results in an overestimation of potential risk.

There is a great deal of inherent uncertainty in the toxicity values used for assessing potential risk to humans. Sources of uncertainty for calculating toxicity factors include extrapolation from short-term to long-term exposures, the amount of data supporting the toxicity factors and extrapolation from animal experiments. To the extent that humans differ from animals, the Facility-specific risk estimates based on these animal toxicity data may not reflect actual risk to humans.

In general, the assumptions built into this assessment are based on best practice and tend to overestimate rather than underestimate potential risks, including conservative assumptions for exposure point concentrations and exposure scenarios.

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**TABLE 8.1**  
**1997 AND FIRST QUARTER 1998 CHEMICAL CONSTITUENT DATA SUMMARY AND BENCHMARK COMPARISON FOR**  
**CIMARRON RIVER, SEEPS, AND SHALLOW GROUNDWATER SYSTEMS**  
**CIMARRON CORPORATION**

Contaminant	Range	Frequency of Detection	Mean	95th UCL	Benchmark Values			
					Background	Above/Below Background Values	Maximum Contaminant Level	Above/Below MCL
Shallow Groundwater Upgradient								
Total Uranium (mg/L)	0.0007 - 0.003	3/3	0.002	0.003	NA	NA	0.02	Below
Total Uranium (pCi/L) <sup>(1)</sup>	1.3 - 5.0	3/3	2.77	5.0	NA	NA	30	Below
Shallow Groundwater Downgradient								
Total Uranium (mg/L)	0.0005 - 3.1	67/67	0.12	0.23	0.0007 - 0.003 <sup>(2)</sup>	Above	0.02	Above
Total Uranium (pCi/L) <sup>(1)</sup>	1.2 - 3,044	67/67	161.4	278.7	1.3 - 5.0 <sup>(2)</sup>	Above	30	Above
Water at Seeps								
Total Uranium (mg/L)	0.007 - 0.114	9/9	0.05	0.076	0.0007 - 0.003 <sup>(2)</sup>	Above	0.02	Above
Total Uranium (pCi/L) <sup>(1)</sup>	12.4 - 189.1	9/9	93.0	136.9	1.3 - 5.0 <sup>(2)</sup>	Above	30	Above

<sup>(1)</sup> As determined by modified HASL300 analytical method

<sup>(2)</sup> Background values based on 1997 Shallow Groundwater Upgradient Well Data.

**TABLE 8.2**  
**PATHWAY-SPECIFIC FORMULAS USED FOR CHEMICAL EXPOSURE CALCULATIONS**

Dermal Contact with Contaminants in Water	Drinking Water Ingestion
$Intake (mg / kg / day) = \frac{C_w \times SA \times PC \times EF \times ED \times ET \times CF}{BW \times AT}$	$Intake (mg / kg / day) = \frac{C_w \times CF \times IR \times ABS \times EF \times ED \times FI}{BW \times AT}$
<p>where:</p> <p><math>C_w</math> =Chemical concentration in water (mg/Lg)</p> <p>CF =Conversion factor for chemical fraction of water (1 L/1000cm<sup>3</sup>)</p> <p>EF =Exposure frequency (days/year)</p> <p>ED =Exposure duration (years)</p> <p>BW =Body weight (kg)</p> <p>AT =Averaging time for pathway-specific exposure period</p> <p>ET =Exposure time (hours/day)</p> <p>SA =Skin surface area available for contact (cm<sup>2</sup>)</p> <p>PC =Chemical-specific dermal permeability constant (cm/hr)</p>	<p>where: <math>C_w</math> =Chemical concentration in drinking water (mg/L)</p> <p>CF =Conversion factor (10<sup>-3</sup> mg/mg)</p> <p>FI =Fraction Ingested from contaminated source</p> <p>IR =Ingestion rate (1/day)</p> <p>ABS =Fractional Absorption (unitless)</p> <p>EF =Exposure frequency (days/year)</p> <p>ED =Exposure duration (years)</p> <p>BW =Body weight (kg)</p> <p>AT =Averaging time for pathway-specific exposure period (days)</p>

**TABLE 8.3**  
**SUMMARY OF EXPOSURE FACTORS**

Exposure Factor	Value	Source
Body Weight (BW) (kg)	adult : 70	NRC
Averaging time (AT) (days)	noncarcinogens: exposure duration x 365	EPA
Drinking water ingestion (IR <sub>water</sub> ) adult (L/day)	adult: 2	NUREG- 5512
Exposure frequency (EF) (days/year)	residential: 365	NRC
	trespasser: 12	EPA
Exposure time (ET) (hours/event)	residential 0.5	EPA
	trespasser 1.5	
Exposure duration (ED) residential (years)	residential - adult: 30	NRC
	trespasser: 8	EPA
Gastrointestinal Absorption (ABS) (unitless)	adult 0.02	ATSDR
Skin surface area - adult (SA) (cm <sup>2</sup> )	hands/forearms: 1,980	EPA
	full body: 19,400	
Dermal absorption rate - inorganics (cm/hr)	1 x 10 <sup>-3</sup>	EPA

**TABLE 8.4. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH DERMAL CONTACT WITH SHALLOW GROUNDWATER  
TRESPASSER SCENARIO, CIMARRON CORPORATION**

Chemical	95th UCL Concentration (mg/L)	Surface Area (sq cm)	Permeability Constant (cm/hr)	Exposure Time (hrs)	Exposure Frequency (days/year)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	0.23 <sup>(a)</sup>	1980	1.00E-03	1.5	12	8	70	2920	3.21E-07	3.00E-03	1.07E-04

<sup>(a)</sup> 278.7 pCi/L

**TABLE 8.5. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH DERMAL CONTACT WITH WATER AT THE SEEPS  
TRESPASSER SCENARIO, CIMARRON CORPORATION**

Chemical	95th UCL Concentration (mg/L)	Surface Area (sq cm)	Permeability Constant (cm/hr)	Exposure Time (hours)	Exposure Frequency (days/year)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	0.076 <sup>(a)</sup>	1980	1.00E-03	1.5	12	8	70	2920	1.06E-07	3.00E-03	3.53E-05

<sup>(a)</sup> 136.9 pCi/L

**TABLE 8.6. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH DERMAL CONTACT WITH SHALLOW GROUNDWATER  
GROUNDWATER CONSUMER SCENARIO AT 1997/FIRST QUARTER 1998 MAXIMUM CONCENTRATION, CIMARRON CORPORATION**

Chemical	Maximum Concentration (mg/L)	Surface Area (sq cm)	Permeability Constant (cm/hr)	Exposure Time (hr)	Exposure Frequency (days)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	3.1	19400	1.00E-03	0.5	365	30	70	10950	4.30E-04	3.00E-03	1.43E-01

Maximum Concentration: Well 1315, 3/97, 3,044 pCi/L

**TABLE 8.7. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH INGESTION OF SHALLOW GROUNDWATER  
GROUNDWATER CONSUMER SCENARIO AT 1997/FIRST QUARTER 1998 MAXIMUM CONCENTRATION, CIMARRON CORPORATION**

Chemical	Maximum Concentration (mg/L)	Ingestion Rate (L/day)	Exposure Frequency (days)	Fractional Absorption (unitless)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	3.1	2	365	0.02	30	70	10950	1.77E-03	3.00E-03	5.90E-01

Maximum Concentration: Well 1315, 3/97, 3,044 pCi/L

<b>TOTAL HAZARD INDEX FOR GROUNDWATER CONSUMER SCENARIO:</b>	<b>7.34E-01</b>
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**TABLE 8.8. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH DERMAL CONTACT WITH SHALLOW GROUNDWATER GROUNDWATER CONSUMER SCENARIO AT 95th UCL CONCENTRATION, CIMARRON CORPORATION**

Chemical	95th UCL Concentration (mg/L)	Surface Area (sq cm)	Permeability Constant (cm/hr)	Exposure Time (hr)	Exposure Frequency (days)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	0.23 <sup>(a)</sup>	19,400	1.00E-03	0.5	365	30	70	10950	3.187E-05	3.00E-03	1.06E-02

<sup>(a)</sup> 278.7 pCi/L

**TABLE 8.9. SUMMARY OF INTAKE AND RISK ASSOCIATED WITH INGESTION OF SHALLOW GROUNDWATER GROUNDWATER CONSUMER SCENARIO AT 95th UCL CONCENTRATION, CIMARRON CORPORATION**

Chemical	95th UCL Concentration (mg/L)	Ingestion Rate (L/day)	Fractional Absorption (unitless)	Exposure Frequency (days)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Average Daily Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Uranium	0.23 <sup>(a)</sup>	2	0.02	365	30	70	10950	1.31E-04	3.00E-03	4.38E-02

<sup>(a)</sup> 278.7 pCi/L

<b>TOTAL HAZARD INDEX FOR GROUNDWATER CONSUMER SCENARIO:</b>	<b>5.44E-02</b>
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## **9.0 JUSTIFICATION FOR SITE UNRESTRICTED RELEASE LICENSE TERMINATION**

### **9.1 Discussion Of The NRC December, 1997 Proposed Values**

Cimarron requested NRC review the Commission Action Plan for Decommissioning and other potentially applicable drinking water standards and interpret their potential application at the Cimarron site as unrestricted use release criteria. The NRC conducted the review and proposed reference standards which Cimarron should consider for the protection of groundwater resources at the site in December, 1997 (NRC, 1997). In their letter, the NRC referenced the "Interim Primary Drinking Regulations" in 40 CFR Part 141 as possibly applicable standards and also stated that other groundwater criteria could be proposed by Cimarron.

For Tc-99 and other beta emitters, the cited reference standard (NRC, 1997) was based on the total average annual concentration of beta particle and photon radioactivity from man-made radionuclides which would result in an annual whole body dose of less than or equal to 4 mrem/year (based on consumption of 2 L/day of water) (EPA, 1976).

The NRC's referenced limit (NRC, 1997) for uranium was 30 pCi/L or 0.02 mg/L (20 µg/L) as provided in the proposed 1991 EPA Maximum Contaminant Level (EPA, 1991). This proposed level was based on chemical toxicity, not radiation effects. In developing this limit, EPA assumed a fractional absorption equal to 1.0 and therefore, multiplied the RfD of 3E-03 mg/kg-day (See Section 8.1.3) by 70 kg and divided by 2 liter per day water intake to derive a drinking water exposure limit and then applied a 20 percent relative source contribution factor to arrive at

0.02 mg/L MCL value. In proposing the standard, EPA indicated that the MCL was based on kidney toxicity rather than the carcinogenic potential associated with the radiogenicity of uranium. In general, EPA and ATSDR have characterized the carcinogenic potential of uranium as low (EPA, 1991; ATSDR, 1997).

The NRC also indicated that the reference standard for Radium-226 was 20 pCi/L and for adjusted gross alpha of other alpha emitting radionuclides (excluding uranium and Radium-226), the standard was 15 pCi/L.

## **9.2 Discussion Of Overlapping Requirements With Oklahoma Department Of Environmental Quality (DEQ) For Chemical Constituents**

The DEQ, the successor agency to the Oklahoma Department of Health, has asserted jurisdiction over the chemical constituents: nitrate, fluoride and uranium (chemical toxicity only) in groundwater at the Cimarron site. As a part of the review of the site, the DEQ requested that Cimarron prepare a risk assessment for groundwater which addressed the three chemical contaminants since some site data exceeded the Oklahoma Drinking Water Standards (which are equivalent to the EPA Maximum Contaminant Levels) for fluoride, nitrate, and uranium of 4 mg/L, 10 mg/L, and 0.02 mg/L (30 pCi/L), respectively.

A work plan (RSA, 1997) was prepared and approved by DEQ (DEQ, 1997) which outlined the exposure scenarios to be addressed in the assessment. As a part of the review of the work plan, the DEQ concurred with Cimarron's assertion that because of the naturally occurring dissolved solids, chloride and nitrate content, the low long-term sustainable pumping rates, and the availability of high quality alternative



water sources, groundwater consumption by a domestic user was unlikely to occur in the future. Therefore, a resident farmer scenario was excluded from the assessment sent to DEP for assessment of current and/or future groundwater use at the site.

A trespasser scenario equivalent to the trespasser scenario evaluated in Section 8.2 was utilized for the assessment prepared for DEQ. The Hazard Index for noncancer risks calculated for fluoride, nitrate, and uranium were several orders of magnitude below the acceptable value of one. It was concluded that the groundwater at the site did not pose a risk to human health or the environment for these constituents.

Cimarron anticipates that DEQ will not require any corrective actions at the site in light of the absence of any meaningful likelihood of the use of the affected water. Rather, DEQ will require continued monitoring of the groundwater in localized areas for some period of time, as well as on-going oversight of the property by Cimarron. As a part of the risk assessment Cimarron has proposed "re-opening criteria" to the DEQ. The "re-opening" criteria represent risk-based concentrations which will be utilized to assess any need for continued monitoring of groundwater and oversight by Cimarron.

Cimarron proposed use of a background concentration of nitrate for the "re-opening criterion". The State concurred. The background concentration approach was proposed because upgradient groundwater and unaffected wells on site contain nitrate levels which exceed the drinking water standard, primarily related to the use of nitrogen-based fertilizers in the agricultural activities on-going on and surrounding the site. Based on data from the last time a monitoring well was sampled, eighteen (18) of the 27 downgradient shallow groundwater wells and "seeps" were

found to have nitrate concentrations below 40 mg/L, the current background concentration arising from agricultural activities on and around the site. Areas which have nitrate levels above background and are affected by past facility operations are the two "seeps", Uranium Waste Pond #1 and Uranium Waste Pond #2.

For fluoride, the Maximum Contaminant Level of 4 mg/L was proposed for use as the "re-opening criteria". Evaluation of the groundwater data from the last time a monitoring well was sampled, revealed that 21 of the 27 downgradient shallow wells and seeps have fluoride concentrations below the Maximum Contaminant Level of 4 mg/L. Elevated fluoride concentrations occur in the area of Waste Pond No. #1 and Waste Pond No. #2. In those areas, the highest fluoride concentration occurring during 1997 and first quarter 1998 was 88 mg/L. When only dermal exposure is considered (the most likely exposure scenario), the fluoride concentrations in the shallow groundwater are not a concern.

A risk-based "re-opening criterion" was proposed for uranium (chemical toxicity). The risk-based criterion was based on the unlikely scenario that a resident farmer would consume site groundwater as the sole source of water for domestic uses. Consumption by ingestion was the only exposure route considered, since it had been demonstrated that dermal exposure contributed only minimal exposure. Because of the nature of uranium and its poor to non-existent percutaneous absorption, DEQ did not require potential dermal absorption be included in the calculation of the risk-based "re-opening" criterion. The proposed risk-based "re-opening criteria" for uranium is 0.11 mg/L based solely on ingestion of groundwater and on an assumed fractional absorption of 1.0. Table 9.1 presents the calculation of the chemical risk-based criterion. For uranium, all but two of the 27 downgradient shallow wells and "seeps" have

uranium concentrations below the 0.11 mg/L "re-opening criterion"; in fact 20 of the 27 downgradient wells and "seeps" have uranium concentrations on the last sampling below the Maximum Contaminant Level of 0.02 mg/L (30 pCi/L). When the actual fractional absorption for uranium of 0.02 is utilized, the risk-based criteria is 5.5 mg/L; all of the wells and seeps meet this criteria.

These chemical data and the risk assessment is provided in the document entitled *Risk Assessment for Groundwater, Cimarron Corporation, Crescent, Oklahoma* submitted to the DEQ on June 2, 1998.

### **9.3 Proposed Unrestricted Use Radionuclide Release Criteria**

Cimarron is proposing the following criteria for radiological constituents in groundwater to be utilized by the NRC in evaluating the site groundwater regime for unrestricted release. In some cases, the concentrations are different from those proposed as standards by the NRC in December, 1997 (NRC, 1997). The different standard for uranium is justified based on the scientific underpinnings of the limit, site hydrogeology, current and future land uses, the existence of a strong governmental infrastructure, and Cimarron's continued control and use of the facilities for non-radiological research and development activities associated by Kerr-McGee's Chemical Division.

#### **9.3.1 Criteria for Technetium**

Cimarron agrees with the use of a dose-based criteria for Technetium based on an annual dose equivalent to the total body of 4 mrem/year. As discussed in Section 7.0, the dose equivalent calculated for groundwater at the Cimarron site, based on 1997 sampling results, are all below the 4 mrem/year criteria. Therefore, the site has met the criteria for unrestricted release for this species.

### 9.3.2 Criteria for Uranium

Cimarron proposes use of a risk-based criterion for uranium of 0.11 mg/L (180 pCi/L) total uranium, which corresponds to a theoretical annual dose of approximately 25 mrem/year calculated utilizing the method discussed in Section 7.1. The calculation of the risk-based criterion is presented in Table 9.1 and assumes only the direct ingestion of groundwater. It assumes that an adult resident would consume 2 L of water per day, every day for a period of 30 years, and absorbs 100 percent (fractional absorption of 1) of the uranium in the water. A fractional absorption of 1.0, which is considerably above the measured fractional absorption of uranium of 0.2, was utilized in order to allow for significant conservatism in the calculation of the criterion. Because uranium is poorly absorbed through skin, potential dermal absorption does not represent a major contributor to the risk and thus, was not included in the calculation of the risk-based criterion.

As discussed in Section 9.1, the reference standard for uranium suggested by the NRC, the current EPA-proposed MCL for uranium, allows for water consumption to contribute only 20 percent of the total exposure. Consistent with previous determinations at the site as discussed in Section 6, Cimarron has attributed 100 percent of potential exposure to ingestion of groundwater, since other potential exposure routes are insignificant. The attribution of 100 percent of the potential exposure to direct ingestion of water accounts for the differences in the risk-based criterion proposed by Cimarron and the reference standard proposed by the NRC.

As was noted in the discussion in Section 8.1.2, the gastrointestinal fractional absorption of soluble uranium salts is generally less than 0.02 which is considerably below the assumed fractional absorption rate of 1

for the criterion concentration. If the actual fractional absorption rate of 0.02 is utilized, the risk-based criterion would be 5 mg/L (calculated by dividing the criteria calculated in Table 9.1 by the fractional absorption of 0.02). Therefore, the risk-based 0.11 mg/L criterion selected for use is still extremely conservative.

It should be noted that in light of the conservative nature of the assumptions that were applied in the development of the criterion, the true potential likelihood of developing an adverse effect associated with the consumption of groundwater which is at or below the criterion level is extremely low and may be zero. Further, because of the difference in chemical risk and radiogenic dose, the two doses or risks are not additive.

The concentration of 0.11 mg/L for uranium is consistent with the "re-opening criterion" or no further action proposed to the DEQ and with preliminary media goals set forth by EPA Regions 3, 6 and 9 (EPA, 1997, 1996b, 1996a) for use in evaluating contaminated sites. Further, this concentration is generally consistent with a revised MCL (0.05 to 0.07 mg/L) under consideration by EPA for promulgation in 2000 (Kirk, 1998) in which EPA has determined that the fractional absorption and source contribution factor need to be adjusted from the originally proposed MCL. Of course, the MCL proposed by the EPA in 1991 has never been promulgated as a final regulation and thus has no binding legal effect.

Further, as shown by Section 7.1 and Table 7.2, the risk-based criteria for uranium of 0.11 mg/L (180 pCi/L) corresponds to a theoretical annual dose of approximately 25 mrem/year. The limit thus is also consistent with generally accepted radiation dose-based criteria, that is, annual radiation doses at or below 25 mrem/year are generally considered acceptable. As discussed in Section 8.1.1, due to the low specific activity of uranium in

groundwater it is unlikely that radiation doses of this magnitude would even occur.

Reviewing the data from the last sampling event of each of the 27 shallow downgradient monitoring wells and "seeps" at the Cimarron site, all but two locations (MW-1315 and SW-1206) are below the proposed risk-based criteria. All of the monitoring wells and "seeps" would be far below the less conservative 5 mg/L risk-based concentration for uranium.

#### **9.4 References**

- ATSDR, 1997. Toxicological Profile for Uranium (draft), Agency for Toxic Substances and Disease Registry, Atlanta, GA, September, 1997.
- DEQ, 1997. Letter to S. Jess Larsen, Cimarron Corporation from Glen Jones, Water Quality Division, Oklahoma Department of Environmental Quality, Oklahoma City, OK, dated October 24, 1997.
- EPA, 1976. 40 Code of Federal Regulations 141.16, Interim Primary Drinking Water Standards.
- EPA, 1991. 40 Code of Federal Regulations 141.15, 1991 Proposed National Primary Drinking Water Rule for Radionuclides, July 18, 1991.
- EPA, 1996a. Region 9 Preliminary Remediation Goals (PRGs) 1996, memorandum from Stanford J. Smucker, Technical Support Team, Region 9, Environmental Protection Agency, San Francisco, CA, August 1, 1996.
- EPA, 1996b. Region 6 Human Health Media-Specific Screening Levels, Region 6, Environmental Protection Agency, Dallas, TX, October 30, 1996.
- EPA, 1997. Risk-Based Concentration Table, memorandum from Eric W. Johnson, Technical Support Section, Region 3, Environmental Protection Agency, Philadelphia, PA, dated October 22, 1997.
- Kirk, S., 1998. EPA Holds Stakeholder Meeting on the Safe Drinking Water Act Amendments, HPS Newsletter, March 1998.
- NRC, 1997. NRC Action Plan for Decommissioning, Nuclear Regulatory Commission, Washington, D.C.

NRC, 1997. Letter to Jess Larsen, Cimarron Corporation from Kenneth L. Kalman, Facilities Decommissioning Section, Nuclear Regulatory Commission, Washington, D.C., dated December 18, 1997.

RSA, 1997. Cimarron Corporation, Crescent, Oklahoma, Work Plan for A Risk Assessment for Groundwater, Roberts/Schornick and Associates, August 22, 1997.

RSA, 1998. Risk Assessment for Groundwater, Cimarron Corporation, Crescent, Oklahoma, Roberts/Schornick and Associates, April, 1998.

**TABLE 9.1 CHEMICAL RISK-BASED UNRESTRICTED USE RELEASE CRITERIA  
CIMARRON CORPORATION**

Chemical	Target Hazard Index	Ingestion Rate (IR) (L/day)	Fractional Absorption (unitless)	Exposure Frequency (EF) (days)	Exposure Duration (ED) (years)	Body Weight (BW) (kg)	Averaging Time (AT) (days)	RfD (mg/kg-day)	Chemical Risk-based Criteria (mg/L)
Uranium	1	2	1	365	30	70	10950	3.00E-03	1.1E-01 <sup>(a)</sup>

Chemical Risk-based Criteria (mg/L) = (THI x BW x AT) / EF x ED x (1/RfD) x (IR x FA)

where:

- THI = Target Hazard Index
- BW = Body Weight
- AT = Averaging Time = ED x 365 days/year
- EF = Exposure Frequency
- ED = Exposure Duration
- RfD = Oral Reference Dose
- IR = Ingestion Rate
- FA = Fractional Absorption

See Table 8.3 for source of default values.

<sup>(a)</sup> 1.1E-01 mg/L is equivalent to 182.5 pCi/L.



## 10.0 CONCLUSION

As demonstrated in this report, Cimarron believes that all of the conditions and criteria for approval of the Cimarron Decommissioning Plan, including a derivation of appropriate groundwater criteria and a program to address any remaining groundwater impacts above the criteria, have been met. Also within this report, Cimarron has addressed each of the NRC staff comments regarding groundwater as described in NRC letters dated November 18, 1997 and December 18, 1997, as well as NRC staff comments provided in the NRC letter dated February 26, 1998 regarding the February 17, 1998 meeting with NRC staff in Washington, D.C.

As discussed in this report, there are effective confining mudstone strata between each of the groundwater zones of Sandstones A, B, and C found on-site. These mudstones influence the lateral flow of groundwater and act to limit the potential downward migration of shallow groundwater between the three sandstone units. Shallow groundwater in the A and B sandstone units generally discharges to the incised drainage pathways and seeps found in the low-lying bluffs and cliffs that border the floodplain of the Cimarron River. Deeper groundwater in both Sandstones B and C discharges to the alluvial deposits that underlie and comprise the Cimarron River bottom and the adjoining floodplain. Also, as discussed in this report, deeper groundwater is of poor quality and has not been impacted by prior site operations.

As documented in this report and in previous submittals to the NRC, the background quality and quantity of groundwater at the Cimarron site varies significantly, but is generally poor to marginal. The bluffs overlooking the Cimarron River represent a very large discharge zone that continually drains the upper sandstones and, in fact, the upper sandstones are not saturated in those site areas near the bluffs. Any recovery wells located in these areas, which include the areas impacted by prior site operations (e.g. Waste Ponds #1 and

#2), would experience a further decline in water level because they would be pumping from an already partially de-watered zone. Under these conditions, Cimarron believes it is highly unlikely that an individual would incur the cost to drill wells and install treatment systems (to reduce hardness) for that groundwater when alternate sources of better quality water with higher volumes are readily available. Alternate sources of water include the rural water system that presently supplies water to the site and the surrounding vicinity, and the large on-site reservoirs. The on-site reservoirs were constructed and used as sources of process and drinking water during early facility operations in lieu of groundwater that did not provide an adequate supply or quality. The rural water district was not available until after operations at the facility ceased.

The historical and more recent groundwater and surface water investigations clearly show that groundwater radionuclide impacts have abated and continue their decreasing trends from those levels presented in the 1989 Grant report. With additional sources removed in these areas and the site in the final phase of decommissioning, these recorded decreasing trends will continue.

As discussed in Sections 7.0, 8.0 and 9.0, Cimarron proposes the use of a uranium criterion for groundwater, based upon consideration of chemical toxicity and radiological impacts, to account for the limited possibility that the groundwater may be used in the future. The proposed uranium criterion corresponds to 0.11 mg/L for total uranium, or approximately 25 mrem/year TEDE to the hypothetical individual drinking the water. This report demonstrates that all areas of the Cimarron site meet the criterion for Tc-99 as proposed by NRC (i.e., 4 mrem/y TEDE). These proposed criteria serve to ensure that any risk of chemical toxicity or radiological impact to members of the public will be avoided.

The results of analyses undertaken in this report clearly show that, using conservative methods, only the shallow groundwater (Cimarron River alluvium) in

close proximity to former Burial Area #1 at the Cimarron site exceeds the proposed uranium criterion. Former Burial Area #1 is within the Cimarron River flood plain and is prone to inundation on a regular basis, thereby minimizing the likelihood of a downgradient residence or well.

In order to address the fact that groundwater in the vicinity of former Burial Area #1 does not meet the proposed criterion, Cimarron is moving forward with a further evaluation of former Burial Area #1 utilizing the protocols described below:

- A. Cimarron will continue to monitor Former Burial Area #1 groundwater on a quarterly basis. Even though Cimarron believes that groundwater concentrations will continue to decrease, it will conduct additional studies for the purpose of understanding the attenuation mechanisms. These studies will include additional hydrogeologic evaluations of the general area.
  
- B. Former Burial Area #1 is being surveyed and mapped using both conductivity and magnetometer non-intrusive subsurface investigation techniques. In an effort to assure that no other solid wastes remain:
  1. Any areas that are suspect due to the above studies will be investigated.
  
  2. Any discovered waste (e.g., drums, scrap, etc.) will be removed, properly packaged and shipped to an appropriate disposal site.
  
  3. Any suspect localized area soils that are revealed as a result of waste removal activities will be evaluated utilizing the NRC's Branch Technical Position and volumetric averaging guidance.

These activities will serve to assure that any identifiable source of lingering groundwater contamination is identified and removed.

- C. Cimarron, through its parent Kerr-McGee Corporation, will retain and control the property areas formerly licensed under SNM-928 until the proposed groundwater criteria are met. In the unlikely event that the uranium concentrations do not decline sufficiently during the monitoring period, Cimarron will prepare a corrective action program.

The main plant site area will continue to be used by the Chemical Division, KMCLLC., for pilot plant studies related to titanium dioxide pigment activities. These research activities do not require the use or application of radioactive materials. With the submission of this report, Cimarron believes that it is now appropriate to approve the Cimarron Decommissioning Plan.

**TABLE A-1  
CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1201 - CIMARRON RIVER UP-STREAM	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
6/85	<10	<20	<0.2	<5	0.005			
6/86	<10	21	0.3	4	0.004			
6/87	<10	<20	0.4	<1	0.01			
6/88	11	<20	<1	<1	0.018			
6/89	<10	<20	0.12	0.67	0.006			
6/90	10	<20	<0.5	1.4	0.005	3.61	4.21	0.033
6/91	<10	<20	0.4	0.65				
6/92	<10	<20	<0.4	0.8	0.006			
6/93	<10	<20	<0.2	0.5	0.008			
6/94	<10	<20	3.8	0.1	<0.005			
6/95	3.2	12.1	0.1	0.11	0.001			
4/96	4	9	0.37	<0.05	0.0085	2.66	3.63	0.37
6/97	14.5	ND	0.4	5.3		2.5	5.5	0.1

**TABLE A-2  
CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1202 - CIMARRON RIVER DOWN-STREAM	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
6/85	23	22	<0.2	<5	<0.002			
6/86	<10	<20	0.3	4	0.004			
6/87	14	<20	0.4	1.1	0.021			
6/88	14	<20	<1	<1	0.018			
6/89	<10	<20	<0.20	0.6	<0.005			
6/90	<10	<20	<0.5	<0.5	<0.005	2.2	4.47	0.094
6/91	<10	<20	<0.4	<0.5				
6/92	<10	<20	<0.4	0.8	0.007			
6/93	<10	<20	<0.2	0.5	0.008			
6/94	<10	<20	3.9	0.1	<0.005			
6/95	3.9	16.2	0.2	<0.05	0.005			
4/96	10	15	0.39	<0.05	0.0085	2.50	3.29	0.25
6/97	15.4	15.7	0.4	<0.05		3.1	4.1	0.1

**TABLE A-3**  
**CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1204 - POND WEST RESERVOIR #1	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
6/85	22	<20	0.4	2	<0.002			
6/86	<10	<20	0.4	1	0.006			
6/87	<10	<20	0.3	2.4	<0.005			
6/88	23	<20	<1	1.7	0.029			
6/89	10	<20	0.33	1	<0.005			
6/90	10	<20	<0.5	0.55	<0.005	2.4	9.4	0.21
6/91	12	<20	<0.4	<0.5				
6/92	<10	<20	<0.4	1	<0.005			
6/93	<10	<20	<0.2	3.6	<0.005			
6/94	<10	<20	0.3	0.1	<0.005			
6/95	1.1	11.9	0.1	<0.05	0.002			
5/96	10.5	11	0.38	0.25	0.0097	2.53	9.26	0.45
6/97	11.8	12.7	0.5	0.2		0.5	1.6	ND

**TABLE A-4**  
**CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1205 - RESERVOIR #2 EAST	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
6/85	16	<20	0.3	<0.2	<0.002			
6/86	<10	<20	0.3	<1	0.002			
6/87	<10	<20	0.3	2	<0.005			
6/88	<10	<20	<1	<1	<0.005			
6/89	<10	<20	0.34	0.94	<0.005			
6/90	<10	<20	<0.5	<0.5	<0.005	0.37	0.61	0.02
6/91	<10	<20	<0.4	<0.5				
6/92	<10	<20	<0.4	0.9	<0.005			
6/93	<10	<20	<0.2	<0.7	<0.005			
6/94	<10	<20	0.3	0.1	<0.005			
6/95	1.3	3.3	<0.1	<0.05	0.001			
4/96	1	3.6	0.29	<0.05	0.0011	0.54	0.79	0.099
6/97	8.9	8.9	0.3	3.4		0.2	0.5	ND

TABLE A-5

## CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER

#1206 - SEEP/ SURFACE DRAINAGE	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
6/85	195	216	4	130	0.15				
6/86	130	199	3.4	21	0.11				
6/87	27	<20	1.4	5.7	0.039				
6/88	330	150	2.7	36	0.39				
6/89	190	52	2	80	0.13				
6/90	260	62	3.4	53	0.14	69.0	230.0	9.1	
6/91	195	76	4.1	87	0.17	61.77	162.6	7.13	
6/92	126	<20	2.7	3.7	0.093	30.16	126.65	5.03	
6/93	11	<20	1.9	0.5	<0.005	<5.9	<4.95	<2.6	
6/94	261	37	3.6	61	0.14	182	252	83.4	
6/95	59.6	28.1	2.5	35.9	0.063				
4/96	258	77.6	3.5	39	0.2	63.5	164.3	8.68	
12/96	96.2	55.2			0.053	27.6	76.6	2.2	
3/97	162.0	40.5		16.6	0.01	33.2	125	5.3	12.2
6/97	273.0	116.0	3.7	48.9	0.096	42.4	117	3.7	25.4
9/97	155	64.1	4.2	58.4		25.6	97.2	5.2	54.4
12/97	DRY	DRY	DRY	DRY		DRY	DRY	DRY	
3/98	89.3	30.5	3.6	16.7		64.5	115	9.6	

**TABLE A-6  
CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1208 - SEEP NORTH U Pond #2	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
6/85	<10	<20	0.6	0.6	<0.002				
6/86	46	600	18	15	0.008				
6/87	<10	<20	0.8	2.6	0.005				
6/88	<10	<20	<1	<1	0.007				
6/89	<10	<20	<0.2	1.3	<0.005				
6/90	<10	<20	<0.5	6.8	<0.005	0.55	1.3	0.041	
6/91	41	106	9.5	64	0.007	2.97	14.52	0.67	
6/92	10	21	<0.4	6.7	<0.005	1.61	8.047	0.36	
6/93	296	30	3.4	49	0.2	77.1	217	9.2	
6/94	1016	2360	35	1650	<0.005	26.3	52.5	9.3	
6/95	ND	72.8	0.3	953	0.005				
4/96	50	2990	34	1000	0.033	13.3	33.8	1.85	
10/96	24.7	2590	32.5	1750	<.6				
12/96	288	3190			0.026	14	38.3	2.8	
3/97	88.5	2210		1244	0.035	11.7	37	1.8	3,960
6/97	103	3060	62.5	1440		3.5	8.3	0.6	2,800
9/97	169	2590	31.8	1040	0.025	8	24.7	1.3	3,040
12/97	88.1	2730	30.7	1250		12.6	35	0.4	2,080
3/98	19.6	1330	27.6	915		17.6	29	1.8	2,300

**TABLE A-7  
CIMARRON FACILITY - ENVIRONMENTAL SURFACE WATER**

#1209 - RESERVOIR # WEST	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
6/85	<10	<20	8.1	43	<0.002			
6/86	<10	<20	0.4	2	0.002			
6/87	<10	<20	0.2	1	<0.005			
6/88	<10	<20	<1	<1	<0.005			
6/89	<10	<20	0.45	0.66	<0.005			
6/90	<10	<20	<0.5	<0.5	<0.005	0.11	0.45	0.038
6/91	<10	<20	<0.4	<0.5				
6/92	<10	<20	<0.4	0.7	<0.005			
6/93	<10	<20	<0.2	0.5	<0.005			
6/94	<10	<20	2.3	0.2				
6/95	ND	6.7	0.1	0.05	0.002			
4/96	1.6	2.5	0.31	<0.05	<.001	0.31	0.41	0.108
6/97	2.3	7.7	0.3	3.03		1.1	1.7	0.1



**TABLE A-8  
CIMARRON FACILITY - ENVIRONMENTAL GRONDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1311	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
6/85	10	31	<0.2	57	<0.002				
4/86	<10	<20	1.0	80	0.003				
6/86	<10	<20	0.4	87	0.003				
6/87	<10	<20	0.4	34	0.005				
6/88	<10	<20	<1	38	<0.005				
3/89	<10	23	<0.2	66		0.77	0.99	0.018	
6/89	10	<20	0.32	0.34	<0.005				
10/89	<10	<20	0.21	45	<0.005	1.01	1.37	0.029	
6/90	32	45	<0.5	69	<0.005	1.87	4.11	0.084	
6/91	<10	<20	<0.5	36					
6/92	32	49	<0.2	160	<0.005	1.65	4.02	0.1	
6/93	13	<20	0.3	69	<0.005	1.7	1.6	0.4	
6/94	<10	<20	0.6	20.5	<0.005	0.3	24.1	1.1	
6/95	5.3	7.8	0.3	17.9	<0.001	0.4	1.2	0.1	
4/96	5.8	5.1	0.48	15	0.0029	0.89	1.52	0.14	
12/96	ND	3.6			<.001	1.2	1	0.1	
3/97	4.4	16.4		78.4	<.001	0.9	1.3	0.1	18.1
6/97	13.3	18.3	0.5	55.3		2.1	3	0.4	

**TABLE A-9  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1312	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/l
6/85	2220	8272	83	<20	0.26				
4/86	340	11800	96	1560	0.25				
6/86	94	7300	59	1310	0.017				
6/87	41	65	18	620	0.045				
6/88	90	231	22	480	0.144				
3/89	59	2370	50	1020		15.3	41.6	1.23	
6/89	250	8000	54	1100	0.15				
10/89	64	6200	<0.2	980	0.076	22.7	75	1.7	
6/90	200	1320	<0.5	490	0.017	7.3	20.1	1.02	
6/91	953	2620	31	837	0.033	10.8	32.7	1.9	
6/92	840	1200	28	530	0.029	9.44	30.52	1.33	
6/93	116	176	<.2	320	0.012	10.7	30.2	3.3	
6/94	348	521	22	406	0.016	0.6	1.6	0	
6/95	82.6	1670	22.2	12	0.025	7.9	23.3	1.4	
4/96	37	2600	36	736*	0.028	9.26	27.8	1.33	
10/96						8.9	29.6	1.6	856
12/96	34.6	1940			0.01	5.8	20.8	1.20	
3/97	33.5	1550		723	0.02	5.8	18.5	0.7	3680
6/97	92.5	1230	20.6	527		6.0	18.7	0.9	1470
9/97	31.3	1610	21.4	435		5.7	17.2	0.8	2190
12/97	27.3	1800	24.4	604		5.5	13.0	0.2	1570
3/98	15.8	1400	20.5	521		10.0	21.0	1.1	1850

\*Data from resample event.

**TABLE A-10**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1313	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
6/85	453	1512	120	<5	0.070				
4/86	140	208	140	630	0.078				
6/86	230	3000	157	690	0.077				
6/87	84	25	120	450	0.078				
6/88	61	24	3.1	570	0.128				
3/89	260	2200	140	720		30	84	2.7	
6/89	345	6400	221	1100	0.510				
10/89	100	3100	<0.2	540	0.120	36.7	130	2.65	
6/90	840	5760	200	1100	0.190	64.3	287	6.3	
6/91	880	2004	135	734	0.110	35.8	115.8	5	
6/92	1510	1580	97	640	0.062	20.19	69.08	2.83	
6/93	647	791	89	410	0.032	17.7	45.7	2.9	
6/94	936	1240	100	497	0.046	2.7	21.5	0.8	
6/95	115	2960	108	509	0.048	15.2	46.8	2.8	
4/96	28.5	1202	87	280	0.023	8.88	24	1.71	
10/96						8.3	25.9	1.9	1410
6/97	65.8	768	78.5	366		10.0	31.0	1.0	1190
9/97	65.4	1280	86	1600		8.4	28.2	1.0	1560
12/97	26.7	955	88	341		7.1	21.1	0.1	874
3/98	30.6	614	82	194		10.3	27.7	1.3	562

**TABLE A-11**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1314	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
7/85	<10	<20	0.4	2	<0.002			
6/86	<10	<20	1.5	9	0.002			
6/87	<10	<20	1.3	4.8	0.005			
6/88	<10	<20	1.8	12	0.007			
3/89	<10	<20	<0.2	0.36		0.31	0.77	0.039
6/89	21	<20	<1	1	0.016			
10/89	<10	<20	<0.2	2.1	<0.005	0.48	1.47	0.027
6/90	<10	<20	<0.5	1.8	<0.005	0.69	1.61	0.022
6/91	<10	<20	<0.5	2				
6/92	<10	<20	<0.4	2	<0.005			
6/93	<10	<20	<.2	2.4	<.005			
6/94	<10	<20	1.2	0.5	<0.005			
6/95	ND	5.6	0.20	1.86	0.002	0.6	1.6	0.1
4/96	0.7	1.6	0.31	1.8	<.001	0.56	1.24	0.012
6/97	2.9	1.8	0.4	9.48		0.6	1.3	0.1

**TABLE A-12  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1315	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
7/85	3125	189	<0.2	11	5.56			
6/86	5400	740	0.5	5	7			
6/87	3850	2450	0.6	6.7	4.9			
6/88	3800	989	<1	<2	4.83			
9/88	3560	240	<1	<10	4.07			
12/88	6760	390	0.52	6.7		2038	3517	87
3/89	6440	660	0.22	13		1550	3570	110
6/89	5680	1120	<1	30	0.66			
10/89	2600	2200	0.38	6.5	4.21	2180	3270	130
1/90	5420	195	1.8	0.36		2000	3720	165
3/90	7000	770	1.6	9.8	8.8	2860	4990	230
6/90	6000	1300	1.2	6.1	5.81	2680	4090	162
9/90	1710	560	<0.5	4.5	2.05	970	1370	46
12/90	2500	300			2.56	1100	1870	51
6/91	2460	229	0.57	4	2.87	944.6	1243.6	69.6
6/92	2590	273	0.4	6.3	2.8	921.18	1386.56	69.91
6/93	2970	250	0.6	7.3	2.86	1240	2000	71.3
12/93	1440	115	0.5	3.8	1.27	550	790	38.7
3/94	2190	427			2.87	969	1490	65.38
4/94	1340	167			1.96	788	1190	70.7
5/94	2470	337			2.96	903	1250	170
6/94	1710	148	1	<0.1	1.3	609	853	77.8
7/94					1.75	476	750	74.9
8/94					1.54	614	898	55.7
9/94					1.43	526	842	43.1
10/94					1.4			
11/94						399	457	118
12/94					1.41			
1/95					1.49	676	950	51.7
2/95	2530	232			2.66	1050	1490	85.1
3/95	1540	126			1.99	545	811	52.9
4/95	1650	673			2.77	987	1620	75.5
5/95	1400	611			2.66	981	1640	143
6/95	1340	438	0.50	4.84	2.46	857	1340	56.4
7/95	2510	226			2.78	813	1260	70.7
8/95	806	274			1.36	505	753	40.4
9/95	484	105			1.04	292	420	22.2
10/95	1680	105			2	534	763	45.4
11/95	939	266			2.26	640	941	51.1
12/95	2450	258			2.79	792	1230	61.1
1/96	2320	407			3.2	741	1180	46.6
2/96	1970	362			2.85	1020	1460	173
3/96	2950	286			2.53	838	1540	86.5
4/96	2600	474	0.6	7.8	1.9	999	1710	87
5/96	3520	319			3.1	593	996	52.9
6/96	1940	184			1.76	578	807	45.4
7/96	1660	119			1.6	482	712	42.7
8/96	846	72.4			1.42	392	595	54
9/96	1180	96.8			1.06	434	682	23.5
10/96	685	112			0.9	254	375	30.4
11/96	1760	159			1.9	868	1280	57.5
12/96	1880	229			1.87	655	1070	43.8
3/97	3700	477			3.1	819	1410	76
6/97	3440	639	0.6	10.3		1200	1770	74.2
9/97	1080	145	0.7	8.32		374	546	24.9
12/97	1040	321	0.6	7.75		563	694	19.4
3/98	2100	755	0.5	19.7		855	1320	25

**TABLE A-13**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1316	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
7/85	200	<20	<0.2	11	0.19			
6/86	608	140	0.8	4	1.6			
6/87	420	300	0.6	4.6	0.54			
6/88	378	116	<1	12	0.3			
3/89	331	100	<0.20	16		67	210	10
6/89	820	160	<1	57	0.73			
10/89	320	200	0.14	12	0.539	236	590	11.6
6/90	680	77	<0.5	9.2	0.57	215	547	22
6/91	2030	138	0.52	17	1.7	556.1	1262	62.4
6/92	776	85	0.4	5.9	0.68	222.62	505.1	23.79
6/93	473	37	0.5	7.7	0.35	164	388	23.4
12/93	474	43.3	0.6	1.1	0.37	50.7	111	5.6
3/94	163	28.6			0.23	96.5	174	4
4/94	89.7	23.1			0.21	63.1	143	6.1
5/94	232	57.8			0.27	71.8	155	13.4
6/94	233	<20	1.1	<0.1	0.18	84	166	14.6
7/94					0.18	40.5	93.7	5
8/94					0.14	37	89.2	3.2
9/94					0.07	20.1	48.2	2.1
10/94					0.07			
11/94						64.8	79.3	25.8
12/94					0.10			
1/95					0.17	64.8	152	6.8
2/95	132	22.5			0.16	70.2	154.0	8.6
3/95	290	16.4			0.45	133	293.0	17.2
4/95	92	63.7			0.2	71.6	168.0	10.5
5/95	120	51.2			0.187	58.7	137	13.5
6/95	290	46.4			0.267	67.2	153	5.9
7/95	204	25.4			0.28	89	186	12.3
8/95	146	62.1			0.146	48.2	107	4.5
9/95	135	39.4			0.288	73.5	157	6.1
10/95	154	18.2			0.16	47.4	108	3.5
11/95	73.6	25			0.151	43.4	100	4.6
12/95	116	60.8			0.164	40.3	94.1	4.7
1/96	165	20.5			0.137	48	106	12.7
2/96	131	40.2			0.158	67.6	166	29.1
3/96	61.8	15.6			0.109	24.5	73.9	7.9
4/96	85	15.5	0.52	6.2	0.082	29.8	70.8	4.1
5/96	102	21.8			0.087	36.7	73.1	9.4
6/96	86	17.6			0.063	28.8	65	2.7
7/96	74.2	28.9			0.052	19.4	40.9	2.3
8/96	47.4	18			0.042	19	37.3	1.5
9/96	49.4	11.3			0.087	18.8	51.7	4.8
10/96	72.7	19.9			0.051	24.5	47.8	7.4
11/96	103.0	17.1			0.101	33.5	73.8	3.5
12/96	169.0	29.2			0.105	33.7	85.1	3.1
3/97	172.0	22.0			0.110	33.4	73.9	3.7
6/97	190.0	18.3	0.6	9.9		59.5	136.0	5.0
9/97	90.5	3.3	0.5	12.2		24.2	53.5	2.4
12/97	50.4	4.7	0.6	8.0		21.6	48.2	1.5
3/98	55.0	11.2	0.4	6.9		40.7	65.6	3.1

TABLE A-14

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1317	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
7/85	20	27	<0.2	25	<0.002			
6/86	<10	21	0.4	8	0.02			
6/87	13	<20	0.3	2.2	0.01			
6/88	105	<20	<1	<1	0.128			
12/88	165	29	0.1	0.4		22.8	38.6	1.7
3/89	66	26	<0.20	0.38		8.1	15	0.58
6/89	49	<20	<1	2	0.070			
10/89	68	<20	<0.2	0.27	0.083	32.2	49.7	1.88
1/90	84	<20	1.1	7.2		34.9	57.4	1.94
3/90	92	<20	2.5	7.9	0.088	34.6	52.7	1.87
6/90	440	91	<0.5	0.71	0.31	160	326	12.9
9/90	260	39	<0.5	1.1	0.24	118	193	11
12/90	160	29			0.21	82.9	127	4.85
6/91	171	<20	<.5	<.5	0.2	65.8	99	5.1
6/92	311	41	0.4	1.1	0.33	108.5	163.4	8.57
6/93	286	37	0.2	0.5	0.26	100	170	3.8
6/94	56	20	1	<0.1	0.046	11.3	18.2	1.2
6/95	141	62	0.10	0.10	0.228	76.4	131.0	8.0
5/96	156	87	0.24	0.11	0.12	67.0	109.8	7.3
6/97	328	98.7	0.3	2		150	247	11.7
3/98	27.8	14.5	0.2	1.68		20.4	39.5	2.8

**TABLE A-15  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1320	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
3/89	<10	<20	0.42	20		3.1	5.58	0.17	
6/89	12	<20	0.55	18	<0.005				
10/89	10	<20	0.49	15	0.005	1.3	2.99	0.045	
6/90	<10	<20	<0.5	16	<0.005	0.85	1.48	0.27	
6/91	10	<20	0.5	17					
6/92	14	<20	0.7	21	<0.005				
6/93	14	24	<.2	25	<.005	0.80	1.4	0.1	
6/94	19	<20	0.9	27	<0.005	10.7	20.8	0.6	
6/95	12.7	59.6	0.70	32.8	0.002	0.4	1.1	0.1	
4/96	3.9*	20.9*	0.66	21	0.002	0.81	1.48	0.146	
6/97	11.6	30.3	0.8	26.1		1	1.2	ND	34.0

\* Data from Resample Event

**TABLE A-16  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1321	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	18	26	<0.2	9.1		2.75	8.1	0.12
6/89	14	<20	<0.2	3.0	0.015			
10/89	18	<20	<0.2	1.6	<0.005	6.8	15	0.2
6/90	16	<20	<0.5	1.6	0.015	7.4	16	0.29
6/91	22	<20	<0.5	<0.5	0.021	6.9	14.3	0.3
6/92	20	<20	<0.2	1.0	0.016	5.28	12.88	0.31
6/93	21	<20	0.4	1.3	0.012	6.4	14.5	0.3
6/94	16	<20	2	0.9	0.007	3.7	6.6	0.22
6/95	38.9	17.8	0.20	0.89	0.015	5.2	11.6	0.4
4/96	14.2	7.8	0.30	0.59	0.015	4.87	11.76	0.59
6/97	30.7	ND	0.40	1.81		5.3	11.1	0.2

**TABLE A-17**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1322	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	15	<20	<0.2	9.2		3.9	8.2	0.13
6/89	17	<20	0.29	7.5	0.009			
10/89	16	<20	<0.2	6.0	0.010	5.19	11.5	0.31
6/90	11	<20	<0.5	5.9	0.010	3.5	8.7	0.26
6/91	26	<20	<1	8.4	0.018	6.98	22.11	0.47
6/92	16	<20	0.4	4.7	0.010	3.29	7.43	0.26
6/93	22	<20	0.2	3.9	0.006	1.9	12.9	5.6
6/94	16	<20	0.9	4.8	0.006	3.4	6.3	0.4
6/95	40.4	37.6	0.40	21	0.009	3.1	6.2	0.4
5/96	5.7	10.7	0.42	5.2	0.011	3.5	6.14	0.53
6/97	34.4	16.5	0.3	6.3		3.8	7.5	0.1

**TABLE A-18**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1323	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	51	<20	<0.20	1.7		9.8	17	0.42
6/89	37	<20	<0.2	1.6	0.028			
10/89	31	<20	<0.2	1.1	<0.005	13.1	27.1	0.45
6/90	38	<20	<0.5	1.9	0.034	10.8	26.7	0.22
6/91	172	44	<0.4	1.2	0.035	11.6	23.8	0.53
6/92	32	<20	<0.2	2.1	0.033	10.91	22.47	0.51
6/93	32	<20	<.2	1.7	0.021	12.6	22.1	1.3
6/94	42	<20	2.2	1	0.014	0.7	0.8	0
6/95	80.9	34.1	0.20	1.72	0.033	8.7	18.4	0.7
5/96	34	0	0.27	1.2	0.038	11.8	22.6	0.96
6/97	25.9	16	0.2	1.72		9.7	20	0.6

**TABLE A-19**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1324	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	<10	<20	0.26	18		0.2	0.44	0.022
6/89	<10	<20	1.3	18	<0.005			
10/89	<10	<20	0.29	17	<0.005	0.54	1.07	0.022
6/90	<10	<20	<0.5	22	<0.005	0.62	1.15	0.048
6/91	<10	<20	<1	18				
6/92	10	<20	0.4	14	<.005			
6/93	<10	<20	0.3	14	<.005			
6/94	<10	<20	0.9	9.9	<0.005			
6/95	6.0	9.3	0.50	11.9	0.002	0.5	1.3	0.1
4/96	1.3	2.8	0.63	6.1	0.0013	0.43	0.81	0.157
6/97	3.7	12.4	0.7	11.2		0.4	0.9	ND

**TABLE A-20**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1325	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	<10	<20	0.35	13		1	1.49	0.046
6/89	<10	<20	<1	51	0.006			
10/89	<10	<20	0.46	13	<0.005	0.82	1.63	0.028
6/90	<10	24	<0.5	13	<0.005	0.64	1.75	0.094
6/91	<10	<20	0.5	14				
6/92	<10	<20	0.4	14.4	<0.005			
6/93	<10	<20	0.3	14	<0.005			
6/94	<10	<20	0.8	14.7	<0.005			
6/95	5.3	6.3	0.50	14.7	0.001	3.4	10.3	0.6
4/96	1.7	5.1	0.64	9.3	0.0012	0.49	1.08	0.096
6/97	3.1	ND	0.7	17.8		0.3	0.9	0.01



TABLE B-21

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1326	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
3/89	14	25	<0.20	14		1.48	4.43	0.058	
6/89	175	9640	1.2	21	0.014				
10/89	16	<20	<0.2	16	<0.005	2.25	5.2	0.11	
6/90	16	21	<0.5	17	0.007	2.3	5.8	0.79	
6/91	14	<20	<1	10					
6/92	17	20	0.3	15	0.006	1.98	0.74	0.09	
6/93	16	<20	<.2	14	<.005	2.6	5.1	0	
6/94	19	<20	0.5	14.5	<0.005	6.3	14.3	0.6	
6/95	62.9	56.9	0.30	300	0.006	1.4	3.6	0.2	
4/96	96	457	0.39	5.5	0.0053	2.41	5.15	0.45	
10/96						1.5	2.8	0.2	8.6
12/96	3.8	26.7			0.003	2.4	3.7	0.2	
3/97	19.5	30		25.2	0.004	1.6	5.0	0.7	21.9
6/97	24.8	28.1	0.2	16.6		2.2	4.8	0.1	13.1
9/97	12.5	17.8	0.4	17.8	0.006	1.1	4	0.1	41.3
12/97	5.9	10.8	0.4	19.4		1.7	2.9	0.1	

TABLE A-22

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1327 B	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	<10	<20	0.2	8.2		1.52	2.8	0.14
6/89	<10	<20	0.36	6.6	<0.005			
10/89	<10	<20	<0.2	8.3	0.007	4.18	6.8	0.069
6/90	<10	<20	<0.5	7.2	<0.005	1.43	2	0.29
6/91	<10	<20	<0.5	7.5				
6/92	<10	<20	0.5	10	<0.005			
6/93	11	<20	10	10	0.006			
6/94	<10	<20	0.8	7.9	<0.005			
6/95	5.2	1.4	0.40	8.20	0.004	1.8	2.3	ND
5/96	1.6	2.9	0.48	5.8	0.0046	1.53	3.24	0.165
6/97	4.7	5.3	0.3	8.19		1.2	3.1	ND

TABLE A-23

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1328	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	29	<20	<0.2	2.2		9	18	0.66
6/89	23	20	<0.2	2	0.03			
10/89	30	<20	<0.2	1.8	0.04	15.1	28.2	0.37
6/90	35	<20	<0.5	2.1	0.033	14	25	0.41
6/91	38	<20	<0.4	1.7	0.034	11.2	21	0.51
6/92	31	<20	0.4	1.9	0.032	10.58	21.79	0.49
6/93	31	<20	<.2	2	<.005	11.3	18.9	1.8
6/94	28	<20	3	0.4	0.02	11.1	21.5	0.8
6/95	31.1	17.9	0.20	1.86	0.034	10.2	19.6	1.3
4/96	17	16	0.23	1.3	0.037	11.59	23.1	0.77
6/97	76.9	6.5	0.1	1.8		10.5	20.7	0.5

TABLE A-24

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1329	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	12	<20	<0.20	0.4		2.04	5.3	0.093
6/89	<10	<20	0.32	3.8	0.006			
10/89	<10	<20	0.29	3.5	<0.005	2.54	6.11	0.099
6/90	70	<20	<0.5	3.5	0.08	33.9	47.3	3.1
1/91	<10	<20	<0.4	4.5				
6/92	<10	<20	<0.4	3.9	0.006			
6/93	<10	<20	0.2	4.1	<.005			
6/94	<10	<20	4.3	0.7	<0.005			
6/95	5.2	16.8	0.30	6.22	0.005	1.6	2.9	0.1
4/96	26*	9.5*	0.43	5.7	0.0065	2.22	4.25	0.223
6/97	16.7	5.4	0.2	12.6		2	4.5	0.2

\*Data from Resample Event

TABLE A-25

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1330	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	16	62	<0.2	172		2.4	5.17	0.1
6/89	19	25	<0.20	130	0.007			
10/89	<10	55	<0.2	110	0.007	3.6	8.5	0.26
6/90	18	<20	<0.5	77	0.009	2.99	9.2	0.38
6/91	<10	<20	0.91	77				
6/92	22	21	<.4	68	0.01	3.28	7.43	.33
6/93	27	<20	0.5	<.5	<.005	2.4	7.3	0.3
6/94	18	<20	1	55	0.006	3.8	9	0.9
6/95	8.8	23.4	0.40	44	0.007	2.9	9.5	0.6
5/96	4	15.8	0.59	35	0.0093	3.29	8.19	0.61
6/97	19.1	25.2	0.5	42.3		2.8	7.4	0.2

TABLE A-26

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1331	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	190	23	<0.2	5.7		35	126	3.7
6/89	280	39	0.29	14	0.114			
10/89	167	62	<0.2	11	0.12	63	309	0.85
6/90	330	25	<0.5	8.6	0.17	54	324	10.5
6/91	347	20	<0.5	14	0.17	72.1	120.98	4.56
6/92	289	<20	<0.4	10.3	0.13	41.85	193.13	9
6/93	135	<20	0.2	9.3	0.036	38.5	118	9.3
6/94	198	<20	1.1	22.6	0.09	40.5	139	25.1
6/95	250	40.8	0.30	17.00	0.103	38.7	168	10.8
5/96	111	23	0.47	17	0.071	23.9	100.2	5.23
6/97	202	29.9	0.5	18.0		25.0	127.0	4.7
9/97	200	13.4	0.6	26.0		31.0	137.0	6.7
12/97	134	19.5	0.6	32.3		25.5	116.0	4.5
3/98	131	25.1	0.6	22.2		31.5	110.0	3.2

**TABLE A-27**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1332	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	23	<20	1.3	3.4		6.4	13.9	0.12
6/89	15	<20	<0.2	2	0.023			
10/89	17	<20	<0.2	0.39	0.031	13.1	25.3	0.042
6/90	32	<20	<0.5	1.5	0.03	13	23	0.33
6/91	31	<20	<0.4	2.5	0.032	10.6	19.8	0.48
6/92	30	<20	<0.4	1.2	0.03	9.92	20.43	0.46
6/93	35	<20	<.2	1.6	0.026	12.9	19.7	0.7
6/94	39	<20	4.5	0.3	0.008	12.7	21.4	1.5
6/95	77	55.7	0.30	1.50	0.035	10.1	19.2	0.8
4/96	18.9	9.1	0.87	5	0.012	4.42	12.27	0.88
6/97	107	53.7	0.2	<.05		9.3	18.9	0.3

**TABLE A-28**  
**CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1333	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	47	<20	<0.20	6.3		6.2	18	0.71
6/89	26	<20	0.39	3.4	0.018			
10/89	12	<20	<0.2	2.8	0.002	9.54	26.6	0.91
6/90	32	<20	<0.5	3.5	0.025	9.2	26	0.61
6/91	20	<20	<0.5	2.1	0.033	5.91	14.55	0.02
6/92	25	<20	<0.4	1.5	0.016	5.25	10.89	0.49
6/93	28	<20	0.5	1.6	0.016	8.2	21.6	1.6
6/94	20	<20	1.3	1.5	0.01	2.8	9.7	0.2
6/95	53.4	47.9	0.60	4.00	0.013	0.5	1.7	0.2
4/96	17	17		1.2	0.037	11.77	20.6	1.06
6/97	37.4	28.9	0.5	5.5		3.8	9.1	0.3

TABLE A-29

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1334	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	30	<20	0.26	6.1		5	13.2	0.23
6/89	25	<20	0.44	3.9	0.016			
10/89	<10	<20	<0.2	1.4	0.005	23.2	35.4	1
6/90	43	<20	<0.5	1.9	0.044	23.6	37	1.46
6/91	22	<20	<0.5	1.5	0.025	7.0	14.3	0.2
6/92	12	<20	0.42	1.5	0.01	3.28	7.43	0.3
6/93	11	<20	0.5	1.1	<0.005			
6/94	15	<20	0.3	2	<0.005	1.4	3.7	0.2
6/95	46.5	15.3	0.40	2.99	0.027	6.6	10.7	0.4
5/96	13.2	7.4	0.56	2	0.021	6.82	11.1	0.81
6/97	14.8	4.9	0.6	2.8		3.2	7.4	0.3

TABLE A-30

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1335	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
3/89	<10	<20	0.24	22		1.25	1.64	0.1
6/89	<10	<20	0.41	22	<0.005			
10/89	<10	<20	0.26	22	<0.005	1.52	2.14	0.023
6/90	<10	<20	<0.5	23	<0.005	0.74	1.22	0.022
6/91	<10	<20	<0.5	23				
6/92	<10	<20	<0.4	20	<0.005			
6/93	<10	<20	0.3	0.3	<0.005			
6/94	<10	<20	0.9	20	<0.005			
6/95	ND	2.5	0.30	17.91	0.001	0.3	0.6	ND
4/96	1.6	0.2	0.58	14	0.0017	0.62	1.03	0.069
10/96 (1335A)	5	7		8.7	<.001	0.5	0.7	0.1
6/97	17.9	11.7	0.6	8.8		0.7	1.6	ND

TABLE A-31

## CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1336	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
3/89	140	4970	17	1260		23	76	2.4	
6/89	170	11000	<1	860	0.015				
10/89	28	8300	<0.2	1600	0.02	5.83	19.6	0.3	
6/90	980	5300	55	1600	0.077	32.2	99	3.4	
6/91	1010	2082	28	980	0.062	17.8	73.57	2.61	
WELL NO. 1336 OUT OF SERVICE AFTER 1991 - REPLACED WITH 1336A 6/94									
<b>WELL NO. 1336A</b>									
6/94	682	1100	36	673	0.014	5.7	17.3	1.1	
1/95	38.1	1140			0.016	5.8	19.3	1.0	
2/95	31	948			0.011	6.9	19.1	1.4	
3/95	37	1060			0.026	5.9	18.1	0.7	
4/95	53.4	1740			0.017	7.8	22.2	0.8	
5/95	18.5	1980			0.024	6.7	19	2.1	
6/95	67.6	2150	33.70	ND	0.023	7.3	24.3	1.1	
7/95	80.3	1500			0.028	7.1	20.8	0.8	
8/95	93	2090			0.022	6.1	23.6	1.3	
9/95	40.1	937			0.019	4.5	14.9	0.8	
10/95	50.8	1490			0.025	8.2	23.7	0.8	
11/95	26.7	1340			0.029	7.6	21.7	1.0	
12/95	32.3	1630			0.026	7.3	20.0	1.2	
1/96	43.1	1700			0.020	12.6	24.2	6.6	
2/96	21.0	1290			0.022	21.8	74.1	15.8	
3/96	41.6	1170			0.032	23.4	47.3	ND	
4/96	39	1398	32	400	0.024	8.6	25.3	1.09	
5/96	93.1	1210			0.022	13.1	22.8	3.3	
6/96	54.1	1330			0.023	9.4	26.8	1	
7/96	91.5	1060			0.034	11.7	31.8	3.6	
8/96	88.7	1520			0.034	32.7	47.3	17.1	
9/96	158	1470			0.027	12.1	36.2	2	
10/96	117	1730			0.029	13.1	30.7	5.2	
11/96	39.8	1400			0.026	8.3	27.9	1.3	
12/96	69.9	1340			0.021	7.1	24.6	1.2	
3/97	46.6	1520		786	0.028	15	37.5	8.1	2590
6/97	61.4	1430	35.2	766		9.1	23.2	1.1	1930
9/97	54.9	1390	31.5	589	0.027	7.2	23.6	1.8	1880
12/97	109	2200	37.5	725		8.1	22.9	0.8	1200
3/98	27.2	1400	34.3	667		12.3	28.7	3.1	1600

TABLE A-32

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1337	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
2/97	39.3	343.0	10.8	86.7	<.05	5.0	13.3	0.5
6/97	17.0	143.0	7.6	51.9		3.1	8.0	0.6

TABLE A-33

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1338	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
2/97	44.6	130.0	1.3	24.4	0.09	1.0	2.8	0.1
6/97	10.1	102	0.8	33.1		0.4	0.7	0.1

TABLE A-34

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1339	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
2/97	40.3	9.8	0.5	<.05	0.1	3.7	11.0	0.2

TABLE A-35

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1340	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
2/97	53.1	430.0	14.1	213	0.12	0.9	3.4	0.1
6/97	7.8	144.0	23.7	127		1.0	2.7	0.2
9/97	10.0	98.6	35.7	109				

TABLE A-36

CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS

ENVIRONMENTAL WELL NO. 1341	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
2/97	10.9	117.0	5.0	28.6	0.16	1.3	1.8	ND
6/97	30.0	620.0	0.3	230		0.6	1.5	0.1
9/97	1.1	194.0	0.7	73.2				



**TABLE A-37  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO.1342 (West)	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
10/97	20.2	21.0	0.6	0.15		1.7	3.7	0.3	11.4
12/97	14.3	1.2	0.3	1.12		3.1	4.9	0.3	
3/98	1.1	9.5	0.3	0.95		2.5	3.7	0.3	

**TABLE A-38  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1343 (Middle)	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	Tc-99
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
10/97	82.6	46.5	0.5	19.2		13.8	20.9	0.9	12.5
12/97	25.2	7.9	0.5	32.2		9.5	14.0	1.0	
3/98	9.8	10.4	0.4	7.99		7.6	10.5	0.6	

**TABLE A-39  
CIMARRON FACILITY - ENVIRONMENTAL GROUNDWATER SAMPLE RESULTS**

ENVIRONMENTAL WELL NO. 1344 (East)	GROSS ALPHA	GROSS BETA	F	NO3 (N)	U	238 U	234 U	235 U	235 U
SAMPLE DATE	pCi/L	pCi/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L
10/97	24.4	17.5	0.3	0.58		3.5	5.0	0.1	9.0
12/97	4.1	10.0	0.5	0.36		1.0	1.7	0.2	
3/98	0.3	6.9	0.4	1.1		1.9	2.5	0.1	