GW - 52

WORK PLANS

1996

SETTLEMENT AGREEMENT

and

ALTERNATIVE CLOSURE PLAN

for

TRANSWESTERN PIPELINE COMPANY
ROSWELL COMPRESSOR STATION NO. 9
SURFACE IMPOUNDMENTS

RECEIVED
JUL 24 1996
Environmental Bureau
Oil Conservation Division

Prepared by:

Transwestern Pipeline Company
Houston, Texas

June 27, 1996

SETTLEMENT AGREEMENT

and

ALTERNATIVE CLOSURE PLAN

for

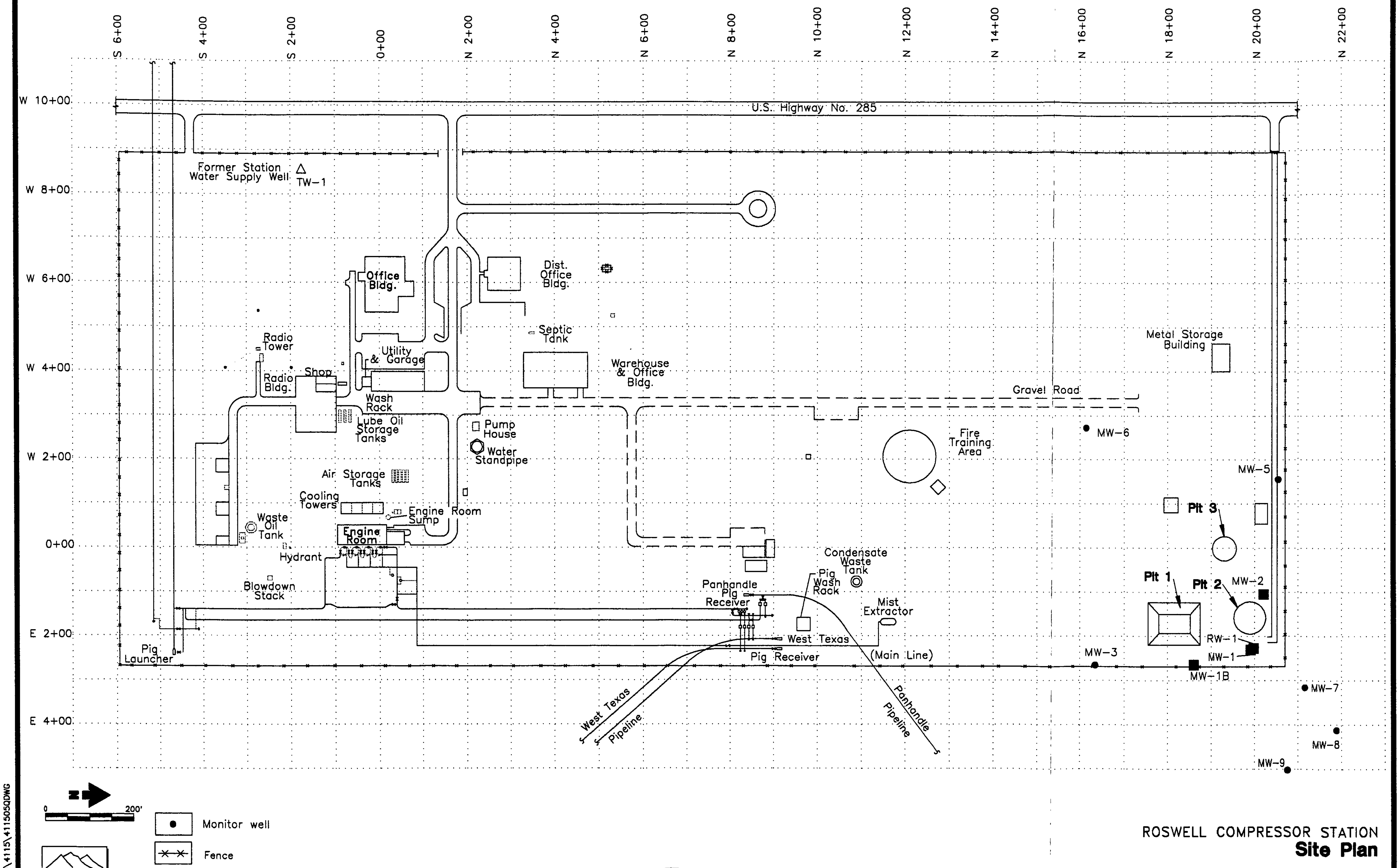
TRANSWESTERN PIPELINE COMPANY
ROSWELL COMPRESSOR STATION NO. 9
SURFACE IMPOUNDMENTS

RECEIVED
JUL 24 1996
Environmental Bureau
Oil Conservation Division

Prepared by:

Transwestern Pipeline Company
Houston, Texas

June 27, 1996

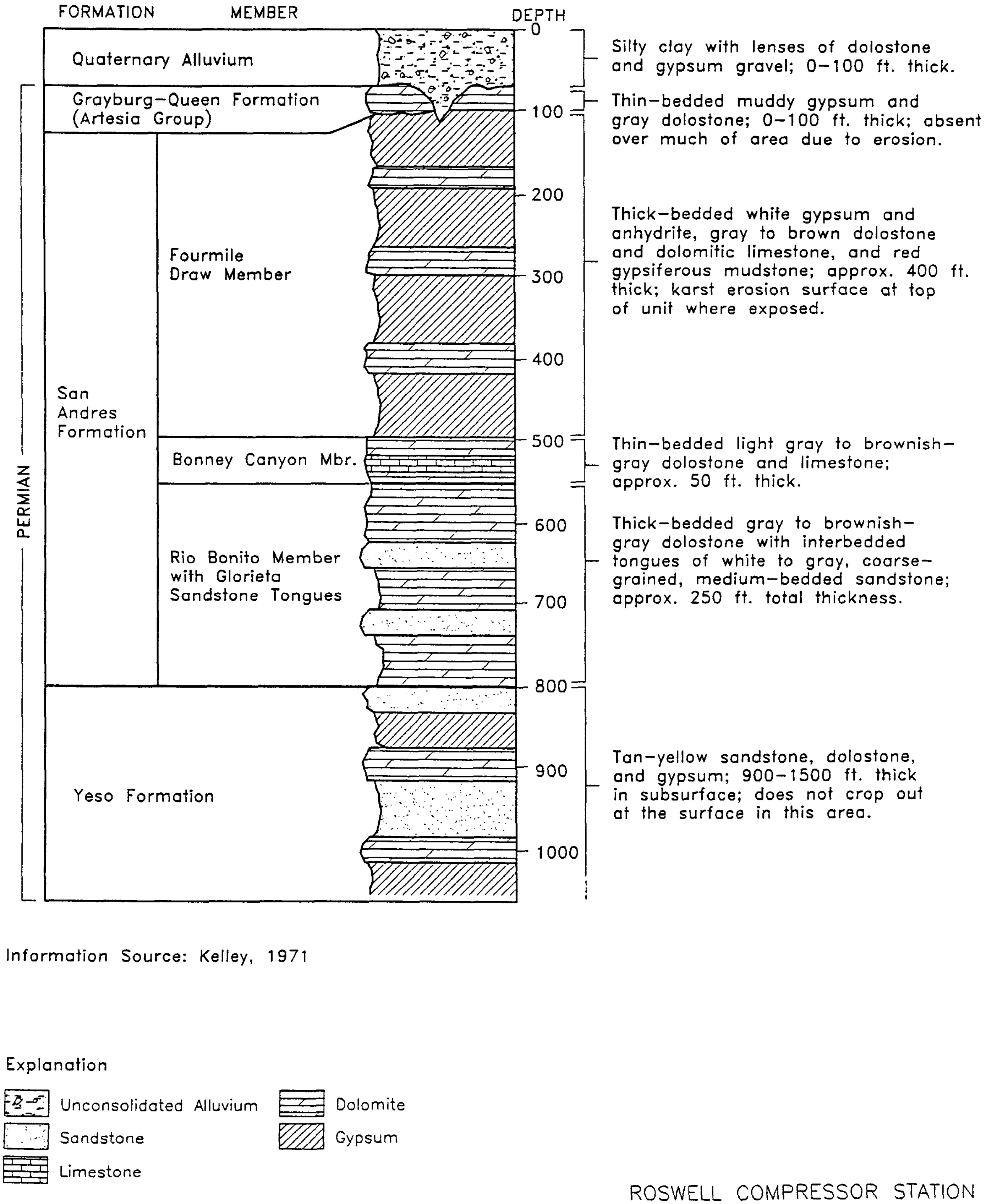


DANIEL B. STEPHENS & ASSOCIATES, INC.
6-27-96
JN 4115

ROSWELL COMPRESSOR STATION
Site Plan

Figure 2-1

D\4115\411505QDWG



Silty clay with lenses of dolostone and gypsum gravel; 0–100 ft. thick.

Thin-bedded muddy gypsum and gray dolostone; 0–100 ft. thick; absent over much of area due to erosion.

Thick-bedded white gypsum and anhydrite, gray to brown dolostone and dolomitic limestone, and red gypsiferous mudstone; approx. 400 ft. thick; karst erosion surface at top of unit where exposed.

Thin-bedded light gray to brownish-gray dolostone and limestone; approx. 50 ft. thick.

Thick-bedded gray to brownish-gray dolostone with interbedded tongues of white to gray, coarse-grained, medium-bedded sandstone; approx. 250 ft. total thickness.

Tan-yellow sandstone, dolostone, and gypsum; 900–1500 ft. thick in subsurface; does not crop out at the surface in this area.

Information Source: Kelley, 1971

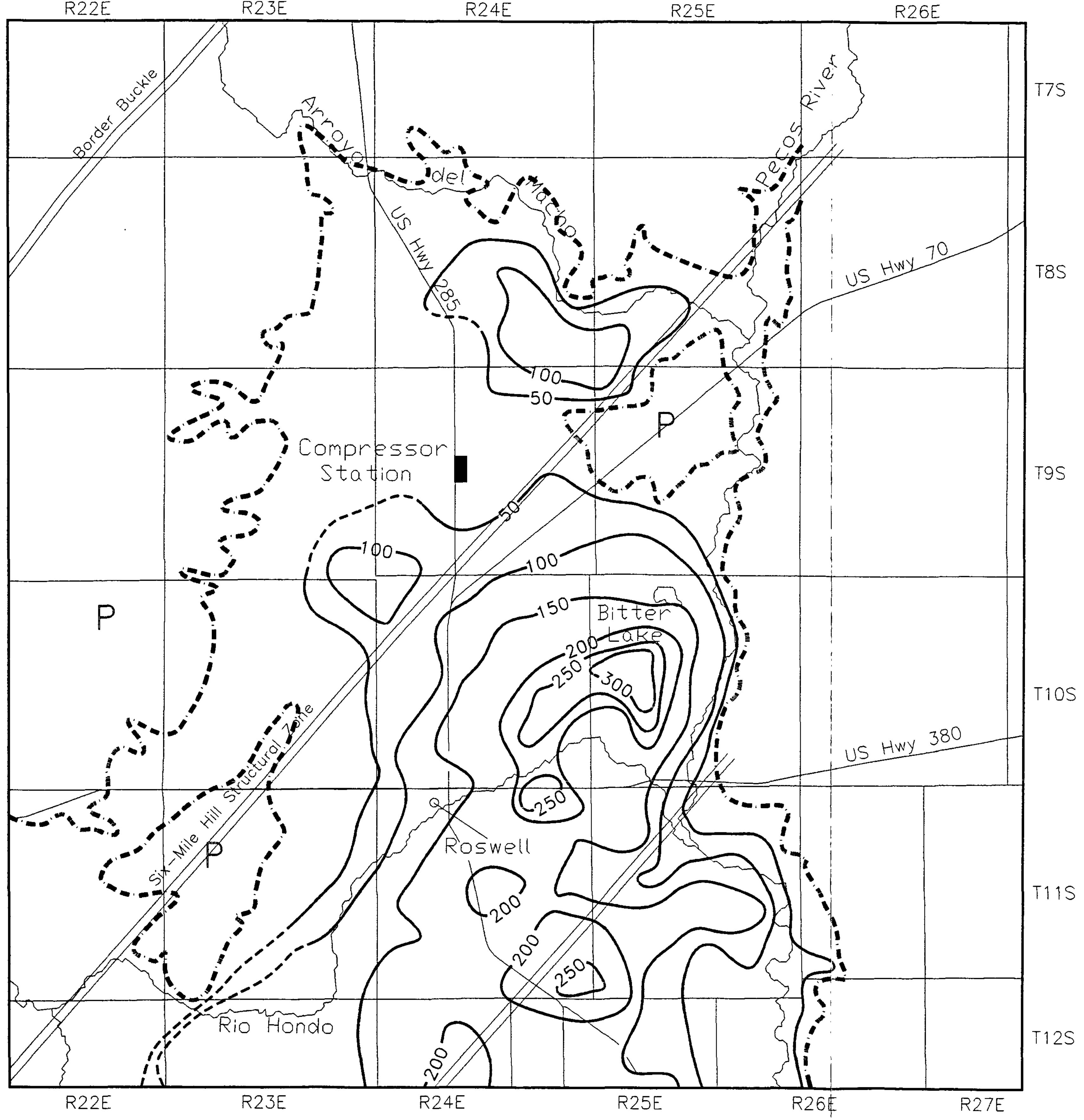
ROSWELL COMPRESSOR STATION

Generalized Stratigraphic Section Near Roswell Compressor Station

DANIEL B. STEPHENS & ASSOCIATES, INC.
5-94 JN 4115

Figure 2-2

D/4115/2-2GS



Information Sources: Kelley, 1971; Lyford, 1973

N

0 10 Miles

Explanation

Thickness of valley fill alluvium (feet)

Approx. surface contact between Permian rocks and valley fill alluvium

P Outcrop area of Permian rocks

DANIEL B. STEPHENS & ASSOCIATES, INC.

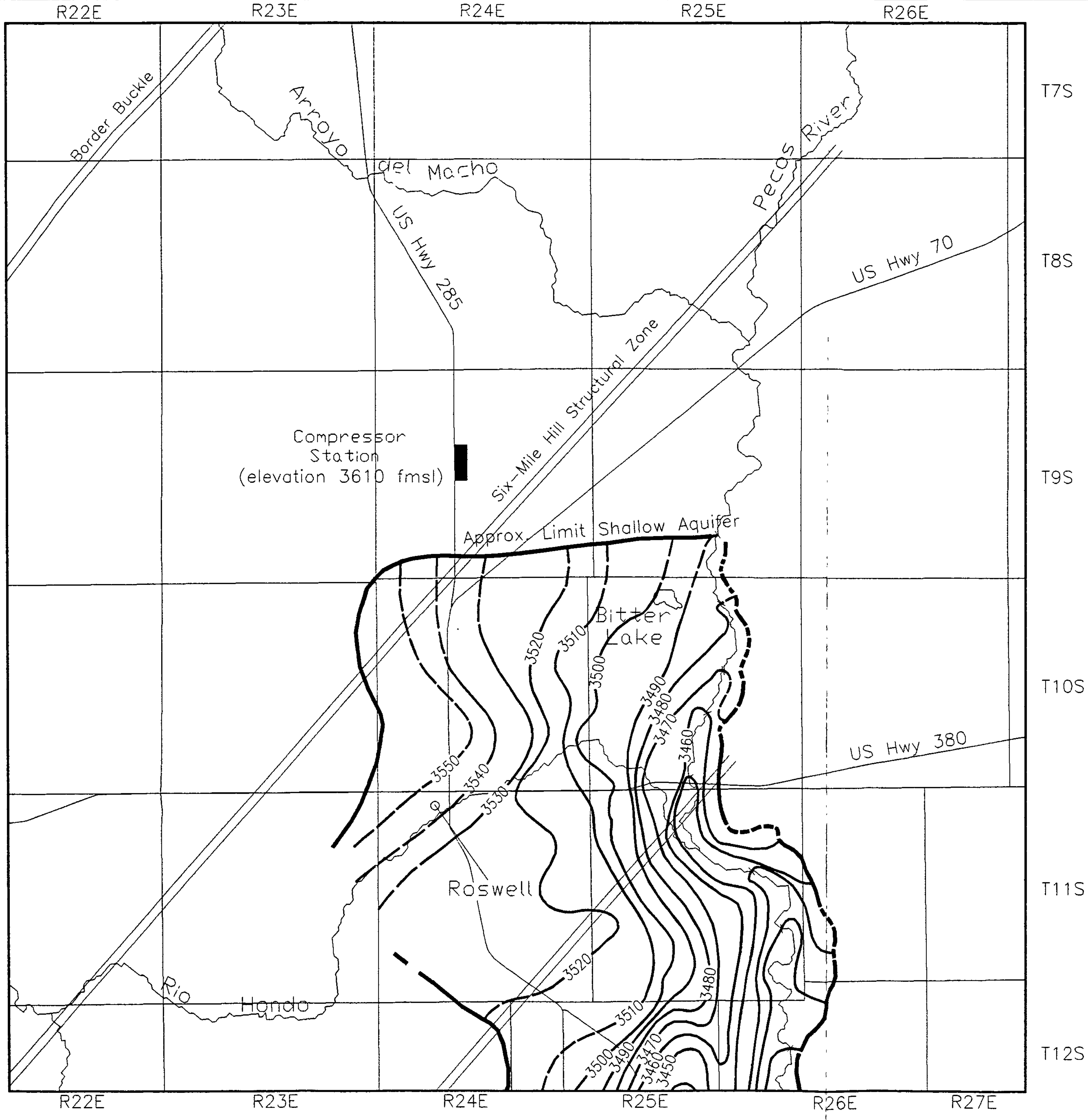
6-14-96 JN4115

D\4115\2 AA

ROSWELL COMPRESSOR STATION

Approximate Thickness of Shallow Alluvial Aquifer

Figure 2-3



Information Source: Welder, 1983

N

0 10 Miles

Explanation

3350 Water level contour (feet above mean sea level [fmsl])

— — Approximate extent of shallow alluvial aquifer

▨ Structural zone (Maddox, 1968; Kelley, 1971)

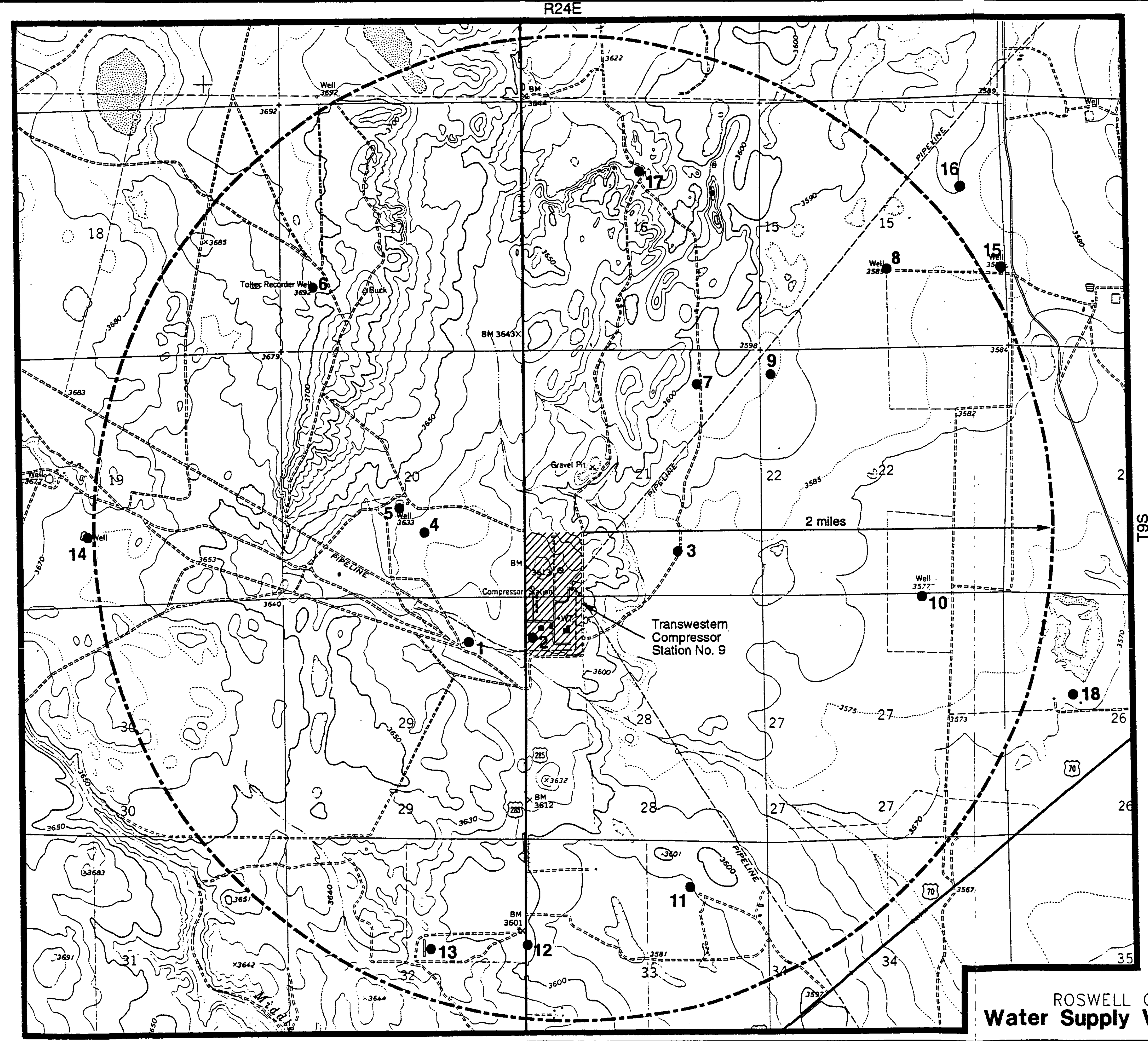
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

D\4115\2-2

ROSWELL COMPRESSOR STATION

Water Levels in Shallow Alluvial Aquifer, January 1984

Figure 2-4



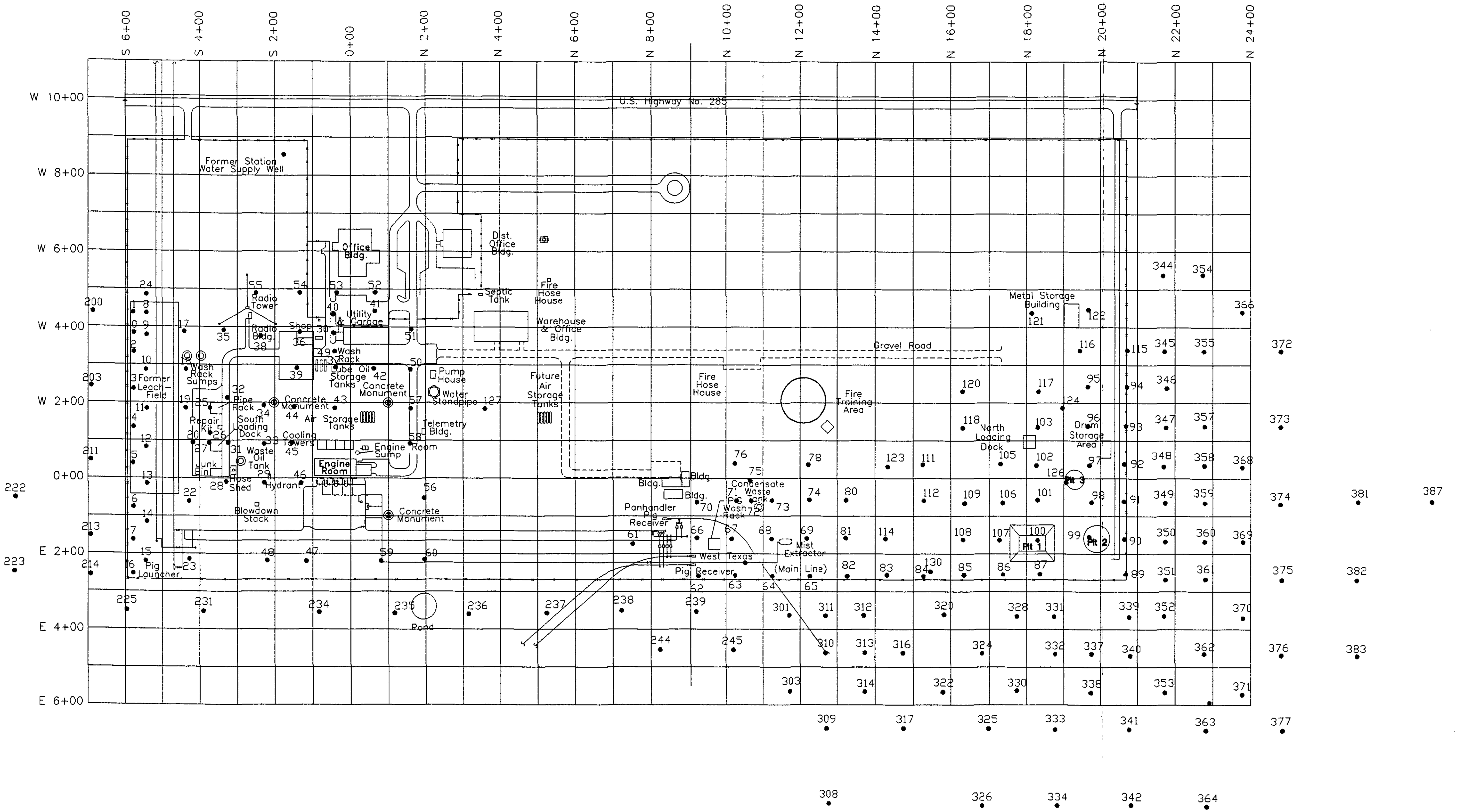
Note: Well Numbers refer to well listed on table 2-1

D\4115\2-3WSW.DWG

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

ROSWELL COMPRESSOR STATION
Water Supply Well Location Map

Figure 2-5



Source: Harding Lawson Associates, 1991a

0 250'

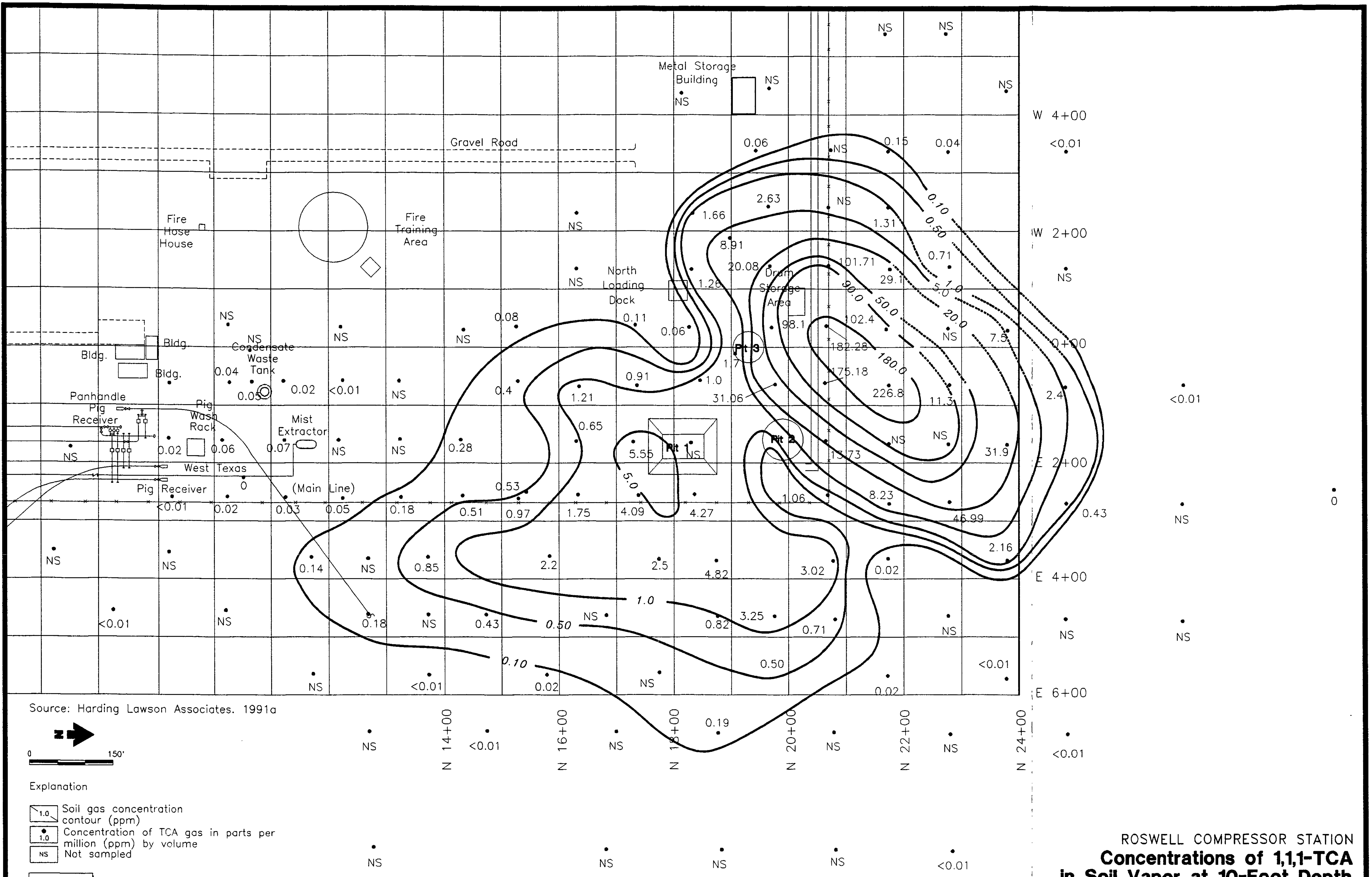
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

ROSWELL COMPRESSOR STATION

Harding Lawson Associates
Soil Vapor Sample Locations

Figure 3-1

D/4115/4-1SV.DWG



Source: Harding Lawson Associates. 1991a

Explanation

1.0	Soil gas concentration contour (ppm)
● 1.0	Concentration of TCA gas in parts per million (ppm) by volume
NS	Not sampled

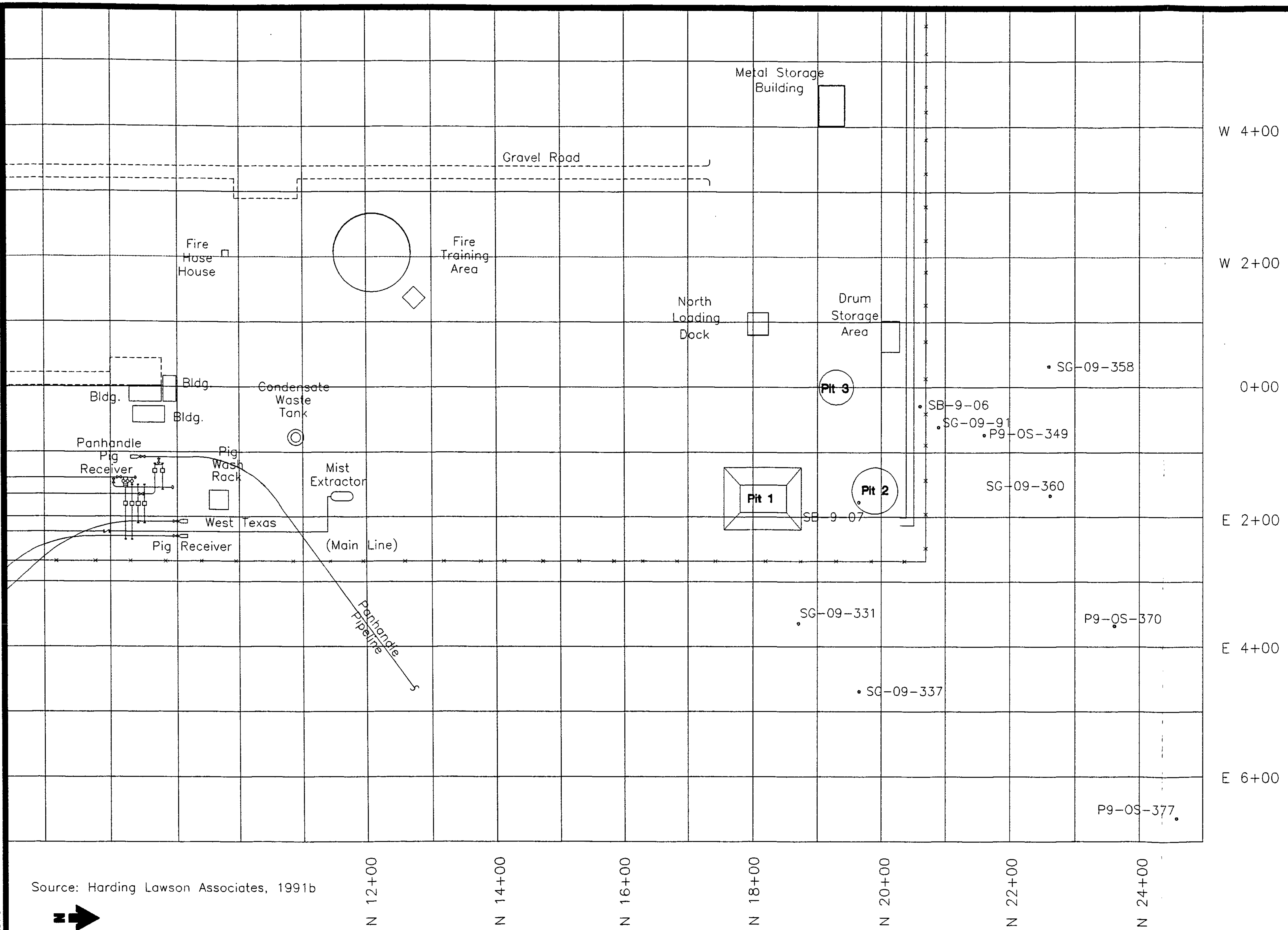
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

D/4115/4-2TCA2.DWG

ROSWELL COMPRESSOR STATION

Concentrations of 1,1,1-TCA in Soil Vapor at 10-Foot Depth

Figure 3-2



Source: Harding Lawson Associates, 1991b

N

0 150'

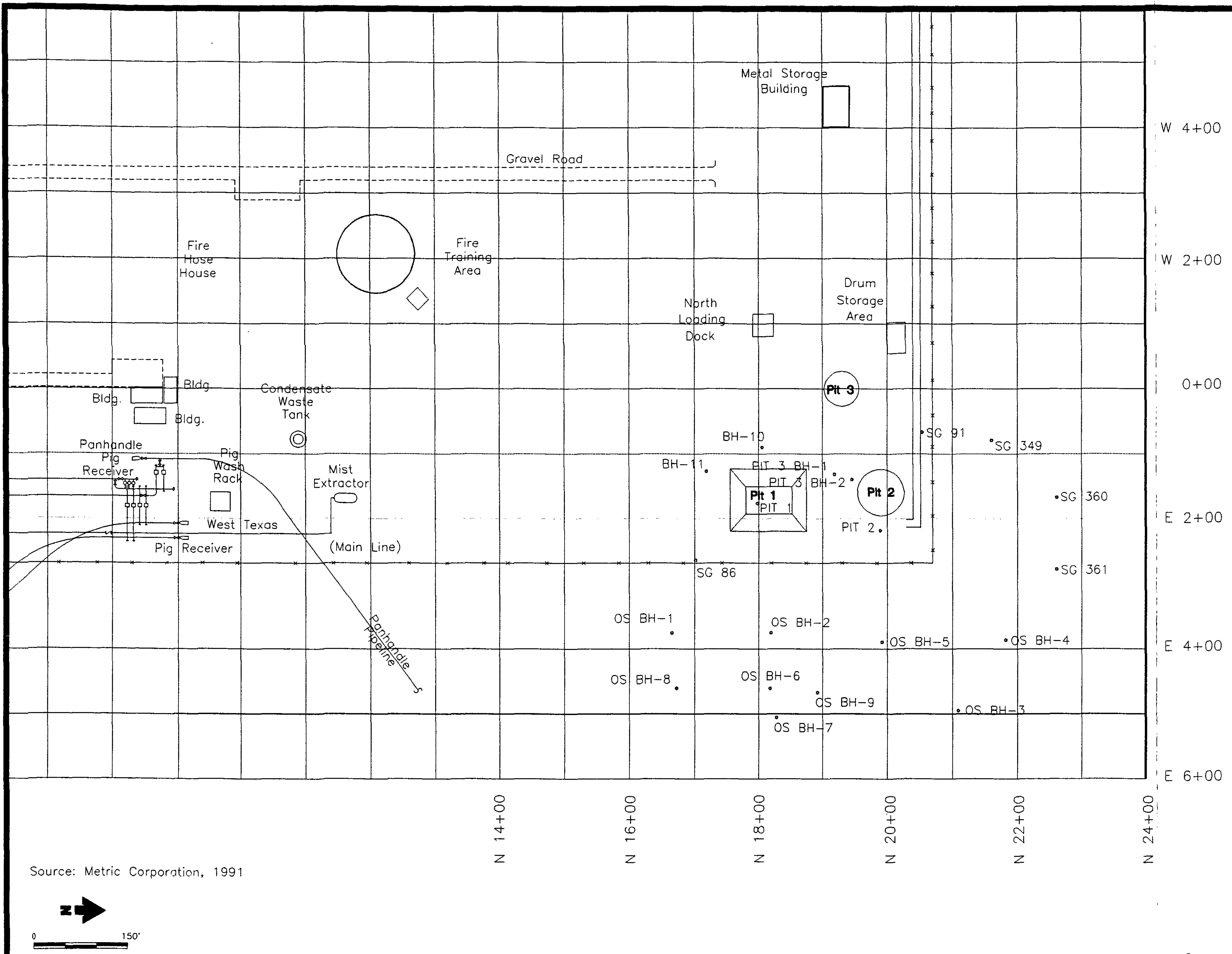
D:\4115\4-3HLA.DWG

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

ROSWELL COMPRESSOR STATION

Locations of Harding Lawson Associates Soil Borings

Figure 3-3



Source: Metric Corporation, 1991

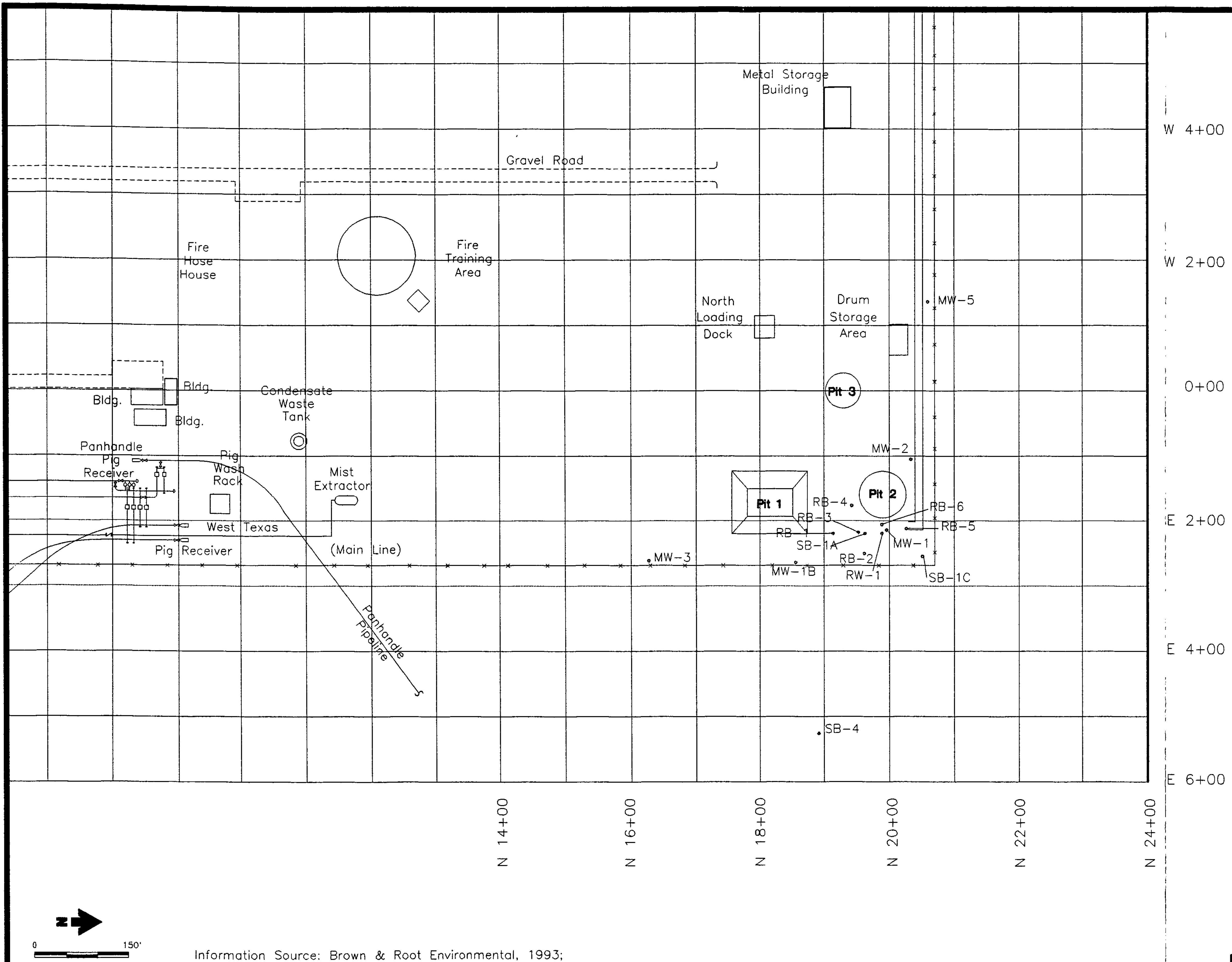
D:\4115\4-4MC.DWG

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN4115

ROSWELL COMPRESSOR STATION

Locations of Metric Corporation Soil Borings

Figure 3-4



Information Source: Brown & Root Environmental, 1993;
Halliburton–NUS Environmental Corp., 1992

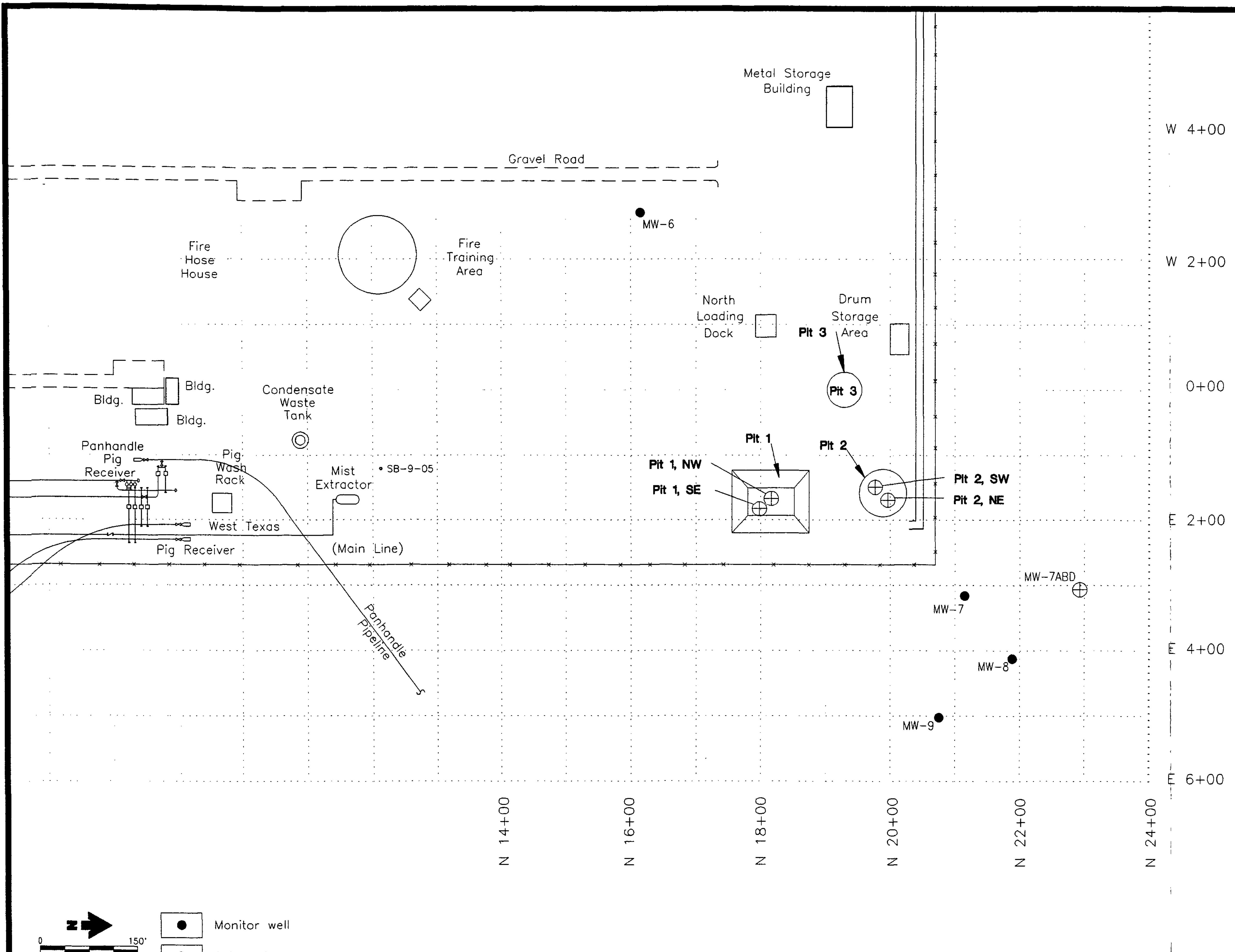
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96
JN 4115

D:\4115\4-5HBR.DWG

ROSWELL COMPRESSOR STATION

Locations of Halliburton and Brown & Root Soil Borings

Figure 3-5



ROSWELL COMPRESSOR STATION

Locations of Daniel B. Stephens & Associates Monitor Wells and Soil Borings

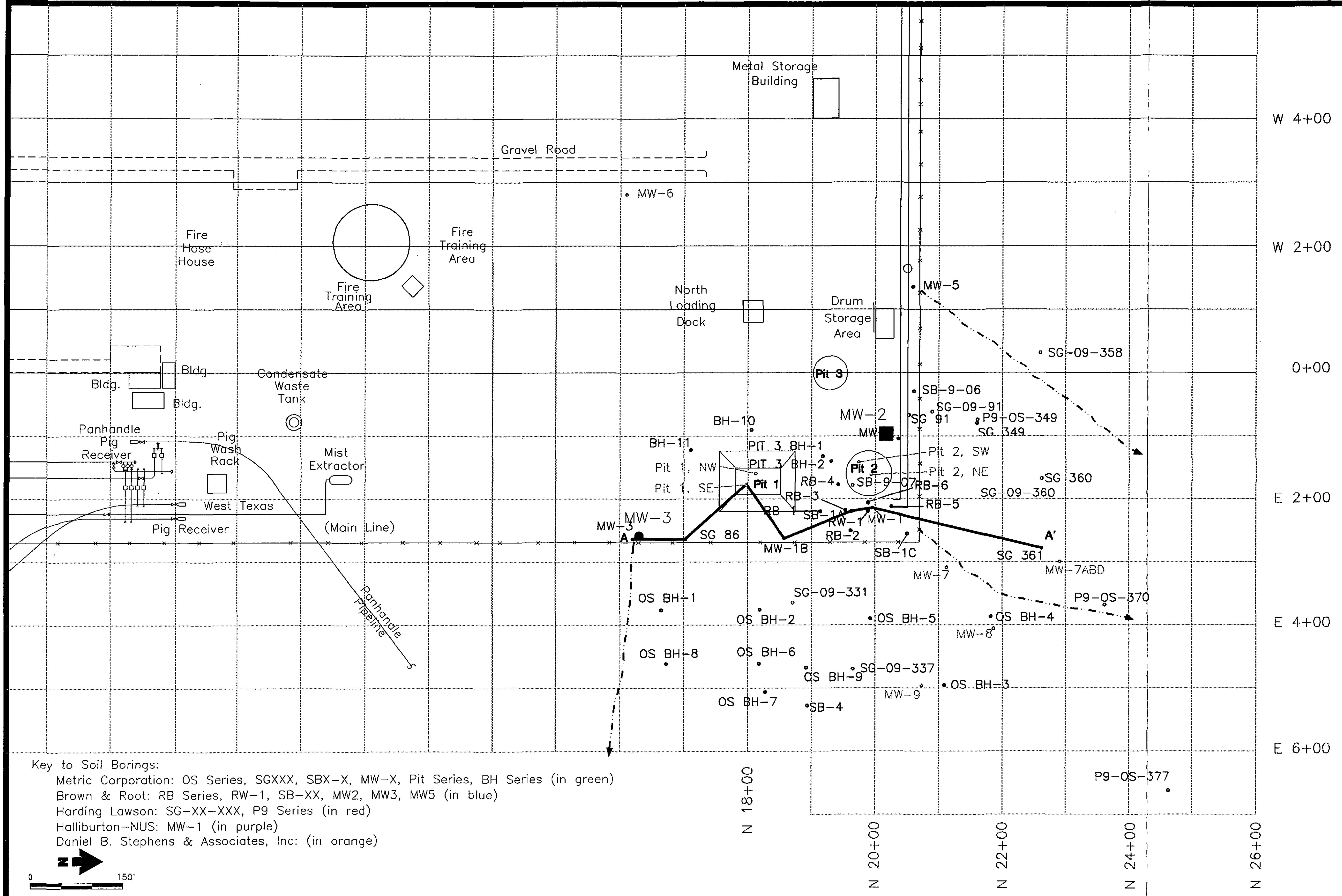
DANIEL B. STEPHENS & ASSOCIATES, INC.

6-27-96

JN 4115

Figure 3-6

D:\4115\411510R.DWG



Key to Soil Borings:

Metric Corporation: OS Series, SGXXX, SBX-X, MW-X, Pit Series, BH Series (in green)
Brown & Root: RB Series, RW-1, SB-XX, MW2, MW3, MW5 (in blue)
Harding Lawson: SG-XX-XXX, P9 Series (in red)
Halliburton-NUS: MW-1 (in purple)
Daniel B. Stephens & Associates, Inc: (in orange)

N ➜

0 150'

A—A' Cross Section Line

Surface Drainage

ROSWELL COMPRESSOR STATION

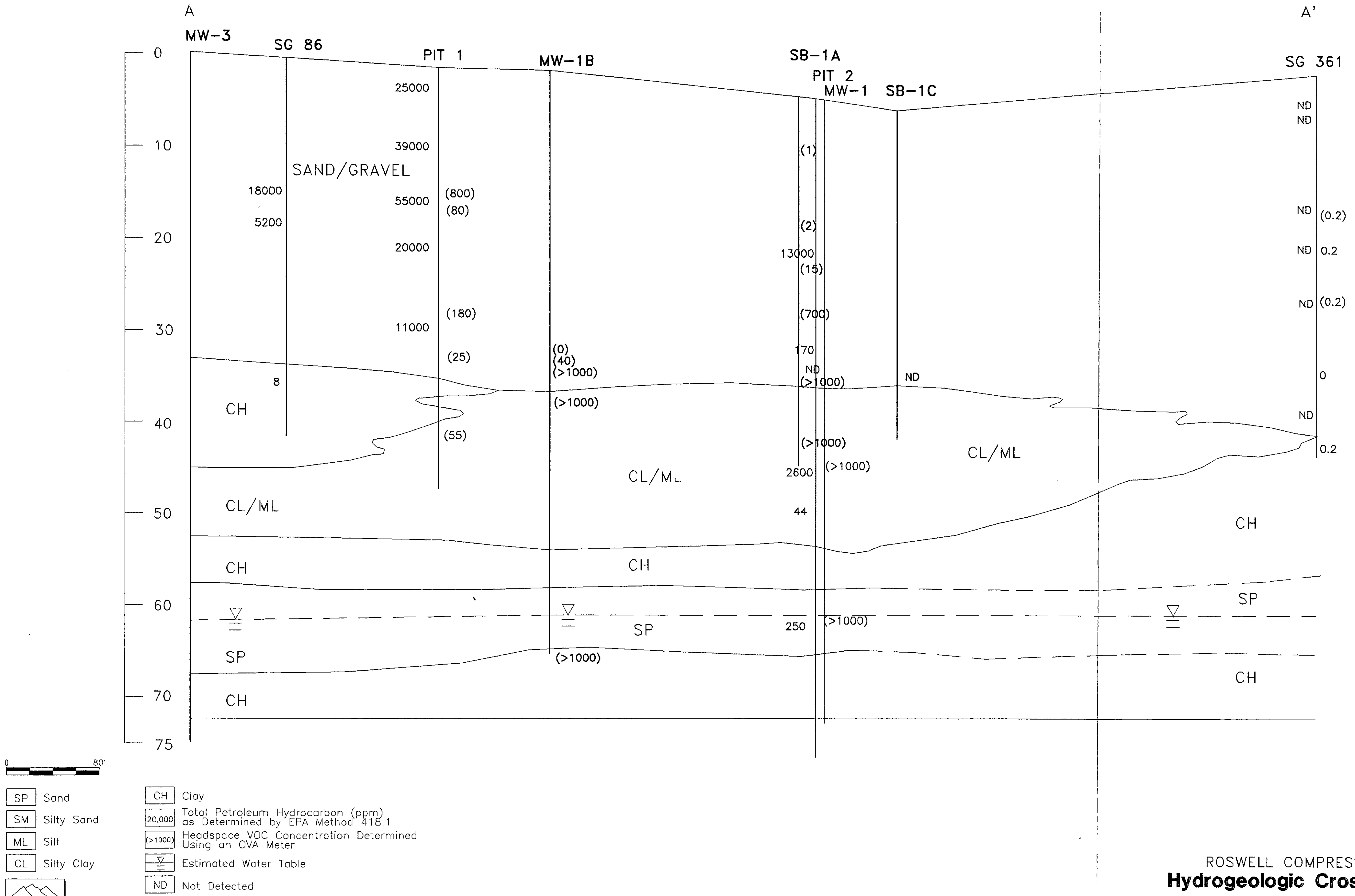
Locations of Previous Soil Borings and Existing Monitor Wells and Recovery Wells

Figure 3-7

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-27-96 JN4115

D:\4115\4-6PSB.DWG

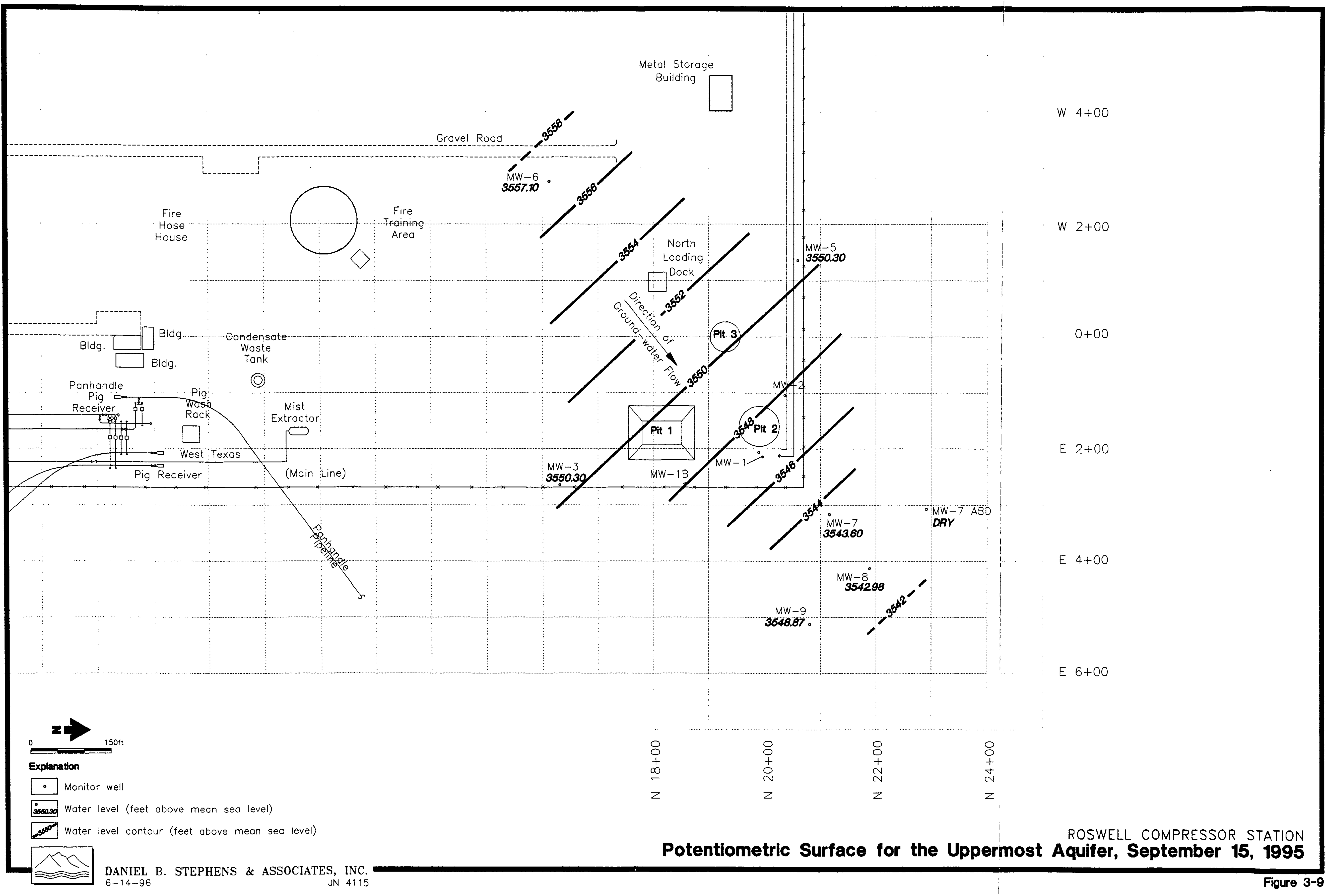
D\4115\4-7HCS.DWG



DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN 4115

ROSWELL COMPRESSOR STATION
Hydrogeologic Cross Section

Figure 3-8



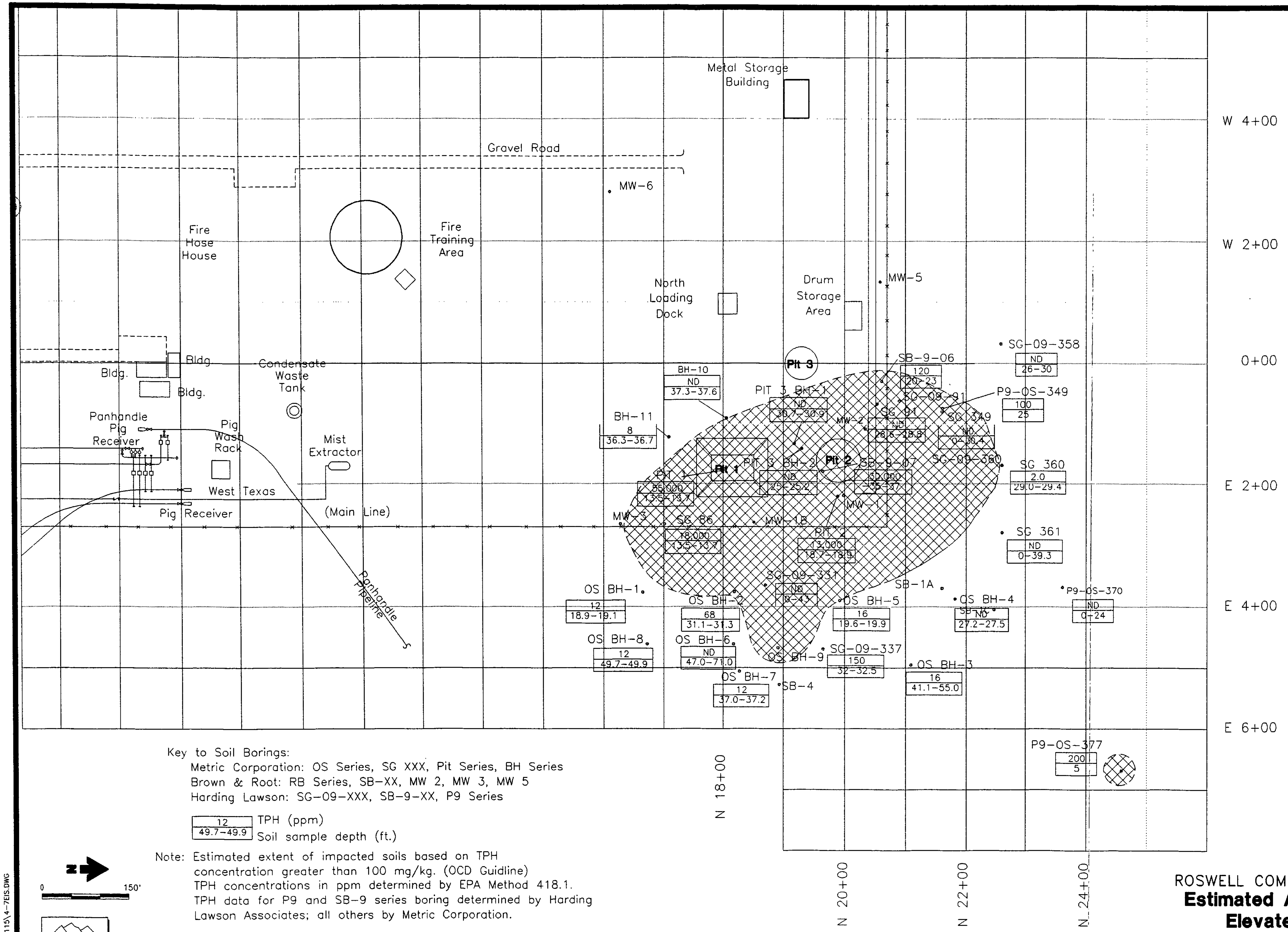
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96 JN 4115

ROSWELL COMPRESSOR STATION

Potentiometric Surface for the Uppermost Aquifer, September 15, 1995

Figure 3-9

D\4115\411504F.DWG



Key to Soil Borings:
Metric Corporation: OS Series, SG XXX, Pit Series, BH Series
Brown & Root: RB Series, SB-XX, MW 2, MW 3, MW 5
Harding Lawson: SG-09-XXX, SB-9-XX, P9 Series

12 49.7-49.9	TPH (ppm) Soil sample depth (ft.)

Note: Estimated extent of impacted soils based on TPH concentration greater than 100 mg/kg. (OCD Guidline)
TPH concentrations in ppm determined by EPA Method 418.1.
TPH data for P9 and SB-9 series boring determined by Harding Lawson Associates; all others by Metric Corporation.

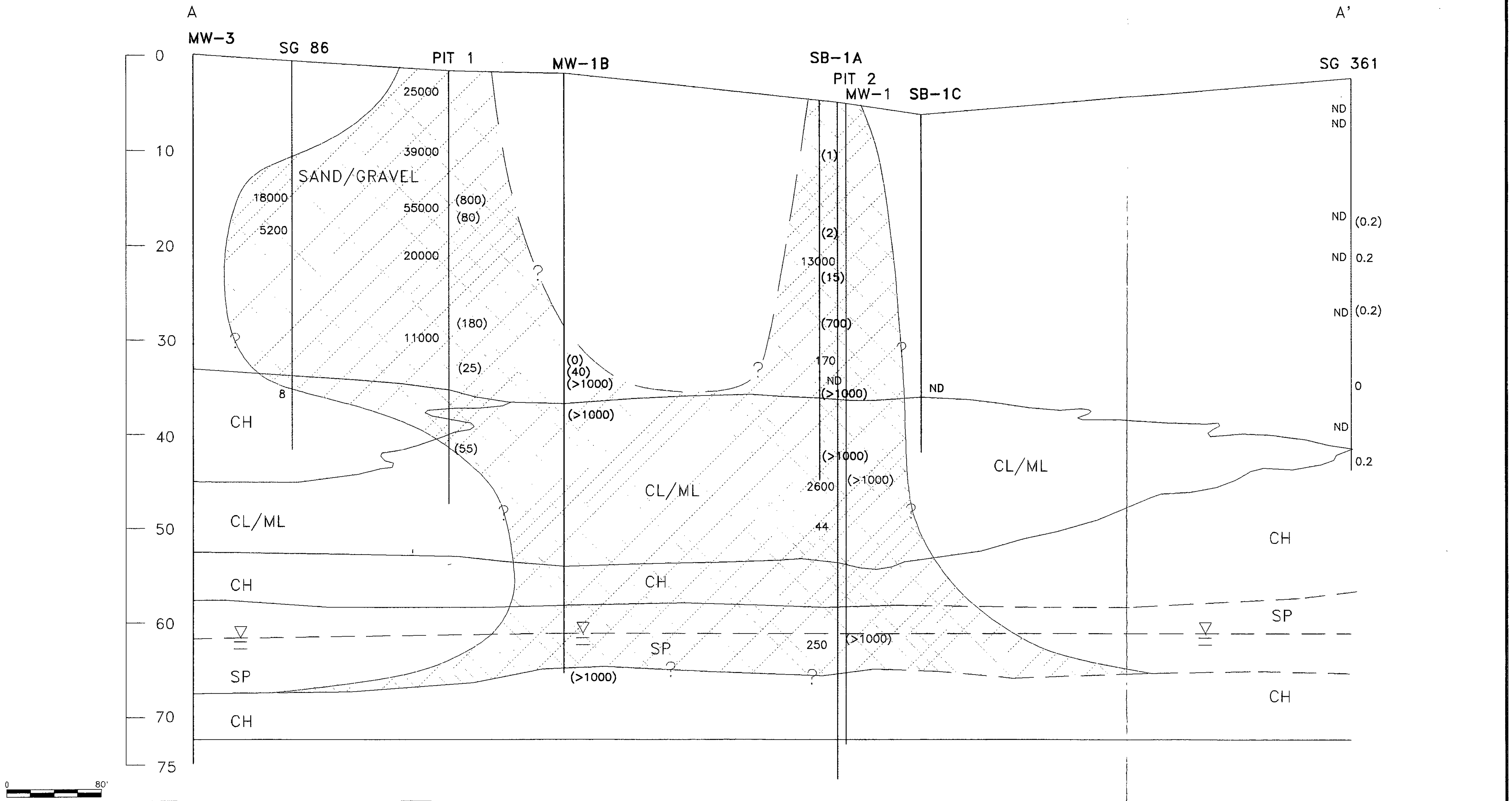
DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96
JN4115

D:\4115\4-7EIS.DWG

ROSWELL COMPRESSOR STATION
Estimated Areal Extent of Elevated TPH in Soils

Figure 3-10

D\4115\4-9EAS.DWG



SP Sand

SM Silty Sand

ML Silt

CL Silty Clay

CH Clay

Estimated Extent of Impacted Soil

20,000 Total Petroleum Hydrocarbon (ppm) as Determined by EPA Method 418.1

(>1000) Headspace VOC Concentration Determined Using an OVA Meter

▽ Estimated Water Table

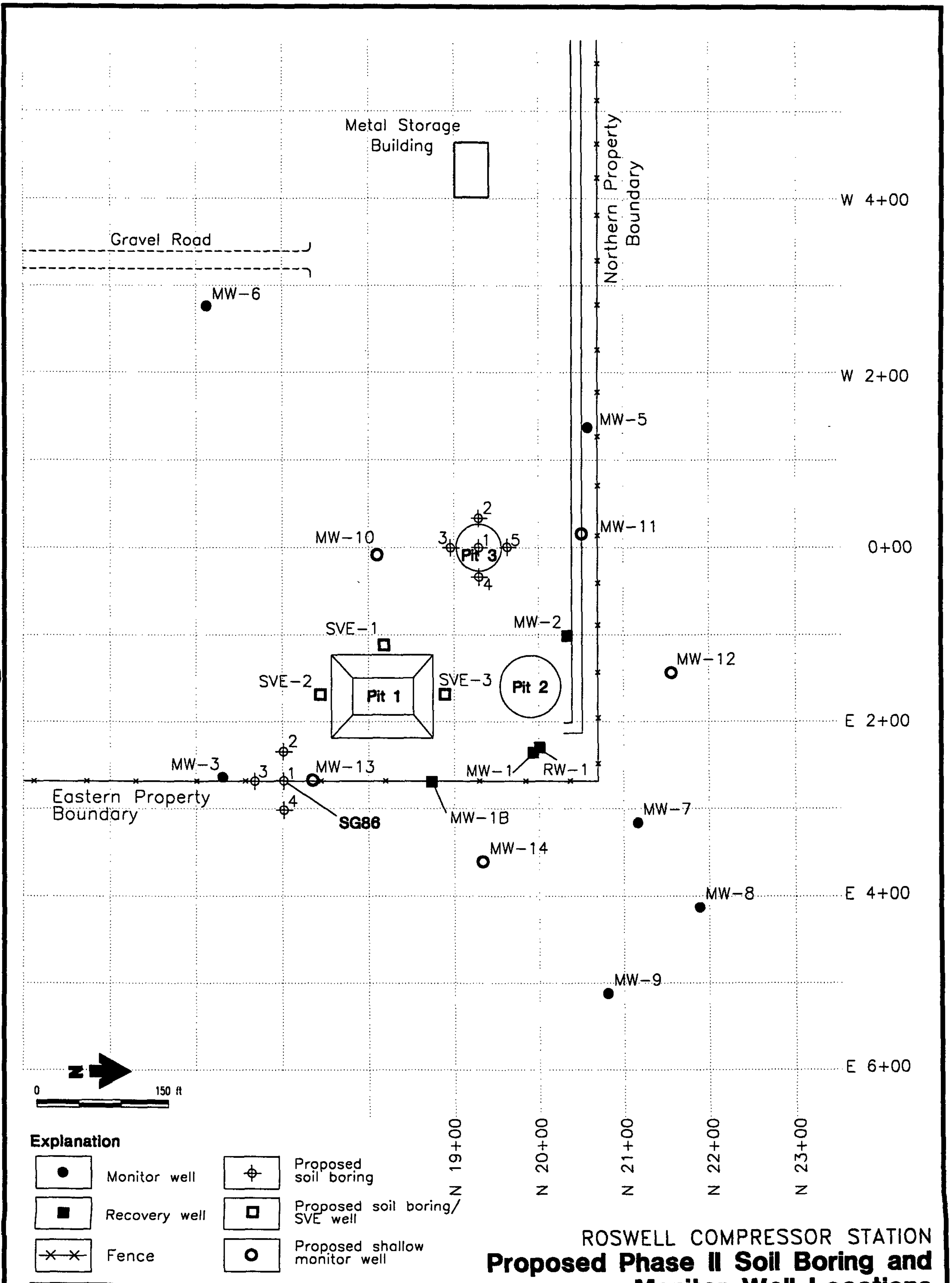
ND Not Detected

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96
JN 4115

ROSWELL COMPRESSOR STATION

Estimated Vertical Extent of Elevated TPH in Soils

Figure 3-11

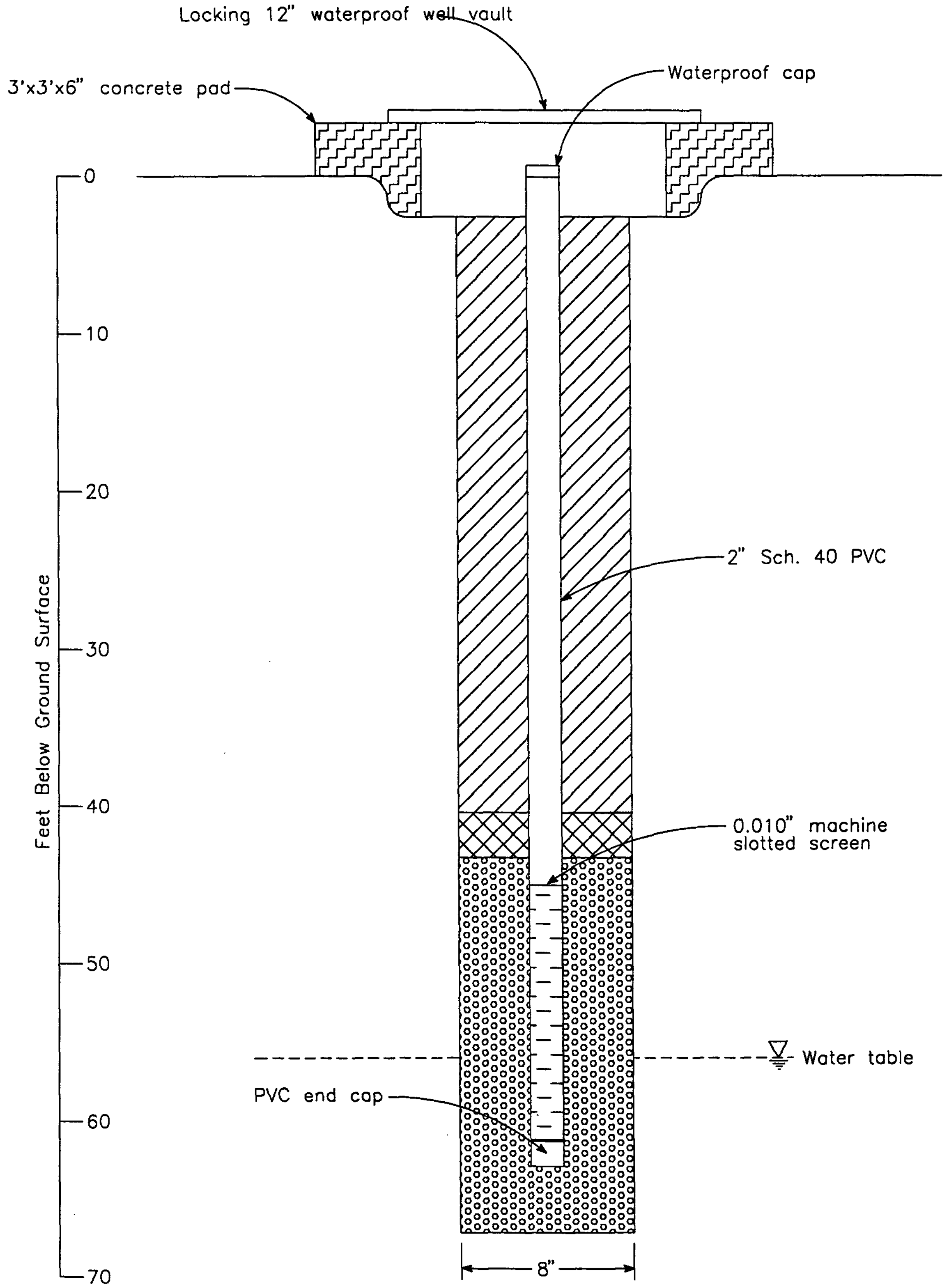


ROSWELL COMPRESSOR STATION

Proposed Phase II Soil Boring and Monitor Well Locations

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96
JN 4115

Figure 4-1



Note: Actual depth and screened interval will be determined following initiation of ground-water assessment plan.

▨ Cement/Bentonite Grout
▩ Hydrated Bentonite Plug
░ 20/40 Silica Sand Pack

Not to Scale

D\4115\6-[illegible].DWG

DANIEL B. STEPHENS & ASSOCIATES, INC.
6-14-96
4115

ROSWELL COMPRESSOR STATION
Monitor Well Schematic

Figure 5-1

TABLES

Table 2-1. Water Supply Wells Located Within 2 Miles of Roswell Compressor Station No. 9

Well Number[1]	Latitude	Longitude	Well ID	Well Depth (ft)	Depth to Water (ft) / Year	Aquifer	Distance From Site (miles)	Date Drilled	Use	Status
1	333028	1043119	09S.24E.29.223313	NA	63 / 1961	San Andres Fm	0.66	NA	Livestock	Abandoned; plugged
2	333031	1043103	09S.24E.28.113132	352	65 / 1994	San Andres Fm	0.49	09/17/69	Observation	Abandoned; open
3	333050	1043025	09S.24E.21.43213	58	15 / 1937	Alluvial Fill	0.45	NA	Livestock	Abandoned; plugged
4	333053	1043134	09S.24E.20.413	NA	NA	San Andres Fm	0.63	NA	NA	Abandoned; not found
5	333059	1043135	09S.24E.20.32422	370	63 / 1948	San Andres Fm	0.73	NA	Industrial	In use
6	333145	1043159	09S.24E.17.331222	208	119 / 1948	Artesia Group	1.54	NA	Observation	NA
7	333128	1043022	09S.24E.21.2124	NA	NA	NA	0.83	NA	Livestock	Abandoned; plugged
8	333149	1042931	09S.24E.15.41313	425	47 / 1961	San Andres Fm	1.72	03/18/59	Irrigation	In use
9	333128	1043004	09S.24E.22.1113	386	281 / 1968	San Andres Fm	1.06	NA	Livestock	Abandoned; open
10	333041	1042924	09S.24E.27.21212	NA	NA	NA	1.50	NA	Irrigation	Not in use
11	332934	1043021	09S.24E.33.21443	510	53 / 1965	San Andres Fm	1.60	NA	Irrigation	NA
12	332927	1043106	09S.24E.32.242443	NA	43 / 1961	Artesia Group	1.66	NA	Livestock	Abandoned
13	332921	1043134	09S.24E.32.233324	116	72 / 1960	San Andres Fm	1.86	NA	Livestock	NA
14	333055	1043236	09S.24E.19.41331	550	126 / 1962	San Andres Fm	2.01	NA	Irrigation	NA
15	333151	1042903	09S.24E.15.42442	375	55 / 1959	San Andres Fm	2.08	12/15/58	Domestic	Abandoned; open
16	333207	1042914	09S.24E.15.24321	365	66 / 1966	San Andres Fm	2.12	11/15/65	Irrigation	Abandoned; has pump
17	333211	1043037	09S.24E.16.1422	NA	NA	NA	1.53	NA	Irrig/Stock	In use
18	333021	1042845	09S.24E.26.1431	NA	NA	NA	2.15	NA	Domestic	In use

Sources: USGS Ground-Water Site Inventory; field verification by Transwestern using GPS.

[1] Well numbers correspond to well locations shown on Figure 2-5.
NA = Not available

Table 3-1. Summary of Previous Soil Borings and Monitor Wells
Roswell Compressor Station No. 9
Page 1 of 4

Boring No.	Source[1]	Boring Type[2]	Date of Completion	Location North	Location East	Measuring Point[3] Elevation (fmsl)	Total Depth (feet bgs)	Casing Diameter (inches)	Screened Interval (feet bgs)	Top of Sand Pack (feet bgs)	Top of Upper Clay[4] (feet bgs)
SB-9-06	HLA	ASB	04/03/90	NA	NA	NA	29.0	N/A	N/A	N/A	28.0
SB-9-07	HLA	ASB	04/03/90	NA	NA	NA	38.5	N/A	N/A	N/A	38.0
P9-OS-349	HLA	ASB	05/02/90	NA	NA	NA	40.0	N/A	N/A	N/A	34.0
P9-OS-377	HLA	ASB	05/02/90	NA	NA	NA	30.0	N/A	N/A	N/A	12.0
SG-09-91	HLA	ASB	05/15/90	NA	NA	NA	33.0	N/A	N/A	N/A	31.0
SG-09-331	HLA	ASB	05/16/90	NA	NA	NA	43.0	N/A	N/A	N/A	38.0
SG-09-337	HLA	ASB	05/17/90	NA	NA	NA	33.0	N/A	N/A	N/A	28.0
SG-09-358	HLA	ASB	05/17/90	NA	NA	NA	30.0	N/A	N/A	N/A	21.0
SG-09-360	HLA	ASB	05/16/90	NA	NA	NA	34.5	N/A	N/A	N/A	30.0
SG-09-370	HLA	ASB	05/16/90	NA	NA	NA	24.0	N/A	N/A	N/A	12.0
Pit 1	Metric	ASB	07/16/91	1798	176.6	3615.72	47.8	N/A	N/A	N/A	30.6
Pit 2	Metric	ASB	07/17/91	1995	216.6	3615.72	71.6	N/A	N/A	N/A	10.1
Pit 3 (BH-1)	Metric	ASB	07/18/91	1918	131.5	3615.71	32.8	N/A	N/A	N/A	ND
Pit 3 (BH-2)	Metric	ASB	07/18/91	1948	138.5	3615.68	29.5	N/A	N/A	N/A	ND

[1] HLA = Harding Lawson Associates, 1991
Metric = Metric Corporation, 1991
Hall-NUS = Halliburton NUS, 1992
B&R = Brown & Root Environmental, 1993
DBS&A = Daniel B. Stephens & Associates, Inc., 1994 and 1995

[2] ASB = Abandoned soil boring
MW = Monitor well
RW = Product recovery well

[3] Measuring point is top of PVC casing or top of cement plug for abandoned soil borings

[4] Depth below ground surface (feet) to uppermost clay reported on boring log

[5] Original survey to arbitrary datum corrected to elevations above sea level by referencing boring elevations to the surveyed elevation of MW-3 (3614.88 fmsl).

fmsl = Feet above mean sea level
bgs = Below ground surface
NA = Not available
N/A = Not applicable
ND = Not detected

Table 3-1. Summary of Previous Soil Borings and Monitor Wells
Roswell Compressor Station No. 9
Page 2 of 4

Boring No.	Source[1]	Boring Type[2]	Date of Completion	Location		Measuring Point[3] Elevation (fmsl)	Total Depth (feet bgs)	Casing Diameter (inches)	Screened Interval (feet bgs)	Top of Sand Pack (feet bgs)	Top of Upper Clay[4] (feet bgs)
				North	East						
SG 86	Metric	ASB	07/22/91	1710	268.2	3613.52	40.7	N/A	N/A	N/A	33.6
SG 91	Metric	ASB	07/22/91	2053.2	66.5	3612.28	33.0	N/A	N/A	N/A	28.2
SG 349	Metric	ASB	07/25/91	2160.2	79.0	3615.56	30.4	N/A	N/A	N/A	29.7
SG 360	Metric	ASB	07/25/91	2261.5	166.8	3610.83	29.4	N/A	N/A	N/A	28.9
SG 361	Metric	ASB	07/25/91	2261.5	277.8	3610.15	41.3	N/A	N/A	N/A	38.9
OS BH-1	Metric	ASB	07/22/91	1664.9	375.9	3622.30	35.7	N/A	N/A	N/A	34.5
OS BH-2	Metric	ASB	07/24/91	1826.0	379.0	3618.39	70.6	N/A	N/A	N/A	22.1
OS BH-3	Metric	ASB	07/26/91	2108.7	495.1	3607.04	55.0	N/A	N/A	N/A	10.2
OS BH-4	Metric	ASB	07/29/91	2181.6	386.6	3604.95	31.0	N/A	N/A	N/A	24.4
OS BH-5	Metric	ASB	07/30/91	1992.0	389.5	3611.12	24.8	N/A	N/A	N/A	19.9
OS BH-6	Metric	ASB	07/30/91	1817.5	460.9	3619.15	72.6	N/A	N/A	N/A	ND
OS BH-7	Metric	ASB	07/31/91	1827.6	505.7	3616.69	40.3	N/A	N/A	N/A	22.0
OS BH-8	Metric	ASB	07/31/91	1671.9	460.8	3620.04	49.9	N/A	N/A	N/A	33.9
OS BH-9	Metric	ASB	08/01/91	1891.6	467.2	3614.77	49.7	N/A	N/A	N/A	31.0

[1] HLA = Harding Lawson Associates, 1991
Metric = Metric Corporation, 1991
Hall-NUS = Halliburton NUS, 1992
B&R = Brown & Root Environmental, 1993
DBS&A = Daniel B. Stephens & Associates, Inc., 1994 and 1995

[2] ASB = Abandoned soil boring
MW = Monitor well
RW = Product recovery well

[3] Measuring point is top of PVC casing or top of cement plug for abandoned soil borings

[4] Depth below ground surface (feet) to uppermost clay reported on boring log

[5] Original survey to arbitrary datum corrected to elevations above sea level by referencing boring elevations to the surveyed elevation of MW-3 (3614.88 fmsl).

fmsl = Feet above mean sea level
bgs = Below ground surface
NA = Not available
N/A = Not applicable
ND = Not detected

Table 3-1. Summary of Previous Soil Borings and Monitor Wells
Roswell Compressor Station No. 9
Page 3 of 4

Boring No.	Source[1]	Boring Type[2]	Date of Completion	Location		Measuring Point[3] Elevation (fmsl)	Total Depth (feet bgs)	Casing Diameter (inches)	Screened Interval (feet bgs)	Top of Sand Pack (feet bgs)	Top of Upper Clay[4] (feet bgs)
				North	East						
BH-10	Metric	ASB	11/15/91	NA	NA	3617.33	37.8	N/A	N/A	N/A	27.8
BH-11	Metric	ASB	11/15/91	NA	NA	3617.60	37.8	N/A	N/A	N/A	28.9
MW-1	Hall-NUS	MW/RW	07/21/92	2001.4	217.6	NA	68	4	28-68	25.2	NA
MW-1B	B&R	MW/RW	04/21/93	1854.0	265.5	3609.96[5]	65.5	2	55-65	53	34.5
MW-2	B&R	MW/RW	04/21/93	2034.3	102.4	3611.76[5]	65.0	2	55-65	53	30
MW-3	B&R	MW	04/26/93	1629.8	265.3	3614.88[5]	72.5	2	60-70	58	32
MW-5	B&R	MW	04/28/93	2049.7	−151.0	3612.76[5]	70	2	60-70	58	19.5
SB-1A	B&R	ASB	04/20/93	NA	NA	3613.48[5]	41.5	N/A	N/A	N/A	ND
SB-1C	B&R	ASB	04/29/93	NA	NA	3606.08[5]	36.0	N/A	N/A	N/A	30
SB-4	B&R	ASB	04/25/93	NA	NA	3604.78[5]	75	N/A	N/A	N/A	18
RB-1	B&R	ASB	06/13/93	1914	222	3613.22[5]	36.3	N/A	N/A	N/A	36.0
RB-2	B&R	ASB	06/12/93	1962	254	3611.11[5]	34.5	N/A	N/A	N/A	34.30
RB-3	B&R	ASB	06/12/93	1953	220	3612.76[5]	42	N/A	N/A	N/A	41.25
RB-4	B&R	ASB	06/13/93	1943	175	3614.41[5]	39	N/A	N/A	N/A	37.75

[1] HLA = Harding Lawson Associates, 1991
Metric = Metric Corporation, 1991
Hall-NUS = Halliburton NUS, 1992
B&R = Brown & Root Environmental, 1993
DBS&A = Daniel B. Stephens & Associates, Inc., 1994 and 1995

[2] ASB = Abandoned soil boring
MW = Monitor well
RW = Product recovery well

[3] Measuring point is top of PVC casing or top of cement plug for abandoned soil borings

[4] Depth below ground surface (feet) to uppermost clay reported on boring log

[5] Original survey to arbitrary datum corrected to elevations above sea level by referencing boring elevations to the surveyed elevation of MW-3 (3614.88 fmsl).

fmsl = Feet above mean sea level
bgs = Below ground surface
NA = Not available
N/A = Not applicable
ND = Not detected

Table 3-1. Summary of Previous Soil Borings and Monitor Wells
Roswell Compressor Station No. 9
Page 4 of 4

Boring No.	Source[1]	Boring Type[2]	Date of Completion	Location		Measuring Point[3] Elevation (fmsl)	Total Depth (feet bgs)	Casing Diameter (inches)	Screened Interval (feet bgs)	Top of Sand Pack (feet bgs)	Top of Upper Clay[4] (feet bgs)
				North	East						
RB-5	B&R	ASB	06/13/93	2027	213	3608.61[5]	32	N/A	N/A	N/A	31.50
RB-6	B&R	ASB	NA	1989	206	3613.36[5]	38.5	N/A	N/A	N/A	38.5
RW-1 (RB-7)	B&R	RW	06/13/93	1987	222	3612.32[5]	42.5	4	36.8-41.7	34.8	41.5
MW-6	DBS&A	MW	12/01/94	1607.4	266.2	3618.62	79	2	59.9-74.9	57.1	35.5
MW-7	DBS&A	MW	08/22/95	2118.0	328.4	3599.20	70.5	2	50.0-70.0	48.1	
MW-8	DBS&A	MW	08/16/95	2178.0	414.7	3595.80	76.8	2	59.0-74.0	57.2	
MW-9	DBS&A	MW	08/18/95	2071.4	512.9	3599.35	70.0	2	50.0-70.0	47.9	
Pit 1, NW	DBS&A	ASB	08/18/95	1812.3	172.9	3615.68	12.0	NA	NA	NA	NA
Pit 1, SE	DBS&A	ASB	08/18/95	1798.2	181.5	3615.61	14.0	NA	NA	NA	NA
Pit 2, NE	DBS&A	ASB	08/17/95	1990.3	174.7	3614.81	20.0	NA	NA	NA	NA
Pit 2, SW	DBS&A	ASB	08/18/95	1970.1	150.2	3616.05	6.0	NA	NA	NA	NA
MW-7ABD	DBS&A	ASB	08/15/95	2289.6	306.6	3599.37	74.0	NA	NA	NA	NA

[1] HLA = Harding Lawson Associates, 1991
Metric = Metric Corporation, 1991
Hall-NUS = Halliburton NUS, 1992
B&R = Brown & Root Environmental, 1993
DBS&A = Daniel B. Stephens & Associates, Inc., 1994 and 1995

[2] ASB = Abandoned soil boring
MW = Monitor well
RW = Product recovery well

[3] Measuring point is top of PVC casing or top of cement plug for abandoned soil borings

[4] Depth below ground surface (feet) to uppermost clay reported on boring log

[5] Original survey to arbitrary datum corrected to elevations above sea level by referencing boring elevations to the surveyed elevation of MW-3 (3614.88 fmsl).

fmsl = Feet above mean sea level
bgs = Below ground surface
NA = Not available
N/A = Not applicable
ND = Not detected

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 1 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
SB9-6 @ 8-11'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20
SB9-6 @ 18-20'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20
SB9-6 @ 20-23'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	120
SB9-6 @ 26-28'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20
SB9-6 @ 26-28' Tube #5	HLA	<5	ND	<10	<5	ND	<5	ND	6	16	ND	ND	<5	<5	<20
SB9-6 @ 26-28' Tube #6	HLA	<7	ND	<14	<7	ND	<7	ND	23*	9*	ND	ND	<7	<7	<20
SB9-7 @ 9-12'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1100
SB9-7 @ 21.5-24'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2000
SB9-7 @ 25.5-28'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2500
SB9-7 @ 29-32'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11000
SB9-7 @ 29-32' Tube #7	HLA	<1300	ND	<2600	<1300	ND	<1300	ND	5100	<1300	ND	ND	720	1800	5000
SB9-7 @ 35-37'	HLA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4600
SB9-7 @ 35-37' Tube #8	HLA	<640	ND	<1300	<640	ND	<640	ND	<640	<640	ND	ND	1800	4200	13000
SB9-7 @ 35-37' Tube #9	HLA	2000	ND	<1300	<670	ND	2100	ND	<670	<670	ND	ND	2800	6500	30000
P9-OS-349 @ 5'	HLA	<5	ND	<11	<5	ND	<5	ND	26*	6*	ND	ND	<5	<5	<20
P9-OS-349 @ 10'	HLA	<6	ND	<11	<6	ND	<6	ND	18	9	ND	ND	<6	<6	100
P9-OS-349 @ 20'	HLA	<5	ND	<11	<5	ND	<5	ND	45*	<5*	ND	ND	<5	<5	<20
P9-OS-349 @ 25'	HLA	<5	ND	<11	<5	ND	<5	ND	21	10	ND	ND	<5	<5	100

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 2 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
P9-OS-349 @ 30'	HLA	<7	ND	<14	<7	ND	<7	ND	45*	<7	ND	ND	<7	<7	<20
P9-OS-349 @ 35'	HLA	<7	ND	<14	<7	ND	<7	ND	39	15	ND	ND	<7	<7	<20
P9-OS-349 @ 40'	HLA	<5	ND	<10	<5	ND	<5	ND	40	8	ND	ND	<5	<5	<20
P9-OS-377 @ 5'	HLA	<6	ND	34*	<6	ND	<6	ND	<6	<6	ND	ND	<6	<6	200
P9-OS-377 @ 10'	HLA	<6	ND	27*	<6	ND	<6	ND	<6	<6	ND	ND	<6	<6	<20
P9-OS-377 @ 15'	HLA	<6	ND	27*	<6	ND	<6	ND	<6	11	ND	ND	<6	<6	<20
P9-OS-377 @ 20'	HLA	<7	ND	37*	<7	ND	<7	ND	<7	7	ND	ND	<7	<7	<20
P9-OS-377 @ 25'	HLA	<6	ND	<12	<6	ND	<6	ND	46	36	ND	ND	<6	<6	<20
P9-OS-377 @ 30'	HLA	<7	ND	<13	<7	ND	<7	ND	69	23	ND	ND	<7	<7	<20
Pit 1 @ 2.8-3.0'	Metric	3200	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	25000
Pit 1 @ 9.2-9.4'	Metric	19000	ND	NA	ND	ND	ND	260	NA	ND	NA	NA	NA	NA	39000
Pit 1 @ 13.5-13.7'	Metric	18000	590	NA	ND	200	ND	330	NA	ND	NA	NA	NA	NA	55000
Pit 1 @ 18.8-19.0'	Metric	330	ND	NA	ND	ND	ND	870	NA	ND	NA	NA	NA	NA	20000
Pit 1 @ 26.8-27.0'	Metric	ND	ND	NA	ND	ND	ND	160	NA	ND	NA	NA	NA	NA	11000
Pit 1 @ 30.6-30.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	16
Pit 1 @ 41.6-41.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	16
Pit 1 @ 43.5-43.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	56

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 3 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
Pit 2 #1 @ 18.7-18.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
Pit 2 #2 @ 18.7-18.9'	Metric	370	ND	NA	ND	ND	ND	650	NA	ND	NA	NA	NA	NA	13000
Pit 2 @ 26.0-26.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	170
Pit 2 @ 29.1-29.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
Pit 2 @ 39.8-39.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	2600
Pit 2 @ 44.1-44.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	44
Pit 2 @ 57.5-57.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	250
Pit 2 @ 69.9-70.1'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Pit 3 BH-1 @ 30.7-30.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
Pit 3 BH-2 @ 25.0-25.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
SG 86 @ 13.5-13.7'	Metric	240	ND	NA	ND	ND	ND	1900	NA	ND	NA	NA	NA	NA	18000
SG 86 @ 18.7-18.9'	Metric	ND	ND	NA	ND	ND	ND	230	NA	ND	NA	NA	NA	NA	5200
SG 86 @ 24.9-25.1'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 86 @ 35.0-35.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	8.0
SG 86 @ 40.5-40.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
SG 91 @ 28.6-28.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
SG 349 @ 0.0-1.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 349 @ 2.9-4.6'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 4 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
SG 349 @ 9.0-10.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 349 @ 14.0-14.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 349 @ 20.3-21.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 349 @ 5.3-26.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 349 @ 29.7-30.4'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
SG 360 @ 0.0-2.5'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 4.0-5.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 9.0-9.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 14.0-14.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 19.0-20.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 24.0-25.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 360 @ 29.0-29.4'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	2.0
SG 361 @ 0.0-2.5'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 361 @ 4.0-5.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 361 @ 9.0-10.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 361 @ 16.0-16.4'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 361 @ 19.5-19.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
SG 361 @ 24.0-25.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 5 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
SG 361 @ 38.0-39.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-1 @ 18.9-19.1'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	12
OS BH-1 @ 34.3-34.5'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-2 @ 9.9-10.1'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-2 @ 22.5-22.6'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-2 @ 31.1-31.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	68
OS BH-2 @ 41.8-42.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	24
OS BH-2 @ 55.2-55.4'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	16
OS BH-2 @ 69.0-69.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	16
OS BH-3 @ 21.0-21.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
OS BH-3 @ 44.1-44.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	16
OS BH-3 @ 54.7-55.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	16
OS BH-4 @ 27.5-27.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
OS BH-5 @ 14.0-14.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-5 @ 19.6-19.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	16
OS BH-5 @ 23.4-23.6'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	12
OS BH-6 @ 13.6-13.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	12
OS BH-6 @ 47.0-47.2'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-2. Summary of Organic Compounds Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 6 of 6

Sample ID	Source[2]	Concentration[1]													
		1,1,1-TCA	1,1-DCA	Acetone	Chloro-benzene	Chloro-form	PCA	PCE	Freon-113	Methylene chloride	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TPH (mg/kg)
OS BH-6 @ 52.6-52.8'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-6 @ 70.0-71.0'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
OS BH-7 @ 22.1-22.3'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND
OS BH-7 @ 33.5-33.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	ND
OS BH-7 @ 37.0-37.2'	Metric	ND	ND	NA	ND	ND	ND	170	NA	ND	ND	ND	190	440	12
OS BH-8 @ 4.6-4.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	12
OS BH-8 @ 33.9-34.1'	Metric	ND	ND	NA	120	ND	ND	160	NA	ND	NA	NA	NA	NA	ND
OS BH-8 @ 49.7-49.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	140	300	12
OS BH-9 @ 4.5-4.9'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	8
OS BH-9 @ 32.0-32.5'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	NA	NA	NA	NA	150
OS BH-9 @ 49.5-49.7'	Metric	ND	ND	NA	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	8
BH-10 @ 37.3-37.6'	Metric	NA	NA	NA	ND	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND
BH-11 @ 36.3-36.7'	Metric	NA	NA	NA	ND	NA	NA	NA	NA	NA	ND	ND	ND	ND	8
SB-1C @ 25-26'	B&R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20
SB-5 @ 19-21'	B&R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20
SB-5 @ 64-66'	B&R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<20

[1] Concentrations are in µg/kg unless otherwise noted

[2] HLA = Harding Lawson Associates (1991a)
Metric = Metric Corporation (1991)
B&R = Brown and Root Environmental (1993)
Note: All HLA analyses performed in on-site mobile laboratory

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
PCA = Tetrachloroethane
PCE = Tetrachloroethene
Freon-113 = 1,1,2-Trichloro-1,2,2-trifluoroethane
TPH = Total petroleum hydrocarbons

NA = Not analyzed
ND = Not detected
* = Compound was also detected in the QC blanks

Table 3-3. Summary of TCLP Inorganic Constituents Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 1 of 2

Sample ID	Source[1]	Concentration (mg/L)							
		Arsenic (TCLP Extract)	Barium (TCLP Extract)	Cadmium (TCLP Extract)	Chromium (TCLP Extract)	Lead (TCLP Extract)	Mercury (TCLP Extract)	Selenium (TCLP Extract)	Silver (TCLP Extract)
TCLP Limit	---	***5.0***	***100.0***	***1.0***	***5.0***	***5.0***	***0.2***	***1.0***	***5.0***
SB9-6 @ 8-11'	HLA	0.004	0.63	0.0010	<0.006	<0.002	<0.0002	<0.003	<0.0005
SB9-6 @ 18-20'	HLA	<0.003	1.21	<0.0005	<0.006	<0.002	<0.0002	<0.003	<0.0005
SB9-6 @ 20-23'	HLA	<0.003	0.7	<0.0005	0.011	<0.002	<0.0002	<0.003	0.0026
SB9-6 @ 26-28'	HLA	<0.003	1.22	0.0006	0.006	0.008	<0.0002	<0.003	<0.0005
SB9-6 @ 26-28' Tube #5	HLA	<0.003	1.3	0.0012	0.007	0.002	<0.0002	<0.003	<0.0005
SB9-6 @ 26-28' Tube #6	HLA	0.009	0.010	0.0008	0.011	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 9-12'	HLA	<0.003	0.75	0.0005	0.007	0.003	<0.0002	<0.003	<0.0005
SB9-7 @ 21.5-24'	HLA	0.004	2.22	0.0010	<0.006	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 25.5-28'	HLA	<0.003	1.81	<0.0005	0.009	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 29-32'	HLA	0.008	3.59	0.0011	0.009	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 29-32' Tube #7	HLA	0.008	1.81	0.0012	0.006	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 35-37'	HLA	0.008	1.72	0.0007	0.007	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 35-37' Tube #8	HLA	0.005	1.84	0.0006	<0.006	<0.002	<0.0002	<0.003	<0.0005
SB9-7 @ 35-37' Tube #9	HLA	0.004	3.12	0.0006	0.01	<0.002	<0.0002	<0.003	<0.0005
P9-OS-349 @ 5'	HLA	0.007	1.21	0.0009	0.012	0.012	<0.0002	<0.003	<0.0006
P9-OS-349 @ 10'	HLA	0.005	0.4	<0.0006	0.013	0.011	<0.0002	<0.01	<0.0006
P9-OS-349 @ 20'	HLA	<0.003	0.77	<0.0006	0.009	0.004	<0.0002	<0.003	<0.0006

[1] HLA = Harding Lawson Associates (1991a)

Table 3-3. Summary of TCLP Inorganic Constituents Detected in Soil Samples (Pre-1995)
Roswell Compressor Station No. 9
Page 2 of 2

Sample ID	Source[1]	Concentration (mg/L)							
		Arsenic (TCLP Extract)	Barium (TCLP Extract)	Cadmium (TCLP Extract)	Chromium (TCLP Extract)	Lead (TCLP Extract)	Mercury (TCLP Extract)	Selenium (TCLP Extract)	Silver (TCLP Extract)
TCLP Limit	---	***5.0***	***100.0***	***1.0***	***5.0***	***5.0***	***0.2***	***1.0***	***5.0***
P9-OS-349 @ 30'	HLA	<0.003	1.48	<0.0006	0.009	0.007	<0.0002	<0.003	<0.0006
P9-OS-349 @ 35'	HLA	<0.003	1.36	<0.0006	0.011	0.005	<0.0002	<0.003	<0.0006
P9-OS-349 @ 40'	HLA	0.005	0.23	0.0013	<0.007	<0.002	<0.0002	<0.003	<0.0006
P9-OS-377 @ 5'	HLA	0.004	1.05	<0.0006	0.009	0.003	<0.0002	<0.003	<0.0006
P9-OS-377 @ 10'	HLA	0.01	0.19	0.0018	0.007	0.004	<0.0002	<0.01	<0.0006
P9-OS-377 @ 15'	HLA	<0.003	0.15	0.003	0.011	0.009	<0.0002	<0.003	<0.0006
P9-OS-377 @ 20'	HLA	0.003	0.16	0.0010	0.011	0.003	<0.0002	<0.01	<0.0006
P9-OS-377 @ 25'	HLA	0.006	0.06	0.0009	<0.007	<0.002	<0.0002	<0.02	<0.0006
P9-OS-377 @ 30'	HLA	0.011	0.32	<0.0006	<0.007	<0.002	<0.0002	<0.003	<0.0006

[1] HLA = Harding Lawson Associates (1991a)

Table 3-4. Summary of Organic Compounds Detected in Ground-Water Samples (Pre-1995)
Roswell Compressor Station No. 9

			Concentration[1]											
Sample ID	Source[2]	Date	Benzene	Toluene	Ethyl-benzene	o-Xylene	p-Xylene, m-Xylene	1,1,1-TCA	1,1-DCA	2-Butanone (MEK)	Naphthalene	2-Methyl-naphthalene	4-Methyl-phenol	Petroleum Hydrocarbons (mg/L)
NMWQCC Ground-Water Standard			10	750	750	620[3]		60	NS	NS	NS	30[4]	NS	NS
MW-1	HB	09/21/92	370	61	110	120	820	180	560	220	34	51	250	37
MW-2	B&R	10/09/93	6,500	15,000	2,100	13,000[3]		<300	<300	NA	NA	NA	NA	NA
MW-3	B&R	04/30/93	<5	<5	<5	NA	NA	<5	<5	NA	NA	NA	NA	<0.2
MW-5	B&R	04/30/93	<5	<5	<5	NA	NA	<5	<5	NA	NA	NA	NA	<0.2
MW-6	DBS&A	12/02/94	<0.5	<0.5	<0.5	<0.5[3]		<0.2	<0.2	NA	NA	NA	NA	<2.5
TW-1	DBS&A	12/22/94	<1	<5	<5	<5		<5	<5	<100	<10	<10	<10	NA
Well #5[5]	DBS&A	12/22/94	<1	<5	<5	<5		<5	<5	<100	NA	NA	NA	NA

[1] Concentrations are in µg/L unless otherwise noted

[2] HB = Halliburton NUS Environmental Corp. (1992)
B&R = Brown and Root Environmental (1993)
DBS&A = Daniel B. Stephens & Associates, Inc. (1994)

[3] Total xylenes

[4] Sum of naphthalene and methylnaphthalene

[5] Off-site water supply well; see Figure 2-5 for location

1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
MEK = Methyl ethyl ketone

NA = Not analyzed
ND = Not detected
NS = No standard

Table 3-5. Summary of Inorganic Constituents Detected in Ground-Water Samples (Pre-1995)
Roswell Compressor Station No. 9

Sample ID	Source[1]	Date	Concentration (mg/L)																
			Arsenic		Barium		Cadmium		Chromium		Lead		Mercury		Selenium		Silver		TDS
			T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	
NMWQCC Ground-Water Standards			NS	0.1	NS	1.0	NS	0.01	NS	0.05	NS	0.05	0.002	NS	NS	0.05	NS	0.05	1000
MW-1	HB	09/21/92	0.19	NA	4.4	NA	<0.005	NA	0.01	NA	<0.05	NA	<0.0002	NA	<0.003	NA	<0.01	NA	NA
MW-3	B&R	04/30/93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3,400
	CES	03/23/94	<0.03	<0.03	0.09	0.02	<0.01	<0.01	<0.01	<0.01	0.04	<0.03	<0.0002	<0.0002	<0.04	<0.04	<0.01	<0.01	NA
MW-5	B&R	04/30/93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3,800
	CES	03/23/94	<0.03	<0.03	0.38	0.01	<0.01	<0.01	0.03	<0.01	0.04	<0.03	<0.0002	<0.0002	<0.04	<0.04	<0.01	<0.01	NA
TW-1	DBS&A	12/22/94	<0.05	NA	0.14	NA	<0.005	NA	<0.01	NA	0.06	NA	<0.0002	NA	<0.1	NA	<0.01	NA	1,290
Well #5[2]	DBS&A	12/22/94	<0.05	NA	0.02	NA	<0.005	NA	<0.01	NA	<0.05	NA	<0.0002	NA	<0.1	NA	<0.01	NA	2,420

[1] HB = Halliburton NUS Environmental Corp. (1992)
B&R = Brown and Root Environmental (1993)
CES = Cypress Engineering Services (1994)
DBS&A = Daniel B. Stephens & Associates, Inc. (1994)

[2] Off-site water supply well; see Figure 2-5 for location.

TDS = Total dissolved solids
T = Total metals concentrations determined on unfiltered samples
D = Dissolved metals concentrations determined on samples filtered in the laboratory prior to analysis
NA = Not analyzed
NS = Not standard

Note: New Mexico Water Quality Control Commission (NMWQCC) ground-water standards pertain to dissolved constituents, except mercury; the mercury standard applies to the total (unfiltered) mercury concentration.

Table 3-6. Summary of Detected Constituents in Phase I Soil Samples from Pit Area Borings Roswell Compressor Station No. 9 Page 1 of 2

Analyte	Soil Screening Level[a]	Risk-Based Concentration[b]	Sample No. (Sample Date)			
			Pit 1 NW Boring (08/18/95)	Pit 1 SE Boring (08/18/95)	Pit 2 NE Boring (08/17/95)	Pit 2 SW Boring (08/18/95)
Volatile Organic Compounds (mg/kg) by EPA Method 8240						
Acetone	8	7,800	**1.4**	<0.50	<0.50	<0.10
Benzene	0.02	22	**0.21**	**0.85**	**0.14**	<0.005
Carbon disulfide	14	7,800	<0.02	**0.06**	<0.02	<0.005
1,1-Dichloroethane (1,1-DCA)	11	7,800	**1.0**	**1.20**	<0.02	<0.005
1,1-Dichloroethene (1,1-DCE)	0.03	1.1	**0.04**	**0.04**	<0.02	<0.005
Ethylbenzene	5	7,800	**0.04**	**0.37**	**0.9**	<0.005
2-Hexanone	NA	NA	<0.02	**0.46**	<0.02	<0.005
Methylene chloride (dichloromethane)	0.01	85	<0.02	**0.16**	<0.02	<0.005
Tetrachloroethene (PCE)	0.04	12	<0.02	**0.04**	<0.02	**0.009**
Toluene	5	16,000	**0.5**	**9.1**	**1.9**	<0.005
1,1,1-Trichloroethane (1,1,1-TCA)	0.9	7,000	**1.9**	**16.0**	<0.02	**0.017**
Vinyl acetate	84	78,000	**0.2**	**7.0**	<6.0	<0.05
Xylene(s)[c]	74	160,000	**0.27**	**2.4**	**16.0**	<0.005
Semivolatile Organic Compounds (mg/kg) by EPA Method 8270						
Benzo(j)fluoranthene	NA	NA	<3.3	<3.3	<0.33	**0.33**
Bis(2-ethylhexyl)phthalate	11	46	**4.8**	<3.3	<0.33	<0.33
Chrysene	1	88	<3.3	<3.3	<0.33	**0.33**
Fluoranthene	980	3,100	<3.3	<3.3	<0.33	**0.76**
2-Methylnaphthalene	NA	NA	**4.8**	<3.3	**0.46**	<0.33
Phenanthrene	NA	NA	**5.6**	**5.0**	<0.33	**0.45**
Phenol (carbolic acid)	49	47,000	**30.0**	**200**	<0.33	<0.33
Pyrene	1,400	2,300	<3.30	<3.3	<0.33	**0.89**

Notes: This table lists only those analytes that were detected in at least one of the pit soil samples.
Bold values highlight concentrations above reporting limits.
Core Laboratories results for VOCs and SVOCs converted from µg/kg to mg/kg.

[a] Soil screening level for protection of ground water based on a dilution-attenuation factor of 10 (EPA, 1994)
[b] Risk-based concentration for soil ingestion at residential sites (EPA, 1995)
[c] Soil screening level for mixed xylene

NA = Not available

Table 3-6. Summary of Detected Constituents in Phase I Soil Samples from Pit Area Borings Roswell Compressor Station No. 9
Page 2 of 2

Analyte	Soil Screening Level[a]	Risk-Based Concentration[b]	Sample No. (Sample Date)			
			Pit 1 NW Boring (08/18/95)	Pit 1 SE Boring (08/18/95)	Pit 2 NE Boring (08/17/95)	Pit 2 SW Boring (08/18/95)
PCBs (µg/kg) by EPA Method 8080 *(No analytes detected)*						
Metals (mg/kg) by EPA Methods 6010 and 7471 (for Mercury)						
Aluminum (Al)	NA	78,000	**5,950**	**1,690**	**1,430**	**1,63**
Antimony (Sb)	NA	31	**10**	<10	<10	<10
Arsenic (As)	15	23	**9**	**17**	**6**	<5
Barium (Ba)	32	5,500	**415**	**171**	**233**	**734**
Beryllium (Be)	180	0.15	<0.5	<0.5	**0.5**	<0.5
Chromium (Cr)[d]	19	390	**9**	**9**	**8**	**7**
Copper (Cu)	NA	2,900	**144**	**337**	**56**	**18**
Lead (Pb)	NA	NA	<5	**11**	<5	<5
Mercury (Hg)	3	23	**0.59**	**1.36**	<0.10	<0.10
Nickel (Ni)	21	1,600	**9**	**5**	**5**	<4
Selenium (Se)	3	390	<10	<10	<10	**10**
Tin (Sn)	NA	47,000	<5	**6**	**5**	<5
Vanadium (V)	NA	550	**14**	**10**	**21**	**11**
Zinc (Zn)	42,000	23,000	**97**	**282**	**45**	**34**
Miscellaneous (mg/kg) by EPA Methods 9010, 9030, and 418.1, respectively						
Total cyanide[e]	NA	11.290	**1.1**	**1.4**	<0.4	<0.4
Total sulfide	NA	NA	**1,800**	**940**	**530**	**370**
Total petroleum hydrocarbons	NA	NA	**4,700**	**26,000**	**5,300**	<50

Notes: This table lists only those analytes that were detected in at least one of the pit soil samples.
Bold values highlight concentrations above reporting limits.

[d] Concentrations based on chromium VI
[e] Includes barium/calcium/copper cyanide

NA = Not available

J:\6033\TABLES\PIT-RES.3-6

Table 3-7. Summary of Detected Constituents in Phase I Soil Samples from Off-Site Borings Roswell Compressor Station No. 9

Analyte	Sample No. and Depth (Sample Date)												
	MW-7ABD 5-10' (08/15/95)	MW-7ABD 40-42' (08/15/95)	MW-7ABD 60-62' (08/15/95)	MW-7 10-12' (08/22/95)	MW-7 30-32' (08/22/95)	MW-7 40-42' (08/22/95)	MW-7 50-52' (08/22/95)	MW-7 70-72' (08/22/95)	MW-8 10' (08/16/95)	MW-8 65' (08/16/95)	MW-9 10' (08/16/95)	MW-9 40-42' (08/16/95)	MW-9 60-62' (08/22/95)
Volatile Organic Compounds (µg/kg) by EPA Method 8240													
Methylene chloride (dichloromethane)	<5	<5	<5	**6** B	**7** B	**8** B	**8** B	**9** B	<5	<5	<5	<5	**10** B
Metals (mg/kg) by EPA Methods 6010 and 7471 (for Mercury)													
Arsenic (As)	<5	**8**	**5**	<5	<5	<5	**7**	**12**	<5	<5	**8**	**12**	**14**
Barium (Ba)	**319**	**210**	**165**	**301**	**48**	**30**	**157**	**102**	**95**	**8**	**151**	**176**	**76**
Chromium (Cr)	**7**	**16**	**14**	**6**	**11**	**9**	**19**	**16**	**8**	**5**	**7**	**13**	**15**
Lead (Pb)	<5	**18**	**8**	<5	**6**	**5**	**6**	**11**	<5	<5	<5	**5**	**5**
Mercury (Hg)	<0.10	<0.10	**0.42**	<0.10	<0.10	<0.10	<0.10	<0.10	**0.12**	<0.10	<0.10	<0.10	<0.10

B = Analyte also present in method blank

Notes: These tables list only those analytes that were detected in at least one of the soil samples from off-site soil borings.
Bold values highlight concentrations above reporting limits.

Table 3-8. Summary of Detected Constituents in Phase I Ground-Water Samples
Roswell Compressor Station No. 9

Analyte	NMWQCC Standard	Monitor Well (Sample Date)					
		MW-3 (08/22/95)	MW-5 (08/22/95)	MW-6 (08/22/95)	MW-7 (08/23/95)	MW-8 (08/22/95)	MW-9 (08/23/95)
Volatile Organic Compounds (µg/L) by EPA Method 8240							
Benzene	10	<5	<5	<5	<5	**6**	<5
Methyl ethyl ketone (2-Butanone)	None	<100	<100	<100	**900**	<100	<100
Methyl methacrylate	None	<5	<5	<5	**5**	<5	<5
Semivolatile Organic Compounds (µg/L) by EPA Method 8270 *(No analytes detected)*							
Organochlorine Pesticides/PCBs (µg/L) by EPA Method 8080 *(No analytes detected)*							
Metals (mg/L) by EPA Methods 6010 and 7470 (for Mercury)							
Aluminum (Al)	5.0	**0.24**	**0.38**	**0.69**	**1.39**	**0.33**	**3.13**
Barium (Ba)	1.0	<0.01	<0.01	<0.01	**0.02**	<0.01	**0.04**
Copper (Cu)	1.0	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**
Mercury (Hg)	0.002	**0.0002**	<0.0002	**0.0005**	**0.0004**	**0.0003**	**0.0005**
Zinc (Zn)	10	**0.03**	**0.01**	**0.03**	**0.02**	**0.01**	**0.03**
Indicator Parameters (mg/L) *(EPA methods shown in parentheses)*							
Bicarbonate (2320B)	None	**142**	**149**	**134**	**166**	**163**	**151**
Calcium (6010)	None	**587**	**623**	**458**	**668**	**587**	**896**
Chloride (325.2)	250	**405**	**574**	**344**	**284**	**362**	**391**
Magnesium (6010)	None	**136**	**145**	**148**	**235**	**193**	**232**
Nitrate + nitrite as N (353.2)	10	**0.80**	**3.10**	**1.00**	**0.12**	**0.10**	**0.38**
Potassium (6010)	None	**3.2**	**3.8**	**3.9**	**8.2**	**3.7**	**17**
Sodium (6010)	None	**215**	**204**	**124**	**149**	**117**	**230**
Sulfate (375.2)	600	**1,800**	**1,800**	**1,600**	**2,000**	**2,000**	**2,200**
Sulfide (376.2)	None	<0.05	<0.05	<0.05	**0.08**	<0.05	**0.10**
Total alkalinity (as $CaCO_3$) (310.1)	None	**116**	**122**	**110**	**136**	**134**	**124**
Total dissolved solids (160.1)	1,000	**3,650**	**3,440**	**2,800**	**3,640**	**3,640**	**4,060**

Notes: This table lists only those analytes that were detected in at least one of the ground-water samples.
Bold values highlight concentrations above reporting limits.

NMWQCC = New Mexico Water Quality Control Commission

Table 3-9. Well Coordinates and Depth to Water for Existing Monitor Wells
Roswell Compressor Station No. 9

Monitor Well	Location[1]	Measuring Point Elevation[2] (fmsl)	Depth to Water[3] (feet)	Ground-Water Elevation (fmsl)
RW-1	N1999.1 E224.4	3612.03	NA	NA
MW-1	N2001.4 E217.6	3612.95	NA	NA
MW-1B	N1854.0 E265.5	3610.44	NA	NA
MW-2	N2034.3 E102.4	3612.83	NA	NA
MW-3	N1629.8 E265.3	3614.88	64.58	3550.30
MW-5	N2049.7 W151.0	3612.76	62.46	3550.30
MW-6	N1607.4 W266.2	3618.62	61.52	3557.10
MW-7	N2118.0 E328.4	3599.20	55.60	3543.60
MW-8	N2178.0 E414.7	3595.80	52.82	3542.98
MW-9	N2071.4 E512.9	3599.35	50.48	3548.87

[1] Horizontal coordinates relative to station datum (see Figure 2-1).
[2] Measuring point elevation for each monitor well determined relative to station datum.
[3] Depth to water measured on September 15, 1995.
fmsl = Feet abovve mean sea level

Table 6-1. Analytical Parameters, Methods, and Data Quality Objectives

Analyte Class	EPA Method[1]	Precision Objective (RPD)[2]	Accuracy Objective (%R)[3]	Completeness Objective (%)
VOCs	8010/8020/8240	20	80–120	90
PAHs	8100	30	60–140	90
SVOCs	8270	30	60–140	90
PCBs	8080	30	60–140	90
Appendix IX total metals[4]	6010/7000	20	80–120	90
Total cyanide	9012	20	80–120	90
Total sulfide	9030	20	80–120	90
Total petroleum hydrocarbons	418.1	20	NA	90
Major cations[5]	6010	20	NA	90
Total alkalinity	310.1	20	NA	90
Chloride	9250	20	NA	90
Sulfate	9038	20	NA	90
Nitrate and nitrite	9200	20	NA	90
TDS	160.1	20	NA	90

[1] U.S. EPA, 1986.
[2] Relative percent difference between duplicate.
[3] Percent recovery of matrix spike.
[4] Includes Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Tl, V, Zn.
[5] Includes Ca, K, Mg, Na, Fe, Mn.

Note: The proposed analysis for each sample is described in the Phase II work plan.

Table 6-2. Sample Collection Protocol

Analyte	EPA Method	Sample Volume/Container	Sample Preservation	Holding Time
Soil Matrix				
VOCs	8010/8020	2.5" x 6" brass ring	Chill to 4°C	14 days
SVOCs	8270	2.5" x 6" brass ring	Chill to 4°C	14/40 days
PCBs	8080	2.5" x 6" brass ring	Chill to 4°C	14/40 days
Appendix IX metals[1]	6010/7000	2.5" x 6" brass ring	Chill to 4°C	6 months
Total cyanide	9010	2.5" x 6" brass ring	Chill to 4°C	14 days
Total sulfide	9030	2.5" x 6" brass ring	Chill to 4°C	7 days
TPH (gasoline)	418.1	2.5" x 6" brass ring	Chill to 4°C	28 days
Ground-Water Matrix				
VOCs	8240	Two 40-mL septum vials	HCl to pH<2; chill to 4°C	14 days
SVOCs	8270	1 L glass	Chill to 4°C	7/40 days
Pests/PCBs	8080	1 L glass	Chill to 4°C	7/40 days
Phosphorus pesticides	8140	1 L glass	Chill to 4°C	7/40 days
Chlorinated herbicides	8150	1 L glass	Chill to 4°C	7/40 days
Appendix IX metals[1]	6010/7000	1 L glass	Chill to 4°C	6 months
Total cyanide	9010	1 L glass	NaOH to pH>12	14 days
Total sulfide	9030	1 L glass	ZnAc + NaOH to pH>12	7 days
TPH (gasoline)	418.1	Two 40-mL septum vials	HCl to pH<2; chill to 4°C	28 days
Major cations[2]	3010/6010	500-mL plastic	HNO_3 to pH<2	6 months
Bicarbonate (total)	310.1	500-mL plastic	Chill to 4°C	14 days
Chloride (total)	9250	500-mL plastic	Chill to 4°C	28 days
Nitrate (total)	9200	500-mL plastic	H_2SO_4 to pH<2; chill to 4°C	28 days
Sulfate (total)	9038	500-mL plastic	Chill to 4°C	28 days
TDS	160.1	500-mL plastic	Cihll to 4°C	7 days

Note: All laboratory analyses to be performed on unfiltered ground-water samples.

[1] Includes Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Tl, V, Zn.
[2] Includes Ca, K, Mg, Na, Fe, Mn.

Table 7.1: Performance Standards for Soil

		Max. conc. detected in any sample (mg/kg)	Performance Standard (mg/kg)	Source of standard
MAHs	Total BTEX	19	50	NM OCD
	benzene	0.85	10	NM OCD
Other VOCs	acetone	1.4	1,020	TX RRR
	2-butanone (MEK)		511	TX RRR
	carbon disulfide	0.06	1,020	TX RRR
	carbon tetrachloride		0.5	TX RRR
	chlorobenzene		10	TX RRR
	chloroethane		204	TX RRR
	chloroform	0.2	10	TX RRR
	1,1-dichloroethane	1.2	1,020	TX RRR
	1,2-dichloroethane		0.5	TX RRR
	1,1-dichloroethene	0.04	0.7	TX RRR
	c-1,2-dichloroethene		7	TX RRR
	t-1,2-dichloroethene		10	TX RRR
	2-hexanone (MNBK)	0.46		(no standard)
	MIBK		511	TX RRR
	methyl methacrylate		818	TX RRR
	methylene chloride	0.16	0.5	TX RRR
	1,1,1,2-tetrachloroethane	2.1	11	TX RRR
	1,1,2,2-tetrachloroethane		1.43	TX RRR
	tetrachloroethene	1.9	0.5	TX RRR
	1,1,1-trichloroethane	19	20	TX RRR
	1,1,2-trichloroethane		0.5	TX RRR
	trichloroethene		0.5	TX RRR
	vinyl acetate	7	10,200	TX RRR
	vinyl chloride		0.2	TX RRR
PAHs	acenaphthene		613	TX RRR
	acenaphthylene			(no standard)
	benzo(b)fluoranthene		4	EPA Reg. III
	benzo(k)fluoranthene		4	EPA Reg. III
	benzo(j)fluoranthene	0.33		(no standard)
	benzo(a)pyrene		4	EPA Reg. III
	chrysene	0.33	1	EPA Reg. III
	fluoranthene	0.76	409	TX RRR
	fluorene		409	TX RRR
	2-methylnaphthalene	4.8		(no standard)
	naphthalene		30	EPA Reg. III
	phenanthrene	5.6		(no standard)
	pyrene	0.89	0.484	TX RRR
Other SVOCs	bis(2-ethylhexyl)phthalate	4.8	2.04	TX RRR
	m-cresol (3-methylphenol)		511	TX RRR
	o-cresol (2-methylphenol)		511	TX RRR
	p-cresol (4-methylphenol)		511	TX RRR
	m-dichlorobenzene (1,3)		60	TX RRR
	o-dichlorobenzene (1,2)		60	TX RRR
	p-dichlorobenzene (1,4)		7.5	TX RRR
	phenol	200	6,130	TX RRR
Other	PCBs		0.05	TX RRR
	cyanide	1.4	20	TX RRR
	TPH	55,000	1,000/5,000	NM OCD
Metals	aluminum	5,950	3,700	EPA Reg. III (TWx100)
	antimony	10	0.6	TX RRR
	arsenic	17	5	TX RRR
	barium	734	200	TX RRR
	beryllium	0.5	0.4	TX RRR
	cadmium		0.5	TX RRR
	chromium (III/IV)	19	10	TX RRR
	cobalt		220	EPA Reg. III (TWx100)
	copper	337	150	EPA Reg. III (TWx100)
	lead	18	1.5	TX RRR
	mercury	1.36	0.2	TX RRR
	nickel	9	10	TX RRR
	selenium	10	5	TX RRR
	silver		51.1	TX RRR
	zinc	282	42,000	EPA Reg. III

NM OCD - New Mexico Oil Conservation Division, Guidelines for Remediation of Leaks, Spills, and Releases
TX RRR - Texas Risk Reduction Rules Media Specific Concentrations for Standard No. 2 (Industrial)
EPA Reg. III - EPA Region III Risk-Based Concentration Table
EPA Reg. III (TWx100) - EPA Region III Risk-Based Concentration Table (Tap Water Standard x 100)

APPENDIX A

NEW MEXICO
OIL CONSERVATION DIVISION
GUIDELINES FOR REMEDIATION OF LEAKS, SPILLS, AND RELEASES

GUIDELINES

FOR

REMEDIATION

OF

LEAKS, SPILLS AND RELEASES

(AUGUST 13, 1993)

New Mexico Oil Conservation Division
State Land Office Building
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

TABLE OF CONTENTS

INTRODUCTION

The following document is to be used as a guide on all federal, state and fee lands when remediating contaminants resulting from leaks, spills and releases of oilfield wastes or products. The New Mexico Oil Conservation Division (OCD) requires that corrective actions be taken for leaks, spills or releases of any material which has a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property. These guidelines are intended to provide direction for remediation of soils and fresh waters contaminated as a result of leaks, spills or releases of oilfield wastes and products in a manner that assures protection of fresh waters, public health and the environment.

Fresh waters (to be protected) includes the water in lakes, playas, surface waters of all streams regardless of the quality of the water within any given reach, and all underground waters containing 10,000 milligrams per liter (mg/l) or less of total dissolved solids (TDS) except for which, after notice and hearing, it is found that there is no present or reasonably foreseeable beneficial use which would be impaired by contamination of such waters. The water in lakes and playas shall be protected from contamination even though it may contain more than 10,000 mg/l of TDS unless it can be shown that hydrologically connected fresh ground water will not be adversely affected.

Procedures may deviate from the following guidelines if it can be shown that the proposed procedure will either remediate, remove, isolate or control contaminants in such a manner that fresh waters, public health and the environment will not be impacted. Specific constituents and/or requirements for soil and ground water analysis and/or remediation may vary depending on site specific conditions. Deviations from approved plans will require OCD notification and approval.

****** Note:** **Notification to OCD of leaks, spills and releases does not relieve an operator of responsibility for compliance with any other federal, state or local law and/or regulation regarding the incident. Other agencies (ie. BLM, Indian Tribes, etc) may also have guidelines or requirements for remediation of leaks spills and releases.**

I. NOTIFICATION OF LEAK, SPILL OR RELEASE

Leaks, spills and releases of any wastes or products from oilfield operations are required to be reported to the OCD pursuant to OCD Rule 116 (Appendix A) or New Mexico Water Quality Control Commission (WQCC) Regulation 1-203 (Appendix B). Appendix C contains the phone numbers and addresses for reporting incidents to the OCD district and Santa Fe offices. Notification will include all information required under the respective rule or regulation. Below is a description of some of the information required:

A. RESPONSIBLE PARTY AND LOCAL CONTACT

The name, address and telephone number of the person/persons in charge of the facility/operation as well as the owner and/or operator of the facility/operation and a local contact.

B. FACILITY

The name and address of the facility or operation where the incident took place and the legal location listed by quarter-quarter, section, township and range, and by distance and direction from the nearest town or prominent landmark so that the exact site location can be readily located on the ground.

C. TIME OF INCIDENT

The date, time and duration of the incident.

D. DISCHARGE EVENT

A description of the source and cause of the incident.

E. TYPE OF DISCHARGE

A description of the nature or type of discharge. If the material leaked, spilled or released is anything other than crude oil, condensate or produced water include its chemical composition and physical characteristics.

F. QUANTITY

The known or estimated volume of the discharge.

G. SITE CHARACTERISTICS

The relevant general conditions prevailing at the site including precipitation, wind conditions, temperature, soil type, distance to nearest residence and population centers and proximity of fresh water wells or watercourse (ie. any river, lake, stream, playa, arroyo, draw, wash, gully or natural or man-made channel through which water flows or has flowed).

H. IMMEDIATE CORRECTIVE ACTIONS

Any initial response actions taken to mitigate immediate threats to fresh waters, public health and the environment.

II. INITIAL RESPONSE ACTIONS

Upon learning of a leak, spill or release of any material which has a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property, the responsible party (RP) should take the following immediate actions unless the actions could create a safety hazard which would result in a threat to personal or public injury:

A. SOURCE ELIMINATION AND SITE SECURITY

The RP should take the appropriate measures to stop the source of the leak, spill or release and limit access to the site as necessary to reduce the possibility of public exposure.

B. CONTAINMENT

Once the site is secure, the RP should take steps to contain the materials leaked, spilled or released by construction of berms or dikes, the use of absorbent pads or other containment actions to limit the area impacted by the event and prevent potential fresh water contaminants from migrating to watercourses or areas which could pose a threat to public health and safety.

C. SITE STABILIZATION

After containment, the RP should recover any products or wastes which can be physically removed from the surface within the containment area. The disposition of all wastes or products removed from the site must be approved by the OCD.

III. SITE ASSESSMENT

Prior to final closure (Section VIII), soils into which nonrecoverable products or wastes have infiltrated and which have a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property should be assessed for their potential environmental impacts and remediated according to the procedures contained in the following sections. Assessment results form the basis of any required remediation. Sites will be assessed for severity of contamination and potential environmental and public health threats using a risk based ranking system.

The following characteristics should be determined in order to evaluate a sites potential risks, the need for remedial action and, if necessary, the level of cleanup required at the site:

A. GENERAL SITE CHARACTERISTICS

1. Depth To Ground Water

The operator should determine the depth to ground water at each site. The depth to ground water is defined as the vertical distance from the lowermost contaminants to the seasonal high water elevation of the ground water. If the exact depth to ground water is unknown, the ground water depth can be estimated using either local water well information, published regional ground water information, data on file with the New Mexico State Engineer Office or the vertical distance from adjacent ground water or surface water.

2. Wellhead Protection Area

The operator should determine the horizontal distance from all water sources including private and domestic water sources. Water sources are defined as wells, springs or other sources of fresh water extraction. Private and domestic water sources are those water sources used by less than five households for domestic or stock purposes.

3. Distance To Nearest Surface Water Body

The operator should determine the horizontal distance to all downgradient surface water bodies. Surface water bodies are defined as perennial rivers, streams, creeks, irrigation canals and ditches, lakes, ponds and playas.

B. SOIL/WASTE CHARACTERISTICS

Soils/wastes within and beneath the area of the leak, spill or release should be evaluated to determine the type and extent of contamination at the site. In order to assess the level of contamination, observations should be made of the soils at the surface and samples of the impacted soils should be taken in the leak, spill or release area. Observations should note whether previous leaks, spills or releases have occurred at the site. Additional samples may be required to completely define the lateral and vertical extent of contamination. Soil samples should be obtained according to the sampling procedures in Sections V.A. and V.B. This may be accomplished using a backhoe, drill rig, hand auger, shovel or other means.

Initial assessment of soil contaminant levels is not required if an operator proposes to determine the final soil contaminant concentrations after a soil removal or remediation pursuant to section VI.A.

Varying degrees of contamination described below may co-exist at an individual site. The following sections describe the degrees of contamination that should be documented during the assessment of the level of soil contamination:

1. Highly Contaminated/Saturated Soils

Highly contaminated/saturated soils are defined as those soils which contain a free liquid phase or exhibit gross staining.

2. Unsaturated Contaminated Soils

Unsaturated contaminated soils are defined as soils which are not highly contaminated/saturated, as described above, but contain benzene, toluene, ethylbenzene and xylenes (BTEX) and total petroleum hydrocarbons (TPH) or other potential fresh water contaminants unique to the leak, spill or release. Action levels and sampling and analytical methods for determining contaminant concentrations are described in detail in Sections IV. and V.

**** **(NOTE: Soils contaminated as a result of spills, leaks or releases of non-exempt wastes must be evaluated for all RCRA Subtitle C hazardous waste characteristics. The above definitions apply only to oilfield contaminated soils which are exempt from federal RCRA Subtitle C hazardous waste provisions and nonexempt oilfield contaminated soils which are characteristically nonhazardous according to RCRA Subtitle C regulations. Any nonexempt contaminated soils which are determined to be characteristically hazardous cannot be remediated using this guidance document and will be referred to the New Mexico Environment Department Hazardous Waste Program.)**

C. GROUND WATER QUALITY

If ground water is encountered during the soil/waste characterization of the impacted soils, a sample should be obtained to assess the incidents potential impact on ground water quality. Ground water samples should be obtained using the sampling procedures in Section V.C. Monitor wells may be required to assess potential impacts on ground water and the extent of ground water contamination, if there is a reasonable probability of ground water contamination based upon the extent and magnitude of soil contamination defined during remedial activities.

IV. SOIL AND WATER REMEDIATION ACTION LEVELS

A. SOILS

The sections below describe the OCD's recommended remediation action levels for soils contaminated with petroleum hydrocarbons. Soils contaminated with substances other than petroleum hydrocarbons may be required to be remediated based upon the nature of the contaminant and it's potential to impact fresh waters, public health and the environment.

1. Highly Contaminated/Saturated Soils

All highly contaminated/saturated soils should be remediated insitu or excavated to the maximum extent practicable. These soils should be remediated using techniques described in Section VI.A to the contaminant specific level listed in Section IV.A.2.b.

2. Unsaturated Contaminated Soils

The general site characteristics obtained during the si assessment (Section III.A.) will be used to determine the appropriate soil remediation action levels using a risk based approach. Soils which are contaminated by petroleum constituents will be scored according to the ranking criteria below to determine their relative threat to public health, fresh waters and the environment.

a. Ranking Criteria

Depth To Ground Water	Ranking Score
<50 feet	20
50 - 99	10
>100	0

Wellhead Protection Area	
<1000 feet from a water source,or;	
<200 feet from private domestic water source	
Yes	20
No	0

Distance To Surface Water Body	
<200 horizontal feet	20
200 - 1000 horizontal feet	10
>1000 horizontal feet	0

b. Recommended Remediation Action Level

The total ranking score determines the degree of remediation that may be required at any given site. The total ranking score is the sum of all four individual ranking criteria listed in Section IV.A.2.a. The table below lists the remediation action level that may be required for the appropriate total ranking score.

(NOTE: The OCD retains the right to require remediation to more stringent levels than those proposed below if warranted by site specific conditions (ie. native soil type, location relative to population centers and future use of the site or other appropriate site specific conditions.)

	Total Ranking Score		
	≥19	10 - 19	0 - 9
Benzene(ppm)*	10	10	10
BTEX(ppm)*	50	50	50
TPH(ppm)**	100	1000	5000

* A field soil vapor headspace measurement (Section V.B.1) of 100 ppm may be substituted for a laboratory analysis of the Benzene and BTEX concentration limits.

** The contaminant concentration for TPH is the concentration above background levels.

B. GROUND WATER

Contaminated ground water is defined as ground water of a present or foreseeable beneficial use which contains free phase products, dissolved phase volatile organic constituents or other dissolved constituents in excess of the natural background water quality. Ground water contaminated in excess of the WQCC ground water standards or natural background water quality will require remediation.

V. SOIL AND WATER SAMPLING PROCEDURES

Below are the sampling procedures for soil and ground water contaminant investigations of leaks, spills or releases of RCRA Subtitle C exempt oil field petroleum hydrocarbon wastes. Leaks, spills or releases of non-exempt RCRA wastes must be tested to demonstrate that the wastes are not characteristically hazardous according to RCRA regulations. Sampling for additional constituents may be required based upon the nature of the contaminant which was leaked, spilled or released.

A. HIGHLY CONTAMINATED OR SATURATED SOILS

The following method is used to determine if soils are highly contaminated or saturated:

1. Physical Observations

Study a representative sample of the soil for observable free petroleum hydrocarbons or immiscible phases and gross staining. The immiscible phase may range from a free hydrocarbon to a sheen on any associated aqueous phase. A soil exhibiting any of these characteristics is considered highly contaminated or saturated.

B. UNSATURATED CONTAMINATED SOILS

The following methods may be used for determining the magnitude of contamination in unsaturated soils:

1. Soil Sampling Procedures for Headspace Analysis

A headspace analysis may be used to determine the total volatile organic vapor concentrations in soils (ie. in lieu of a laboratory analysis for benzene and BTEX but not in lieu of a TPH analysis). Headspace analysis procedures should be conducted according to OCD approved industry standards or other OCD-approved procedures. Accepted OCD procedures are as follows:

a) Fill a 0.5 liter or larger jar half full of sample and seal the top tightly with aluminum foil or fill a one quart zip-lock bag one-half full of sample and seal the top of the bag leaving the remainder of the bag filled with air.

b) Ensure that the sample temperature is between 15 to 25 degrees Celsius (59-77 degrees Fahrenheit).

c) Allow aromatic hydrocarbon vapors to develop within the headspace of the sample jar or bag for 5 to 10 minutes. During this period, the sample jar should be shaken vigorously for 1 minute or the contents of the bag should be gently massaged to break up soil clods.

d) If using a jar, pierce the aluminum foil seal with the probe of either a PID or FID organic vapor meter (OVM), and then record the highest (peak) measurement. If using a bag, carefully open one end of the bag and insert the probe of the OVM into the bag and re-seal the bag around the probe as much as possible to prevent vapors from escaping. Record the peak measurement. The OVM must be calibrated to assume a benzene response factor.

2. Soil Sampling Procedures For Laboratory Analysis

a. Sampling Procedures

Soil sampling for laboratory analysis should be conducted according to OCD approved industry standards or other OCD-approved procedures. Accepted OCD soil sampling procedures and laboratory analytical methods are as follows:

i) Collect samples in clean, air-tight glass jars supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier.

ii) Label the samples with a unique code for each sample.

iii) Cool and store samples with cold packs or on ice.

iv) Promptly ship sample to the lab for analysis following chain of custody procedures.

v) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

b. Analytical Methods

All soil samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are laboratory analytical methods commonly accepted by OCD for analysis of soil samples analyzed for petroleum related constituents. Additional analyses may be required if the substance leaked, spilled or released has been anything other than petroleum based fluids or wastes.

i) Benzene, toluene, ethylbenzene and xylene

- EPA Method 602/8020

ii) Total Petroleum Hydrocarbons

- EPA Method 418.1, or;
- EPA Method Modified 8015

C. GROUND WATER SAMPLING

If an investigation of ground water quality is deemed necessary, it should be conducted according to OCD approved industry standards or other OCD-approved procedures. The following methods are standard OCD accepted methods which should be used to sample and analyze ground water at RCRA Subtitle C exempt sites (Note: The installation of monitor wells may not be required if the OCD approves of an alternate ground water investigation or sampling technique):

1. **Monitor Well Installation/Location**

   One monitor well should be installed adjacent to and hydrologically down-gradient from the area of the leak, spill or release to determine if protectable fresh water has been impacted by the disposal activities. Additional monitor wells, located up-gradient and down-gradient of the leak, spill or release, may be required to delineate the full extent of ground water contamination if ground water underlying the leak, spill or release has been found to be contaminated.

2. **Monitor Well Construction**

   a) Monitor well construction materials should be:

      i) selected according to industry standards;

      ii) chemically resistant to the contaminants to be monitored; and

      iii) installed without the use of glues/adhesives.

   b) Monitor wells should be constructed according to OCD approved industry standards to prevent migration of contaminants along the well casing. Monitor wells should be constructed with a minimum of fifteen (15) feet of well screen. At least five (5) feet of the well screen should be above the water table to accommodate seasonal fluctuations in the static water table.

3. **Monitor Well Development**

   When ground water is collected for analysis from monitoring wells, the wells should be developed prior to sampling. The objective of monitor well development is to repair damage done to the formation by the drilling operation so that the natural hydraulic properties of the formation are restored and to remove any fluids introduced into the formation that could compromise the integrity of the sample. Monitoring well development is accomplished by purging fluid from the well until the pH and specific conductivity have stabilized and turbidity has been reduced to the greatest extent possible.

4. **Sampling Procedures**

   Ground water should be sampled according to OCD accepted standards or other OCD approved methods. Samples should be collected in clean containers supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier. Samples for different analyses require specific types of containers. The laboratory can provide information on the types of containers and preservatives required for sample collection. The following procedures are accepted by OCD as standard sampling procedures:

a) Monitor wells should be purged of a minimum of three well volumes of ground water using a clean bailer prior to sampling to ensure that the sample represents the quality of the ground water in the formation and not stagnant water in the well bore.

b) Collect samples in appropriate sample containers containing the appropriate preservative for the analysis required. No bubbles or headspace should remain in the sample container.

c) Label the sample containers with a unique code for each sample.

d) Cool and store samples with cold packs or on ice.

e) Promptly ship sample to the lab for analysis following chain of custody procedures.

f) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

5. Ground Water Laboratory Analysis

Samples should be analyzed for potential ground water contaminants contained in the waste stream, as defined by the WQCC Regulations. All ground water samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are OCD accepted laboratory analytical methods for analysis of ground water samples analyzed for petroleum related constituents. Additional analyses may be required if the substance leaked, spilled or release has been anything other than a petroleum based fluid or waste.

a. <u>Analytical Methods</u>

i.) Benzene, Toluene, Ethylbenzene and Xylene

- EPA Method 602/8020

ii.) Major Cations and Anions

- Various EPA or standard methods

iii.) Heavy Metals

- EPA Method 6010, or;
- Various EPA 7000 series methods

iv.) Polynuclear Aromatic Hydrocarbons

- EPA Method 8100

VI. REMEDIATION

The following discussion summarizes recommended techniques for remediation of contaminated soil and ground water as defined in Section IV.A. and IV.B. OCD approval for remediation of an individual leak, spill or release site is not required if the company is operating under an OCD approved spill containment plan. All procedures which deviate from the companies spill containment plan must be approved by OCD.

A. SOIL REMEDIATION

When RCRA Subtitle C exempt or RCRA nonhazardous petroleum contaminated soil requires remediation, it should be remediated and managed according to the criteria described below or by other OCD approved procedures which will remove, treat, or isolate contaminants in order to protect fresh waters, public health and the environment.

In lieu of remediation, OCD may accept an assessment of risk which demonstrates that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh waters, public health and the environment.

1. Contaminated Soils

Highly contaminated/saturated soils and unsaturated contaminated soils exceeding the standards described in Section IV.A. should be either:

a) Excavated from the ground until a representative sample from the walls and bottom of the excavation is below the contaminant specific remediation level listed in Section IV.A.2.b or an alternate approved remediation level, or;

b) Excavated to the maximum depth and horizontal extent practicable. Upon reaching this limit a sample should be taken from the walls and bottom of the excavation to determine the remaining levels of soil contaminants, or;

c) Treated in place, as described in Section VI.A.2.b.ii. - Treatment of Soil in Place, until a representative sample is below the contaminant specific remediation level listed in Section IV.A.2.b, or an alternate approved remediation level, or;

d) Managed according to an approved alternate method.

2. Soil Management Options

All soil management options must be approved by OCD. The following is a list of options for either on-site treatment or off-site treatment and/or disposal of contaminated soils:

a. Disposal

Excavated soils may be disposed of at an off-site OCD approved or permitted facility.

b. Soil Treatment and Remediation Techniques

i. Landfarming

Onetime applications of contaminated soils may be landfarmed on location by spreading the soil in an approximately six inch lift within a bermed area. Only soils which do not contain free liquids can be landfarmed. The soils should be disced regularly to enhance biodegradation of the contaminants. If necessary, upon approval by OCD, moisture and nutrients may be added to the soil to enhance aerobic biodegradation.

In some high risk areas an impermeable liner may be required to prevent leaching of contaminants into the underlying soil.

Landfarming sites that will receive soils from more than one location are considered centralized sites and must be approved separately by the OCD prior to operation.

ii. Insitu Soil Treatment

Insitu treatment may be accomplished using vapor venting, bioremediation or other approved treatment systems.

iii. Alternate Methods

The OCD encourages alternate methods of soil remediation including, but not limited to, active soil aeration, composting, bioremediation, solidification, and thermal treatment.

B. GROUND WATER REMEDIATION

1. Remediation Requirements

Ground water remediation activities will be reviewed and approved by OCD on a case by case basis prior to commencement of remedial activities. When contaminated ground water exceeds WQCC ground water standards, it should be remediated according to the criteria described below.

a. Free Phase Contamination

Free phase floating product should be removed from ground water through the use of skimming devices, total-fluid type pumps, or other OCD-approved methods.

b. Dissolved Phase Contamination

Ground water contaminated with dissolved phase constituents in excess of WQCC ground water standards can be remediated by either removing and treating the ground water, or treating the ground water in place. If treated waters are to be disposed of onto or below the ground surface, a discharge plan must be submitted and approved by OCD.

c. Alternate Methods

The OCD encourages other methods of ground water remediation including, but not limited to, air sparging and bioremediation. Use of alternate methods must be approved by OCD prior to implementation.

VII. TERMINATION OF REMEDIAL ACTION

Remedial action may be terminated when the criteria described below have been met:

A. SOIL

Contaminated soils requiring remediation should be remediated so that residual contaminant concentrations are below the recommended soil remediation action level for a particular site as specified in Section IV.A.2.b.

If soil action levels cannot practicably be attained, an evaluation of risk may be performed and provided to OCD for approval showing that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh water, public health and the environment.

B. GROUND WATER

A ground water remedial action may be terminated if all recoverable free phase product has been removed, and the concentration of the remaining dissolved phase contaminants in the ground water does not exceed New Mexico WQCC water quality standards or background levels. Termination of remedial action will be approved by OCD upon a demonstration of completion of remediation as described in above.

VIII. FINAL CLOSURE

Upon termination of any required remedial actions (Section VII.) the area of a leak, spill or release may be closed by backfilling any excavated areas, contouring to provide drainage away from the site, revegetating the area or other OCD approved methods.

IX. FINAL REPORT

Upon completion of remedial activities a final report summarizing all actions taken to mitigate environmental damage related to the leak, spill or release will be provided to OCD for approval.

APPENDIX A

RULE 116. - NOTIFICATION OF FIRE, BREAKS, LEAKS, SPILLS AND BLOWOUTS

(as of 3-1-91)

A. The Division shall be notified of any fire, break, leak, spill, or blowout occurring at any injection or disposal facility or at any oil or gas drilling, producing, transporting, or processing facility in the State of New Mexico by the person operating or controlling such facility.

B. "Facility," for the purpose of this rule, shall include any oil or gas well, any injection or disposal well, and any drilling or workover well; any pipe line through which crude oil, condensate, casinghead or natural gas, or injection or disposal fluid (gaseous or liquid) is gathered, piped, or transported (including field flow-lines and lead-lines but not including natural gas distribution systems); any receiving tank, holding tank, or storage tank, or receiving and storing receptacle into which crude oil, condensate, injection or disposal fluid, or casinghead or natural gas is produced, received, or stored; any injection or disposal pumping or compression station including related equipment; any processing or refining plant in which crude oil, condensate, or casinghead or natural gas is processed or refined; and any tank or drilling pit or slush pit associated with oil or gas well or injection or disposal well drilling operations or any tank, storage pit, or pond associated with oil or gas production or processing operations or with injection or disposal operations and containing hydrocarbons or hydrocarbon waste or residue, salt water, strong caustics or strong acids, or other deleterious chemicals or harmful contaminants.

C. Notification of such fire, break, leak, spill, or blowout shall be in accordance with the provisions set forth below:

(1) <u>Well Blowouts</u>. Notification of well blowouts and/or fires shall be "immediate notification" described below. ("Well blowout" is defined as being loss of control over and subsequent eruption of any drilling or workover well, or the rupture of the casing, casinghead, or wellhead or any oil or gas well or injection or disposal well, whether active or inactive, accompanied by the sudden emission of fluids, gaseous or liquid, from the well.)

(2) <u>"Major" Breaks, Spills, or Leaks</u>. Notification of breaks, spills, or leaks of 25 or more barrels of crude oil or condensate, or 100 barrels or more of salt water, none of which reaches a watercourse or enters a stream or lake; breaks, spills, or leaks in which one or more barrels of crude oil or condensate or 25 barrels or more of salt water does reach a watercourse or enters a stream or lake; and breaks, spills, or leaks of hydrocarbons or hydrocarbon waste or residue, salt water, strong caustics or strong acids, gases, or other deleterious chemicals or harmful contaminants of any magnitude which may with reasonable probability endanger human health or result in substantial damage to property, shall be "immediate notification" described below.

(3) <u>"Minor" Breaks, Spills, or Leaks</u>. Notification of breaks, spills, or leaks of 5 barrels or more but less than 25 barrels of crude oil or condensate, or 25 barrels or more but less than 100 barrels of salt water, none of which reaches a watercourse or enters a stream or lake, shall be "subsequent notification" described below.

(4) <u>"Gas Leaks and Gas Line Breaks</u>. Notification of gas leaks from any source or of gas pipe line breaks in which natural or casinghead gas of any quantity has escaped or is escaping which may with reasonable probability endanger human health or result in substantial damage to property shall be "immediate notification" described below. Notification of gas pipe line breaks or leaks in which the loss is estimated to be 1000 or more MCF of natural or casinghead gas but in which there is no danger to human health nor of substantial damage to property shall be "subsequent notification" described below.

(5) Tank Fires. Notification of fires in tanks or other receptacles caused by lightning or any other cause, if the loss is, or it appears that the loss will be, 25 or more barrels of crude oil or condensate, or fires which may with reasonable probability endanger human health or result in substantial damage to property, shall be "immediate notification" as described below. If the loss is, or it appears that the loss will be at least 5 barrels but less than 25 barrels, notification shall be "subsequent notification" described below.

(6) Drilling Pits, Slush Pits, and Storage Pits and Ponds. Notification of breaks and spills from any drilling pit, slush pit, or storage pit or pond in which any hydrocarbon or hydrocarbon waste or residue, strong caustic or strong acid, or other deleterious chemical or harmful contaminant endangers human health or does substantial surface damage, or reaches a watercourse or enters a stream or lake in such quantity as may with reasonable probability endanger human health or result in substantial damage to such watercourse, stream, or lake, or the contents thereof, shall be "immediate notification" as described below. Notification of breaks or spills of such magnitude as to not endanger human health, cause substantial surface damage, or result in substantial damage to any watercourse, stream, or lake, or the contents thereof, shall be "subsequent notification" described below, provided however, no notification shall be required where there is no threat of any damage resulting from the break or spill.

(7) IMMEDIATE NOTIFICATION. "Immediate Notification" shall be as soon as possible after discovery and shall be either in person or by telephone to the district office of the Division district in which the incident occurs, or if the incident occurs after normal business hours, to the District Supervisor, the Oil and Gas Inspector, or the Deputy Oil and Gas Inspector. A complete written report ("Subsequent Notification") of the incident shall also be submitted in DUPLICATE to the appropriate district office of the Division within ten days after discovery of the incident.

(8) SUBSEQUENT NOTIFICATION. "Subsequent Notification" shall be a complete written report of the incident and shall be submitted in duplicate to the district office of the Division district in which the incident occurred within ten days after discovery of the incident.

(9) CONTENT OF NOTIFICATION. All reports of fires, breaks, leaks, spills, or blowouts, whether verbal or written, shall identify the location of the incident by quarter-quarter, section, township, and range, and by distance and direction from the nearest town or prominent landmark so that the exact site of the incident can be readily located on the ground. The report shall specify the nature and quantity of the loss and also the general conditions prevailing in the area, including precipitation, temperature, and soil conditions. The report shall also detail the measures that have been taken and are being taken to remedy the situation reported.

(10) WATERCOURSE, for the purpose of this rule, is defined as any lake-bed or gully, draw, stream bed, wash, arroyo, or natural or man-made channel through which water flows or has flowed.

APPENDIX B

1-203. NOTIFICATION OF DISCHARGE--REMOVAL.

A. With respect to any discharge from any facility of oil or other water contaminant, in such quantity as may with reasonable probability injure or be detrimental to human health, animal or plant life, or property, or unreasonably interfere with the public welfare or the use of property, the following notifications and corrective actions are required:

1. As soon as possible after learning of such a discharge, but in no event more than twenty-four (24) hours thereafter, any person in charge of the facility shall orally notify the Chief, Ground Water Bureau, Environmental Improvement Division, or his counterpart in any constituent agency delegated responsibility for enforcement of these rules as to any facility subject to such delegation. To the best of that person's knowledge, the following items of information shall be provided:

a. the name, address, and telephone number of the person or persons in charge of the facility, as well as of the owner and/or operator of the facility;

b. the name and address of the facility;

c. the date, time, location, and duration of the discharge;

d. the source and cause of discharge;

e. a description of the discharge, including its chemical composition;

f. the estimated volume of the discharge; and

g. any actions taken to mitigate immediate damage from the discharge.

2. When in doubt as to which agency to notify, the person in charge of the facility shall notify the Chief, Ground Water Bureau, Environmental Improvement Division. If that division does not have authority pursuant to Commission delegation, the division shall notify the appropriate constituent agency.

3. Within one week after the discharger has learned of the discharge, the facility owner and/or operator shall send written notification to the same division official, verifying the prior oral notification as to each of the foregoing items and providing any appropriate additions or corrections to the information contained in the prior oral notification.

4. The oral and written notification an reporting requirements contained in the three preceding paragraphs and the paragraphs below are not intended to be duplicative of discharge notification and reporting requirements promulgated by the Oil Conservation Commission (OCC) or by the Oil Conservation Division (OCD); therefore, any facility which is subject to OCC or OCD discharge notification and reporting requirements need not additionally comply with the notification/and reporting requirements herein.

5. As soon as possible after learning of such a discharge, the owner/operator of the facility shall take such corrective actions as are necessary or appropriate to contain and remove or mitigate the damage caused by the discharge.

6. If it is possible to do so without unduly delaying needed corrective actions, the facility owner/operator shall endeavor to contact and consult with the Chief, Ground Water Bureau, Environmental Improvement Division or appropriate counterpart in a delegated agency, in an effort to determine the division's views as to what further corrective actions may be necessary or appropriate to the discharge in question. In any event, no later than fifteen (15) days after the discharger learns of the discharge, the facility owner/operator shall send to said Bureau Chief a written report describing any corrective actions taken and/or to be taken relative to the discharge. Upon a written request and for good cause shown, the Bureau Chief may extend the time limit beyond fifteen (15) days.

7. The Bureau Chief shall approve or disapprove in writing the foregoing corrective action report within thirty (30) days of its receipt by the division. In the event that the report is not satisfactory to the division, the Bureau Chief shall specify in writing to the facility owner/operator any shortcomings in the report or in the corrective actions already taken or proposed to be taken relative to the discharge, and shall give the facility owner/operator a reasonable and clearly specified time within which to submit a modified corrective action report. The Bureau Chief shall approve or disapprove in writing the modified corrective action report within fifteen (15) days of its receipt by the division.

8. In the event that the modified corrective action report also is unsatisfactory to the division, the facility owner/operator has five (5) days from the notification by the Bureau Chief that it is unsatisfactory to appeal to the division director. The division director shall approve or disapprove the modified corrective action report within five (5) days of receipt of the appeal from the Bureau Chief's decision. In the absence of either corrective action consistent with the approved corrective action report or with the decision of the director concerning the shortcomings of the modified corrective action report, the division may take whatever enforcement or legal action it deems necessary or appropriate.

APPENDIX C

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT

BRUCE KING
GOVERNOR

ANITA LOCKWOOD
SECRETARY

OIL CONSERVATION COMMISSION

LAND COMMISSIONER
DESIGNEE, MEMBER

STATE PETROLEUM ENGINEER
WILLIAM J. LEMAY, CHAIRMAN

WILLIAM WEISS
MEMBER

OIL CONSERVATION DIVISION

PRINCIPAL OFFICE: STATE LAND OFFICE BUILDING, 310 OLD SANTA FE TRAIL, SANTA FE
MAILING ADDRESS: POST OFFICE BOX 2088 87504
TELEPHONE: (505) 827-5800

WILLIAM J. LEMAY, DIRECTOR

CHIEF ENGINEER
L. O. VAN RYAN

GENERAL COUNSEL
ROBERT G. STOVALL

ENVIRONMENTAL BUREAU
ROGER ANDERSON, CHIEF
WILLIAM OLSON
KATHY BROWN
CHRIS EUSTICE

ENGINEERS
MICHAEL E. STOGNER
DAVID R. CATANACH

GAS MARKETING BUREAU
RONALD H. MERRETT, CHIEF
RAND CARROLL
DAN HALL
J. CHRIS WILLIAMS

RECORDS, PUBLIC INFORMATION
AND ADMINSTRATION BUREAU
PRENTISS CHILDS, CHIEF

GEOLOGIST
ROY E. JOHNSON

BOND ADMINISTRATOR
DIANE RICHARDSON

WELL RECORDS MANAGER
ELIZABETH ROYBAL

HEARING ADMINISTRATOR
FLORENE DAVIDSON

DATA PROCESSING BUREAU
DAVID NELSON, CHIEF

DISTRICT OFFICES

DISTRICT I - HOBBS 88240

1000 W. BROADWAY
P. O. Box 1980
Telephone: (505) 393-6161

J. T. Sexton, Supervisor and Oil & Gas Inspector
P. F. Kautz, Geologist and Deputy Oil & Gas Inspector
Deputy Oil & Gas Inspectors:

J. R. Griffin
L. W. Hill
C. T. Perrin
L. F. Tunnicliff

DISTRICT II - ARTESIA 88210

811 S. FIRST STREET
P. O. Drawer DD
Telephone: (505) 748-1283

M. E. Williams, Supervisor and Oil & Gas Inspector

Deputy Oil & Gas Inspectors:

D. R. Smith
J. D. Robinson
M. C. Stubblefield
Gary Williams

DISTRICT III - AZTEC, 87410

1000 RIO BRAZOS ROAD
Telephone: (505) 334-6178

F. T. Chavez, Supervisor and Oil & Gas Inspector
E. L. Busch, Geologist and Deputy Oil & Gas Inspector

Deputy Oil & Gas Inspectors:
C. C. Gholson
D. G. Foust
D. K. Fairhurst

DISTRICT IV - SANTA FE 87504

STATE LAND OFFICE BUILDING
310 OLD SANTA FE TRAIL, Room 206
P. O. Box 2088
Telephone: (505) 827-5800

R. E. Johnson, Geologist and Oil & Gas Inspector

APPENDIX B

NEW MEXICO
WATER QUALITY CONTROL COMMISSION
GROUND WATER STANDARDS

ATTACHMENT I

NEW MEXICO WATER QUALITY CONTROL COMMISSION
GROUND WATER STANDARDS

A. Human Health Standards - Ground water shall meet the standards of Section A and B unless otherwise provided. If more than one water contaminant affecting human health is present, the toxic pollutant criteria of WQCC Section 1-101.UU. for the combination of contaminants, or the Human Health Standard of WQCC Section 3-103.A. for each contaminant shall apply, whichever is more stringent

Arsenic (As)	0.1 mg/l
Barium (Ba)	1.0 mg/l
Cadmium (Cd)	0.01 mg/l
Chromium (Cr)	0.05 mg/l
Cyanide (CN)	0.2 mg/l
Fluoride (F)	1.6 mg/l
Lead (Pb)	0.05 mg/l
Total Mercury (Hg)	0.002 mg/l
Nitrate (NO_3 as N)	10.0 mg/l
Selenium (Se)	0.05 mg/l
Silver (Ag)	0.05 mg/l
Uranium (U)	5.0 mg/l
Radioactivity: Combined Radium-226 & Radium-228	30.0 pCi/l
Benzene	0.01 mg/l
Polychlorinated biphenyls (PCB's)	0.001 mg/l
Toluene	0.75 mg/l
Carbon Tetrachloride	0.01 mg/l
1,2-Dichloroethane (EDC)	0.01 mg/l
1,1-Dichloroethylene (1, 1-DCE)	0.005 mg/l
1,1,2,2-tetrachloroethylene (PCE)	0.02 mg/l
1,1,2-trichloroethylene (TCE)	0.1 mg/l
ethylbenzene	0.75 mg/l
total xylenes	0.62 mg/l
methylene chloride	0.1 mg/l
chloroform	0.1 mg/l
1,1-dichloroethane	0.025 mg/l
ethylene dibromide (EDB)	0.0001 mg/l
1,1,1-trichloroethane	0.06 mg/l
1,1,2-trichloroethane	0.01 mg/l
1,1,2,2-tetrachloroethane	0.01 mg/l
vinyl chloride	0.001 mg/l
PAH's: total naphthalene plus monomethylnaphthalenes	0.03 mg/l
benzo-a-pyrene	0.0007 mg/l

B. Other Standards for Domestic Water Supply

Chloride (Cl)	250. mg/l
Copper (Cu)	1.0 mg/l
Iron (Fe)	1.0 mg/l
Manganese (Mn)	0.2 mg/l
Phenols	0.005 mg/l
Sulfate (SO_4)	600. mg/l
Total Dissolved Solids (TDS)	1000. mg/l
Zinc (Zn)	10. mg/l
pH	between 6 and 9

C. Standards for Irrigation Use - Ground water shall meet the standards of subsections A, B, and C unless otherwise provided.

Aluminum (Al)	5.0 mg/l
Boron (B)	0.75 mg/l
Cobalt (Co)	0.05 mg/l
Molybdenum (Mo)	1.0 mg/l
Nickel (Ni)	0.2 mg/l

From the New Mexico Water Quality Control Commission Regulations as amended through August 18, 1991, pages 21 to 21.2.

APPENDIX C

EPA REGION III
RISK-BASED CONCENTRATION TABLE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region III
841 Chestnut Street
Philadelphia, Pennsylvania 19107

October 20, 1995

SUBJECT: Risk-Based Concentration Table, July - December 1995

FROM: Roy L. Smith, Ph.D.
Office of RCRA
Technical & Program Support Branch (3HW70)

TO: RBC Table mailing list

Attached is the EPA Region III risk-based concentration (RBC) table, which we distribute semi-annually to all interested parties.

> *IMPORTANT MESSAGE*
>
> *EPA Region III has established a homepage on the World Wide Web which you can find at http://earth1.epa.gov:80/ or http://www.epa.gov/. Our homepage will soon include the RBC table in downloadable form. We strongly encourage all RBC table users having Internet access to obtain the table electronically rather than on paper. In this way, users can obtain the most current issue immediately in a form that can be used directly as input for risk assessment calculations. This distribution method will also save large amounts of paper and cost substantially less.*
>
> *For those lacking Internet access, it's once again time to re-register to receive a paper copy of the RBC table. We need to hear from you periodically to ensure that you still have an interest and that we have your correct address. Please fax your registration request to Vanessa Sizer at 215-597-9890, including your name, address, and phone number. Please don't phone to re-register; we need hard copy to document your continued interest. If we don't hear from you by March 30, 1996, we'll assume you no longer need a paper copy. Thanks for your cooperation.*

CONTENTS, USES, AND LIMITATIONS OF THE RBC TABLE

The table contains reference doses and carcinogenic potency slopes (obtained from IRIS through September 1, 1995, HEAST through May 1995, the EPA-NCEA Superfund Health Risk Technical Support Center, and other EPA sources) for nearly 600 chemicals. These toxicity constants have been combined with "standard" exposure scenarios to calculate RBCs--chemical concentrations corresponding to fixed levels of risk (*i.e.*, a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

The RBC table also includes soil screening levels (SSLs) for protection of groundwater

Exposure variables	**Value**	**Symbol**
Occupational:		
Exposure frequency (d/y):	250	EFo
Exposure duration (y):	25	EDo
Fraction of contaminated soil ingested (unitless)	0.5	FC

*: Contaminant-specific toxicological constants. The priority among sources of toxicological constants was as follows: (1) IRIS, (2) HEAST, (3) HEAST alternative method, (4) EPA-NCEA Superfund Health Risk Technical Support Center, (5) withdrawn from IRIS or HEAST, and (6) other EPA documents. Each source was used only if numbers from higher-priority sources were unavailable. The EPA Superfund Health Risk Technical Support Center, part of the EPA National Center for Environmental Assessment in Cincinnati, develops provisional RfDs and CPSs on request for contaminants not in IRIS or HEAST. These provisional values are labeled "E = EPA-NCEA provisional" in the table. It is possible they may be obsolete. If one of the "E" constants is important to a Superfund risk assessment, consider requesting, through a Regional risk assessor, a new provisional value.

Age-adjusted factors

Because contact rates with tap water, ambient air, and residential soil are different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors. These factors approximated the integrated exposure from birth until age 30 by combining contact rates, body weights, and exposure durations for two age groups - small children and adults. The age-adjusted factor for soil was obtained from RAGS IB; the others were developed by analogy.

Air inhalation

$$IFAadj\ \frac{m^3\cdot y}{kg\cdot d} = \frac{EDc\cdot IRAc}{BWc} + \frac{(EDtot - EDc)\cdot IRAa}{BWa}$$

Tap water ingestion

$$IFWadj\ \frac{L\cdot y}{kg\cdot d} = \frac{EDc\cdot IRWc}{BWc} + \frac{(EDtot - EDc)\cdot IRWa}{BWa}$$

Soil ingestion

$$IFSadj\ \frac{mg\cdot y}{kg\cdot d} = \frac{EDc\cdot IRSc}{BWc} + \frac{(EDtot - EDc)\cdot IRSa}{BWa}$$

Residential water

Volatilization terms were calculated only for compounds with a mark in the "VOC" column. Compounds having a Henry's Law constant greater than 10^{-5} were considered volatile. The list may be incomplete, but is unlikely to include false positives. The equations and the volatilization factor (K, above) were obtained from RAGS IB. Oral potency slopes and reference doses were used for both oral and inhaled exposures for volatile compounds lacking inhalation values. Inhaled potency slopes were substituted for unavailable oral potency slopes only for volatile compounds; inhaled RfDs were substituted for unavailable oral RfDs for both volatile and non-volatile compounds. RBCs for carcinogens were based on combined childhood and adult exposure; for non-carcinogens RBCs were based on adult exposure.

Carcinogens

$$RBC\ \tfrac{\mu g}{L} = \frac{TR \cdot ATc \cdot 1000\ \tfrac{\mu g}{mg}}{EFr \cdot ([K \cdot IFAadj \cdot CPSi] + [IFWadj \cdot CPSo])}$$

Non-carcinogens

$$RBC\ \tfrac{\mu g}{L} = \frac{THQ \cdot BWa \cdot ATn \cdot 1000\ \tfrac{\mu g}{mg}}{EFr \cdot EDtot \cdot \left(\frac{K \cdot IRAa}{RfDi} + \frac{IRWa}{RfDo}\right)}$$

Ambient air

Oral potency slopes and references were used where inhalation values were not available. RBCs for carcinogens were based on combined childhood and adult exposure; for non-carcinogens RBCs were based on adult exposure.

Carcinogens

$$RBC\ \tfrac{\mu g}{m^3} = \frac{TR \cdot ATc \cdot 1000\ \tfrac{\mu g}{mg}}{EFr \cdot IFAadj \cdot CPSi}$$

Non-carcinogens

$$RBC\ \tfrac{\mu g}{m^3} = \frac{THQ \cdot RfDi \cdot BWa \cdot ATn \cdot 1000\ \tfrac{\mu g}{mg}}{EFr \cdot EDtot \cdot IRAa}$$

Edible fish

All RBCs were based on adult exposure.

Carcinogens

$$RBC\ \tfrac{mg}{kg} = \frac{TR \cdot BWa \cdot ATc}{EFr \cdot EDtot \cdot \frac{IRF}{1000\ \tfrac{g}{kg}} \cdot CPSo}$$

Non-carcinogens

$$RBC\ \tfrac{mg}{kg} = \frac{THQ \cdot RfDo \cdot BWa \cdot ATn}{EFr \cdot EDtot \cdot \frac{IRF}{1000\ \tfrac{g}{kg}}}$$

ANSWERS TO FREQUENTLY ASKED QUESTIONS

To help you better understand the RBC table, here are answers to our most often-asked questions:

1. How can the age-adjusted inhalation factor (11.66) be less than either the inhalation rate for a child (12) or for an adult (20)?

Age-adjusted factors are not intake rates, but rather partial calculations which have different units than intake rates do. The fact that these partial calculations have values similar to intake rates is really coincidental, an artifact of the similar magnitude of years of exposure and time-averaged body weight.

2. Why does arsenic appear in the RBC table separately as a carcinogen and a non-carcinogen, while other contaminants do not?

Arsenic is double-entered to ensure that the risk assessor realizes that non-carcinogenic concerns are significant for arsenic. Otherwise, one might be tempted to accept a 1e-4 risk (37 ppm in residential soil), when the oral reference dose would be exceeded at 23 ppm.

Also, EPA has a little-known risk management policy for arsenic (dating from 1988) that suggests that arsenic-related cancer risks of up to 1e-3 can be accepted because the cancers are squamous cell carcinomas with a low mortality rate. Thus, noncarcinogenic RBCs represent an important limitation on acceptable arsenic concentrations.

3. Many contaminants have no inhaled reference dose or carcinogenic potency slope in IRIS, yet these numbers appear in the RBC table with IRIS given as the source. Where did the numbers come from?

Most inhaled reference doses and potency slopes in the RBC table are converted from reference concentrations and unit risk values which do appear in IRIS. These conversions assume 70-kg persons inhaling 20 m^3/d. For example, the inhalation unit risk for arsenic (4.3e-3 risk per $\mu g/m^3$) is divided by 20 m^3/d and multiplied by 70 kg times 1000 μg/mg, yielding a CPSi of 15.1 risk per mg/kg/d.

4. Why does the RBC table base soil RBCs for cadmium and manganese on reference doses that apply only to drinking water?

The RBC table's use of the drinking water RfDs for cadmium and manganese reflects (1) the limited space available in the already-crowded table, and (2) the intended use of the table as a screening tool rather than a source of cleanup levels (thereby making false positives acceptable). For a formal risk assessment, Region III would use the food RfDs for soil ingestion.

At this time, only two substances (as far as we know) have distinct oral RfDs for water and food--cadmium and manganese. Adding the two food RfDs to the table would require an entire column, which would be about 99.9% blank. The table has become so crowded that it would be difficult to accommodate another column. Also, we ve given this problem a relatively low priority because the table's primary purpose is to identify environmental problems needing further study. RBCs were never intended for uncritical use as cleanup levels, merely to identify potential problems which need a closer look.

5. What is the source of the child inhalation rate of 12 m3/d?

The calculation comes from basic physiology. It's a scaling of the mass-specific 20 m3/d rate for adults from a body mass of 70 kg to 15 kg, using the 2/3 power of mass, as follows:

Let: IRcm = mass-specific child inhalation rate (m3/kg/d)
IRc = child inhalation rate (m3/d)

$20\ \text{m3/d} \div 70\text{kg} = 0.286\ \text{m3/kg/d}$ (mass-specific adult inhalation rate)

$0.286\ \text{m3/kg/d} \times (70^{.67}) = (\text{IRcm}) \times (15^{.67})$

$\text{IRcm} = (0.286) \times (70^{.67}) \div (15^{.67}) = 0.286 \times 2.807 = 0.803\ \text{m3/kg/d}$

$\text{IRc} = \text{IRcm} \times 15\text{kg} = 0.803\ \text{m3/kg/d} \times 15\text{kg} = 12.04\ \text{m3/d}$

A short (but algebraically equivalent) way to do the conversion:

$20 \times (15 \div 70)^{.333} = 11.97$ (different from, but actually more correct than, 12.04 because of rounding error in the long form).

6. Can the oral RfDs in the RBC table be applied to dermal exposure?

Not directly. EPA's Office of Research and Development is working on dermal RfDs for some substances, but has not yet produced any final values. When dermal RfDs do appear, they will undoubtedly be based on absorbed dose rather than administered dose. Oral RfDs are (usually) based on administered dose and therefore tacitly include a GI absorption factor. Thus, any use of oral RfDs in dermal risk calculations would have to involve removing this absorption factor.

*7. The exposure variables table in the RBC background document lists the averaging time for non-carcinogens as "ED*365". What does that mean?*

ED is exposure duration, in years. Multiplying ED by 365 simply converts the duration to days. In fact, the ED term is included in both the numerator and denominator of the RBC algorithms for non-cancer risk, canceling it altogether. We expressed the algorithm this way to allow users to realize this. The total exposure is really corrected only by EF (days exposed per year) divided by 365. (Note that this explanation applies to noncarcinogenic risk only; for carcinogens, exposure is pro-rated over the number of days in a 70-year life span.)

8. Why is inorganic lead not included in the RBC table?

The reason lead is missing from the RBC table is simple, and fundamental: EPA has no

Commercial/industrial soil ingestion

RBCs were based on adult occupational exposure, including an assumption that only 50% of total soil ingestion is work-related.

Carcinogens

$$RBC\ \frac{mg}{kg} = \frac{TR\ BWa\ ATc}{EFo \cdot EDo \cdot \frac{IRSa}{10^{6}\ \frac{mg}{kg}} \cdot FC \cdot CPSo}$$

Non-carcinogens

$$RBC\ \frac{mg}{kg} = \frac{THQ \cdot RfDo \cdot BWa \cdot ATn}{EFo \cdot EDo \cdot \frac{IRSa}{10^{6}\ \frac{mg}{kg}} \cdot FC}$$

Residential soil ingestion

RBCs for carcinogens were based on combined childhood and adult exposure; RBCs for non-carcinogens were based on childhood exposure only.

Carcinogens

$$RBC\ \frac{mg}{kg} = \frac{TR \cdot ATc}{EFr \cdot \frac{IFSadj}{10^{6}\ \frac{mg}{kg}} \cdot CPSo}$$

Non-carcinogens

$$RBC\ \frac{mg}{kg} = \frac{THQ \cdot RfDo \cdot BWc \cdot ATn}{EFr \cdot EDc \cdot \frac{IRSc}{10^{6}\ \frac{mg}{kg}}}$$

Development of Soil Screening Levels

General

In December 1994 the EPA Office of Solid Waste and Emergency Response proposed Soil Screening Guidance (Document 9355.4-1, PB95-963530, EPA540/R-94/101, available through NTIS at 703-487-4650). This draft document provides (1) a framework in which soil screening levels are to be used, (2) a detailed methodology for calculating soil screening levels, and (3) soil screening levels for 107 substances.

Consistent with this new guidance, the risk-based concentration table now includes two columns of generic soil screening levels (SSLs). OSWER's 107 proposed soil screening levels have been added verbatim. In addition, the proposed SSL methodology has been used to calculate soil screening levels for more substances, which are also included in the new table. The table clearly distinguishes the OSWER SSLs from the "unofficial" ones.

These SSLs provide reasonable maximum estimates of transfers of contaminants from soil to other media. One column contains soil concentrations protective of groundwater quality; the other contains soil concentrations protective of air quality. "Protective" is defined in the same terms as the risk-based concentrations for tap water and air -- that residential contact scenarios will yield a fixed upper bound risk of 10^{-6} or a fixed hazard quotient of 1 (whichever occurs at the lower concentration).

OSWER's SSLs should be used only within the framework proposed in the guidance document. The additional SSLs included in the RBC table are intended for the same uses (although they obviously carry less weight than the formally proposed numbers).

The SSLs are based on the following assumptions:

Input variables	**Value**	**Symbol***
Surface soil moisture content (g/g)	0.1	W_s
Vadose zone soil moisture content (kg/kg)	0.2	W_v
Surface soil bulk density (g/cm^3)	1.5	ρ_{bs}
Vadose zone soil bulk density (kg/L)	1.5	ρ_{bv}
Surface soil particle density (g/cm^3)	2.65	ρ_{ss}
Vadose zone soil particle density (g/cm^3)	2.65	ρ_{sv}
Total surface soil porosity (L pore /L soil)	0.43	N_s
Total vadose zone soil porosity (L pore/L soil)	0.43	N_v
Air-filled surface soil porosity (L air/L soil)	0.28	θ_{as}
Water-filled surface soil porosity (L water/L soil)	0.15	θ_{ws}
Air-filled vadose zone soil porosity (L air/L soil)	0.13	θ_{av}
Water-filled vadose zone soil porosity (L water/L soil)	0.30	θ_{wv}
Organic carbon fraction of surface soil (g/g)	0.006	FOC_s
Organic carbon fraction of vadose zone soil (g/g)	0.002	FOC_v
Dispersion factor for 0.5 acres (g/m^{2}s per kg/m^3)	35.1	Q/C
Particulate emission factor (m^3/kg)	6.79e+08	PEF
Exposure interval (s)	9.50e+08	T
Dilution-attenuation factor (unitless)	10	DAF

*: Symbols were adjusted, variables were rearranged, and derived and chemical-specific variables were omitted for simplicity and clarity. Presentation of the input variables in a single table using the same terms as in the OSWER SSL document would have been confusing. The terms used here are generally similar to OSWER's, and can easily be compared with the SSL guidance document.

With two exceptions described in the following section, SSL calculations were based on the same algorithms presented in the OSWER draft SSL guidance document. For details of the calculations (and for general background information on SSLs), I strongly recommend reference dose or potency slope for inorganic lead, so it wasn't possible to calculate risk-based concentrations. EPA considers lead a special case because:

(1) Lead is ubiquitous in all media, so human exposure comes from multiple sources. Comparing single-medium exposures with a reference dose would be misleading.

(2) If EPA did develop a reference dose for lead by the same methods other reference doses, we would probably find that most people already exceed it. Since EPA already knows this and is moving aggressively to lower lead releases nationally, such findings at individual sites would be irrelevant and unduly alarming.

(3) EPA decided to take a new approach to separate important lead exposures from trivial ones. EPA developed a computer model (the IEUBK model) which predicts children's blood lead concentrations using lead levels in various media as inputs. The idea is to evaluate a child's entire environment, and reduce lead exposures in the most cost-effective way.

On the practical side, there are several EPA policies which effectively substitute for RBCs. The EPA Office of Solid Waste has released a detailed directive on risk assessment and cleanup of residential soil lead. The directive recommends that soil lead levels less than 400 ppm be considered safe for residential use. Above that level, the document suggests collecting certain types of data and modeling children's blood lead with the IEUBK model. For the purposes of the RBC table, the de facto residential soil number would be 400 mg/kg. For water, we suggest 15 ppb (from the national EPA Action Level), and for air, the National Ambient Air Quality Standard.

9. Where did the potency slopes for carcinogenic PAHs come from?

The source of the potency slopes for PAHs is "Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons", Final Draft, EPA Environmental Criteria and Assessment Office, Cincinnati, OH. It's available from NTIS as document number ECAO-CIN-842 (March, 1993). The slopes are expressed in terms of order-of-magnitude equivalence factors relating the compounds to benzo[a]pyrene; we have converted these TEQs to potency slopes to fit the format of the table.

10. May I please have a copy of the January 1991 RBC table?

We're sorry, but no. The RBC table doesn't represent regulation or guidance, so past issues should have no legal importance. Each time we update the table we destroy all obsolete copies, electronic and paper. We do this to ensure that only one set of RBCs, that based on current information, exists at any time.

11. I've noticed that some soil RBCs are 1 million parts per million. Since some of these substances are liquids, that's obviously ridiculous. What is that basis for these calculations?

A soil RBC of 1 million parts per million means that no amount of the contaminant in soil will cause a receptor to exceed the oral reference dose by incidental ingestion of soil. In fact, some contaminants would have RBCs of more than 1 million ppm, but the algorithms cap concentrations at 100%. The reason we retain these admittedly impossible numbers is to let users see that the contaminant is not a threat via soil ingestion.

However, it's important to realize that the RBC calculations do not consider the potential of soil contaminants to leach to groundwater or escape to air by volatilization or dust entrainment. To consider these inter-media transfers, it's necessary to either monitor air and groundwater, or to use a model. Measured or modeled air and groundwater concentrations should then be compared to the RBCs for air and tap water.

We have begun to incorporate inter-media transfers into the RBC table in the form of soil screening levels (SSLs). However, EPA Headquarters has proposed only about a hundred SSLs so far, so the list is still rather short.

12. Please elaborate on the meaning of the 'W' source code in the table.

The "W" code means that a reference dose or potency slope for a contaminant is currently not present on either IRIS or HEAST, but that it once was present on either IRIS or HEAST and was removed. Such withdrawal usually indicates that consensus on the number no longer exists among EPA scientists, but not that EPA believes the contaminant to be unimportant. Older versions of the RBC table had separate codes for IRIS and HEAST withdrawals, but we changed to a single code for both because, after all, it hardly matters.

We retain withdrawn numbers in the table because we still need to deal with these contaminants during the sometimes very long delays before replacement numbers are ready. We take the position that for the purpose of screening an obsolete RBC is better than none at all. The 'W' code should serve as a clear warning that before making any serious decision involving that contaminant you will need to develop an interim value based on current scientific understanding.

If you are assessing risks at a site where a major contaminant is coded "W", consider working with your Regional EPA risk assessor to develop a current toxicity constant. If the site is being studied under CERCLA, the EPA-NCEA Regional Technical Support group may be able to assist.

13. Can I get copies of supporting documents for interim toxicity constants which are coded "E" in the RBC table?

Unfortunately, Region 3 does not have a complete set of supporting documents. The EPA-NCEA Superfund Health Risk Technical Support Center prepares these interim toxicity constants in response to site-specific requests from Regional risk assessors, and sends the documentation only to the requestor. The RBC tables contain only the interim values (those with "E" codes) that we've either requested ourselves or otherwise obtained copies of. There may be many more interim values of which we are unaware. Also, we don't receive automatic updates when NCEA revisits a contaminant, so it's likely that some interim values in the RBC table are obsolete.

consulting that document. The "unofficial" SSLs were developed under the following conditions:

Soil Screening Levels for Inhalation

Inhaled reference doses and potency slopes were used if available. If inhalation values were not available, oral RfDs and potency slopes were substituted. SSLs were calculated only for substances for which aqueous solubility, Koc, Henry's Law constant, and diffusivity in air were available. SSLs were calculated only for substances for which a volatilization factor could be calculated. This was done because OSWER's large proposed particulate emission factor rendered it pointless to estimate SSLs for particulate emissions alone. The final calculated SSL shown in the RBC table is the smaller of the risk-based SSL and the soil saturation concentration. All calculated SSLs were rounded to 2 significant figures.

The OSWER risk algorithms for inhalation were revised in order to be consistent with the rest of the RBC table. Only calculated SSLs were affected by this; SSLs proposed by OSWER are presented verbatim. Calculated SSLs for inhalation of carcinogens were based on an integrated lifetime exposure rather than adult exposure. SSLs for inhalation of noncarcinogens were based on adult exposure for 350 days per year rather than 365 days per year. The following algorithms were used to calculate inhalation SSLs:

Carcinogens

$$SSL\ \frac{mg}{kg} = \frac{TR \cdot ATc}{EFr \cdot IFAadj \cdot \left(\frac{1}{VF} + \frac{1}{PEF}\right) \cdot CPSi}$$

Non-carcinogens

$$SSL\ \frac{mg}{kg} = \frac{THQ \cdot BWa \cdot ATn \cdot RfDi}{EFr \cdot EDtot \cdot IRAa \cdot \left(\frac{1}{VF} + \frac{1}{PEF}\right)}$$

Soil Screening Levels for Groundwater Use

All algorithms were as proposed by OSWER. MCLs were used as target groundwater concentrations if available. If MCLs were unavailable the risk-based concentration in the "tap water" column of the RBC table was used as the target groundwater concentration. All SSLs for groundwater are based on a dilution-attenuation factor (DAF) of 10. Since these SSLs scale linearly with DAF, the SSLs for DAF=1 would be ten times lower. They were omitted to conserve space. All groundwater SSLs were rounded to 2 significant figures and capped at unity.

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	VOC	Tap Water	Ambient Air	Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Acephate	30560191	4.00E-03 I		8.70E-03 I			7.7 C	0.72 C	0.36 C	660 C	73 C		
Acetaldehyde	75070		2.57E-03 I		7.70E-03 I		94 N	0.81 C					
Acetochlor	34256821	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Acetone	67641	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N	62000 E	8 E
Acetone cyanohydrin	75865	7.00E-02 H	4.00E-02 A				2600 N	150 N	95 N	140000 N	5500 N		
Acetonitrile	75078	6.00E-03 I	1.43E-02 A				220 N	52 N	8.1 N	12000 N	470 N		
Acetophenone	98862	1.00E-01 I	5.71E-06 W			☒	0.042 N	0.021 N	140 N	200000 N	7800 N		
Acifluorfen	62476599	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Acrolein	107028	2.00E-02 H	5.71E-06 I				730 N	0.021 N	27 N	41000 N	1600 N		
Acrylamide	79061	2.00E-04 I		4.50E+00 I	4.55E+00 I		0.015 C	0.0014 C	0.0007 C	1.3 C	0.14 C		
Acrylic acid	79107	5.00E-01 I	2.86E-04 I				18000 N	1 N	680 N	1E+06 N	39000 N		
Acrylonitrile	107131	1.00E-03 H	5.71E-04 I	5.40E-01 I	2.38E-01 I		0.12 C	0.026 C	0.0058 C	11 C	1.2 C		
Alachlor	15972608	1.00E-02 I		8.00E-02 H			0.84 C	0.078 C	0.039 C	72 C	8 C		
Alar	1596845	1.50E-01 I					5500 N	550 N	200 N	310000 N	12000 N		
Aldicarb	116063	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N	570 S	0.036 M
Aldicarb sulfone	1646884	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Aldrin	309002	3.00E-05 I		1.70E+01 I	1.71E+01 I		0.004 C	0.00037 C	0.00019 C	0.34 C	0.038 C	0.5 E	0.005 E
Ally	74223646	2.50E-01 I					9100 N	910 N	340 N	510000 N	20000 N		
Allyl alcohol	107186	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Allyl chloride	107051	5.00E-02 W	2.86E-04 I				1800 N	1 N	68 N	100000 N	3900 N		
Aluminum	7429905	1.00E+00 E					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Aluminum phosphide	20859738	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Amdro	67485294	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Ametryn	834128	9.00E-03 I					330 N	33 N	12 N	18000 N	700 N		
m-Aminophenol	591275	7.00E-02 H					2600 N	260 N	95 N	140000 N	5500 N		
4-Aminopyridine	504245	2.00E-05 H					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Amitraz	33089611	2.50E-03 I					91 N	9.1 N	3.4 N	5100 N	200 N		
Ammonia	7664417		2.86E-02 I				1000 N	100 N					
Ammonium sulfamate	7773060	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		
Aniline	62533		2.86E-04 I	5.70E-03 I			10 N	1 N	0.55 C	1000 C	110 C	45 N	0.031 N
Antimony and compounds	7440360	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Antimony pentoxide	1314609	5.00E-04 H					18 N	1.8 N	0.68 N	1000 N	39 N		
Antimony potassium tartrate	304610	9.00E-04 H					33 N	3.3 N	1.2 N	1800 N	70 N		
Antimony tetroxide	1332316	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
Antimony trioxide	1309644	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
Apollo	74115245	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Aramite	140578	5.00E-02 H		2.50E-02 I	2.49E-02 I		2.7 C	0.25 C	0.13 C	230 C	26 C		
Arsenic	7440382	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N	380 E	15 E
**Arsenic (as carcinogen)	7440382			1.50E+00 I	1.51E+01 I		0.045 C	0.00041 C	0.0021 C	3.8 C	0.43 C	380 E	15 E

It has been NCEA's policy to deny requests for documentation of interim toxicity constants. Although Region 3 has sometimes provided this documentation on request, for the above-stated reasons we have no assurance that the documentation, or even the interim numbers, are current. We've decided to discontinue distributing information that may be misleading. If one of the "E"-coded contaminants is a major risk contributor at your site, we strongly suggest that you work with EPA to develop an up-to-date reference dose or slope factor.

CHANGES IN THIS ISSUE OF THE RBC TABLE

New or revised EPA toxicity constants are now marked with "**" before the contaminant name. This is to help users quickly pick out substances with new RBCs. Formerly these contaminants were printed in underlined boldface type that copied badly. A new basis code, "M" for MCL, has been added to the upper right corner of each page. This code denotes soil screening levels for groundwater protection that are based on EPA Maximum Contaminant Levels.

If you want to raise issues or get answers to questions about the RBC table, please call the Technical Support Help Line at 215-597-1116. The line has a voice mail system to take your calls if we're not available. We'll return your call as soon as we can. Please limit calls to RBC issues; if you have a question about applying RBCs to a site, please call the EPA Regional office handling the project. Thanks for your help and cooperation, and we hope the RBC table continues to be a useful resource.

Attachment

EPA Region III Risk-Based Concentration Table

Background Information

Roy L. Smith, Ph.D.
Toxicologist
October 4, 1995

Development of Risk-Based Concentrations

General

Separate carcinogenic and non-carcinogenic risk-based concentrations were calculated for each compound for each pathway. The concentration in the table is the lower of the two, rounded to two significant figures. The following terms and values were used in the calculations:

Exposure variables	Value	Symbol
General:		
Carcinogenic potency slope oral (risk per mg/kg/d):	*	CPSo
Carcinogenic potency slope inhaled (risk per mg/kg/d):	*	CPSi
Reference dose oral (mg/kg/d):	*	RfDo
Reference dose inhaled (mg/kg/d):	*	RfDi
Target cancer risk:	1e-06	TR
Target hazard quotient:	1	THQ
Body weight, adult (kg):	70	BWa
Body weight, age 1-6 (kg):	15	BWc
Averaging time carcinogens (d):	25550	ATc
Averaging time non-carcinogens (d):	ED*365	ATn
Inhalation, adult (m3/d):	20	IRAa
Inhalation, child (m3/d):	12	IRAc
Inhalation factor, age-adjusted (m3-y/kg-d):	11.66	IFAadj
Tap water ingestion, adult (L/d):	2	IRWa
Tap water ingestion, age 1-6 (L/d):	1	IRWc
Tap water ingestion factor, age-adjusted (L-y/kg-d):	1.09	IFWadj
Fish ingestion (g/d):	54	IRF
Soil ingestion, adult (mg/d):	100	IRSa
Soil ingestion, age 1-6 (mg/d):	200	IRSc
Soil ingestion factor, age adjusted (mg-y/kg-d):	114.29	IFSadj
Residential:		
Exposure frequency (d/y):	350	EFr
Exposure duration, total (y):	30	EDtot
Exposure duration, age 1-6 (y):	6	EDc
Volatilization factor (L/m3):	0.5	K

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water	Ambient Air		Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	VOC			Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Arsine	7784421		1.43E-05 I				0.52 N	0.052 N					
Assure	76578148	9.00E-03 I					330 N	33 N	12 N	18000 N	700 N		
Asulam	3337711	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Atrazine	1912249	3.50E-02 I		2.22E-01 H			0.3 C	0.028 C	0.014 C	26 C	2.9 C		
Avermectin B1	65195553	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Azobenzene	103333			1.10E-01 I	1.08E-01 I		0.61 C	0.058 C	0.029 C	52 C	5.8 C		
Barium and compounds	7440393	7.00E-02 I	1.43E-04 A				2600 N	0.52 N	95 N	140000 N	5500 N	350000 E	32 E
Baygon	114261	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Bayleton	43121433	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
Baythroid	68359375	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Benefin	1861401	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N		
Benomyl	17804352	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Bentazon	25057890	2.50E-03 I					.91 N	9.1 N	3.4 N	5100 N	200 N		
Benzaldehyde	100527	1.00E-01 I				☒	610 N	370 N	140 N	200000 N	7800 N		
Benzene	71432		1.71E-03 E	2.90E-02 I	2.90E-02 I	☒	0.36 C	0.22 C	0.11 C	200 C	22 C	0.5 E	0.02 E
Benzenethiol	108985	1.00E-05 H					0.37 N	0.037 N	0.014 N	20 N	0.78 N		
Benzidine	92875	3.00E-03 I		2.30E+02 I	2.35E+02 I		0.00029 C	0.00003 C	0.00001 C	0.025 C	0.0028 C	1.3 C	1.100E-06 C
Benzoic acid	65850	4.00E+00 I					150000 N	15000 N	5400 N	1E+06 N	310000 N	320 S	280 E
Benzotrichloride	98077			1.30E+01 I			0.0052 C	0.00048 C	0.00024 C	0.44 C	0.049 C	0.012 C	0.000073 C
Benzyl alcohol	100516	3.00E-01 H					11000 N	1100 N	410 N	610000 N	23000 N		
Benzyl chloride	100447			1.70E-01 I		☒	0.062 C	0.037 C	0.019 C	34 C	3.8 C	0.5 C	0.00036 C
Beryllium and compounds	7440417	5.00E-03 I		4.30E+00 I	8.40E+00 I		0.016 C	0.00075 C	0.00073 C	1.3 C	0.15 C	690 E	180 E
Bidrin	141662	1.00E-04 I					3.7 N	0.37 N	0.14 N	200 N	7.8 N		
Biphenthrin (Talstar)	82657043	1.50E-02 I					550 N	55 N	20 N	31000 N	1200 N		
1,1-Biphenyl	92524	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N	9000 S	110 N
Bis(2-chloroethyl)ether	111444			1.10E+00 I	1.16E+00 I	☒	0.0092 C	0.0054 C	0.0029 C	5.2 C	0.58 C	0.3 E	0.0003 E
Bis(2-chloroisopropyl)ether	39638329	4.00E-02 I		7.00E-02 H	3.50E-02 H	☒	0.26 C	0.18 C	0.045 C	82 C	9.1 C		
Bis(chloromethyl)ether	542881			2.20E+02 I	2.17E+02 I	☒	0.00005 C	0.00003 C	0.00001 C	0.026 C	0.0029 C	0.00004 C	1.000E-07 C
Bis(2-chloro-1-methylethyl)ether				7.00E-02 W	7.00E-02 W		0.96 C	0.089 C	0.045 C	82 C	9.1 C		
Bis(2-ethylhexyl)phthalate (DEHP)	117817	2.00E-02 I		1.40E-02 I			4.8 C	0.45 C	0.23 C	410 C	46 C	210 E	11 E
Bisphenol A	80057	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Boron (and borates)	7440428	9.00E-02 I	5.71E-03 H				3300 N	21 N	120 N	180000 N	7000 N		
Boron trifluoride	7637072		2.00E-04 H				7.3 N	0.73 N					
Bromodichloromethane	75274	2.00E-02 I		6.20E-02 I		☒	0.17 C	0.1 C	0.051 C	92 C	10 C	1800 E	0.3 E
Bromoethene	593602				1.10E-01 H	☒	0.096 C	0.057 C					
Bromoform (tribromomethane)	75252	2.00E-02 I		7.90E-03 I	3.85E-03 I	☒	2.4 C	1.6 C	0.4 C	720 C	81 C	46 E	0.5 E
Bromomethane	74839	1.40E-03 I	1.43E-03 I			☒	8.7 N	5.2 N	1.9 N	2900 N	110 N	2 E	0.1 E
4-Bromophenyl phenyl ether	101553	5.80E-02 O					2100 N	210 N	78 N	120000 N	4500 N		
Bromophos	2104963	5.00E-03 H					180 N	18 N	6.8 N	10000 N	390 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Bromoxynil	1689845	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Bromoxynil octanoate	1689992	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
1,3-Butadiene	106990				9.80E-01 I	☒	0.011 C	0.0064 C				0.0013 C	0.000072 C
1-Butanol	71363	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N	9700 E	8 E
Butyl benzyl phthalate	85687	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N	530 E	68 E
Butylate	2008415	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
sec-Butylbenzene	135988	1.00E-02 E				☒	61 N	37 N	14 N	20000 N	780 N	80 S	0.27 M
tert-Butylbenzene	104518	1.00E-02 E				☒	61 N	37 N	14 N	20000 N	780 N		0.27 M
Butylphthalyl butylglycolate	85701	1.00E+00 I					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Cacodylic acid	75605	3.00E-03 H					110 N	11 N	4.1 N	6100 N	230 N		
**Cadmium and compounds	7440439	5.00E-04 I	5.71E-05 E		6.30E+00 I		18 N	0.00099 C	0.68 N	1000 N	39 N	920 E	6 E
Caprolactam	105602	5.00E-01 I					18000 N	1800 N	680 N	1E+06 N	39000 N		
Captafol	2425061	2.00E-03 I		8.60E-03 H			7.8 C	0.73 C	0.37 C	670 C	74 C		
Captan	133062	1.30E-01 I		3.50E-03 H			19 C	1.8 C	0.9 C	1600 C	180 C		
Carbaryl	63252	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N	0.34 S	23 N
Carbofuran	1563662	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
**Carbon disulfide	75150	1.00E-01 I	2.00E-01 I			☒	1000 N	730 N	140 N	200000 N	7800 N	11 E	14 E
Carbon tetrachloride	56235	7.00E-04 I	5.71E-04 E	1.30E-01 I	5.25E-02 I	☒	0.16 C	0.12 C	0.024 C	44 C	4.9 C	0.2 E	0.03 E
Carbosulfan	55285148	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Carboxin	5234684	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Chloral	75876	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Chloramben	133904	1.50E-02 I					550 N	55 N	20 N	31000 N	1200 N		
Chloranil	118752			4.03E-01 H			0.17 C	0.016 C	0.0078 C	14 C	1.6 C		
Chlordane	57749	6.00E-05 I		1.30E+00 I	1.29E+00 I		0.052 C	0.0049 C	0.0024 C	4.4 C	0.49 C	10 E	2 E
Chlorimuron-ethyl	90982324	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Chlorine	7782505	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Chlorine dioxide	10049044		5.71E-05 I				2.1 N	0.21 N					
Chloroacetaldehyde	107200	6.90E-03 O					250 N	25 N	9.3 N	14000 N	540 N		
Chloroacetic acid	79118	2.00E-03 H					73 N	7.3 N	2.7 N	4100 N	160 N		
2-Chloroacetophenone	532274		8.57E-06 I				0.31 N	0.031 N					
4-Chloroaniline	106478	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N	1200 S	0.3 E
Chlorobenzene	108907	2.00E-02 I	5.71E-03 A			☒	39 N	21 N	27 N	41000 N	1600 N	94 E	0.6 E
Chlorobenzilate	510156	2.00E-02 I		2.70E-01 H	2.70E-01 H		0.25 C	0.023 C	0.012 C	21 C	2.4 C		
p-Chlorobenzoic acid	74113	2.00E-01 H					7300 N	730 N	270 N	410000 N	16000 N		
4-Chlorobenzotrifluoride	98566	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N	86 N	7.5 N
2-Chloro-1,3-butadiene	126998	2.00E-02 A	2.00E-03 H			☒	14 N	7.3 N	27 N	41000 N	1600 N		
1-Chlorobutane	109693	4.00E-01 H				☒	2400 N	1500 N	540 N	820000 N	31000 N		
Chlorodibromomethane	124481	2.00E-02 I		8.40E-02 I		☒	0.13 C	0.075 C	0.038 C	68 C	7.6 C	1900 E	0.2 E
**1-Chl[illegible]1,1-difluoroethane	75683	I	1.43E+01			☒	87000 N	52000 N					

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels- Transfers from Soil to:	
										Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	VOC	Tap Water	Ambient Air	Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Chlorodifluoromethane	75456		1.43e+01 I			☒	87000 N	52000 N					
Chloroethane	75003	4.00E-01 E	2.86E+00 I			☒	8600 N	10000 N	540 N	820000 N	31000 N	2600 S	33 N
2-Chloroethyl vinyl ether	110758	2.50E-02 O				☒	150 N	91 N	34 N	51000 N	2000 N		
Chloroform	67663	1.00E-02 I		6.10E-03 I	8.05E-02 I	☒	0.15 C	0.078 C	0.52 C	940 C	100 C	0.2 E	0.3 E
Chloromethane	74873			1.30E-02 H	6.30E-03 H	☒	1.4 C	0.99 C	0.24 C	440 C	49 C	0.063 C	0.0066 C
4-Chloro-2,2-methylaniline hydrochloride	3165933			4.60E-01 H			0.15 C	0.014 C	0.0069 C	12 C	1.4 C		
4-Chloro-2-methylaniline	95692			5.80E-01 H			0.12 C	0.011 C	0.0054 C	9.9 C	1.1 C		
beta-Chloronaphthalene	91587	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N	2.8 S	140 N
o-Chloronitrobenzene	88733			2.50E-02 H		☒	0.42 C	0.25 C	0.13 C	230 C	26 C		
p-Chloronitrobenzene	100005			1.80E-02 H		☒	0.59 C	0.35 C	0.18 C	320 C	35 C		
2-Chlorophenol	95578	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N	53000 E	2 E
2-Chloropropane	75296		2.86E-02 H			☒	170 N	100 N				22 N	0.64 N
Chlorothalonil	1897456	1.50E-02 I		1.10E-02 H			6.1 C	0.57 C	0.29 C	520 C	58 C		
o-Chlorotoluene	95498	2.00E-02 I				☒	120 N	73 N	27 N	41000 N	1600 N	1200 N	5.6 N
Chlorpropham	101213	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		
Chlorpyrifos	2921882	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Chlorpyrifos-methyl	5598130	1.00E-02 H					370 N	37 N	14 N	20000 N	780 N		
Chlorsulfuron	64902723	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Chlorthiophos	60238564	8.00E-04 H					29 N	2.9 N	1.1 N	1600 N	63 N		
Chromium III and compounds	16065831	1.00E+00 I	5.71E-07 W				37000 N	0.0021 N	1400 N	1E+06 N	78000 N		
Chromium VI and compounds	18540299	5.00E-03 I			4.20E+01 I		180 N	0.00015 C	6.8 N	10000 N	390 N	140 E	19 E
Coal tar	8001589				2.20E+00 W			0.0028 C					
Cobalt	7440484	6.00E-02 E					2200 N	220 N	81 N	120000 N	4700 N		
Coke Oven Emissions	8007452				2.17E+00 I			0.0029 C					
**Copper and compounds	7440508	4.00E-02 E					1500 N	150 N	54 N	82000 N	3100 N		
Crotonaldehyde	123739	1.00E-02 W		1.90E+00 H	1.90E+00 W		0.035 C	0.0033 C	0.0017 C	3 C	0.34 C		
Cumene	98828	4.00E-02 I	2.57E-03 H				1500 N	9.4 N	54 N	82000 N	3100 N	81 N	65 N
Cyanides:													
Barium cyanide	542621	1.00E-01 W					3700 N	370 N	140 N	200000 N	7800 N		
Calcium cyanide	592018	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Copper cyanide	544923	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Cyanazine	21725462	2.00E-03 H		8.40E-01 H			0.08 C	0.0075 C	0.0038 C	6.8 C	0.76 C		
Cyanogen	460195	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Cyanogen bromide	506683	9.00E-02 I					3300 N	330 N	120 N	180000 N	7000 N		
Cyanogen chloride	506774	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Free cyanide	57125	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Hydrogen cyanide	74908	2.00E-02 I	8.57E-04 I				730 N	3.1 N	27 N	41000 N	1600 N		
Potassium cyanide	151508	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Potassium silver cyanide	506616	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo	RfDi	CPSo	CPSi	VOC	Risk-Based Concentrations					Soil Screening Levels- Transfers from Soil to:	
							Tap Water	Ambient Air	Fish	Soil Ingestion		Air	Groundwater
										Industrial	Residential		
		mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Silver cyanide	506649	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Sodium cyanide	143339	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
**Thiocyanate		2.00E-02 E					730 N	73 N	27 N	41000 N	1600 N		
Zinc cyanide	557211	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Cyclohexanone	108941	5.00E+00 I				☒	30000 N	18000 N	6800 N	1E+06 N	390000 N		
Cyclohexlamine	108918	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		
Cyhalothrin/Karate	68085858	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Cypermethrin	52315078	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Cyromazine	66215278	7.50E-03 I					270 N	27 N	10 N	15000 N	590 N		
Dacthal	1861321	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Dalapon	75990	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
Danitol	39515418	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
DDD	72548			2.40E-01 I			0.28 C	0.026 C	0.013 C	24 C	2.7 C	37 S	0.7 E
DDE	72559			3.40E-01 I			0.2 C	0.018 C	0.0093 C	17 C	1.9 C	10 S	0.5 E
DDT	50293	5.00E-04 I		3.40E-01 I	3.40E-01 I		0.2 C	0.018 C	0.0093 C	17 C	1.9 C	80 E	1 E
Decabromodiphenyl ether	1163195	1.00E-02 I				☒	61 N	37 N	14 N	20000 N	780 N		
Demeton	8065483	4.00E-05 I					1.5 N	0.15 N	0.054 N	82 N	3.1 N		
Diallate	2303164			6.10E-02 H		☒	0.17 C	0.1 C	0.052 C	94 C	10 C		
Diazinon	333415	9.00E-04 H					33 N	3.3 N	1.2 N	1800 N	70 N	5400 S	2.8 N
Dibenzofuran	132649	4.00E-03 E					150 N	15 N	5.4 N	8200 N	310 N	120 S	120 N
1,4-Dibromobenzene	106376	1.00E-02 I				☒	61 N	37 N	14 N	20000 N	780 N		
1,2-Dibromo-3-chloropropane	96128		5.71E-05 I	1.40E+00 H	2.42E-03 H	☒	0.048 C	0.21 N	0.0023 C	4.1 C	0.46 C	1.9 N	0.00061 M
1,2-Dibromoethane	106934		5.71E-05 H	8.50E+01 I	7.70E-01 I	☒	0.00075 C	0.0081 C	0.00004 C	0.067 C	0.0075 C	0.0058 C	0.00018 M
Dibutyl phthalate	84742	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N	100 E	120 E
Dicamba	1918009	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
1,2-Dichlorobenzene	95501	9.00E-02 I	4.00E-02 A			☒	270 N	150 N	120 N	180000 N	7000 N	300 E	6 E
1,3-Dichlorobenzene	541731	8.90E-02 O				☒	540 N	320 N	120 N	180000 N	7000 N		
1,4-Dichlorobenzene	106467		2.29E-01 I	2.40E-02 H		☒	0.44 C	0.26 C	0.13 C	240 C	27 C	7700 E	1 E
3,3'-Dichlorobenzidine	91941			4.50E-01 I			0.15 C	0.014 C	0.007 C	13 C	1.4 C	52 S	0.01 E
1,4-Dichloro-2-butene	764410				9.30E+00 H	☒	0.0011 C	0.00067 C					
Dichlorodifluoromethane	75718	2.00E-01 I	5.71E-02 A			☒	390 N	210 N	270 N	410000 N	16000 N	37 N	7.5 N
1,1-Dichloroethane	75343	1.00E-01 H	1.43E-01 A			☒	810 N	520 N	140 N	200000 N	7800 N	980 E	11 E
1,2-Dichloroethane (EDC)	107062		2.86E-03 E	9.10E-02 I	9.10E-02 I	☒	0.12 C	0.069 C	0.035 C	63 C	7 C	0.3 E	0.01 E
1,1-Dichloroethylene	75354	9.00E-03 I		6.00E-01 I	1.75E-01 I	☒	0.044 C	0.036 C	0.0053 C	9.5 C	1.1 C	0.04 E	0.03 E
1,2-Dichloroethylene (cis)	156592	1.00E-02 H				☒	61 N	37 N	14 N	20000 N	780 N	1500 E	0.2 E
1,2-Dichloroethylene (trans)	156605	2.00E-02 I				☒	120 N	73 N	27 N	41000 N	1600 N	3600 E	0.3 E
1,2-Dichloroethylene (mixture)	540590	9.00E-03 H				☒	55 N	33 N	12 N	18000 N	700 N		
2,4-Dichlorophenol	120832	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N	4800 S	0.5 E
2,4-Dichlorophenoxyacetic Acid (2,4-D)	94757	1.00E-02 I				☒	61 N	37 N	14 N	20000 N	780 N	7000 S	1.7 M

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels- Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
4-(2,4-Dichlorophenoxy)butyric Acid	94826	8.00E-03 I					290 N	29 N	11 N	16000 N	630 N		
1,2-Dichloropropane	78875		1.14E-03 I	6.80E-02 H		☒	0.16 C	0.092 C	0.046 C	84 C	9.4 C	11 E	0.02 E
2,3-Dichloropropanol	616239	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
1,3-Dichloropropene	542756	3.00E-04 I	5.71E-03 I	1.75E-01 H	1.30E-01 H	☒	0.077 C	0.048 C	0.018 C	33 C	3.7 C	0.1 E	0.001 E
Dichlorvos	62737	5.00e-04 I	1.43E-04 I	2.90E-01 I			0.23 C	0.022 C	0.011 C	20 C	2.2 C	3.5 C	0.00072 C
Dicofol	115322			4.40E-01 W			0.15 C	0.014 C	0.0072 C	13 C	1.5 C		
Dicyclopentadiene	77736	3.00E-02 H	5.71E-05 A			☒	0.42 N	0.21 N	41 N	61000 N	2300 N		
Dieldrin	60571	5.00E-05 I		1.60E+01 I	1.61E+01 I		0.0042 C	0.00039 C	0.0002 C	0.36 C	0.04 C	2 E	0.001 E
Diesel emissions			1.43E-03 I				52 N	5.2 N					
Diethyl phthalate	84662	8.00E-01 I					29000 N	2900 N	1100 N	1E+06 N	63000 N	520 E	110 E
Diethylene glycol, monobutyl ether	112345		5.71E-03 H				210 N	21 N					
Diethylene glycol, monoethyl ether	111900	2.00E+00 H					73000 N	7300 N	2700 N	1E+06 N	160000 N		
Diethylforamide	617845	1.10E-02 H					400 N	40 N	15 N	22000 N	860 N		
Di(2-ethylhexyl)adipate	103231	6.00E-01 I		1.20E-03 I			56 C	5.2 C	2.6 C	4800 C	530 C		
Diethylstilbestrol	56531			4.70E+03 H			0.00001 C	1E-06 C	7E-07 C	0.0012 C	0.00014 C		
Difenzoquat (Avenge)	43222486	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Diflubenzuron	35367385	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
1,1-Difluoroethane	75376		1.14E+01 I			☒	69000 N	42000 N					
Diisopropyl methylphosphonate (DIMP)	1445756	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Dimethipin	55290647	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Dimethoate	60515	2.00E-04 I					7.3 N	0.73 N	0.27 N	410 N	16 N		
3,3'-Dimethoxybenzidine	119904			1.40E-02 H			4.8 C	0.45 C	0.23 C	410 C	46 C		
Dimethylamine	124403		5.71E-06 W				0.21 N	0.021 N					
2,4-Dimethylaniline hydrochloride	21436964			5.80E-01 H			0.12 C	0.011 C	0.0054 C	9.9 C	1.1 C		
2,4-Dimethylaniline	95681			7.50E-01 H			0.09 C	0.0083 C	0.0042 C	7.6 C	0.85 C		
N-N-Dimethylaniline	121697	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
3,3'-Dimethylbenzidine	119937			9.20E+00 H			0.0073 C	0.00068 C	0.00034 C	0.62 C	0.069 C	29 C	0.00039 C
N,N-Dimethylformamide	68122	1.00E-01 H	8.57E-03 I				3700 N	31 N	140 N	200000 N	7800 N		
1,1-Dimethylhydrazine	57147			2.60E+00 W	3.50E+00 W		0.026 C	0.0018 C	0.0012 C	2.2 C	0.25 C		
1,2-Dimethylhydrazine	540738			3.70E+01 W	3.70E+01 W		0.0018 C	0.00017 C	0.00009 C	0.15 C	0.017 C		
2,4-Dimethylphenol	105679	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N	5400 S	3 E
2,6-Dimethylphenol	576261	6.00E-04 I					22 N	2.2 N	0.81 N	1200 N	47 N		
3,4-Dimethylphenol	95658	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Dimethyl phthalate	131113	1.00E+01 H					370000 N	37000 N	14000 N	1E+06 N	780000 N	1600 E	1200 E
Dimethyl terephthalate	120616	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
1,2-Dinitrobenzene	528290	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
1,3-Dinitrobenzene	99650	1.00E-04 I					3.7 N	0.37 N	0.14 N	200 N	7.8 N		
1,4-Dinitrobenzene	100254	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
4,6-Dinitro-o-cyclohexyl phenol	131895	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
2,4-Dinitrophenol	51285	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N	360 N	0.1 E
Dinitrotoluene mixture				6.80E-01 I			0.099 C	0.0092 C	0.0046 C	8.4 C	0.94 C		
2,4-Dinitrotoluene	121142	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N	120 S	0.2 E
2,6-Dinitrotoluene	606202	1.00E-03 H					37 N	3.7 N	1.4 N	2000 N	78 N	370 S	0.1 E
Dinoseb	88857	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
di-n-Octyl phthalate	117840	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N	1000000 S	1000000 E
1,4-Dioxane	123911			1.10E-02 I			6.1 C	0.57 C	0.29 C	520 C	58 C		
Diphenamid	957517	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
Diphenylamine	122394	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
1,2-Diphenylhydrazine	122667			8.00E-01 I	7.70E-01 I		0.084 C	0.0081 C	0.0039 C	7.2 C	0.8 C		
Diquat	85007	2.20E-03 I					80 N	8 N	3 N	4500 N	170 N		
Direct black 38	1937377			8.60E+00 H			0.0078 C	0.00073 C	0.00037 C	0.67 C	0.074 C		
Direct blue 6	2602462			8.10E+00 H			0.0083 C	0.00077 C	0.00039 C	0.71 C	0.079 C		
Direct brown 95	16071866			9.30E+00 H			0.0072 C	0.00067 C	0.00034 C	0.62 C	0.069 C		
Disulfoton	298044	4.00E-05 I					1.5 N	0.15 N	0.054 N	82 N	3.1 N		
1,4-Dithiane	505293	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Diuron	330541	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Dodine	2439103	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Endosulfan	115297	6.00E-03 I					220 N	22 N	8.1 N	12000 N	470 N	1 S	3 E
Endothall	145733	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Endrin	72208	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N	16 S	0.4 E
Epichlorohydrin	106898	2.00E-03 H	2.86E-04 I	9.90E-03 I	4.20E-03 I		6.8 C	1 N	0.32 C	580 C	65 C		
1,2-Epoxybutane	106887		5.71E-03 I				210 N	21 N					
Ethephon (2-chloroethyl phosphonic acid)	16672870	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Ethion	563122	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
2-Ethoxyethanol acetate	111159	3.00E-01 A					11000 N	1100 N	410 N	610000 N	23000 N		
2-Ethoxyethanol	110805	4.00E-01 H	5.71E-02 I				15000 N	210 N	540 N	820000 N	31000 N		
Ethyl acrylate	140885			4.80E-02 H			1.4 C	0.13 C	0.066 C	120 C	13 C		
EPTC (S-Ethyl dipropylthiocarbamate)	759944	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Ethyl acetate	141786	9.00E-01 I					33000 N	3300 N	1200 N	1E+06 N	70000 N		
Ethylbenzene	100414	1.00E-01 I	2.86E-01 I			☒	1300 N	1000 N	140 N	200000 N	7800 N	260 E	5 E
Ethylene cyanohydrin	109784	3.00E-01 H					11000 N	1100 N	410 N	610000 N	23000 N		
Ethylene diamine	107153	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N		
Ethylene glycol	107211	2.00E+00 I					73000 N	7300 N	2700 N	1E+06 N	160000 N		
Ethylene glycol, monobutyl ether	111762		5.71E-03 H				210 N	21 N					
Ethylene oxide	75218			1.02E+00 H	3.50E-01 H		0.066 C	0.018 C	0.0031 C	5.6 C	0.63 C		
Ethylene thiourea (ETU)	96457	8.00E-05 I		1.19E-01 H			0.57 C	0.053 C	0.027 C	48 C	5.4 C		
Ethyl ether	60297	2.00E-01 I				☒	1200 N	730 N	270 N	410000 N	16000 N		
Ethyl methacrylate	97632	9.00E-02 H					3300 N	330 N	120 N	180000 N	7000 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis: C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
						V	Tap	Ambient		Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	O	Water	Air	Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg	C	µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Ethyl p-nitrophenyl phenylphosphorothioate	2104645	1.00E-05 I					0.37 N	0.037 N	0.014 N	20 N	0.78 N		
Ethylnitrosourea	759739			1.40E+02 W			0.00048 C	0.00005 C	0.00002 C	0.041 C	0.0046 C		
Ethylphthalyl ethyl glycolate	84720	3.00E+00 I					110000 N	11000 N	4100 N	1E+06 N	230000 N		
Express	10120	8.00E-03 I					290 N	29 N	11 N	16000 N	630 N		
Fenamiphos	22224926	2.50E-04 I					9.1 N	0.91 N	0.34 N	510 N	20 N		
Fluometuron	2164172	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Fluoride	7782414	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N		
Fluoridone	59756604	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Flurprimidol	56425913	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Flutolanil	66332965	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N		
Fluvalinate	69409945	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Folpet	133073	1.00E-01 I		3.50E-03 I			19 C	1.8 C	0.9 C	1600 C	180 C		
Fomesafen	72178020			1.90E-01 I			0.35 C	0.033 C	0.017 C	30 C	3.4 C		
Fonofos	944229	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Formaldehyde	50000	2.00E-01 I			4.55E-02 I		7300 N	0.14 C	270 N	410000 N	16000 N		
Formic Acid	64186	2.00E+00 H					73000 N	7300 N	2700 N	1E+06 N	160000 N		
Fosetyl-al	39148248	3.00E+00 I					110000 N	11000 N	4100 N	1E+06 N	230000 N		
Furan	110009	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Furazolidone	67458			3.80E+00 H			0.018 C	0.0016 C	0.00083 C	1.5 C	0.17 C		
Furfural	98011	3.00E-03 I	1.43E-02 A				110 N	52 N	4.1 N	6100 N	230 N		
Furium	531828			5.00E+01 H			0.0013 C	0.00013 C	0.00006 C	0.11 C	0.013 C		
Furmecyclox	60568050			3.00E-02 I			2.2 C	0.21 C	0.11 C	190 C	21 C		
Glufosinate-ammonium	77182822	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Glycidaldehyde	765344	4.00E-04 I	2.86E-04 H				15 N	1 N	0.54 N	820 N	31 N		
Glyphosate	1071836	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Haloxyfop-methyl	69806402	5.00E-05 I					1.8 N	0.18 N	0.068 N	100 N	3.9 N		
Harmony	79277273	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
HCH (alpha)	319846			6.30E+00 I	6.30E+00 I		0.011 C	0.00099 C	0.0005 C	0.91 C	0.1 C	0.9 E	0.0004 E
HCH (beta)	319857			1.80E+00 I	1.80E+00 I		0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C	16 E	0.002 E
HCH (gamma) Lindane	58899	3.00E-04 I		1.30E+00 H			0.052 C	0.0048 C	0.0024 C	4.4 C	0.49 C	4.2 C	0.006 E
HCH-technical	608731			1.80E+00 I	1.79E+00 I		0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C		
Heptachlor	76448	5.00E-04 I		4.50E+00 I	4.55E+00 I	☒	0.0023 C	0.0014 C	0.0007 C	1.3 C	0.14 C	0.3 E	0.06 E
Heptachlor epoxide	1024573	1.30E-05 I		9.10E+00 I	9.10E+00 I	☒	0.0012 C	0.00069 C	0.00035 C	0.63 C	0.07 C	1 E	0.03 E
Hexabromobenzene	87821	2.00E-03 I				☒	12 N	7.3 N	2.7 N	4100 N	160 N		
Hexachlorobenzene	118741	8.00E-04 I		1.60E+00 I	1.61E+00 I	☒	0.0066 C	0.0039 C	0.002 C	3.6 C	0.4 C	1 E	0.8 E
Hexachlorobutadiene	87683	2.00E-04 H		7.80E-02 I	7.70E-02 I	☒	0.14 C	0.081 C	0.04 C	73 C	8.2 C	1 E	0.1 E
Hexachlorocyclopentadiene	77474	7.00E-03 I	2.00E-05 H			☒	0.15 N	0.073 N	9.5 N	14000 N	550 N	2 E	10 E
Hexachlorodibenzo-p-dioxin mixture	19408743			6.20E+03 I	4.55E+03 I		0.00001 C	1E-06 C	5E-07 C	0.0009 C	0.0001 C		
Hexachloroethane	67721	1.00E-03 I		1.40E-02 I	1.40E-02 I	☒	0.75 C	0.45 C	0.23 C	410 C	46 C	49 E	0.2 E

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Hexachlorophene	70304	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Hexahydro-1,3,5-trinitro-1,3,5-triazine	121824	3.00E-03 I		1.10E-01 I			0.61 C	0.057 C	0.029 C	52 C	5.8 C		
1,6-Hexamethylene diisocyanate	822060		2.86E-06 I				0.1 N	0.01 N					
n-Hexane	110543	6.00E-02 H	5.71E-02 I			☒	350 N	210 N	81 N	120000 N	4700 N	32 N	13 N
Hexazinone	51235042	3.30E-02 I					1200 N	120 N	45 N	67000 N	2600 N		
Hydrazine, hydrazine sulfate	302012			3.00E+00 I	1.71E+01 I		0.022 C	0.00037 C	0.0011 C	1.9 C	0.21 C		
**Hydrogen chloride	7647010		5.71E-03 I				210 N	21 N					
**Hydrogen sulfide	7783064	3.00E-03 I	2.85E-04 I				110 N	1 N	4.1 N	6100 N	230 N		
Hydroquinone	123319	4.00E-02 H					1500 N	150 N	54 N	82000 N	3100 N		
Imazalil	35554440	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Imazaquin	81335377	2.50E-01 I					9100 N	910 N	340 N	510000 N	20000 N		
Iprodione	36734197	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
**Iron	7439896	3.00E-01 E					11000 N	1100 N	410 N	610000 N	23000 N		
Isobutanol	78831	3.00E-01 I				☒	1800 N	1100 N	410 N	610000 N	23000 N		
Isophorone	78591	2.00E-01 I		9.50E-04 I			71 C	6.6 C	3.3 C	6000 C	670 C	3400 E	0.2 E
Isopropalin	33820530	1.50E-02 I					550 N	55 N	20 N	31000 N	1200 N		
Isopropyl methyl phosphonic acid	1832548	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Isoxaben	82558507	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Kepone	143500			1.80E+01 E			0.0037 C	0.00035 C	0.00018 C	0.32 C	0.035 C		
Lactofen	77501634	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Linuron	330552	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Lithium	7439932	2.00E-02 E					730 N	73 N	27 N	41000 N	1600 N		
Londax	83056996	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		
Malathion	121755	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Maleic anhydride	108316	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Maleic hydrazide	123331	5.00E-01 I					18000 N	1800 N	680 N	1E+06 N	39000 N		
Malononitrile	109773	2.00E-05 H					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Mancozeb	8018017	3.00E-02 H					1100 N	110 N	41 N	61000 N	2300 N		
Maneb	12427382	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Manganese and compounds	7439965	5.00E-03 I	1.43e-05 I				180 N	0.052 N	6.8 N	10000 N	390 N		
Mephosfolan	950107	9.00E-05 H					3.3 N	0.33 N	0.12 N	180 N	7 N		
Mepiquat chloride	24307264	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
**Mercuric chloride	7487947	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Mercury (inorganic)	7439976	3.00E-04 H	8.57E-05 H				11 N	0.31 N	0.41 N	610 N	23 N	7 E	3 E
Mercury (methyl)	22967926	1.00E-04 I					3.7 N	0.37 N	0.14 N	200 N	7.8 N		
Merphos	150505	3.00E-05 I					1.1 N	0.11 N	0.041 N	61 N	2.3 N		
Merphos oxide	78488	3.00E-05 I					1.1 N	0.11 N	0.041 N	61 N	2.3 N		
Metalaxyl	57837191	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N		
Methacrylonitrile	126987	1.00E-04 I	2.00E-04 A				3.7 N	0.73 N	0.14 N	200 N	7.8 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Risk-Based Concentrations: Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Soil Ingestion: Industrial mg/kg	Soil Ingestion: Residential mg/kg	Soil Screening Levels- Transfers from Soil to: Air mg/kg	Groundwater mg/kg
Methamidophos	10265926	5.00E-05 I					1.8 N	0.18 N	0.068 N	100 N	3.9 N		
Methanol	67561	5.00E-01 I					18000 N	1800 N	680 N	1E+06 N	39000 N		
Methidathion	950378	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Methomyl	16752775	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Methoxychlor	72435	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N	41 S	62 E
2-Methoxyethanol acetate	110496	2.00E-03 A					73 N	7.3 N	2.7 N	4100 N	160 N		
2-Methoxyethanol	109864	1.00E-03 H	5.71E-03 I				37 N	21 N	1.4 N	2000 N	78 N		
2-Methoxy-5-nitroaniline	99592			4.60E-02 H			1.5 C	0.14 C	0.069 C	120 C	14 C		
Methyl acetate	79209	1.00E+00 H					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Methyl acrylate	96333	3.00E-02 A					1100 N	110 N	41 N	61000 N	2300 N		
2-Methylaniline hydrochloride	636215			1.80E-01 H			0.37 C	0.035 C	0.018 C	32 C	3.5 C		
2-Methylaniline	95534			2.40E-01 H			0.28 C	0.026 C	0.013 C	24 C	2.7 C		
Methyl chlorocarbonate	79221	1.00E+00 W					37000 N	3700 N	1400 N	1E+06 N	78000 N		
4-(2-Methyl-4-chlorophenoxy) butyric acid	94815	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
2-Methyl-4-chlorophenoxyacetic acid	94746	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
2-(2-Methyl-14-chlorophenoxy)propionic acid	93652	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Methylcyclohexane	108872		8.57E-01 H				31000 N	3100 N				60 S	1500 N
Methylene bromide	74953	1.00E-02 A				☒	61 N	37 N	14 N	20000 N	780 N		
Methylene chloride	75092	6.00E-02 I	8.57E-01 H	7.50E-03 I	1.64E-03 I	☒	4.1 C	3.8 C	0.42 C	760 C	85 C	7 E	0.01 E
4,4'-Methylene bis(2-chloroaniline)	101144	7.00E-04 H		1.30E-01 H	1.30E-01 H		0.52 C	0.048 C	0.024 C	44 C	4.9 C		
4,4'-Methylenebisbenzeneamine	101779			2.50E-01 W			0.27 C	0.025 C	0.013 C	23 C	2.6 C		
4,4'-Methylene bis(N,N'-dimethyl)aniline	101611			4.60E-02 I			1.5 C	0.14 C	0.069 C	120 C	14 C		
4,4'-Methylenediphenyl isocyanate	101688		5.71E-06 I			☒	0.035 N	0.021 N					
Methyl ethyl ketone	78933	6.00E-01 I	2.86E-01 I			☒	1900 N	1000 N	810 N	1E+06 N	47000 N		
Methyl hydrazine	60344			1.10E+00 W			0.061 C	0.0057 C	0.0029 C	5.2 C	0.58 C		
Methyl isobutyl ketone	108101	8.00E-02 H	2.29E-02 A				2900 N	84 N	110 N	160000 N	6300 N		
Methyl methacrylate	80626	8.00E-02 H					2900 N	290 N	110 N	160000 N	6300 N		
2-Methyl-5-nitroaniline	99558			3.30E-02 H			2 C	0.19 C	0.096 C	170 C	19 C		
Methyl parathion	298000	2.50E-04 I					9.1 N	0.91 N	0.34 N	510 N	20 N	28 S	0.041 N
2-Methylphenol (o-cresol)	95487	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N	12000 S	6 E
3-Methylphenol (m-cresol)	103394	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
4-Methylphenol (p-cresol)	106445	5.00E-03 H					180 N	18 N	6.8 N	10000 N	390 N		
Methyl styrene (mixture)	25013154	6.00E-03 A	1.14E-02 A			☒	60 N	42 N	8.1 N	12000 N	470 N	100 N	1 N
Methyl styrene (alpha)	98839	7.00E-02 A				☒	430 N	260 N	95 N	140000 N	5500 N	8.8 S	7.5 N
Methyl tertbutyl ether (MTBE)	1634044	5.00E-03 E	8.57E-01 I			☒	180 N	3100 N	6.8 N	10000 N	390 N		
Metolaclor (Dual)	51218452	1.50E-01 H					5500 N	550 N	200 N	310000 N	12000 N		
Metribuzin	21087649	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Mirex	2385855	2.00E-04 I		1.80E+00 W			0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C		
Molinate	2212671	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

						V	Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
		RfDo	RfDi	CPSo	CPSi	O	Tap Water	Ambient Air	Fish	Soil Ingestion			
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg	C	µg/L	µg/m3	mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Molybdenum	7439987	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Monochloramine	10599903	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Naled	300765	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
2-Naphthylamine	91598			1.30e+02 E			0.00052 C	0.00005 C	0.00002 C	0.044 C	0.0049 C		
Napropamide	15299997	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Nickel refinery dust					8.40E-01 I			0.0075 C					
Nickel and compounds	7440020	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N	6900 E	21 E
Nickel subsulfide	12035722				1.70E+00 I			0.0037 C					
Nitrapyrin	1929824	1.50E-03 W					55 N	5.5 N	2 N	3100 N	120 N		
Nitrate	14797558	1.60E+00 I					58000 N	5800 N	2200 N	1E+06 N	130000 N		
Nitric Oxide	10102439	1.00E-01 W					3700 N	370 N	140 N	200000 N	7800 N		
Nitrite	14797650	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
2-Nitroaniline	88744	6.00E-05 W	5.71E-05 H				2.2 N	0.21 N	0.081 N	120 N	4.7 N		
3-Nitroaniline	99092	3.00E-03 O					110 N	11 N	4.1 N	6100 N	230 N		
4-Nitroaniline	100016	3.00E-03 O					110 N	11 N	4.1 N	6100 N	230 N		
Nitrobenzene	98953	5.00E-04 I	5.71E-04 A			☒	3.4 N	2.1 N	0.68 N	1000 N	39 N	110 E	0.09 E
Nitrofurantoin	67209	7.00E-02 H					2600 N	260 N	95 N	140000 N	5500 N		
Nitrofurazone	59870			1.50E+00 H	9.40E+00 H		0.045 C	0.00067 C	0.0021 C	3.8 C	0.43 C		
Nitrogen dioxide	10102440	1.00E+00 W					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Nitroguanidine	556887	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
4-Nitrophenol	100027	6.20E-02 O					2300 N	230 N	84 N	130000 N	4800 N		
2-Nitropropane	79469		5.71E-03 I		9.40E+00 H		210 N	0.00067 C					
N-Nitrosodi-n-butylamine	924163			5.40E+00 I	5.60E+00 I		0.012 C	0.0011 C	0.00058 C	1.1 C	0.12 C		
N-Nitrosodiethanolamine	1116547			2.80E+00 I			0.024 C	0.0022 C	0.0011 C	2 C	0.23 C		
N-Nitrosodiethylamine	55185			1.50E+02 I	1.51E+02 I		0.00045 C	0.00004 C	0.00002 C	0.038 C	0.0043 C		
N-Nitrosodimethylamine	62759			5.10E+01 I	4.90E+01 I		0.0013 C	0.00013 C	0.00006 C	0.11 C	0.013 C		
N-Nitrosodiphenylamine	86306			4.90E-03 I			14 C	1.3 C	0.64 C	1200 C	130 C	29 C	0.2 E
N-Nitroso di-n-propylamine	621647			7.00E+00 I			0.0096 C	0.00089 C	0.00045 C	0.82 C	0.091 C	0.014 C	0.00002 E
N-Nitroso-N-methylethylamine	10595956			2.20E+01 I			0.0031 C	0.00028 C	0.00014 C	0.26 C	0.029 C		
N-Nitrosopyrrolidine	930552			2.10E+00 I	2.13E+00 I		0.032 C	0.0029 C	0.0015 C	2.7 C	0.3 C		
m-Nitrotoluene	99081	1.00E-02 H				☒	61 N	37 N	14 N	20000 N	780 N	460 S	0.42 N
o-Nitrotoluene	88722	1.00E-02 H				☒	61 N	37 N	14 N	20000 N	780 N	460 S	0.42 N
p-Nitrotoluene	99990	1.00E-02 H				☒	61 N	37 N	14 N	20000 N	780 N	460 S	0.42 N
Norflurazon	27314132	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
NuStar	85509199	7.00E-04 I					26 N	2.6 N	0.95 N	1400 N	55 N		
Octabromodiphenyl ether	32536520	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Octahydro-1357-tetranitro-1357-tetrazocine	2691410	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Octamethylpyrophosphoramide	152169	2.00E-03 H					73 N	7.3 N	2.7 N	4100 N	160 N		
Oryzali[illegible]	19044883	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo	RfDi	CPSo	CPSi	VOC	Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water	Ambient Air	Fish	Soil Ingestion		Air	Groundwater
										Industrial	Residential		
		mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Oxadiazon	19666309	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Oxamyl	23135220	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Oxyfluorfen	42874033	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Paclobutrazol	76738620	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Paraquat	1910425	4.50E-03 I					160 N	16 N	6.1 N	9200 N	350 N		
Parathion	56382	6.00E-03 H					220 N	22 N	8.1 N	12000 N	470 N	110 S	3.9 N
Pebulate	1114712	5.00E-02 H					1800 N	180 N	68 N	100000 N	3900 N		
Pendimethalin	40487421	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Pentabromo-6-chloro cyclohexane	87843			2.30E-02 H			2.9 C	0.27 C	0.14 C	250 C	28 C		
Pentabromodiphenyl ether	32534819	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Pentachlorobenzene	608935	8.00E-04 I				☒	4.9 N	2.9 N	1.1 N	1600 N	63 N	570 N	48 N
Pentachloronitrobenzene	82688	3.00E-03 I		2,60E-01 H		☒	0.041 C	0.024 C	0.012 C	22 C	2.5 C		
Pentachlorophenol	87865	3.00E-02 I		1.20E-01 I			0.56 C	0.052 C	0.026 C	48 C	5.3 C	7.9 C	0.2 E
Permethrin	52645531	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Phenmedipham	13684634	2.50E-01 I					9100 N	910 N	340 N	510000 N	20000 N		
Phenol	108952	6.00E-01 I					22000 N	2200 N	810 N	1E+06 N	47000 N	21000 S	49 E
m-Phenylenediamine	108452	6.00E-03 I					220 N	22 N	8.1 N	12000 N	470 N		
p-Phenylenediamine	106503	1.90E-01 H					6900 N	690 N	260 N	390000 N	15000 N		
Phenylmercuric acetate	62384	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
2-Phenylphenol	90437			1.94E-03 H			35 C	3.2 C	1.6 C	3000 C	330 C		
Phorate	298022	2.00E-04 H					7.3 N	0.73 N	0.27 N	410 N	16 N		
Phosmet	732116	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
**Phosphine	7803512	3.00E-04 I	8.57E-05 H				11 N	0.31 N	0.41 N	610 N	23 N		
**Phosphoric acid	7664382	I	2.86E-03				100 N	10 N					
Phosphorus (white)	7723140	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
p-Phthalic acid	100210	1.00E+00 H					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Phthalic anhydride	85449	2.00E+00 I	3.43E-02 H				73000 N	130 N	2700 N	1E+06 N	160000 N		
Picloram	1918021	7.00E-02 I					2600 N	260 N	95 N	140000 N	5500 N		
Pirimiphos-methyl	29232937	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Polybrominated biphenyls		7.00E-06 H		8.90E+00 H			0.0076 C	0.0007 C	0.00035 C	0.64 C	0.072 C		
Polychlorinated biphenyls (PCBs)	1336363			7.70E+00 I			0.0087 C	0.00081 C	0.00041 C	0.74 C	0.083 C		
Aroclor 1016	12674112	7.00E-05 I					2.6 N	0.26 N	0.095 N	140 N	5.5 N		
Aroclor 1254	11097691	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Polychlorinated terphenyls (PCTs)				4.50E+00 E			0.015 C	0.0014 C	0.0007 C	1.3 C	0.14 C		
Polynuclear aromatic hydrocarbons												110000 S	
Acenaphthene	83329	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N	120 S	200 E
Anthracene	120127	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N	6.8 S	4300 E
Benz[a]anthracene	56553			7.30E-01 E	6.10E-01 E		0.092 C	0.01 C	0.0043 C	7.8 C	0.88 C	27 S	0.7 E
Benzo[b]fluoranthene	205992			7.30E-01 E	6.10E-01 E		0.092 C	0.01 C	0.0043 C	7.8 C	0.88 C	23 S	4 E

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Soil Ingestion		Air mg/kg	Groundwater mg/kg
										Industrial mg/kg	Residential mg/kg		
Benzo[k]fluoranthene	207089			7.30E-02 E	6.10E-02 E		0.92 C	*0.1* C	*0.043* C	78 C	8.8 C		4 E
Benzo[a]pyrene	50328			7.30E+00 I	6.10E+00 W		0.0092 C	0.001 C	0.00043 C	0.78 C	0.088 C	11 S	4 E
Carbazole	86748			2.00E-02 H			3.4 C	0.31 C	0.16 C	290 C	32 C	11 S	0.5 E
Chrysene	218019			7.30E-03 E	6.10E-03 E		9.2 C	1 C	0.43 C	780 C	88 C	3.6 S	1 E
Dibenz[ah]anthracene	53703			7.30E+00 E	6.10E+00 E		0.0092 C	0.001 C	0.00043 C	0.78 C	0.088 C	7.2 S	11 E
Fluoranthene	206440	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N	68 S	980 E
Fluorene	86737	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N	89 S	160 E
Indeno[1,2,3-cd]pyrene	193395			7.30E-01 E	6.10E-01 E		0.092 C	0.01 C	0.0043 C	7.8 C	0.88 C	280 S	35 E
Naphthalene	91203	4.00E-02 W					1500 N	150 N	54 N	82000 N	3100 N	180 S	30 E
Pyrene	129000	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N	56 S	1400 E
Prochloraz	67747095	9.00E-03 I		1.50E-01 I			0.45 C	0.042 C	0.021 C	38 C	4.3 C		
Profluralin	26399360	6.00E-03 H					220 N	22 N	8.1 N	12000 N	470 N		
Prometon	1610180	1.50E-02 I					550 N	55 N	20 N	31000 N	1200 N		
Prometryn	7287196	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Pronamide	23950585	7.50E-02 I					2700 N	270 N	100 N	150000 N	5900 N		
Propachlor	1918167	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Propanil	709988	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Propargite	2312358	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Propargyl alcohol	107197	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Propazine	139402	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Propham	122429	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Propiconazole	60207901	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Propylene glycol	57556	2.00E+01 H					730000 N	73000 N	27000 N	1E+06 N	1000000 N		
Propylene glycol, monoethyl ether	52125538	7.00E-01 H					26000 N	2600 N	950 N	1E+06 N	55000 N		
Propylene glycol, monomethyl ether	107982	7.00E-01 H	5.71E-01 I				26000 N	2100 N	950 N	1E+06 N	55000 N		
Propylene oxide	75569		8.57E-03 I	2.40E-01 I	1.29E-02 I		0.28 C	0.49 C	0.013 C	24 C	2.7 C		
Pursuit	81335775	2.50E-01 I					9100 N	910 N	340 N	510000 N	20000 N		
Pydrin	51630581	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Pyridine	110861	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Quinalphos	13593038	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
Quinoline	91225			1.20E+01 H			0.0056 C	0.00052 C	0.00026 C	0.48 C	0.053 C		
Resmethrin	10463868	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
Ronnel	299843	5.00E-02 H					1800 N	180 N	68 N	100000 N	3900 N		
Rotenone	83794	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Savey	78587050	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Selenious Acid	7783008	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Selenium	7782492	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		3 E
Selenourea	630104	5.00E-03 H					180 N	18 N	6.8 N	10000 N	390 N		
Sethoxydim	74051802	9.00E-02 I					3300 N	330 N	120 N	180000 N	7000 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water	Ambient Air	Fish	Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	µg/L	µg/m3	mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Silver and compounds	7440224	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Simazine	122349	5.00E-03 I		1.20E-01 H			0.56 C	0.052 C	0.026 C	48 C	5.3 C		
Sodium azide	26628228	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Sodium diethyldithiocarbamate	148185	3.00E-02 I		2.70E-01 H			0.25 C	0.023 C	0.012 C	21 C	2.4 C		
Sodium fluoroacetate	62748	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Sodium metavanadate	13718268	1.00E-03 H					37 N	3.7 N	1.4 N	2000 N	78 N		
Strontium, stable	7440246	6.00E-01 I					22000 N	2200 N	810 N	1E+06 N	47000 N		
Strychnine	57249	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Styrene	100425	2.00E-01 I	2.86E-01 I			☒	1600 N	1000 N	270 N	410000 N	16000 N	1400 E	2 E
Systhane	88671890	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
2,3,7,8-TCDD (dioxin)	1746016			1.56E+05 H	1.16E+05 H		4E-07 C	5E-08 C	C	4E-05 C	4E-06 C		
Tebuthiuron	34014181	7.00E-02 I					2600 N	260 N	95 N	140000 N	5500 N		
Temephos	3383968	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N		
Terbacil	5902512	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Terbufos	13071799	2.50E-05 H					0.91 N	0.091 N	0.034 N	51 N	2 N		
Terbutryn	886500	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
1,2,4,5-Tetrachlorobenzene	95943	3.00E-04 I				☒	1.8 N	1.1 N	0.41 N	610 N	23 N	91 N	0.69 N
1,1,1,2-Tetrachloroethane	630206	3.00E-02 I		2.60E-02 I	2.59E-02 I	☒	0.41 C	0.24 C	0.12 C	220 C	25 C		
1,1,2,2-Tetrachloroethane	79345			2.00E-01 I	2.03E-01 I	☒	0.052 C	0.031 C	0.016 C	29 C	3.2 C	0.4 E	0.001 E
Tetrachloroethylene (PCE)	127184	1.00E-02 I		5.20E-02 E	2.03E-03 E	☒	1.1 C	3.1 C	0.061 C	110 C	12 C	11 E	0.04 E
2,3,4,6-Tetrachlorophenol	58902	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
p,a,a,a-Tetrachlorotoluene	5216251			2.00E+01 H		☒	0.00053 C	0.00031 C	0.00016 C	0.29 C	0.032 C		
Tetrachlorovinphos	961115	3.00E-02 I		2.40E-02 H			2.8 C	0.26 C	0.13 C	240 C	27 C		
Tetraethyldithiopyrophosphate	3689245	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
Tetraethyl lead	78002	1.00E-07 I					0.0037 N	0.00037 N	0.00014 N	0.2 N	0.0078 N	0.00068 N	0.000034 N
**1,1,1,2-Tetrafluoroethane	811972	I	2.29E+01			☒	140000 N	84000 N					
Thallic oxide	1314325	7.00E-05 W					2.6 N	0.26 N	0.095 N	140 N	5.5 N		
Thallium													0.4 E
Thallium acetate	563688	9.00E-05 I					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium carbonate	6533739	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thallium chloride	7791120	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thallium nitrate	10102451	9.00E-05 I					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium selenite	12039520	9.00E-05 W					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium sulfate	7446186	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thiobencarb	28249776	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
2-(Thiocyanomethylthio)-benzothiazole	21564170	3.00E-02 H					1100 N	110 N	41 N	61000 N	2300 N		
Thiofanox	39196184	3.00E-04 H					11 N	1.1 N	0.41 N	610 N	23 N		
Thiophanate-methyl	23564058	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Thiram	137268	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo	RfDi	CPSo	CPSi	VOC	Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water	Ambient Air	Fish	Soil Ingestion			
										Industrial	Residential	Air	Groundwater
		mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Tin and compounds		6.00E-01 H					22000 N	2200 N	810 N	1E+06 N	47000 N		
Toluene	108883	2.00E-01 I	1.14E-01 I			☒	750 N	420 N	270 N	410000 N	16000 N	520 E	5 E
Toluene-2,4-diamine	95807			3.20E+00 H			0.021 C	0.002 C	0.00099 C	1.8 C	0.2 C		
Toluene-2,5-diamine	95705	6.00E-01 H					22000 N	2200 N	810 N	1E+06 N	47000 N		
Toluene-2,6-diamine	823405	2.00E-01 H					7300 N	730 N	270 N	410000 N	16000 N		
p-Toluidine	106490			1.90E-01 H			0.35 C	0.033 C	0.017 C	30 C	3.4 C		
Toxaphene	8001352			1.10E+00 I	1.12E+00 I		0.061 C	0.0056 C	0.0029 C	5.2 C	0.58 C	5 E	0.04 E
Tralomethrin	66841256	7.50E-03 I					270 N	27 N	10 N	15000 N	590 N		
Triallate	2303175	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Triasulfuron	82097505	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
1,2,4-Tribromobenzene	615543	5.00E-03 I				☒	30 N	18 N	6.8 N	10000 N	390 N		
Tributyltin oxide (TBTO)	56359	3.00E-05 I					1.1 N	0.11 N	0.041 N	61 N	2.3 N		
2,4,6-Trichloroaniline hydrochloride	33663502			2.90E-02 H			2.3 C	0.22 C	0.11 C	200 C	22 C		
2,4,6-Trichloroaniline	634935			3.40E-02 H			2 C	0.18 C	0.093 C	170 C	19 C		
1,2,4-Trichlorobenzene	120821	1.00E-02 I	5.71e-02 H			☒	190 N	210 N	14 N	20000 N	780 N	240 E	2 E
1,1,1-Trichloroethane	71556	9.00E-02 W	2.86E-01 W			☒	1300 N	1000 N	120 N	180000 N	7000 N	980 E	0.9 E
1,1,2-Trichloroethane	79005	4.00E-03 I		5.70E-02 I	5.60E-02 I	☒	0.19 C	0.11 C	0.055 C	100 C	11 C	0.8 E	0.01 E
Trichloroethylene (TCE)	79016	6.00E-03 E		1.10E-02 W	6.00E-03 E	☒	1.6 C	1 C	0.29 C	520 C	58 C	3 E	0.02 E
Trichlorofluoromethane	75694	3.00E-01 I	2.00E-01 A			☒	1300 N	730 N	410 N	610000 N	23000 N	790 N	13 N
2,4,5-Trichlorophenol	95954	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N	8200 S	120 E
2,4,6-Trichlorophenol	88062			1.10E-02 I	1.09E-02 I		6.1 C	0.57 C	0.29 C	520 C	58 C	150 C	0.06 E
2,4,5-Trichlorophenoxyacetic acid	93765	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
2-(2,4,5-Trichlorophenoxy)propionic acid	93721	8.00E-03 I					290 N	29 N	11 N	16000 N	630 N		
1,1,2-Trichloropropane	598776	5.00E-03 I				☒	30 N	18 N	6.8 N	10000 N	390 N	13 N	0.14 N
1,2,3-Trichloropropane	96184	6.00E-03 I		7.00e+00 I		☒	0.0015 C	0.00089 C	0.00045 C	0.82 C	0.091 C	0.00003 C	6.000E-06 C
1,2,3-Trichloropropene	96195	5.00E-03 H				☒	30 N	18 N	6.8 N	10000 N	390 N		
1,1,2-Trichloro-1,2,2- trifluoroethane	76131	3.00E+01 I	8.57E+00 H			☒	59000 N	31000 N	41000 N	1E+06 N	1000000 N	2400 S	3100 N
Tridiphane	58138082	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Triethylamine	121448		2.00E-03 I				73 N	7.3 N					
Trifluralin	1582098	7.50E-03 I		7.70E-03 I			8.7 C	0.81 C	0.41 C	740 C	83 C		
**1,2,4-Trimethylbenzene	95636	5.00e-02 E				☒	300 N	180 N	68 N	100000 N	3900 N		
**1,3,5-Trimethylbenzene	108678	5.00e-02 E				☒	300 N	180 N	68 N	100000 N	3900 N	98 S	0.26 M
Trimethyl phosphate	512561			3.70E-02 H			1.8 C	0.17 C	0.085 C	150 C	17 C		
1,3,5-Trinitrobenzene	99354	5.00E-05 I					1.8 N	0.18 N	0.068 N	100 N	3.9 N		
Trinitrophenylmethylnitramine	479458	1.00E-02 H					370 N	37 N	14 N	20000 N	780 N		
2,4,6-Trinitrotoluene	118967	5.00E-04 I		3.00E-02 I			2.2 C	0.21 C	0.11 C	190 C	21 C		
Uranium (soluble salts)	7440611	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Vanadium	7440622	7.00E-03 H					260 N	26 N	9.5 N	14000 N	550 N		
Vanadium pentoxide	1314621	9.00E-03 I					330 N	33 N	12 N	18000 N	700 N		

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
						V	Tap	Ambient		Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	O	Water	Air	Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg	C	µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Vanadium sulfate	36907423	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N		
Vernam	1929777	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Vinclozolin	50471448	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Vinyl acetate	108054	1.00E+00 H	5.71E-02 I				37000 N	210 N	1400 N	1E+06 N	78000 N	370 E	84 E
Vinyl bromide	593602		8.57E-04 I			☒	5.2 N	3.1 N				2 N	0.018 N
Vinyl chloride	75014			1.90E+00 H	3.00E-01 H	☒	0.019 C	0.021 C	0.0017 C	3 C	0.34 C	0.002 E	0.01 E
Warfarin	81812	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N	0.046 N	1800 N
m-Xylene	108323	2.00E+00 H	2.00E-01 W			☒	1400 N	730 N	2700 N	1E+06 N	160000 N	950 S	240 M
o-Xylene	9.55E+04	2.00E+00 H	2.00E-01 W			☒	1400 N	730 N	2700 N	1E+06 N	160000 N	730 S	1.50E+02 M
p-Xylene	1.06E+05		8.57E-02 W			☒	520 N	310 N				1000 S	2.20E+02 M
Xylene (mixed)	1.33E+06	2.00E+00 I				☒	12000 N	7300 N	2700 N	1E+06 N	160000 N	320 E	7.40E+01 E
Zinc	7.44E+06	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N		4.20E+04 E
Zinc phosphide	1.31E+06	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Zineb	1.21E+07	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		

APPENDIX D

DBS&A STANDARD OPERATING PROCEDURES

Closure Plan for
Roswell Compressor Station
Surface Impoundments

Appendix D: DBS&A Standard Operating Procedures

Table of Contents

Section 13.3.1

Drilling Operations

1. PURPOSE

The following provides standard operating guidelines (SOGs) for drilling programs.

2. SCOPE

The SOGs included in this section are applicable to all DBS&A employees and its contractors and subcontractors for the conduct of all drilling activities described in this section. The scope of the guidelines described in this section includes the following topics:

- Drilling Methods
- Drilling Fluids
- Drilling Equipment
- Procedures to Follow During Drilling Programs

Standards for drilling methods and fluids are described in ASTM D 5092-90 ("Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers"). Refer to Driscoll (1986), EPA (September 1986) or Aller et al. (1989) for more detailed guidelines about the above subjects as they relate to the drilling of monitor and extraction wells and borings. Site-specific work plans or sampling plans should identify any special needs or circumstances beyond those described in this SOG.

3. GUIDELINES

3.1 Drilling Methods (ASTM D 5092-90)

The drilling method required to create a stable, open, vertical borehole for drilling a borehole or installation of a monitor or extraction well shall be selected according to the site geology, the site hydrology, and the intended use of the data. Tables 13.3.1-1 and 13.3.1-2 list common drilling methods and will aid in the selection of an appropriate drilling method. Table 13.3.1-1 lists the advantages and disadvantages of the different types of drilling methods. Table 13.3.1-2 assesses the performance of different drilling methods in various types of geologic formations.

3.2 Drilling Fluids (ASTM D 5092-90)

Whenever feasible, drilling procedures should be used that do not require the introduction of water or drilling fluids into the borehole and that optimize cuttings control at ground surface. Where the use of drilling fluids is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process (see Section 13.4.3). If an air compressor is used, it should be equipped with an oil air filter or oil trap.

Water-based drilling fluids are preferred if drilling fluids are needed for the drilling of monitor and extraction wells and borings. Water-based drilling fluids have the least influence on the ground-water quality in the area of drilling. However, potential problems created by the use of water-based drilling fluids need to be kept in mind. These problems include: (1) fluid infiltration/flushing of the intended monitoring zone; (2) well development difficulties (particularly where an artificial filter pack has been installed); (3) chemical, biological and physical reactivity of the drilling fluid with indigenous fluids in the ground; and (4) introduction of halomethanes into the ground water.

3.2.1 Drilling Fluid Properties

The drilling subcontractor is responsible for checking and adjusting the properties (weight and viscosity) of the drilling fluid. The proper weight of the drilling fluid is needed to maintain stability of the borehole, and the proper viscosity controls the ability of the drilling fluid to remove cuttings from the borehole. However, the DBS&A Technical Representative should always make sure that the drilling contractor periodically checks the properties of the drilling fluid.

One simple and common way to measure the viscosity of the drilling fluid is a Marsh Funnel. With the use of a Marsh Funnel, a known volume of drilling fluid is allowed to drain from a special funnel into a cup; the flow time is recorded and calibrated against the time required for an equal volume of water to drain from the funnel [approx. 26 seconds @ 70° F (21.1° C)].

Table 13.3.1-3 describes typical additive concentrations, resulting viscosities, and required uphole velocities for major types of drilling fluids used in various aquifer materials. Table 13.3.1-4 charts drilling fluid weight adjustments with barite or water.

3.2.2 Guidelines for Solving Specific Drilling Fluid Problems (Driscoll, 1986)

The drilling subcontractor is responsible for any drilling fluid problems. However, the DBS&A Technical Representative and Field Representative should be aware of and recognize the problems that may arise. Below are some guidelines for solving specific drilling fluid problems which may be helpful to the DBS&A Technical Representative:

PROBLEM: Inadequate cuttings have been removed from the borehole.

RECOMMENDED ACTION:

1. Clays and polymeric solids in potable water
   a. Increase uphole velocity of the drilling fluid.
   b. Increase viscosity of the drilling fluid by adding more colloidal material.
   c. Increase density of the drilling fluid by adding weighting material (Tables 13.3.1-3 and 13.3.1-4).
   d. Reduce penetration rate to limit cuttings load.
2. Air
   a. Increase uphole velocity of fluid system by adding air or water.
   b. Add surfactant to produce foam or to increase concentration of surfactant.
   c. Decrease air injection rate if air is breaking through the foam mix and preventing formation of stable foam.

   d. Decrease water content of the foam system.

PROBLEM: The rate at which cuttings will drop out is too low because the inadvertent addition of native clays during drilling has produced excessive viscosity in the drilling fluid.

RECOMMENDED ACTION:

1. Add potable water to dilute the drilling fluid (Table 13.3.1-4).
2. Add commercial thinner to reduce the attractive forces between clay colloids.
3. If using clay additives, convert to a polymeric system.
4. Separate the solids from a clay-additive system with a shale shaker or shale shakers and desanders connected in series. A shale shaker or desander may be unnecessary when a polymeric system is being used.
5. Redesign or clean the pit system to increase rate of cuttings settlement.

PROBLEM: Gel strength becomes too great because of strong flocculation, high concentration of solids, or contamination from evaporite deposits or cement. (Excessive gel-strength problems do not occur with polymeric colloids.)

RECOMMENDED ACTION:

1. Add potable water to dilute the drilling fluid.
2. Add polyphosphate or commercial thinner to reduce electrical charges between clay colloids.
3. Use desander or shale shaker to remove solids from a clay-additive system.
4. Lower the pH.

PROBLEM: Excessive fluid loss into the formation causes thick filter cakes that can produce tight places in the hole, development problems, formation (clay) sloughing, and misinterpretation of electric or gamma-ray logs.

RECOMMENDED ACTION:

1. Increase viscosity by adding bentonite or polymeric colloids to any water-based system.
2. Add commercial viscosifiers such as CMC or HEC.
3. Reduce density of the drilling fluid.
4. Prevent drastic changes in downhole pressures and maintain downhole pressures at a minimum. Suggestions include (Bariod):
   a. Raise and lower the drill string slowly.
   b. Drill through any tight section; do not spud.
   c. Begin rotation of the drill pipe, and then start the pump at a low rate and gradually increase the rate.
   d. Operate the pump at the lowest rate that will assure adequate cooling of the bit and removal of cuttings from the bit face.

   e. Prevent balling at the bit; do not drill soft formations so fast that the annulus becomes overloaded and pressure builds up.

PROBLEM: Lost circulation in permeable formations, faulted and jointed rock, solution cavities in dolomite and limestone, or fractures created by excessive borehole pressures in semiconsolidated or well consolidated rock can all create problems.

RECOMMENDED ACTION:

1. Reduce the density of the drilling fluid system.
2. Switch from a clay-additive drilling fluid system to an air-foam fluid, or add surfactant to a dry-air system.
3. Gel natural polymeric fluids at the point of fluid loss.
4. Use commercial sealing materials.
5. Drill remainder of the hole with a cable tool rig.
6. Case off, then resume rotary drilling.
7. Fill the borehole with clean sand to the point above lost circulation. Let the material stand in borehole overnight. Resume drilling, using low pump pressure.

PROBLEM: Confined pressures in the formation can contribute to a problem.

RECOMMENDED ACTION:

1. Increase density by adding heavy mineral additives such as barite to drilling fluid systems made with clay additives (Table 13.3.1-4). To suspend barite, the minimum Marsh funnel viscosity must equal four times the final (desired) drilling fluid weight (in lb/gal).

2. Increase density by adding a salt solution to polymeric drilling fluid systems.

PROBLEM: Hydration (swelling and dispersion), pore pressures, and overburden pressure can cause shale sloughing.

RECOMMENDED ACTION:

1. Use polymeric additive to isolate water from shale.
2. Maintain constant fluid pressures in the borehole.
3. Minimize uphole velocities.
4. Avoid pressure surges caused by raising or lowering drill rods rapidly.
5. Add 3 to 4 percent potassium chloride (KCl) to water-based systems.
6. Raise the pH of the drilling fluid to stiffen the clay.

PROBLEM: Contaminants are present. Contaminants usually consist of cement, soluble salts, and gases (hydrogen sulfide and carbon dioxide). Cement in the hole can cause polymeric drilling fluids to break down, thereby increasing fluid losses. Salts may cause drilling fluids with clay additives to separate into liquid and solid fractions. Gases in water may affect the physical condition of the drilling fluid.

RECOMMENDED ACTION:

1. For cement problems:
   a. Maintain the pH for natural polymeric drilling fluids at 7 or lower.
   b. Add commercial chemicals such as sodium acid pyrophosphate to drilling fluids with clay additives to restore original viscosity.
2. For salt problems:
   a. Change the clay additive from montmorillonite to attapulgite.
   b. Change to a natural polymeric drilling fluid additive.
3. For gas problems:
   a. Add a corrosion inhibitor.

PROBLEM: Drilling at air temperatures significantly below freezing, causing freeze-up of the recirculation system.

RECOMMENDED ACTION:

1. Add sodium chloride (NaCl) or calcium chloride ($CaCl_2$) to a natural polymeric drilling fluid. Salt must not be added to a drilling fluid made with bentonite.

3.3 Drilling Equipment

DBS&A Form Nos. 116 6/93 and 117 6/93, attached to this SOG, are checklists used for the preparation of drilling programs. These two checklists should be used as communication guides between DBS&A and the drilling subcontractor. They should be completed and checked prior to the field stage of the drilling program by both DBS&A and the drilling subcontractor. Form No. 116 6/93 summarizes important phone contacts, length of job, type of rig, underground utility survey, geologic material, sampling, disposal of cuttings, wells and soil borings, grouting, and health and safety issues. Form No. 117 6/93 identifies the drilling equipment and support vehicles that are needed for the drilling program.

3.4 Guidelines to Follow During Drilling Activities

1. A drilling method should be selected that will cause minimal disturbance to the subsurface materials and will not contaminate the subsurface and ground water (40 CFR 265.91(c)).

2. The drilling contractor is responsible for decontaminating the drilling equipment before it is transported onto the project site (ASTM D 5088-90).

3. A decontamination procedure should be followed before use and between borehole locations to prevent cross contamination of wells where contamination has been detected

or is suspected from the site characterization work that precedes the drilling activities (ASTM D 5088-90).

4. The drilling contractor shall be responsible for securing any and all boring or well drilling permits required by state or local authorities and for complying with any and all state or local regulations with regard to the submission of well logs, samples, etc.

5. The drilling contractor shall be responsible for complying with any and all (to include placement) regulations with regard to drilling safety and underground utility detection.

6. Air systems shall not be used for drilling, well installation, well development, or sampling without prior approval by the Project Manager. When used, air systems shall include an air line oil filter, frequently replaced, to remove essentially all oil residue from the air compressor. The use of any air system shall be fully described in the drillers log to include equipment description, manufacturer(s), model(s), air pressures used, frequency of oil filter change and evaluation of air line filtering.

7. When air is used as the drilling fluid, shrouds, canopies, bluooey lines, or directional pipes should be used to contain and direct the drill cuttings away from the drill crew.

8. Any water that is used during the drilling and installation of a well should be of a known chemical source and verified not to alter or impact the chemistry of the ground water of the operation of the well.

9. When using commercially available mud or additives for the drilling fluid, DBS&A Technical Representatives and Field Representative should make sure that the mud or additives to not alter or affect the chemistry of the ground water or the operation of the well.

10. During rotary drilling, the use of portable recirculation tanks is required. No dug sumps (lined or unlined) are allowed without prior approval by the Project Manager.

11. No dyes, tracers, or other substances shall be used or otherwise introduced into borings, wells, lysimeters, grout, backfill, ground water, or surface water unless specifically approved by the Technical Project Manager.

12. For wells over 100-feet deep, plumbness and alignment should be checked at preselected intervals during the drilling of the boreholes by the driller and verified by the DBS&A Field Representative.

13. Any contaminated materials (soil and/or water) should be collected and disposed of in an approved waste disposal container or facility.

14. Soil descriptions, collection of samples, field monitoring, and other pertinent information shall be recorded on the Boring Log Form during drilling operations. The Boring Log

Form, soil logging procedures, and instructions for completing the Boring Log Form are included in Section 13.3.2 of the Operations Manual

4. ATTACHMENTS

- Table 13.3.1-1, Drilling Methods for Monitor Wells
- Table 13.3.1-2, Relative Performance of Different Drilling Methods in Various Types of Geologic Formations
- Table 13.3.1-3, Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials
- Table 13.3.1-4, Drilling Fluid Weight Adjustment with Barite or Water
- Drilling Information Checklist (DBS&A Form No. 116)
- Drilling Equipment and Support Vehicle Checklist (DBS&A Form No. 117)

5. REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Well Design and Installation. National Well Water Association. Dublin, OH. 398 p.

Driscoll, F.G. 1986. Groundwater and Wells. Johnson Division. St. Paul, MN. 1089 p.

EPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, U.S. EPA. Washington, D.C. September. 208 p. and 3 Appendices.

Prepared by: Natalie L. Ala

Reviewed by: Larry M. Com
Quality Assurance Manager

Approved by: DBS
Daniel B. Stephens

Reviewed by: Larry M. Com
Systems Operations Manager

Table 13.3.1-1 Drilling Methods for Monitor Wells

Type	Advantages	Disadvantages
Hollow-stem auger	• No drilling fluid is used, eliminating contamination by drilling fluid additives • Formation waters can be sampled during drilling by using a screened auger or advancing a well point ahead of the augers • Formation samples taken by split-spoon or core-barrel methods are highly accurate • Natural gamma-ray logging can be done inside the augers • Hole caving can be overcome by setting the screen and casing before the augers are removed • Fast • Rigs are highly mobile and can reach most drilling sites • Usually less expensive than rotary or cable tool drilling	• Can be used only in unconsolidated materials • Limited to depths of 100 to 150 ft (30.5 to 45.7 m) • Possible problems in controlling heaving sands • May not be able to run a complete suite of geophysical logs
Direct rotary	• Can be used in both unconsolidated and consolidated formations • Capable of drilling to any depth • Core samples can be collected • A complete suite of geophysical logs can be obtained in the open hole • Casing is not required during drilling • Many options for well construction • Fast • *Smaller rigs can reach most drilling sites* • Relatively inexpensive	• Drilling fluid is required and contaminants are circulated with the fluid • Drilling fluid mixes with the formation water and invades the formation and is sometimes difficult to remove • Bentonitic fluids may absorb metals and may interfere with other parameters • Organic fluids may interfere with bacterial analyses and/or organic-related parameters • During drilling, no information can be obtained on the location of the water table and only limited information on water-producing zones • Formation samples may not be accurate

Table 13.3.1-1 Drilling Methods for Monitor Wells (continued)

Type	Advantages	Disadvantages
Air rotary	• No water-based drilling fluid is used, eliminating contaminantion by additives • Can be used in both unconsolidated and consolidated formations • Capable of drilling to any depth • Formation sampling is excellent in hard, dry formations • Formation water blown out of the hole makes it possible to determine when the first water-bearing zone is encountered • Field analysis of water blown from the hole can provide information regarding changes for some basic water-quality parameters such as chlorides • Fast	• Casing is required to keep the hole open when drilling in soft, caving formations below the water table • When more than one water-bearing zone is encountered and hydrostatic pressures are different, flow between zones occurs during the time drilling is being completed and before the borehole can be cased and grounted properly • Relatively more expensive than other methods • May not be economical for small jobs
Cable Tool	• Only small amounts of drilling fluid are required (generally water with no additives) • Can be used in both unconsolidated and consolidated formations; well suited for extremely permeable formations • Can drill to depths required for most monitoring wells • Highly representative formation samples can be obtained by an experienced driller • Changes in water level can be observed • Relative permeabilities for different zones can be determined by skilled drillers • A good seal between casing and formation is virtually assured if flush-jointed casing is used • Rigs can reach most drilling sites • Relatively inexpensive	• Minimum casing size is 4 in (102 mm) • Steel casing must be used • Cannot run a complete suite of geophysical logs • Usually a screen must be set before a water sample can be taken • Slow

(After Driscoll, 1987)

Table 13.3.1-2 Relative Performance of Different Drilling Methods in Various Types of Geologic Formations

Type of Formation	Cable Tool	Direct Rotary (with fluids)	Direct Rotary (with air)	Direct Rotary (Down-the-hole air hammer)	Direct Rotary (Drill-through casing hammer)	Reverse Rotary (with fluids)	Reverse Rotary (Dual Wall)	Hydraulic Percussion	Jetting	Driven	Auger
Dune sand	2	5	NR	NR	6	5*	6	5	5	3	1
Loose sand and gravel	2	5	NR	NR	6	5*	6	5	5	3	1
Quicksand	2	5	NR	NR	6	5*	6	5	5	NR	1
Loose boulders in alluvial fans or glacial drift	3-2	2-1	NR	NR	5	2-1	4	1	1	NR	1
Clay and silt	3	5	NR	NR	5	5	5	3	3	NR	3
Firm shale	5	5	NR	NR	5	5	5	3	NR	NR	2
Sticky shale	3	5	NR	NR	5	3	5	3	NR	NR	2
Brittle shale	5	5	NR	NR	5	5	5	3	NR	NR	NA
Sandstone-poorly cemented	3	4	NR	NR	NA	4	5	4	NR	NR	NA

*Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures)

NR = Not recommended
NA = Not applicable

Rate of Penetration:

1	Impossible	4	Medium
2	Difficult	5	Rapid
3	Slow	6	Very rapid

(After Driscoll, 1987)

Table 13.3.1-2 Relative Performance of Different Drilling Methods in Various Types of Geologic Formations (continued)

Type of Formation	Cable Tool	Direct Rotary (with fluids)	Direct Rotary (with air)	Direct Rotary (Down-the-hole air hammer)	Direct Rotary (Drill-through casing hammer)	Reverse Rotary (with fluids)	Reverse Rotary (Dual Wall)	Hydraulic Percussion	Jetting	Driven	Auger
Sandstone-well cemented	3	3	5	NR	NA	3	5	3	NR	NR	NA
Chert nodules	5	3	3	NR	NA	3	3	5	NR	NR	NA
Limestone	5	5	5	6	NA	5	5	5	NR	NR	NA
Limestone with chert nodules	5	3	5	6	NA	3	3	5	NR	NR	NA
Limestone with small cracks or fractures	5	3	5	6	NA	2	5	5	NR	NR	NA
Limestone, cavernous	5	3-1	2	5	NA	1	5	1	NR	NR	NA
Dolomite	5	5	5	6	NA	5	5	5	NR	NR	NA

*Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures)

NR = Not recommended
NA = Not applicable

Rate of Penetration:

1	Impossible	4	Medium
2	Difficult	5	Rapid
3	Slow	6	Very rapid

(After Driscoll, 1987)

Table 13.3.1-2 Relative Performance of Different Drilling Methods in Various Types of Geologic Formations (continued)

Type of Formation	Cable Tool	Direct Rotary (with fluids)	Direct Rotary (with air)	Direct Rotary (Down-the-hole air hammer)	Direct Rotary (Drill-through casing hammer)	Reverse Rotary (with fluids)	Reverse Rotary (Dual Wall)	Hydraulic Percussion	Jetting	Driven	Auger
Basalts, thin layers in sedimentary rocks	5	3	5	6	NA	3	5	5	NR	NR	NA
Basalts-thick layers	3	3	4	5	NA	3	4	3	NR	NR	NA
Basalts-highly fractured (lost circulation zones)	3	1	3	3	NA	1	4	1	NR	NR	NA
Metamorphic rocks	3	3	4	5	NA	3	4	3	NR	NR	NA
Granite	3	3	5	5	NA	3	4	3	NR	NR	NA

*Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures)

NR = Not recommended
NA = Not applicable

Rate of Penetration:

1	Impossible	4	Medium
2	Difficult	5	Rapid
3	Slow	6	Very rapid

(After Driscoll, 1987)

Table 13.3.1-3 Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials

Base Fluid	Additive/Concentration	Marsh Funnel Viscosity (seconds)	Annular Uphole Velocity (ft/min)	Observations
Water	None	26 ± 0.5	100 - 120	For normal drilling (sand, silt, and clay)
Water	Clay (High-Grade Bentonite)			Increases viscosity (lifting capacity) of water significantly
	15-25 lb/100 gal	35 - 55	80 - 120	For normal drilling conditions (sand, silt, and clay)
	25-40 lb/100 gal	55 - 70	80 - 120	For gravel and other coarse-grained, poorly consolidated formations
	35-45 lb/100 gal	65 - 75	80 - 120	For excessive fluid losses
Water	Polymer (Natural)			Increases viscosity (lifting capacity) of water significantly
	4.0 lb/100 gal	35 - 55	80 - 120	For normal drilling conditions (sand, silt, and clay)
	6.1 lb/100 gal	65 - 75	80 - 120	For gravel and other coarse-grained, poorly consolidated formations
	6.5 lb/100 gal	75 - 85	80 - 120	For excessive fluid losses
				Cuttings should be removed from the annulus before the pump is shut down, because polymeric drilling fluids have very little gel strength
Air	None	N/A	3,000-5,000	Fast drilling and adequate cleaning of medium to fine cuttings, but may be dust problems at the surface
			4,500-6,000	This range of annular uphole velocities is required for the dual-wall method of drilling
Air	Water (Air Mist) 0.25-2 gpm	N/A	3,000-5,000	Controls dust at the surface and is suitable for formations that have limited entry of water

Table 13.3.1-3 Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials (continued)

Base Fluid	Additive/ Concentration	Marsh Funnel Viscosity (seconds)	Annular Uphole Velocity (ft/min)	Observations
Air	Surfactant/Water (Air-Foam)	N/A	50-1,000	Extends the lifting capacity of the compressor
	1-2 qt/100 gal (0.25-0.5% surfactant)			For light drilling; small water inflow; also for sticky clay, wet sand, fine gravel, hard rock; few drilling problems
	2-3 qt/100 gal (0.5-0.75% surfactant)			For average drilling conditions; larger diameter, deeper holes; large cuttings; increasing volumes of water inflow; excellent hole cleaning
	3-4 qt/100 gal (0.75-1% surfactant)			For difficult drilling; deep, large-diameter holes; large, heavy cuttings; sticky and incompetent formations; large water inflows
				Injection rates of surfactant/water mixture: Unconsolidated formations 3-10 gpm Fractured rock 3-7 gpm Solid rock 3-5 gpm
Air	Surfactant/Colloids/Water (Stiff Foam)	N/A	50-100	Greatly extends lifting capacity of the compressor
	3-5 qt/100 gal (0.75-1% surfactant) plus 3-6 lb polymer/100 gal or 30-50 lb bentonite/100 gal			For difficult drilling; deep, large-diameter holes; large, heavy cuttings; sticky and incompetent formations; large water inflows
	4-8 qt/100 gal (1-2% surfactant) plus 3-6 lb polymer/100 gal or 30-50 lb bentonite/100 gal			For extremely difficult drilling; large, deep holes; lost dirculation; incompentent formations; excessive water inflows

(Compiled by Driscoll, 1984)

Table 13.3.1-4 Drilling Fluid Weight Adjustment with Barite or Water

Initial drilling fluid weight, lb/gal	Desired drilling fluid weight, lb/gal											
	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	1.0	14.5	15.0
9.0	69	140	214	293	371	457	545	638	733	833	940	1050
9.5		69	143	219	298	381	467	557	650	750	855	964
10.0	43		71	145	221	305	390	479	569	667	769	876
10.5	85	30		74	148	229	312	398	488	583	683	788
11.0	128	60	23		74	152	233	319	407	500	598	700
11.5	171	90	46	19		76	157	240	326	417	512	614
12.0	214	120	69	37	16		79	160	245	333	426	526
12.5	256	150	92	56	32	14		81	162	250	343	438
13.0	299	180	115	75	48	27	12		81	167	257	350
13.5	342	210	138	94	63	41	24	11		83	171	264
14.0	385	240	161	112	78	54	36	21	10		86	176
14.5	427	270	185	131	95	68	48	32	19	9		88
15.0	470	300	208	150	110	82	60	43	29	18	8	

The lower left half of this table shows the number of gallons of water which must be added to 100 gal of drilling fluid to produce desired weight reductions. To use this portion of the table, locate the initial drilling fluid weight in the vertical column at the left, then locate the desired drilling fluid weight in the upper horizontal row. The number of gal of water to be added per 100 gal of drilling fluid is read directly across from the initial weight and directly below the desired weight. For example, to reduce an 11 lb/gal drilling fluid to a 9.5 lb/gal drilling fluid, 128 gal of water must be added for every 100 gal of drilling fluid in the system.

The upper right half of this table shows the number of pounds of barite which must be added to 100 gal of drilling fluid to produce desired weight increases. To use this portion of the table, locate the initial drilling fluid weight in the vertical column to the left, then locate the desired drilling fluid weight in the upper horizontal row. The number of pounds of barite to be added per 100 gal of drilling fluid is read directly across from the initial weight and directly below the desired weight. For example, to raise a 9 lb/gal drilling fluid to 10 lb/gal, 140 lb of barite must be added per 100 gal of drilling fluid in the system.

(*After Petroleum Extension Service, 1969*)

DANIEL B. STEPHENS & ASSOCIATES, INC.

Drilling Information Checklist

Project No. ____________ DBS&A Project Manager ____________

DBS&A Technical Representative ____________ DBS&A Field Representative(s) ____________

Drilling Company ____________

Drilling Company Contact ____________ Phone No. ____________

Date and Time for Work to Begin ____________

Estimated Work Days to Complete Job ____________ Access Agreements ____________

Drilling Rig ____________ Driller and Assistant(s) ____________

☐ Hollow Stem Auger ☐ Air/Mud Rotary ☐ Cable Tool ☐ Dual-Tube Air Percussion ☐ Coring Rig

Blu-Stake (NM call 1-800-321-2537 for most utilities) Contacted By ____________

One Week Authorization No. ____________ Date. ____________

Underdetection Services (Private Co.) ____________

Client Contact ____________ Phone No. ____________

Job Site ____________ Phone No. ____________

Location ____________

Surface ☐ Asphalt ☐ Concrete ☐ Dirt ☐ In Roadway

Geologic Material ____________

Sampling Device ☐ Splitspoon ☐ Thin-walled Tube ☐ 140 lb. Hammer (SPT) ☐ Coring

Sampling Length ☐ 12" ☐ 18" ☐ 24" With Rings ☐ 3" ☐ 6"

Sampling Interval(s) ____________

Disposal of Cuttings ☐ Drummed ☐ Leave On-site

Contain Decontamination Water ____________

Hole Diameter	**No. of Borings**	**Total Footage**	**Maximum Depth**	
Well Diameter	**No. of Wells**	**Total Footage**	**Depth to Water**	**Screen Length/Slot Size**

Grouting ☐ Place Bentonite Seal ☐ Grout to Surface ☐ Backfill

Mixed On-site by Drilling Co. ____________ Cement Truck Delivers Grout ____________

Poured from Surface Through Drill Pipe ____________

Pumped Through Tremie Pipe ____________

Water On-site ☐ Yes ☐ No Electricity ☐ Yes ☐ No

Level of Protection ☐ A ☐ B ☐ C ☐ D Health & Safety Plan By ____________

Potential Contaminants ____________ Other Hazards ____________

DBS&A Form No. 116 6/93

DANIEL B. STEPHENS & ASSOCIATES, INC.

Drilling Equipment and Support Vehicle Checklist

Project No. ______________ DBS&A Project Manager ______________

DBS&A Technical Representative ______________ DBS&A Field Representative(s) ______________

Drilling Company ______________

Drilling Company Contact ______________ Phone No. ______________

Date and Time for Work to Begin ______________

Material	Size	Quantity	Equipment Supplier*
Drill Bit			
Rotary Drilling Pipe			
Hollow Stem Auger (O.D. x I.D: 10"x6.25" or 8"x4.25" + Total Footage)			
Dual-Tube Pipe (O.D. / I.D)			
Water Tank			
Steam Cleaner			
Decontamination Trailer to Contain Water from Steam Cleaning			
Drums			
Tank to Mix Grout			
Tremie Pipe			
Grout Pump			
Wooden Plugs (Flowing Sand)			
Welder			
Concrete Saw (Other Subcontractor)			
Development Rig (Bailers, Surge Block, Pump)			
Plastic Sheeting			
Sampler (Length and Type)			
Core Catchers			
Rings - Brass			
Rings - Stainless Steel			
Endcaps			
Teflon Liners			
Tagline (Length and Type)			

DBS&A Form No. 117 Rev. 12/93

*DBS&A or Other (specify)

Section 13.3.2

Soils Logging, Sampling, Handling, and Shipping for Geotechnical and Chemical Analyses

1. PURPOSE

The following SOP describes the appropriate procedures for the logging, sampling, handling, and shipping of soil during soil boring investigations. Sampling methodologies and shipping requirements are provided for collection of geotechnical, physical, and chemical soil samples.

2. SCOPE

This procedure is applicable to all DBS&A employees and subcontractors who are engaged in soil boring activities. It provides the minimum logging requirements, sampling protocols, and shipping requirements for soil boring investigations. The appropriate form for logging soil is included in this SOP as Attachment 1, Soil Boring Log (DBS&A Form No. 080). A soils classification chart is included as Attachment 2. Tables 13.3.2-1 and 13.3.2-2 provide handling and transport, and volume requirements for soil physical analysis samples, respectively.

3. PROCEDURES

3.1 Soils Logging

Soil descriptions and other pertinent information will be recorded on the Soil Boring Log form during boring operations. The Soil Boring Form contains a header for recording the boring specifics and a log for describing and classifying soil and tracking soil sampling. Soils will be identified and described in accordance with ASTM D 2488, Standard Practice for Description and Identification of Soil (Visual-Manual Practice). Table 13.3.2-3 provides a list of equipment that may be required for soils logging, sampling, handling, and shipping.

3.1.1 Completing the Header

Most of the header is self-explanatory. On the first page of the log, it is important to complete the entire header. If subsequent forms are necessary, complete the page number, the site, the client, the person logging the soil, the boring number, and the date. On the first page, sketch a location map for the boring, referencing it to known features or landmarks. When specifying the drilling method and drill rig, note the diameter of the drill bit or augers.

3.1.2 Completing the Boring Log

PID/FID - record head space measurements made with the PID/FID in this column in the appropriate depth interval from which the sample was collected.

Blow Counts - if driving a split-barrel sampling device with a hammer, record the number of hammer "blows" per 6 inches of penetration. Ensure that the driller marks the 6 inch intervals on the drill stem prior to hammering the split-barrel.

Sampling Device - specify the sampling device (i.e., split-barrel, split-barrel with brass or stainless steel rings, Shelby tube); specify the inside diameter of the sampling device.

Sample Interval - specify the sampling interval (starting and finishing) by placing an "X" across the appropriate depth interval in this column.

Sample Recovery - state, in tenths of feet, the amount of sample which is recovered.

Sample Number - record the designated sample number in this column.

Depth (Feet) - complete this column in 5-foot intervals to keep a running tally of the depth of the borehole.

USCS Symbol - provide the USCS symbol for the soil be described; draw a solid contact line at the appropriate depth to signify changes in soil type.

Soil Description - describe the soil in the format listed on the boring log; for non-cohesive soils, estimate the grain distribution, gradation, and grain shape; for cohesive soils, note the plasticity and clay consistency; if possible, a soil classification and geotechnical gauge and a color chart should be used to aid in describing soil.

3.2 Soil Sampling

Soil samples will typically be collected for geotechnical, physical, or chemical analysis. Geotechnical samples will be collected with a split-barrel sampler lined with brass rings or in the case of cohesive soils to be analyzed for compressive strength, a thin-walled tube sampler. Chemical samples will be collected with an unlined split-barrel sampler or a ring-lined split-barrel sampler. Regardless of which sampling device is employed, care should be taken to minimize slough in the borehole. Slow withdrawal of the drill bit prior to sampling will minimize slough. When drilling below the water table, ensure that the water level in the borehole (or within driven casing) is maintained at or above the water table elevation.

3.2.1 Geotechnical/Physical Properties Samples

Geotechnical and/or physical properties samples will be collected with either a ring-lined split-barrel sampler or a thin-walled Shelby tube. If possible, use a ring-lined sampler for physical properties analysis. For triaxial and unconfined compression tests, either a ring-lined sampler or a thin-walled tube sampler may be employed. For cohesive soils, the thin-walled tube sampler should be used for obtaining the least disturbed samples. In non-cohesive soils, a ring-lined sampler is required because of poor sample recovery experienced with a thin-walled sampler.

3.2.1.1 Ring-lined Split-Barrel Sampler (ASTM D 3350)

1. Assemble the sampler with the specified rings. For physical properties analysis, the typical ring is 3 inches in length and constructed of brass. Ring requirements will be specified in the Field Sampling Plan (FSP).

2. Attach the sampler to the drill stem and carefully lower it to the bottom of the borehole.

3. Hydraulically push the sampler into the soil in a rapid, continuous manner to a length not to exceed that of the sampler. In dense, non-cohesive soils, the sampler may have to be driven. If so, record the blow counts.

4. *Carefully disassemble the sampler to minimize soil disturbance. Trim the individual rings flush with a* clean knife, and place plastic caps over the ring ends. Use the soil in one of the rings for field classification. Secure the caps with tape and label the ring, including the vertical orientation.

5. The samples can be shipped in a dry cooler. If the possibility exists the samples will be handled roughly, pack them with shipping material in the cooler.

3.2.1.2 Thin-Walled Tube Sampler (ASTM D 1587)

1. *Attach the sampling tube to the drill stem and carefully lower to the bottom of the borehole.*

2. Rapidly and continuously hydraulically push the Shelby tube a distance of 5 to 10 times the tube diameter in non-cohesive soils and 10 to 15 times the diameter in cohesive soils. In dense, non-cohesive soils it is permissible to drive the sampler. Record the blow counts. It is permissible to "twist" the drill stem to shear the sample bottom prior to retrieval.

3. Carefully withdraw the sampler from the formation to minimize disturbance.

4. *The sample can be shipped either unextruded or after extrusion at the site.*

   Unextruded - Measure the length of the sample in the tube. Remove any slough from the top of the tube. Remove at least 1 inch of soil from the bottom of the tube for field classification. Seal the top and bottom of the tube with plastic caps and secure with tape.

   Extruded - Following extrusion, select a 12- to 15-inch segment of the sample which appears least disturbed. Carefully cut the ends with a clean knife, and immediately wrap the sample in cellophane wrap, then aluminum foil. Place the sample in a plastic tube, and cap the ends. Describe the soil with the remainder of the sample. Describe the prepared interval to the extent practicable. ***DO NOT*** cut or disturb the interval to be submitted to the laboratory.

5. The samples can be shipped in a similar manner as described in 3.2.1.1(5) above.

3.2.2 Soil Chemistry Samples

Soil chemistry samples can be collected with either the split-barrel sampler or with the ring-lined split-barrel sampler. The primary difference in the two methods is the preparation of the samples. In the case of samples obtained from the split-barrel, the soil must be transferred to soil containers (typically glass jars). In the case of the ring-lined sampler, the rings will be either stainless steel or brass which are capped with

Teflon-lined caps. The rings are labeled, secured with toluene-free tape, and submitted directly for analysis. Exact sample methods, volumes, containers, preservation, and chain of custody procedures will be outlined in the FSP. In general, for soil matrix samples, EPA SW-846 (EPA, 1986) methods will be specified. Both the split barrel sampler and the ring-lined sampler are hydraulically pushed or driven in the same manner described in 3.2.1.1(2-3) above.

3.2.2.1 Split-Barrel Samples (ASTM D 1586)

1. Upon retrieval of the sample, carefully open the split-barrel. Trim the sample with a decontaminated, sharp stainless-steel knife. Note the general soil type.

2. As quickly as possible, collect samples for volatile organic and semi-volatile organic analysis. Be sure that headspace is minimized in the volatile organic analysis samples. Collect field duplicates and specify that the laboratory perform matrix spike/matrix spike duplicates from the same interval as the sample. Place the samples in certified clean glass jars with Teflon-lined caps.

3. Collect samples for other required analyses. If the FSP specifies mixing the split barrel sample prior to filling additional sample containers, do so in a stainless-steel mixing bowl. Sample volumes and containers will be specified in the FSP.

4. Label the samples in accordance with the FSP. At a minimum, this will include: (1) the sample number; (2) boring number and interval (if different from the sample number); (3) time and date; and (4) required analysis. If chain of custody seals are required, secure them across the container lid.

5. Place the sample containers in "ziplock" bags and place on ice. Prior to shipment, the sample containers must be wrapped in bubble-pack, or other suitable packing material.

6. Fully describe the soil sample.

7. Log the sample information in the field log book for later transfer to the Chain-of-Custody Form (DBS&A Form No. 095), which is included as Attachment 3 in this SOP.

3.2.2.2 Ring-Lined Split-Barrel Samples (ASTM D 3350)

1. Upon retrieval of the sampler, carefully open the split-barrel. Trim the ends of the rings with a clean stainless-steel knife. Cap the rings with Teflon-lined caps and seal with toluene-free tape.

2. Using one or more of the rings (if possible), and soil trimmed from the ring ends, describe and log the soil.

3. Follow the steps described in 3.2.2.1(5-7) above. Packing material is optional for the ring samples.

3.3 Sample Shipment

Proper shipment of samples is critical for ensuring that reliable analytical results are obtained. In the case of geotechnical or physical properties analysis samples, this involves protecting the samples against excessive impacts which may disturb the samples. For soil chemical analyses, it is important to protect the samples from breakage if they were collected in glass jars. In addition, most chemical methods call for the samples being maintained at a constant 4°C.

3.3.1 Geotechnical and Physical Properties Samples

Shipping requirements for geotechnical and physical properties samples are listed in Table 13.3.2-2. In general, samples should be shipped in a dry cooler. If the cooler is not being hand-carried to the laboratory (i.e., shipped by overnight carrier) the samples should be protected with packing material to prevent sample disturbance. Plastic bubble-wrap, shredded paper, foam "peanuts", and vermiculite provide adequate sample protection when properly used. It is important to provide packing materials between all samples, such that samples do not come in contact. When shipping samples, it important to enclose a chain-of-custody form in the cooler as specified in the FSP.

3.3.2 Soil Chemistry Samples

Soil chemistry samples collected in glass containers must be protected from breakage. Individually wrapping the sample containers in plastic bubble-wrap provides excellent protection. After wrapping the samples in bubble-wrap, they should be placed in sealed "zip-lock" bags. Brass or stainless-steel ring samples need only be placed in sealed "zip-lock" bags. If the FSP calls for chain-of-custody seals to be placed on individual samples, place them across the jar lid or plastic ring cap. Chain-of-custody forms should be filled out in accordance with the FSP, placed in a "ziplock" bag, and taped to the inside of the cooler lid. It is important to use an ample volume of ice in order to maintain the required temperature of 4°C. Chain of custody seals will be placed across the front and back of the cooler lid such that they will be broken in the event of tampering. The cooler lid should be firmly taped shut with several layers of shipping tape encircling the ends of the cooler. Finally, for chemical analyses, *always* ship the samples by overnight carrier.

4.0 REFERENCES

ASTM D 1586-84 Standard Method for Penetration Test and Split-Barrel Sampling of Soils

ASTM D 1587-83 Standard Practice for Thin-Walled Tube Sampling of Soils

ASTM D 2488-90 Practice for Description and Identification of Soils (Visual-Manual)

ASTM D 3350-84 Standard Practice for Ring-Lined Barrel Sampling of Soils

U.S. EPA, 1986, Test Methods for Evaluation of Solid Wastes, SW-846, 3rd Ed.

5.0 ATTACHMENTS

1. Boring Log (DBS&A Form No. 080 3/92)
2. Unified Soil Classification System Chart (DBS&A Form No. 049)
    - Table 13.3.2-1, Soil Physical Sample Handling and Transport
    - Table 13.3.2-2, Soil Physical Sample Volume Requirements
    - Table 13.3.2-3, Soil Sampling Field Equipment List
3. Chain-of-Custody Form (DBS&A Form No. 95)

Prepared by: ____________

Approved by: DBStephens
Daniel B. Stephens

Reviewed by: Larry M. Conn
Quality Assurance Manager

Reviewed by: Larry M. Conn
Systems Operations Manager

DANIEL B. STEPHENS & ASSOCIATES, INC.

Boring Log

Page____of____

Site		Location Map
Logged by	Client/Project #	
Boring Number	Drilling Co.	
Drilling Method	Drill Rig	
Date Started	Date Completed	

PID/FID Reading	Blow Counts	Sampling Device	Sample Recovery	Sample Interval	Sample Number	USCS Symbol	Depth (feet)	*Soil Description/Remarks* Soil type, color, texture, grain size, sorting, roundness, plasticity, consistency, moisture content

DBS&A Form No. 080 3/92

USCS GROUP SYMBOLS

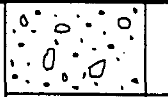
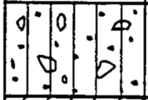
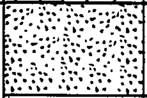
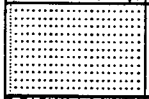
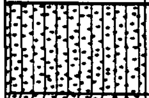
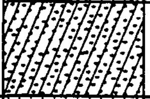
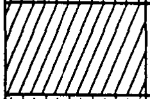
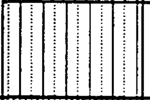
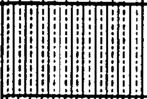
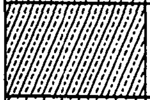
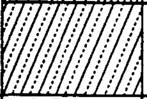
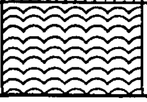
MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
Course Grained Soils More than 50% of Material is Larger than Silt (No. 200 Sieve Size)	Gravel and Gravelly Soils More than 50% of Course Fraction Retained on No. 4 Sieve	Clean Gravels (little or no fines <5%)		GW	Well-graded gravels, gravel-sand mixtures. Little or no fines.
				GP	Poorly-graded gravels. Gravel-sand mixtures. Little or no fines.
		Gravels with Fines (appreciable amount of fines >15%)		GM	Silty gravels. Gravel-sand-silt mixtures.
				GC	Clayey gravels. Gravel-sand-clay mixtures.
	Sand and Sandy Soils More than 50% of Course Fraction Passing No. 4 Sieve	Clean Sand (little or no fines <5%)		SW	Well-graded sands. Gravelly sands. Little or no fines.
				SP	Poorly-graded sands. Gravelly sands. Little or no fines.
		Sands with Fines (appreciable amount of fines >15%)		SM	Silty sands. Sand-silt mixtures.
				SC	Clayey sands. Sand-clay mixtures.
Fine Grained Soils More than 50% of Material is Smaller than Silt (No. 200 Sieve Size)	Silts and Clays	Liquid Limit Less than 50		ML	Inorganic silts and very fine sands. Rock flour. Silty or clayey fine sands or clayey silts with slight plasticity.
				CL	Inorganic clays of low to medium plasticity. Gravelly clays. Sandy clays, silty clays, lean clays.
				OL	Organic silts and organic silty clays or low plasticity.
	Silts and Clays	Liquid Limit Greater than 50		MH	Inorganic silts. Micaceous or diatomaceous fine sand or silty soils.
				CH	Inorganic clays of high plasticity. Fat clays.
				OH	Organic clays of medium to high plasticity. Organic silts.
Highly Organic				PT	Peat, humus, swamp soils with high organic content.

TABLE 13.3.2-1. SOIL PHYSICAL ANALYSIS SAMPLE REQUIREMENTS AND TRANSPORT

PHYSICAL PROPERTY TEST	SAMPLE REQUIREMENT	SHIPPING REQUIREMENT
Soil Moisture	2.5" O.D. x 3" long ring or in double plastic bag with air removed	Dry cooler
Hydraulic Conductivity	2.5" O.D. x 3" sealed ring	Dry cooler
Moisture Retention (Ψ-Θ)	2.5" O.D. x 3" sealed ring	Dry cooler with packing material
Air Permeability	2.5" O.D. x 3" sealed ring	Dry cooler with packing material
Bulk Density	2.5" O.D. x 3" sealed or waxed ring	Dry cooler with packing material
Porosity	2.5" O.D. x 3" sealed ring	Dry cooler with packing material
Specific Gravity	2.5" O.D. x 3" sealed ring or plastic bag for bulk sample	Dry cooler
Particle Size	2.5" O.D. x 3" sealed ring; plastic bag for gravelly soil	Dry cooler
Atterberg Limits	2.5" O.D. x 3" sealed ring or plastic bag	Dry cooler preferred
Proctor Tests	5 gallon plastic bucket or large plastic bags	No shipping requirements
Compression Tests	Unextruded in thin-walled tube; extruded wrapped in cellophane wrap and placed in plastic tube; or 2.5" O.D. x 6" sealed ring	Dry cooler with packing material

TABLE 13.3.2-2. SOIL PHYS[illegible] SAMPLE VOLUME REQUIREMENTS

		PRIMARY TEST REQUESTED											
		Moisture Content (volumetric)	Hydraulic Conductivity K_{sat}	Hydraulic Conductivity K_{unsat}	Moisture Retention $\Psi - \Theta$	Air Permeability K_{air}	Bulk Density	Porosity (Calculated)	Porosity (Air Pycnometer)	Particle Density	Particle Size Analysis	Atterberg Limits	Compaction (Proctor) Test
SAMPLE REQUIREMENTS FOR ADDITIONAL TESTS	Moisture Content (Volumetric)		Same Sample	(3) Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Hydraulic Conductivity	Same Sample		(3) Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Hydraulic Conductivity	(3) Same Sample	Same Sample		Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Moisture Retention	Same Sample	Same Sample	(3) Same Sample		Same Sample	Same Sample	Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Air Permeability	Same Sample	Same Sample	(4) Same Sample	Same Sample		Same Sample	Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Bulk Density	Same Sample	Same Sample	(4) Same Sample	Same Sample	Same Sample		(5) Same Sample	Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Porosity (Calculated)	Same Sample	Same Sample	(4) Same Sample	Same Sample	Same Sample	Same Sample		Same Sample	(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Porosity (Air)	Same Sample	Same Sample	(4) Same Sample	Same Sample	Same Sample	Same Sample	Same Sample		(1) Same Sample	(1) Same Sample	Extra Sample	Extra Sample
	Particle Density	Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	Same Sample	(6) Same Sample	Same Sample		Same Sample	Same Sample	Extra Sample
	Particle Size Analysis	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample	(2) Extra Sample		Extra Sample	Extra Sample
	Atterberg Limits	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Same Sample	Extra Sample		Extra Sample
	Compaction (Proctor)	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	Extra Sample	

(1) Same sample may be run for this additional test provided sample is in a sample ring and meets the sample size requirements for the additional test.

(2) Same sample may be used if sample meets sample size requirements for additional test (is there sufficient sample; usually only fine-grained samples will meet this requirement).

(3) Required for all unsaturated hydraulic conductivity calculations except column imbibition method.

(4) Same sample may be used except for column imbibition test.

(5) Additional test required to perform calculations of primary test.

(6) Additional test preferred for best results of primary test.

TABLE 13.3.2-3. SOIL SAMPLING FIELD EQUIPMENT LIST

	ITEM	DESCRIPTION
1.	Soil Kit	Geologic hammer Electrical and solvent-free tape Flagging tape Assorted sharpies Munsel Soil Color Chart Grain size chart USCS Soil Classification Guide Carpenter's rule (6 feet marked in tenths) Spatulas Dilute Hydrochloride acid
2.	Boring Log forms and clip board	
3.	Field book	
4.	Meters:	Photoionization Detector MX25 explosivity meter Water level meter Flame Ionization Detector or methane meter Geiger-Mueller radiation meter
5.	Tagline:	Fiberglass with weight taped OR Steel tape with steel weight and no tape to attach weight
6.	300-foot fiberglass tape	
7.	Latex gloves (2 or more boxes)	
8.	Health and Safety kits:	Earplugs Hard hat Steel-toed boots Safety glasses Tyvek, Respirator
9.	Coolers:	One for food only 3 or more for samples

TABLE 13.3.2-3. SOILS SAMPLING FIELD EQUIPMENT LIST (CONTINUED)

ITEM	DESCRIPTION
10. Decontamination:	3 plastic tubs Plastic brushes Liquinox Distilled water, 10-15 gallons minimum Paper towels Garbage bags (large/small)
11. Soil sample containers:	Brass rings (for soil physical properties) Stainless steel rings (for organic chem analyses) Teflon liners (for organic chem analyses) Plastic endcaps Sealing tape and/or purifier wax Glass jars (4 or 8 oz for chemical analyses) Quart and gallon ziplock bags

DANIEL B. STEPHENS & ASSOCIATES, INC.

Chain of Custody

To:

______________________ Date __________ Project No. __________

______________________ Client ______________________

______________________ Relinquished by ______________________

Sent by: ☐ Fed Ex ☐ DHL ☐ Other ______________________

Purpose of Shipment ______________________

Possible Contaminants ______________________

Item No.	Sample No.	Analysis to be Done	Sample Container	Comments

Date Received __________ by ______________________
Company Representative

Received the above articles in good condition

Except as noted ______________________

____

____

DBS&A Form No. 095 5/92

Section 13.4.1

Monitor Well Design and Installation

Well Design, Installation, and Abandonment

SECTION 13.4

Effective 01/12/94 • Supersedes n/a • Page 1 of 1

1. PURPOSE

This section provides standard operating procedures (SOPs) and standard operating guidelines (SOGs) for the design, installation, and abandonment of wells.

2. SCOPE

The SOPs and SOGs included in this section are applicable to all DBS&A employees, and its contractors and subcontractors, for the conduct of all activities listed in this section. **All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the Systems Operations Manager or President of DBS&A.** The scope of the procedures described in this section include the following:

13.4.1 Monitor Well Design and Installation
13.4.2 Extraction Well Design and Installation
13.4.3 Well Development
13.4.4 Well and Boring Abandonment
13.4.5 Well Grouting

3. PROCEDURES

These SOPs and SOGs shall be reviewed and updated at least once annually by the Systems Operations Manager (SOM), or person(s) designated by the SOM. Revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made on Form No. 127 in accordance with the procedure described in Section 0.2 of the DBS&A Operations Manual. Form No. 043 of Section 2.2 shall be used in requesting, authorizing, and documenting any SOP/SOG, or part of any SOP/SOG, copied or distributed for uses described in Section 13.4 of the Operations Manual. All or parts of the SOPs/SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of either the SOM or President of DBS&A. The SOM shall be responsible for filing and maintaining requests made on Form Nos. 127 and 043.

Prepared by: Larry M. Cum

Reviewed by: Larry M. Cum
Quality Assurance Manager

Approved by: Daniel B. Stephens
Daniel B. Stephens

Reviewed by: Larry M. Cum
Systems Operations Manager

Section 13.4.1

Monitor Well Design and Installation

Guideline

Monitor Well Design and Installation

Effective 05/12/93 • Supercedes n/a • Page 1 of 14

SECTION 13.4.1

1. PURPOSE

This section provides standard operating guidelines (SOGs) for monitor well design and installation.

2. SCOPE

The SOGs included in this section are applicable to all DBS&A employees, and its contractors and subcontractors, for the conduct of all activities listed in this section. This procedure is applicable to all DBS&A employees and subcontractors who are engaged in monitor well design and installation activities. Tables 13.4.1-1 and 13.4.1-2 will aid in the selection of casing, screen and riser materials and bentonite or cement grouting materials. Figures 13.4.1-1 and 13.4.1-2 are respectively diagrams for typical shallow zone (single-cased) and deep zone (multi-cased) wells used at DBS&A. Attachment 1 to this SOG is a material supply list (Form No. 118, 6/93) and should be used in the preparation of monitor well design and installation activities. Also, a well completion record (Form No. 048) included as Attachment 2, which will be used to record well design and installation information in the field. The scope of the procedures described in this section include the following:

- Initial Site Characterization
- Monitor Well Design
- Monitor Well Installation

Standards for monitor well design and installation are described in ASTM D 5092-90 ("Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers"). Also, DBS&A technical representatives are required to follow all applicable state regulations pertaining to monitor well design and installation. Refer to Driscoll (1986), EPA (September 1986) or Aller et. al. (1989) for more detailed guidelines about the above subjects as they relate to the design and installation of monitor wells.

3. GUIDELINES

3.1 Initial Site Characterization (ASTM D 5092-90)

A conceptual hydrogeologic model that identifies potential flow paths and the target monitoring zone(s) should be developed prior to monitor well design and installation. The following steps for initial site characterization are recommended:

1. Conduct an initial visit to identify and locate aquifers and zones with the greatest potential to contain and transmit ground water and contaminants from the project area and study exposed soil and rocks within or near the project area for soil color and textural changes, landslides, faults, seeps, and springs.
2. Collect and review literature from previous investigations of the project area (i.e. topographic maps, aerial imagery, site ownership and utilization records, geologic and hydrogeologic maps

and reports, mineral resource surveys, water well logs, and personal information from local well drillers).

3. Develop a preliminary conceptual model of the project area using the information gathered during the initial site visit and literature search. Target specific aquifers and/or ground-water zones for additional characterization based on the known hydrogeology and potential contaminant characteristics (e.g., screen across water table for LNAPLs; include a sump for DNAPLs).

3.2 Monitor Well Materials and Design (ASTM D 5092-90)

The following materials and design are for typical shallow zone (single-cased) and deep zone (multi-cased) wells. Figure 13.4.1-1 is a diagram showing a typical design for a shallow zone (single-cased) well used at DBS&A. Figure 13.4.1-2 is a diagram showing a typical design for a deep zone (multi-cased) well used at DBS&A. Attachment 1 to this SOG is a material supply list (Form No. 118) for monitor well installation and should be completed and checked prior to the field stage of the drilling program by both DBS&A and the drilling subcontractor. Attachment 1 to this SOG should be used in conjunction with the "Drilling Information Checklist" and the "Drilling Equipment and Support Vehicles Checklist" (Form Nos. 116 and 117, Section 13.3.1 of the Operations Manual).

3.2.1 Water

Water used in the drilling process, to prepare grout mixtures and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry or should be characterized. The chemical analysis should confirm that the added water does not contain constituents that could compromise the integrity of the well installation or that may be potential contaminants.

3.2.2 Filter Pack

1. The grain-size distribution curve for the filter pack is selected by multiplying the 70% retained size of the finest formation sample by 3 or 4. Typically 10/20 silica sand is usually appropriate for the filter pack.

2. Do not select too fine a filter pack because this will reduce the yield of the well, causing longer sampling times.

3. Uniformity coefficients for filter pack materials should range from 1 to 3.

4. All filter pack material should be purchased from reputable suppliers who have properly cleaned and bagged the material.

5. To prevent downward migration of the bentonite or cement into the screen, the filter pack is extended at least 2 to 15 feet above the top of the screen.

6. The filter pack should not extend into an overlying water-bearing formation because this could permit downward vertical seepage in the pack and either dilute or add to the contamination of the water being monitored.

3.2.3 Well Screen

1. The well screen should be new, machine-slotted or continuous wrapped wire-wound, and composed of materials that are inert to the subsurface water being tested. Table 13.4.1-1 lists the advantages and disadvantages of several common screen materials.

2. The well screen material should be certified by the manufacturer as clean.

3. If not certified by the manufacturer as clean, the well screen should be steam cleaned or high-pressure water cleaned (if appropriate for the selected well screen materials) with water from a source of known chemistry immediately prior to installation.

4. The screen should be plugged at the bottom with the same material as the well screen.

5. The minimum nominal internal diameter of the well screen should be chosen based on the criteria that it will permit effective development and rapid sample recovery. In most instances, a minimal diameter of 2 inches (50 mm) is needed to allow for the introduction and withdrawal of sampling devices.

6. The slot size of the well screen should retain filter pack or natural formation along with permitting efficient development of the wells.

3.2.4 Riser

1. The riser should be new and composed of materials that are inert to the subsurface water being tested. Table 13.4.1-1 lists the advantages and disadvantages of riser materials.

2. The riser material should be certified by the manufacturer as clean.

3. If not certified by the manufacturer as clean, each section of the riser should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to installation.

4. The minimal nominal internal diameter of the riser should be chosen based on the criteria that it will permit effective development and rapid sample recovery. In most instances, a minimum of 2 inches (50 mm) is needed to accommodate sampling devices.

5. Threaded joints are recommended. Alternatively, O-rings composed of materials that would not affect the subsurface water being sampled may be selected for use on flush joint threads.

3.2.5 Casing

1. The casing material should be new and composed of materials that are inert to the subsurface water being tested. Table 13.4.1-1 lists the advantages and disadvantages of casing materials. The exterior casing (temporary or permanent multi-cased wells) is generally constructed of steel although other appropriate materials may be used.

2. Where conditions warrant, the use of permanent casing installed to prevent communication between water-bearing zones is encouraged.

3. The casing material should be certified by the manufacturer as clean.

4. If not certified by the manufacturer as clean, the casing material should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to installation.

5. The material type and minimum wall thickness of the casing should be adequate to withstand forces of installation.

6. All casing that is to remain as a permanent part of the installation (that is, multi-cased wells) should be new and cleaned of interior and exterior protective coatings.

7. The minimal nominal internal diameter of the riser should be chosen based on the criteria that it will permit effective development and rapid sample recovery. In most instances, a minimum of 2 inches (50 mm) is needed to accommodate sampling devices.

8. The diameter of the casing for filter packed wells should be selected so that a minimum annular space of 2 inches (50 mm) is maintained between the inside diameter of the casing and the outside diameter of the riser. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 inches is maintained between the casing and the borehole (that is, a 2-inch diameter screen will require first setting a 6-inch (152-mm) diameter casing in a 10-inch (254-mm) diameter boring).

9. The ends of each casing section should be either flush-threaded or bevelled for welding.

3.2.6 Annular Sealants

The materials used to seal the annulus may be prepared as a slurry or used unmixed in a dry pellet, granular, or chip form. Sealants should be selected to be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well. Table 13.4.1-2 lists the advantages and disadvantages of using bentonite or cement as grouting material for monitor wells. The following guidelines for the bentonite seal and grout backfill should be considered:

1. A bentonite seal of at least 2 feet is placed above the filter pack. Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite furnished in sacks or buckets from a commercial source and free of impurities which adversely impact the water quality in the well. The diameter of pellets or chips selected for monitoring well construction should be less than one fifth the width of the annular space into which they are placed to reduce the potential for bridging.

2. The grout backfill that is placed above the bentonite seal is ordinarily a liquid slurry consisting of either a bentonite (powder or granules, or both) base and water or a Portland cement base and water. A mixture of bentonite and Portland cement can be used for the grout backfill. Refer to ASTM D 5092-90 for standards in mixing and placing the grout backfill.

3.2.7 Annular Seal Equipment

Prior to use, the equipment used to inject the annular seals and filter pack should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a known chemical source. This procedure is performed to prevent the introduction of materials that may ultimately alter the water sample quality.

3.3 Monitor Well Installation (ASTM D 5092-90)

A well completion diagram (DBS&A Form No. 048, Attachment 2) should be completed as an on-going process during the installation of the monitor well. General steps for monitor well installation are as follows:

1. A stable borehole must be constructed prior to installing the monitor well casing, screen and riser (refer to Section 13.3.1 of the Operations Manual for drilling guidelines).

2. The well casing, screen, riser, and bottom plug materials should either be certified by the manufacturer as clean or cleaned with a steam cleaner or high-pressure water combined with a low-sudsing soap or detergent.

3. Working components of the drilling rig (drill pipe, subs, collars, belly, and all parts of the rig chasis near the borehole) should be cleaned as described in step no. 2.

4. All plastic screens and casing should be joined by threads and couplings or flush threads to prevent contamination from solvent glues.

5. The well screen and riser assembly can be lowered to the predetermined level and held into position by a ballast or hydraulic arms on the drilling rig. The assembly must be installed straight with the appropriate centralizers to allow for the introduction and withdrawal of sampling devices.

6. The riser should extend above grade and be capped temporarily to deter entrance of foreign materials during completion operations.

7. The volume of filter pack (gravel and/or silica sand) required to fill the annular space between the well screen and borehole should be estimated, measured during installation, and recorded on the well completion diagram during installation.

8. The filter pack is placed in the annulus from the bottom of the borehole up to 2 to 5 feet above the well screen.

9. If used, the temporary casing or hollow stem auger is withdrawn, usually in stipulated increments. Care should be taken to minimize lifting the riser with the withdrawal of the temporary casing/augers. To limit borehole collapse, the temporary casing or hollow stem auger is usually withdrawn until the lower most point on the temporary casing or hollow stem auger is at least 2 feet, but no more than 5 feet, above the filter pack for unconsolidated materials or at least 5 feet, but no more than 10 feet, for consolidated materials.

10. A bentonite pellet or a slurry seal is placed in the annulus between the borehole and the riser pipe on top of the filter pack. To be effective, the bentonite seal should extend above the filter pack a minimum of 2 feet, depending on local conditions.

11. Sufficient time should be allowed for the bentonite pellet seal to hydrate or the slurry annular seal to expand prior to grouting the remaining annulus. The volume and elevation of the bentonite seal material should be measured and recorded on the well completion diagram.

12. The volume and location of grout used to backfill the remaining annular space is recorded on the well completion diagram. An ample volume of grout should be premixed on site to compensate for unexpected losses.

13. Grout is introduced in one continuous operation until full strength grout flows out at the ground surface without evidence of drill cuttings or fluid.

14. The riser or casing or both should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser, or grout and casing, or both.

15. Specific grouting procedures for single- and multi-cased wells are included in ASTM D 5092-90.

16. Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitor well and to prevent surface water from entering the annulus. Typically a concrete pad, protective shroud with a lock, and vented cap are placed on monitor wells constructed for DBS&A projects.

17. In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), it may be necessary to enhance the normal protection of the monitor well through the use of posts, markers, signs, etc.

18. Once the monitor well installation is complete, the well should be developed according to standards outlined in Section 13.4.3 of the Operations Manual.

19. The drilling subcontractor is required to file a well record with the State Engineer within 10 days after completion of the well.

4. ATTACHMENTS

- Table 13.4.1-1
- Table 13.4.1.2
- Figure 13.4.1-1
- Figure 13.4.1.2

1. Monitor Well Installation Supply List (DBS&A Form No. 118, 6/93)
2. Well Completion Record (DBS&A Form No. 048)

5. REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Well Design and Installation. National Well Water Association. Dublin, OH. 398 p.

Arizona Department of Water Resources. Undated. Well Construction and Licensing of Well Drillers, Handbook.

ASTM. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. Standard D 5092-90. Philadelphia, PA.

Driscoll, F.G. 1986. Groundwater and Wells. Johnson Division. St. Paul, MN. 1089 p.

EPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. U.S. EPA. Washington, D.C. September. 208 p. and 3 Appendices.

Prepared by: Natalyn K. Ala

Reviewed by: M. C
Quality Assurance Manager

Approved by:
Daniel B. Stephens

Reviewed by: M. C
Systems Operations Manager

Table 13.4.1-1 Well Casing, Screen, and Riser Materials

Type	Advantages	Disadvantages
Stainless steel	• Least absorption of halogenated and aromatic hydrocarbons • High strength at a great range of temperatures • Excellent resistance to corrosion and oxidation • Readily available in all diameters and slot sizes	• Heavier than plastics • May corrode and leach some chromium in highly acidic waters • May act as a catalyst in some organic reactions • Screens are higher priced than plastic screens
PVC (Polyvinyl-chloride)	• Lightweight • Excellent chemical resistance to weak alkalies, alcohols, aliphatic hydrocarbons, and oils • Good chemical resistance to strong mineral acids, concentrated oxidizing acids, and strong alkalies • Readily available • Low priced compared to a stainless steel and Teflon	• Weaker, less rigid, and more temperature sensitive than metallic materials • May adsorb some constituents from ground water • May react with and leach some constituents from ground water • Poor chemical resistance to ketones, esters, and aromatic hydrocarbons
Teflon	• Good resistance to attack by most chemicals • Lightweight • High impact strength	• Screen slot openings may decrease in size over time • Tensile strength and wear resistance low compared to other engineering plastics • Expensive relative to other plastics and stainless steel
Mild steel	• Strong, rigid; temperature sensitivity not a problem • Readily available • Low priced relative to stainless steel and Teflon	• Heavier than plastics • May react with and leach some constituents into ground water • Not as chemically resistant as stainless steel

Table 13.4.1-1 Well Casing, Screen, and Riser Materials (Continued)

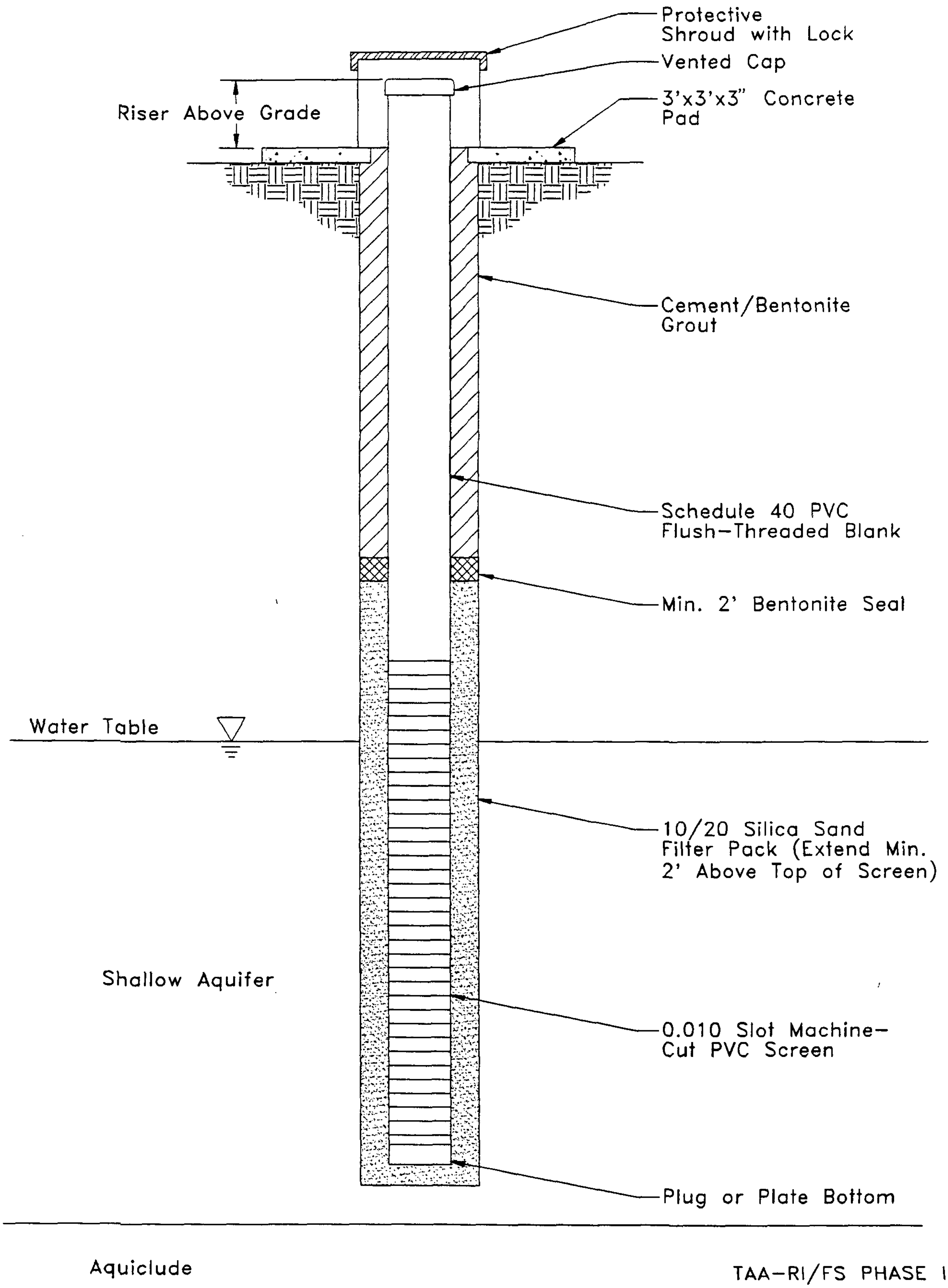
Type	Advantages	Disadvantages
Polypropylene	• Lightweight • Excellent chemical resistance to mineral acids • Good to excellent chemical resistance to alkalies, alcohols, ketones, and esters • Fair chemical resistance to concentrated oxidizing acids, aliphatic hydrocarbons, and aromatic hydrocarbons • Low priced compared to stainless steel and Teflon	• Weaker, less rigid, and more temperature sensitive than metallic materials • May react with and leach some constituents into ground water • Poor machinability--it cannot be slotted because it melts rather than cuts
Kynar	• Greater strength and water resistance than Teflon • Resistant to most chemicals and solvents • Lower priced than Teflon	• Not readily available • Poor chemical resistance to ketones, acetone

(After Driscoll, 1986)

Table 13.4.1-2. Grouting Materials for Monitoring Wells

Type	Advantages	Disadvantages
Bentonite	• Readily available • Inexpensive	• May produce chemical interference with water-quality analysis • May not provide a complete seal because: --There is a limit (14 percent) to the amount of solids that can be pumped in a slurry. Thus, there are few solids in the seal; should wait for liquid to bleed off so solids will settle --During installation, bentonite pellets may hydrate before reaching proper depth, thereby sticking to formation or casing and causing bridging --Cannot determine how effectively material has been placed --Cannot assure complete bond to casing
Cement	• Readily available • Inexpensive • Can use sand/or gravel filter • Possible to determine how well the cement has been placed by temperature logs or acoustic bond logs	• May cause chemical interferences with water-quality analysis • Requires mixer, pump, and tremie line; generally more cleanup than with bentonite • Shrinks when it sets; complete bond to formation and casing not assured

(After Driscoll, 1986)



Not to Scale

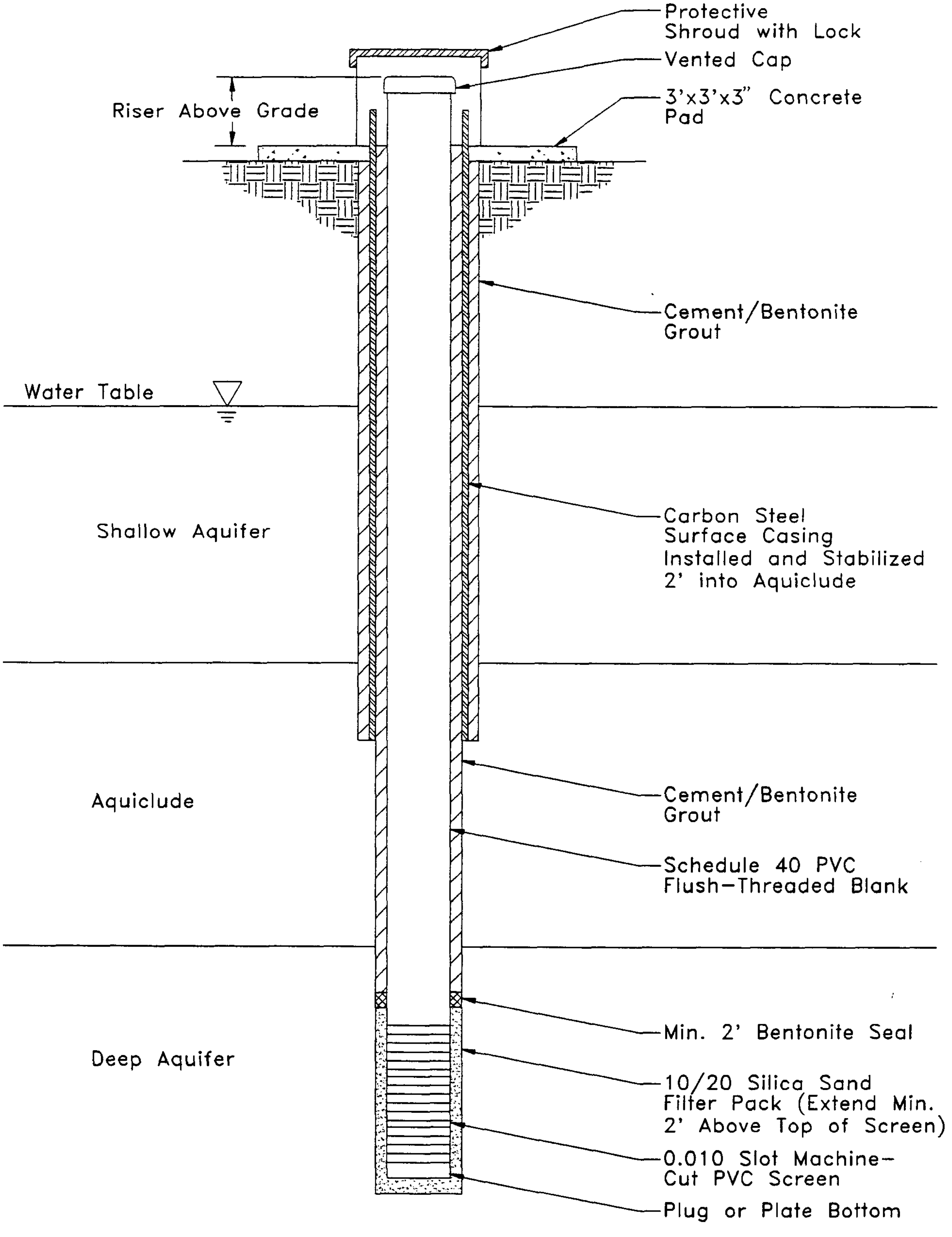
TAA–RI/FS PHASE II

Typical Shallow Zone Monitor Well Design
Single-Cased Well

DANIEL B. STEPHENS & ASSOCIATES, INC.

10–93 3230

Figure 13.4.1–1



TAA-RI/FS PHASE II

Typical Deep Zone Monitor Well Design
Multi-Cased Well

Not to Scale

DANIEL B. STEPHENS & ASSOCIATES, INC.
10-93 3230

Figure 13.4.1-2

DANIEL B. STEPHENS & ASSOCIATES, INC.

Monitor Well Installation Supply List

Project No. ______________________ DBS&A Project Manager ______________________

DBS&A Technical Representative ______________________ DBS&A Field Representative(s) ______________________

Drilling Company ______________________

Drilling Company Contact ______________________ Phone No. ______________________

Date and Time for Work to Begin ______________________

Material	Size	Quantity	Equipment Supplier*
Sand			
Sand			
Pea Gravel			
Bentonite Powder			
Bentonite Pellets			
Bentonite Chips (Ca-montmorill. Slow, NA-montmorill. Fast Hydration)			
PVC (Flush-Threaded Schedule 40)			
PVC (Flush-Threaded Schedule 40)			
PVC (Flush-Threaded Schedule 40)			
PCV Screen Schedule 40 with Slot__________			
PCV Screen Schedule 40 with Slot__________			
PCV Screen Schedule 40 with Slot__________			
Stainless Steel Channel Pack			
Steel Conductor Casing			
Slip Caps			
Slip Caps			
Threaded Endcaps			
Threaded Endcaps			
Locking Caps			
Concrete			
Portland Cement			
Locking Well Vault			

DBS&A Form No. 118 6/93

*DBS&A or Other (specify)

DANIEL B. STEPHENS & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

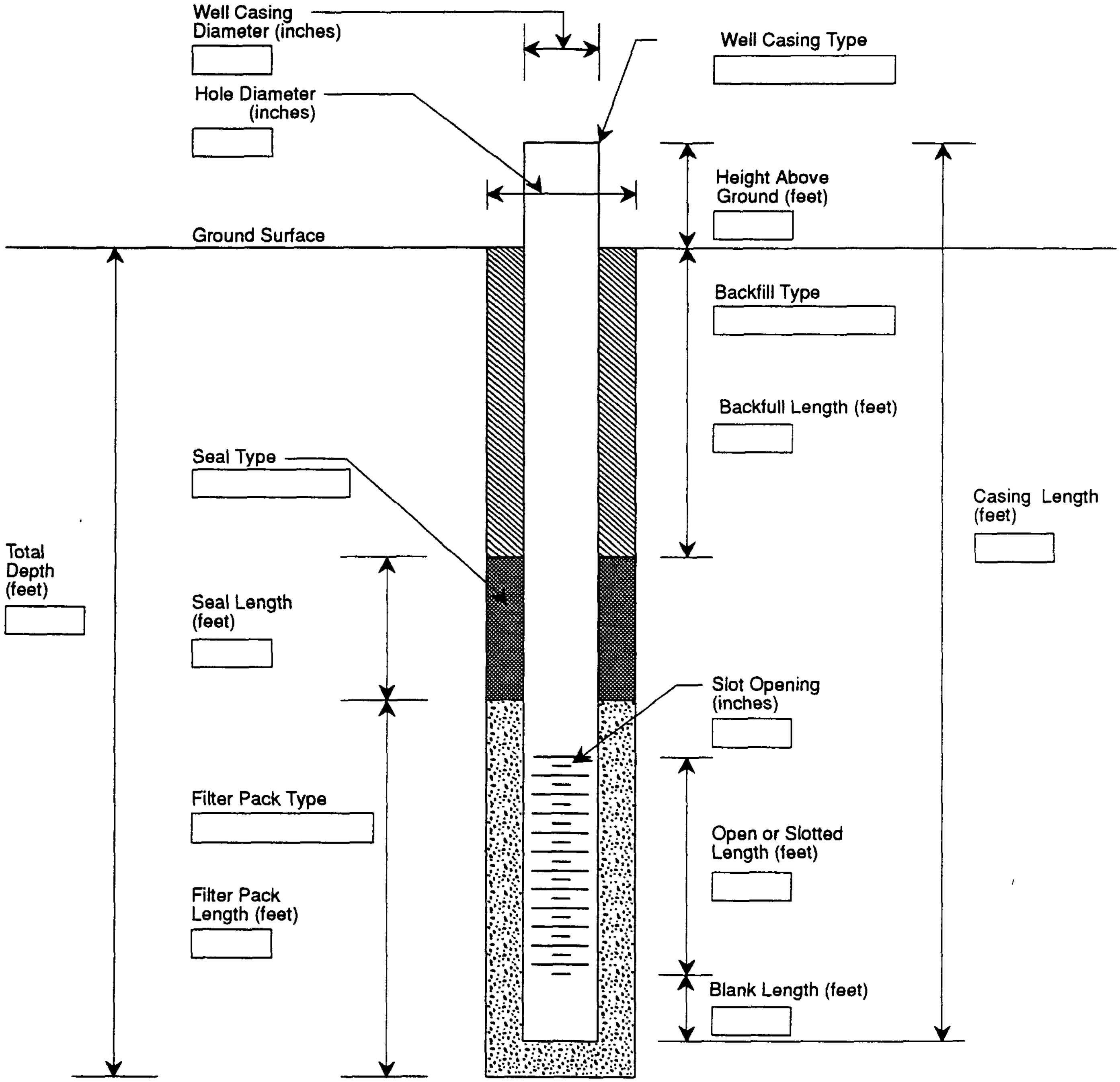
WELL COMPLETION RECORD

Client ______________________________ Project No. ____________

Well No. ____________ Site ____________________ Date Installed ____________

Formation of Completion ______________________________

DBS&A Personnel ____________________ Driller ____________________



Comments ______________________________

Section 13.4.3

Well Development

Guideline
Well Development
SECTION 13.4.3

Effective 06/01/93 • Supersedes n/a • Page 1 of 6

1. PURPOSE

This section provides standard operating guidelines (SOGs) for well development.

2. SCOPE

This procedure is applicable to all DBS&A employees and subcontractors who are engaged in well development activities. Table 13.4.3-1 summarizes disadvantages and advantages for different well development methods. The scope of the procedures described in this section includes the following:

- Development Methods
- Duration of Well Development
- Well Recovery Test

Standards for well development are described in ASTM D 5092-90 ("Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers"). Refer to Driscoll (1986), EPA (September 1986) or Aller et al. (1989) for more detailed guidelines about well development.

3. GUIDELINES

Proper well development serves to 1) remove some finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, 2) restore the ground-water properties disturbed during the drilling process, and 3) improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the screened interval.

3.1 Development Methods (ASTM D 5092-90)

Methods of development most often used include mechanical surging and bailing or pumping, over-pumping, air-lift pumping, and well jetting. An important factor in any method is that the development work be started slowly and gently and be increased in vigor as the well is developed. most methods of well development require the application of sufficient energy to disturb the filter pack, thereby freeing the fines and allowing them to be drawn into the well. The coarser fractions then settle around and stabilize the screen. The well development method chosen should be documented in the field notebook. Table 13.4.3-1 summarizes the opinions of several references on well development methods and can be helpful in selecting an approximate method for development wells screened in varying hydrologic units.

3.1.1 Mechanical Surging

In this method, water is forced to flow into an out of the well screen by operating a plunger (or surge bock) or bailer up and down in the riser. A pump or bailer should then be used to remove the dislodged sediments following surging.

3.1.2 Over Pumping and Backwashing

The easiest, least expensive and most commonly employed technique of well deelopment is some form of pumping. With over pumping, the well is pumped at a rate considerably higher than it would be during normal operation. The fine-grain materials would be dislodged from the filter pack and surrounding strata influenced by the higher pumping rate. This method is usually conducted in conjunction with mechanical surging.

In the case where there is no backflow prevention valve installed, the pump can be alternately started and stopped. This is called backwashing. This starting and stopping allows the column of water that is intially picked up by the pump to be alternately dropped and raised up in a surging action. Each time the water column falls back into the well, an outward surge of water flows into the formation. This surge tends to loosen the bridging of the fine particles into and out of the well.

3.1.3 Air Lift Pumping

In this method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation will provide a surging action that will dislodge fine-grained particles. Applying a steady, low pressure will remove the fines that have been drawn into the well by the surging action. Efforts should be made (that is, through the use of a foot valve) to avoid pumping air into the filter pack and adjacent hydrologic unit because the air may lodge there and inhibit future sampling efforts and may alter ambient water chemistry. Furthermore, application of high air pressures should be avoided to prevent damage to small diameter PVC risers, screens, and filter packs.

3.1.4 Well Jetting

Another method of development involves jetting the well screen area with water while simultaneously air-lift pumping the well. However, the water added during this development procedure will alter the natural, ambient water quality and may be difficult to remove. Therefore, the water added should be obtained from a source with known chemistry. Water from the monitor well being developed may also be used if the suspended sediments are first removed.

3.2 Duration of Well Development (ASTM D 5092-90)

Well development should begin no sooner than 48 hours after the monitor well is completely installed and prior to water sampling. Development should be continued until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. Representative water is assumed to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids. The minumum duration of well development will vary according to the method used to develop the well. The duration of well development and the pH, temperature, and specific conductivity readings should be recorded in the field notebook.

3.3 Well Recovery Test (ASTM D 5092-90)

A well recovery test can be performed immediately after and in conjunction with well development. The well recovery test not only provides an indication of well performnce but it may also provide data for determining the transmissivity of the screened hydrologic unit. Estimates of the hydraulic conductivity of the unit can then be determined. Readings should be taken at intervals suggested in Table 13.4.3-2 until the well has recovered to 90 percent of its static water level and recorded in the field notebook. Section 13.6 of the DBS&A Operations Manual describes methods for aquifer hydraulic testing specifically for establishing aquifer hydraulic parameters in greater detail.

Table 13.4.3-2 Suggested Recording Intervals for Well Recovery Tests

TIME SINCE STARTING TEST	TIME INTERVAL
0 to 15 min	1 min
15 to 50 min	5 min
50 to 100 min	10 min
100 to 300 min (5 hours)	30 min
300 to 1,440 min (24 hours)	60 min

4. ATTACHMENTS

- Table 13.4.3-1

5. REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Well Design and Installation. National Well Water Association. Dublin, OH. 398 p.

ASTM. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. Standard D 5092-90. Philadelphia, PA.

Driscoll, F.G. 1986. Groundwater and Wells. Johnson Division. St. Paul, MN. 1089 p.

EPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. U.S. EPA. Washington, D.C. September. 208 p. and 3 Appendices.

Prepared by: Natalyn K. Ala

Reviewed by:
Quality Assurance Manager

Approved by:
Daniel B. Stephens

Reviewed by:
Systems Operations Manager

Table 13.4.3-1. Summary of Well Development Methods

Reference	Over-pumping	Backwashing	Mechanical Surging		Well Jetting	Air-lift Pumping
			Surge Block	Bailer		
Gass (1986)	Works best in clean coarse formations and some consolidated rock; problems of water disposal and bridging	Breaks up bridging, low cost & simple; preferentially develops	Can be effective; size made for ≥ 2" well; preferential development where screen >5'; surge inside screen		Consolidated and unconsolidated application; opens fractures, develops discrete zones; disadvantage is external water needed	Replaces air surging; filter air
United States Environmental Protection Agency (1986)	Effective development requires flow reversal or surges to avoid bridges	Indirectly indicates method applicable; formation water should be used	Applicable; formation water should be used; in low-yield formation, outside water source can be used if analyzed to evaluate impact	Applicable		Air should not be used
Barcelona et al.** (1983)	Productive wells; surging by alternating pumping and allowing to equilibrate; hard to create sufficient entrance velocities; often used with airlift		Productive wells; use care to avoid casing and screen damage	Productive wells; more common than surge blocks but not as effective		
Scalf et al. (1981)		Suitable; periodic removal of lines	Suitable; common with cable-tool; not easily used on other rigs	Suitable; use sufficiently heavy bailer; advantage of removing fines; may be custom made for small diameters		Suitable

Table 13.4.3-1. Summary of Well Development Methods (Continued)

Reference	Over-pumping	Backwashing	Mechanical Surging		Well Jetting	Air-lift Pumping
			Surge Block	Bailer		
National Council of the Paper Industry for Air and Stream Improvement (1981)	Applicable; drawback of flow in one direction; smaller wells hard to pump if water level below suction		Applicable; caution against collapse of intake or plugging screen with clay		Methods introducing foreign materials should be avoided (i.e., compressed air or water jets)	
Everett (1980)	Development operation must cause flow reversal to avoid bridging; can alternate pump off and on		Suitable; periodic bailing to remove fines		High velocity jets of water generally most effective; discrete zones of development	
Keely and Boateng (1987 a and b)	Probably most desirable when surged; second series of evacuation/recovery cycles is recommended after resting the well for 24 hours; settlement and loosening of fines occurs after the first development attempt; not as vigorous as backwashing	Vigorous surging action may not be desirable due to disturbance of gravel pack	Method quite effective in loosening fines but may be inadvisable in that filter pack and fluids may be displaced to degree that damages value as a filtering media		Popular but less desirable; method different from water wells; water displaced by short downward bursts of high pressure injection; important not to jet air or water across screen because fines driven into screen cause irreversible blockage; may substantially displace native fluids	Air can become entrained behind screen and reduce permeability

* Schalia and Landick (1986) report on special 2' valved block

** For low hydraulic conductivity wells, flush water up annulus prior to sealing; afterwards pump

(Compiled by Aller et al, 1989)

Section 13.4.4

Well and Boring Abandonment

Procedure
Measurement of Field Parameters

1. PURPOSE

This section outlines procedures for field measurement of electrical conductivity, temperature, pH, alkalinity, oxidation/reduction potential (Eh), and dissolved oxygen (DO).

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors involved in water sampling activities. These parameters should be measured during monitor well purging prior to sampling. Surface water samples should also be characterized when they are collected.

3. PROCEDURES

3.1 Conductivity and Temperature

This SOP describes the procedure for determining the specific conductance (conductivity) and temperature of a water sample using the YSI Model 33 SCT Meter. Conductance, or conductivity, is a measure of the ease of flow of electric current, and is the inverse (reciprocal) of resistivity. The term specific conductance (SpC), sometimes referred to simply as "conductivity," is defined as the electrical conductance that would occur through the water between the faces of a 1-cm cube of the water. SpC is usually reported in units of µmhos/cm, which has recently been renamed microsiemens per centimeter (µS/cm). By measuring the specific conductance of a water sample in the field, one can estimate the total dissolved solids (TDS) concentration of the water using the approximate conversion TDS = 0.6 x SpC. Because the SpC of a water allows rapid determination of TDS (salinity), SpC is probably the single most useful water quality parameter.

The conductance of water containing dissolved ions increases with increasing temperature of the water. The temperature dependence varies for different waters and is dependent on the type and concentrations of dissolved ions, but an approximate rule of thumb is that SpC increases 2% per °C temperature increase. For quantitative comparison of SpC values measured on different water samples at different field temperatures, it is necessary to correct all values to the SpC at 25°C. For most qualitative work, however, this is unnecessary. Whether or not temperature corrections are to be applied, <u>the SpC value as measured at field temperature should always be recorded</u> in the field logbook (see Section 13.2.6 of the DBS&A Operations Manual), along with the temperature of the water sample at the time the measurement was made.

The following equipment is needed to measure SpC in the field:

- YSI Model 33 SCT Meter & probe
- Spare D-cell batteries
- Beaker for water sample
- Deionized water in squirt bottle
- KCl conductivity standard solution

The following procedure shall be used to measure SpC in the field:

1. Verify that the meter needle rests on zero prior to turning on the meter. If not, adjust it to zero using the set screw on the face of the meter movement.
2. Calibrate the meter by turning the *MODE* switch to *REDLINE* and adjusting the *REDLINE* control knob until the needle lines up with the small red line on the meter scale. (If unable to calibrate meter, replace the batteries.)
3. Plug in probe cable, and insert gray plastic probe into water sample. Allow at least one minute for temperature equilibration of probe.
4. Set *MODE* control to *TEMPERATURE* and record the temperature of the water sample in the field logbook. (Note that the temperature scale is at the bottom of the meter face and that the values decrease to the right)
5. Switch the *MODE* control to the conductivity setting that gives the maximum needle deflection without going offscale (X100, X10, or X1). Do not allow the probe to touch the sides or bottom of the beaker when making a measurement because this can result in a low reading.
6. Record the SpC value, remembering to multiply the meter reading by the appropriate factor if using the X10 or X100 settings.
7. Rinse the probe with deionized water prior to making another measurement or putting the instrument away.

Other information about the YSI Model 33 SCT Meter may be needed occasionally:

- The probe preferably should be stored in deionized water between uses during each day of field work. If the probe has been stored dry, it is recommended that it be soaked in deionized water at the start of the day prior to making any measurements. This is not absolutely essential, however.
- The *SALINITY* mode will not ordinarily be used unless dealing with brines or other samples with salinity of seawater or above. The *TEMPERATURE* potentiometer only functions in *SALINITY* mode; it does nothing when operating in SpC mode and cannot be used to correct SpC values to 25°C.
- To test probe operation, press the *CELL TEST* button while measuring the SpC of a water sample on the X10 or X100 scales. If the probe is functioning properly, the meter reading should not fall more than 2% when depressed. If the meter reading falls more than 2%, notify the equipment technician that the probe needs attention.
- The meter and probe should be periodically checked against a standard potassium chloride (KCl) solution to verify proper internal calibration. To do so, immerse the (clean) probe in the KCl standard, and record the temperature and SpC values as described above. Check that the SpC value is within

± 5% of the nominal SpC value for that particular KCl solution at that temperature. Record the observed value and the nominal value (from label on bottle) in the field logbook.

3.2 pH

This section describes the procedure for determining the pH of a water sample using the Orion Model 250A pH/mV meter with automatic temperature compensation. Calibration of the meter is performed at least daily using two buffer solutions that bracket the sample pH. A temperature sensor is included on the pH probe to make the minor correction from the sample temperature to 25°C. For information on manual temperature correction, refer to meter instruction manual. The Orion 250A can also be used in millivolt mode with a variety of ion selective electrodes (refer to ISE SOPs).

The following equipment is needed to measure pH in the field:

- Orion Model 250A pH meter
- Buffer solutions (pH 4.01, 7.00, 10.00)
- Spare 9-volt battery
- Beaker for water sample
- Deionized water in squirt bottle

The following procedure shall be used to measure pH in the field:

1. Plug the pH probe and thermistor (ATC) into the appropriate jacks of the meter.

2. Insert battery (if necessary), and press the power button to turn on the meter.

3. If the meter is not already in pH mode as indicated by the caret at the bottom of the display, press the mode button to select pH mode.

4. Rinse the probe with deionized water to remove any dried KCl salts, and slide the silicone rubber sleeve down to expose the electrolyte fill hole. Leave the hole uncovered during measurement, but do not allow the hole to be submerged in the sample.

5. Remove the plastic end cap on the probe, rinse the tip of the probe in deionized water, and insert the probe in the pH 7.0 buffer.

6. Press "2nd," then "Cal" to put the meter in calibration mode. The word "calibrate" should appear on the display, and the designation "P1" indicates that the meter is ready for the first buffer calibration.

7. Stir the probe gently in the pH 7.0 buffer solution. When the reading has stabilized, the meter will beep and the word "ready" will appear. Press "yes" to accept the reading and set the pH 7.0 calibration. "P2" will be displayed, indicating that the meter is ready for the second buffer solution.

8. Rinse the probe with deionized water, and insert it in the pH 4.0 buffer. (If the pH of the water sample is anticipated to be >7, then substitute the pH 10.0 buffer.)

9. When the meter indicates "ready," press "measure" to accept the pH 4.0 calibration. The slope of the calibration curve will be displayed briefly. Record the slope in the field logbook. The slope value should be within the range of 90 to 110. If not, repeat the calibration procedure. The meter will automatically exit the calibration mode, and the word "measure" will be displayed.

10. Rinse the probe and insert it into the water sample to be measured. Stir gently while waiting for the word "ready" to appear. Record the pH value in the field logbook.

11. If more measurements are to be made, rinse the probe and store temporarily in a beaker of deionized water. If finished for the day, turn the meter off, rinse the probe, disconnect the plugs, and store the probe with a few milliliters of the KCl electrode storage solution inside the black plastic end cap.

3.3 Alkalinity

This section describes the procedures for determining the total alkalinity in near-neutral pH, high-alkalinity water samples (most ground waters) using the Hach Test Kit. For information on the procedure for low-alkalinity samples or high pH samples (pH>8), refer to the Hach instruction sheet.

The following equipment is needed to determine total alkalinity in the field:

- Hach Alkalinity Test Kit

The following procedure shall be used to determine total alkalinity in the field:

1. Fill the small plastic test tube with the water to be tested.

2. Pour the contents of the test tube into the square glass bottle.

3. Add the contents of one foil packet containing the *Bromcresol Green/Methyl Red* color indicator. The water will turn a dark green.

4. Carefully begin adding the standard sulfuric acid titrant dropwise using the eye dropper, counting the number of drops added and swirling to mix the solution. Keep the eye dropper nearly vertical to maintain a constant drop volume.

5. When the solution begins to change from green to red, slow down. The titration is complete when the solution is a bright pink color.

6. Record the total number of drops added. Multiply the number of drops by 20 to obtain the total alkalinity, reported as mg/L of $CaCO_3$.

3.4 Oxidation-Reduction Potential (Eh)

This section describes the procedure for determining oxidation reduction potential of water in the field using an electrode.

The following equipment is needed to measure Eh in the field:

- Yellow Oxidation-Reduction Potential (ORP) Electrode
- Orion Model 250A pH/mV meter or YSI Model 3500 flow-thru cell meter
- Standard Zobell solution

The following procedure should be used to measure Eh in the field:

1. Plug the BNC connector into an Orion 250A pH/mV meter (or YSI 3500 meter).

2. Turn on the meter. If using the Orion 250A, use *MODE* key to set meter to "mV" mode (**not** *rel mV*). If using the YSI 3500, turn the black knob to "mV".

3. Check probe operation by immersing it in a disposable beaker with Zobell Solution. The reading should be ± 10 mV of that listed on the table with the Zobell Solution at the temperature of the solution (e.g., 231 mV at 25° C).

4. Rinse the probe and immerse it in the ground-water sample. Following stabilization, record the mV value, along with a ± estimate to indicate the stability of the meter. Also record the sample temperature.

3.5 Dissolved Oxygen (DO)

This section describes the procedure for determining the dissolved oxygen (DO) concentration using the YSI Model 57 DO meter. The meter is calibrated using the air calibration procedure, with corrections for ambient temperature and altitude/barometric pressure. Refer to the instruction manual for details of meter operation and replacement of the probe membrane.

The following equipment is needed to measure dissolved oxygen in the field:

- YSI Model 57 Dissolved Oxygen Meter
- Beaker for water sample
- Deionized water in squirt bottle
- Means of determining the approximate altitude of the site (topo map, altimeter, etc.)

The following procedure shall be used to measure dissolved oxygen in the field:

1. Turn the meter on approximately 15 minutes before measuring samples to allow the probe to polarize. The probe shall be kept in the clear plastic cover. Add a few drops of deionized water

to the small sponge inside the cover to maintain 100% relative humidity around the tip of the probe during storage.

2. Set the salinity knob to "fresh" for normal ground waters, or adjust to the appropriate salinity if brackish or saline waters are to be measured (as determined by specific conductance or previous laboratory analysis).

3. Set the zero on the meter by turning the switch to *ZERO* and adjusting the zero potentiometer until the needle falls on zero.

4. Set the red line on the meter by turning the switch to *RED LINE* and adjusting the appropriate potentiometer.

5. With the probe still in its cover, set the switch to *TEMPERATURE* and note the ambient air temperature displayed on the meter.

6. Determine the maximum (sea level) dissolved oxygen concentration (mg/L) possible for that temperature by referring to the table on the back of the DO meter (also in the instruction manual). Note this value in the field logbook.

7. Determine the approximate altitude of the site, and find the appropriate altitude correction factor on the table on the back of the meter (also in the instruction manual).

8. Multiply the saturated DO concentration determined in Step 5 by the altitude correction factor determined in Step 6. Note the value in the field logbook. This is the corrected saturated DO concentration (corrected for both temperature and altitude). Calibration should be periodically checked during the day as the temperature changes, and adjusted if necessary.

9. Switch the meter to the appropriate measurement scale for the corrected DO concentration determined in Step 7 (e.g., 0-10 mg/L scale), and use the *CALIBRATE* knob to air calibrate the meter by adjusting until the needle falls on the value determined in step 8. The meter is now ready to measure water samples.

10. Rinse the probe with deionized water, and insert it in the water sample and stir gently. Set the switch to *TEMPERATURE*, and record the reading in the field logbook.

11. Set the switch to the appropriate DO scale (e.g., 0-5 mg/L) to keep the needle on scale, and stir gently until a stable reading is obtained. It is important to be stirring the sample when the actual reading is taken. Record the value in the field logbook.

12. The probe may be stored temporarily in deionized water between measurements. When finished for the day, rinse the probe, and store with the dampened sponge in the plastic cap.

Prepared by: Jeffrey Forbes

Reviewed by: Quality Assurance Manager

Approved by: Daniel B. Stephens
Daniel B. Stephens

Reviewed by: Systems Operations Manager

Section 13.5

Water Sampling

Procedure
Water Sampling
SECTION 13.5

Effective 01/12/94 • Supersedes 06/01/93 • Page 1 of 2

1. PURPOSE

The purpose of this standard operating procedure (SOP) is to present guidelines and procedures for collection, preservation, and shipment of water samples for laboratory chemical analysis. This SOP also outlines procedures for measurement of field water quality parameters during sample collection activities.

2. SCOPE

The SOPs included in this section are applicable to all DBS&A employees, and its contractors and subcontractors, for the conduct of all activities listed in this section. **All SOPs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the Systems Operations Manager (SOM) or President of DBS&A.** The scope of the procedure described in this section includes the following:

13.5.1	Preparation for Water Sampling
13.5.2	Decontamination of Field Equipment
13.5.3	Measurement of Field Parameters
13.5.4	Collection of Ground-Water Samples
13.5.5	Collection of Surface Water Samples
13.5.6	Sample Preservation
13.5.7	Sample Filtration
13.5.8	Quality Assurance/Quality Control (QA/QC) Samples

This SOP includes guidelines for preparation for water sampling, collection of surface- and ground-water samples, sample preservation, chain of custody procedures, and quality assurance/quality control procedures. This SOP is applicable to the collection of surface- and ground-water samples to be analyzed for organic, inorganic and radionuclide constituents and for measurement of field parameters including temperature, conductivity, pH, alkalinity, oxidation/reduction potential (Eh), and dissolved oxygen.

3. PROCEDURES

These SOPs shall be reviewed and updated at least once annually by the Systems Operations Manager (SOM), or person(s) designated by the SOM. Revisions and additions to these SOPs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made on Form No. 127 in accordance with the procedure described in Section 0.2 of the DBS&A Operations Manual. The Proprietary Copy Request and Authorization Form (DBS&A Form No. 043) shall be used in requesting, authorizing, and documenting any SOP, or part of any SOP, copied or distributed for uses described in Section 13.5 of the Operations Manual. All or parts of the SOPs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of either the SOM or President of DBS&A. The SOM shall be responsible for filing and maintaining requests made on Form Nos. 127 and 043.

Prepared by: ______________________

Reviewed by: ______________________
Quality Assurance Manager

Approved by: Daniel B. Stephens
Daniel B. Stephens

Reviewed by: ______________________
Systems Operations Manager

Section 13.5.1

Preparation for Water Sampling

1. PURPOSE

The following SOP defines activities to be completed prior to each sampling event. A checklist/summary of water sampling preparation activities is included as Attachment 1 to this SOP.

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors when preparing to sample water.

3. PROCEDURES

3.1 DBS&A Warehouse

Prior to any water sampling event, the water sampler shall requisition all necessary equipment and supplies by completing a DBS&A Field Equipment and Materials Load-Up Sheet (see Section 13.1.1 of the DBS&A Operations Manual) and giving it to the warehouse manager. The load-up sheet should be provided to the warehouse manager as much in advance as is possible, so that equipment and supply requisitions can be made.

All equipment to be used, with the exception of rental equipment, shall be calibrated and tested in the DBS&A warehouse by the warehouse manager prior to being sent to the field per the guidance prescribed in Section 13.1.1 of the DBS&A Operations Manual. Meter calibration shall be conducted in accordance with standard manufacturer recommended procedures using clean, fresh reagents. The warehouse manager shall ensure that all equipment is clean and in working order prior to leaving the DBS&A warehouse.

3.2 Analytical Laboratory

Prior to a water sampling event, the number and type of samples to be collected (field and quality assurance samples) shall be determined by the Project Manager (PM) or designated project Technical Representative (TR). The PM or project TR shall order appropriate sample containers (Section 13.1.1) from the analytical laboratory and shall inform the analytical laboratory of the expected arrival date of the samples, the analytes to be determined for each sample, and the required turnaround time. It is the water sampler's (Field Representative; FR) responsibility to confirm that all sample bottles have been received and are loaded for sampling. The duties and responsibilities of TRs and FRs are described in Section 13.2 of the DBS&A Operations Manual.

3.3 Site-Specific Instructions

The first time that a site is sampled, or the first time that any new location is sampled, the designated sample identification number shall be determined by the PM or TR prior to field sampling.

Prior to each water sampling event, the PM or TR shall compile a list of samples (including quality assurance samples) to be collected. The order in which the samples should be collected shall also be listed. In general, locations with the lowest concentrations of select analytes shall be sampled before wells with higher concentrations, so the potential for cross-contamination can be minimized. The PM or TR will also list any special procedures that are unique to the site or to the sampling event.

Before each sampling round, the PM or TR shall make all access arrangements with the client and/or property owners. The FR(s) will confirm that access arrangements have been made and should determine if additional on-site access procedures are required.

Prior to leaving for the field, FR(s) shall assemble and be familiar with materials that describe the general conditions of the site, the hydrogeology, well completion information, and objectives of the sampling program. The project health and safety plan shall also be consulted before initiation of the field program.

Prepared by: ______________________

Reviewed by: ______________________
Quality Assurance Manager

Approved by: ______________________
Daniel B. Stephens

Reviewed by: ______________________
Systems Operations Manager

Section 13.5.2

Decontamination of Field Equipment

Procedure

Decontamination of Field Equipment

1. PURPOSE

The following SOP defines activities required to decontaminate water sampling equipment in order to prevent cross-contamination of samples from different sampling locations.

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors involved in water sampling activities.

3. PROCEDURES

All non-disposable field equipment that may potentially come in contact with any water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted in the warehouse before each sampling event. In addition, the FR shall decontaminate all equipment in the field as required to prevent cross-contamination of water samples (see Section 13.1.1 of the DBS&A Operations Manual). The procedures described in this section are specifically for field decontamination of sampling equipment.

For wells or surface waters to be sampled for inorganics and/or metals, or for locations outside of the area of known contamination, the following procedures shall be used:

1. Wash the equipment in a solution of non-phosphate detergent (Liquinox) and distilled/deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex or plastic gloves during all washing and rinsing operations.

2. Rinse twice with distilled/deionized water.

3. Dry the equipment before use, to the extent practical.

If the sample is collected from a highly contaminated area or is to be analyzed for organics, follow steps 1 and 2, then rinse once more with organic-free water obtained from the laboratory or other supplier. Contain all wash solutions for proper disposal.

4. REFERENCES

- American Petroleum Institute. 1987. Manual of Sampling and Analytical Methods for Petroleum Hydrocarbons in Groundwater and Soil. API Publication No. 4449. American Petroleum Institute, Washington. DBS&A #3600/API.

Prepared by: Joane Hilton

Approved by:
Daniel B. Stephens

Reviewed by:
Quality Assurance Manager

Reviewed by:
Systems Operations Manager

Section 13.5.3

Measurement of Field Parameters

1. PURPOSE

This section provides standard operating guidelines (SOGs) for well and boring abandonment.

2. SCOPE

This procedure is applicable to all DBS&A employees and subcontractors who are engaged in well and boring abandonment activities. The scope of the procedures described in this section includes the following:

- Need for Sealing Wells and Restoration of Geological Conditions
- Sealing Requirements
- Records of Abandonment Procedures

Abandonment activities conducted by DBS&A personnel will follow all applicable state regulations pertaining to well and boring abandonment.

3. GUIDELINES

Abandoned wells need to be sealed carefully to prevent pollution of the ground water source, eliminate any physical hazard, conserve aquifer yield, maintain confined head conditions, and prevent poor-quality water of one aquifer from entering another. The purpose of sealing an abandoned well is to prevent any further disturbance to the pre-existing hydrogeologic conditions that exist within the subsurface. The plug should prevent vertical movement within the borehole and confine the water to the original zone of occurrence. Driscoll (1986), EPA (September 1986) or Aller et al. (1989) provide more detailed procedures and guidelines for abandonment of wells. The following subsections outline general procedures and guidelines for abandonment of test holes, partially completed wells, and completed wells.

3.1 Need for Sealing Wells and Restoration of Geological Conditions

Abandoned test holes, including test wells, uncompleted wells, and completed wells shall be sealed for the following reasons:

1. Eliminate physical hazard.
2. Prevent contamination of ground water.
3. Conserve yield and hydrostatic head of aquifers.
4. Prevent intermingling of desirable and undesirable waters.

The guiding principle to be followed by the contractor in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed.

3.2 Sealing Requirements

Sealing requirements are as follows:

1. A well shall be measured for depth before it is sealed to ensure freedom from obstructions that may interfere with effective sealing operations.
2. Removal of liner pipe from some wells may be necessary to ensure placement of an effective seal.
3. If the liner pipe cannot be readily removed, it shall be perforated to ensure the proper sealing required.
4. Concrete, cement grout, or neat cement shall be used as primary sealing materials and shall be placed from the bottom upward by methods that will avoid segregation or dilution of material.

3.3 Records of Abandonment Procedures

Complete, accurate information shall be recorded in the field notebook of the entire abandonment procedure to provide detailed records for possible future reference and to demonstrate to the government state or local agency that the hole was properly sealed. Particularly, the following should be recorded accurately:

1. The depth of each layer of all sealing and backfilling materials shall be recorded.
2. The quantity of sealing materials used shall be recorded. Measurements of static water levels and depths shall be recorded.
3. Any changes in the well made during the plugging, such as perforating casing, shall be recorded in detail.

The owner or well permit holder should notify the appropriate state or local agency of the abandonment.

4. REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Well Design and Installation. National Well Water Association. Dublin, OH. 398 p.

ASTM. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. Standard D 5092-90. Philadelphia, PA.

Driscoll, F.G. 1986. Groundwater and Wells. Johnson Division. St. Paul, MN. 1089 p.

Prepared by: Natalyn K. Ala

Approved by:
Daniel B. Stephens

Reviewed by:
Quality Assurance Manager

Reviewed by:
Systems Operations Manager

Section 13.5.4

Collection of Ground-Water Samples

1. PURPOSE

The following SOP defines activities to be completed for the collection of ground-water samples.

2. SCOPE

This procedure is applicable to all DBS&A employees, its contractors and subcontractors, when collecting ground-water samples.

3. PROCEDURES

3.1 Wellhead Preparation

Prior to ground-water sample collection, the following wellhead protection activities shall be conducted:

1. Inspect the area around the well for wellhead integrity, cleanliness, and signs of possible contamination.
2. Spread a clean plastic sheet over the ground around the wellhead, where required.
3. Remove the cap on the wellhead. Note any obvious odors within the wellbore in the field logbook.
4. If possible, measure the static water level (see Section 13.6.1 of the DBS&A Operations Manual) prior to initiation of water sampling. Clean the steel tape or electrical sounder used for water level measurement after each use, as described in Section 13.5.2 of the Operations Manual, to avoid cross contamination.
5. If floating product (e.g., gasoline) is suspected at the site, conduct the following procedures:
    - Use a bailer to extract a sample from the surface of the water within the well, if possible.
    - After an initial visual inspection, slowly pour the fluid from the bailer into a small tub or container in order to check for a sheen or any other sign of free product. Note any obvious odors in the field logbook.
    - If free product is detected, use the bailer to remove as much free product as is possible from the wellbore. Lower the bailer into the water slowly in order to prevent mixing and volatilization. Contain all recovered product for proper disposal and note the quantity of product removed in the field logbook.
    - If the site has not been previously sampled, a sample of the free product may be desired. Consequently, place some of the product in an unpreserved 40-mL glass VOA vial, and store it away from the other samples. Confirm sample analysis with the project manager.

- After any free product has been removed from the wellbore, spread a fresh plastic sheet around the wellhead, and clean all contaminated equipment, or segregate it from the other equipment.

3.2 Well Purging

The purpose of purging the well prior to sampling is to remove stagnant water from the well bore so that a representative ground-water sample can be collected. The method of purging can have a pronounced effect on the quality of the ground-water sample. For example, rapid purging may increase sample turbidity and is, therefore, not recommended.

In general, positive displacement (bladder) pumps are preferred for most sampling situations. However, depending on the hydraulic conductivity of the aquifer to be sampled and the project objectives, wells may either be equipped with dedicated pumps or may need to be purged with bailers. Consequently, purging techniques may vary depending on the aquifer conditions, the presence or absence of a dedicated pump, and the proposed sample analytes.

The optimum amount of water to be purged from each well also varies between sites. According to Barcelona et al., 1985, pg. 47, "The number of well volumes to be pumped from a monitoring well prior to the collection of a water sample must be tailored to the hydraulic properties of the geologic materials being monitored, the well construction parameters, the desired pumping rate, and the sampling methodology to be employed."

Site-specific purging procedures shall be prepared for each site. The following purging procedure can be used as a general guideline:

1. Calculate the volume of water standing in the casing by using the formula:

   $$V = \pi r^2 L$$

   where
   r = the radius of the casing (remember to convert inches to feet)
   L = the length of the water column (total depth of well minus the static water level)

2. Purge the well at a rate equal to or greater than the sampling rate.

3. Measure applicable field parameters (see Section 13.5.3 of the Operations Manual) at the pump outlet at a minimum after each 0.5 casing volume is pumped. Purging is generally considered complete when the above parameters are approximately stable over at least one casing volume. Wherever possible, purge a minimum of three (3) casing volumes from each well.

4. In low permeability formations, it may not be possible to purge three casing volumes before the well goes dry. When the formation permeability is too low to allow for continuous purging, remove all of the standing water in the well by pumping or bailing. As soon as the well has recharged sufficiently, collect a sample so as to minimize volatilization in the wellbore.

5. Contain all fluid from obviously contaminated or potentially contaminated wells for later disposal. Anomalous values for the above field parameters, odor, visible sheen, or the presence of free product may be taken as signs of contamination. Results of previous water sampling events will be consulted when available.

6. Take careful notes in order to document all purging procedures. The notes shall include: date, time, name(s) of sampler(s), weather, purge rate, purge method, field parameters (at each time measured, with corresponding purge volume), visual observations, odor, and any other relevant information.

The following guidelines as outlined in pertinent references on water sampling can be used when developing site-specific purging procedures:

- Pg. 103 of the EPA RCRA Technical Enforcement Guidance Document (TEGD) states, "in low yield formations, water should be purged so that it is removed from the bottom of the well." (NWWA, 1986).

- Pg. 103 of the TEGD also states "Whenever a well is purged to dryness, a sample for field parameters should be collected as soon as the well has recovered sufficiently. A second measurement of field parameters should be made immediately after sampling. Do not pump a well to dryness if it causes formation water to cascade down the well." (Ibid).

- The inlet line of the sampling pump or the submersible pump should be placed near the bottom of the screen section, and pump approximately one well volume of water at the well's recovery rate, and then collect the sample from the discharge line (EPA 1977, pg. 211).

- According to Wehrmann (1984), "For high yielding monitoring wells which cannot be pumped to dryness, bailing without pre-pumping the well is not recommended; there is no absolute safeguard against contaminating the sample with stagnant water." The following procedures should be used:

  Place the inlet line of the sampling pump just below the surface of the well water, and pump three to five volumes of water at a rate equal to the well's recovery rate. This provides reasonable assurance that all stagnant water has been evacuated and that the sample will be representative of the groundwater body at that time.

- Wehrmann (1984) further states, "The rate at which wells are purged should be kept to a minimum. Purging rates should be lower than development rates so that well damage does not occur. Pumping at very low rates in effect, isolates the column of stagnant water in the well bore and negates the need for its removal, if the pump intake is placed at the top of, or in, the well screen. This approach can be very useful when disposal of purge water is a problem."

- If a well completed in a highly permeable formation is being purged, it may be useful to periodically move the intake of the purge pump during purging so that stagnant water does not remain in the well bore while fresh water comes in at only one level (Scalf et al., 1981, pg. 44).

3.3 Ground Water Sample Collection

The following procedure shall be used to collect ground-water samples:

1. If the well is not equipped with a sampling pump, use only teflon or stainless steel bailers for sampling. In order to minimize agitation and volatilization, bailers shall be equipped with bottom emptying devices when VOA samples are collected.

2. Whenever possible, collect ground-water samples first from wells that have the lowest potential concentrations of analytes of interest, and last from the wells with the highest suspected concentrations (i.e., clean → dirty). The specific sampling order will be detailed in the site-specific sampling plan.

3. Pumps equipped with Teflon tubing or disposable teflon bailers are generally recommended for collection of samples to be analyzed for volatile organics.

4. Select the appropriate sample container and preservative as described in Section 13.5.6.

5. After the well has been purged, collect water samples as soon as possible in order to reduce the possibility of volatilization within the wellbore. If a pump has been used for purging, lower the pump rate so that the sampling rate is lower than the purge rate. If volatile organic samples are to be collected, set the pump at the lowest possible setting. If possible, the sampling rate should be less than 100 ml per minute, or the minimum setting on the pump.

6. Collect samples in decreasing order of volatility, i.e. collect samples to be analyzed for volatile organic compounds (VOCs) first, followed by semi-volatile organic compounds, PCBs and pesticides, and inorganics. The preferred order of sampling according to the TEGD is VOCs, SVOCs, purgeable organic halogens (POX), total organic halogens (TOX), total organic carbon (TOC), extractable organics, total metals, dissolved metals, phenols, cyanide, sulfate and chloride, turbidity, nitrate and ammonia, and radionuclides.

7. Do not allow the outlet of the sampling pump discharge tubing to come into direct contact with the sample vial or the water within the vial.

8. Make sure that no air is entrapped in the sample vials to be analyzed for volatile organics. Take the sample by holding the vial at an angle so that aeration is minimized. Avoid touching the lip of the vial or the Teflon liner. If the sample cannot be transferred directly to the vial, (i.e. high production well) use a clean stainless steel cup to pour the water into the vial. Direct the water stream against the inside surface of the vial. Allow a convex meniscus to form across the mouth of the filled vial. Carefully cap the vial, then invert and tap the vial to insure that no entrapped air is present. If entrapped air is present, recollect the sample.

9. If filtering of any samples is required by the site specific sampling plan, use the filtering procedure described in Section 13.5.7.

10. Preserve the sample as indicated in Section 13.5.6. Whenever possible, use pre-preserved containers supplied by the analytical laboratory rather than adding preservatives in the field.

11. Measure field parameters as described in Section 13.5.3. Temperature, electrical conductivity, and pH generally will be measured at all locations. Alkalinity, dissolved oxygen, and Eh will be measured only as required by the site specific sampling plan.

12. If the sample is to be collected from a domestic well or location other than a monitoring well, it may be necessary to clean the sampling port prior to sample collection (e.g., an outside hose bib or an inside water facet). Flush the faucet/line by allowing it to run for a minimum of five minutes.

13. Collect samples from domestic wells downstream of water softeners or chlorinators or in-home filters that modify water quality. However, if the objective of the domestic sampling is to evaluate the ground water prior to treatment, the samples may be taken upstream of such devices.

14. Record all pertinent information in the field notebook. Data to be recorded include the date and time of sample collection, climatic conditions at the time of sampling, well sampling sequence, types of sample containers used, sample identification numbers, field parameter data, name(s) of collector(s), deviations from established sampling protocol (e.g., equipment malfunctions), purpose of sampling (e.g., surveillance, compliance), and collection of quality control samples.

4. REFERENCES

- Barcelona, Michael J., James P. Gibb, John A. Helfrich and Edward E. Garske. 1985. Practical Guide for Ground-Water Sampling. Prepared in cooperation with RSKERL, Ada, Oklahoma. SWS Contract Report 374. DBS&A #560/BAR/1985.

- EPA. 1977. Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities, Manual SW-611. DBS&A 560/EPA.

- NWWA. 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). DBS&A #700/NWWA/1986.

- Scalf, Marion R., James F. McNabb, William J. Dunlap, Roger L. Cosby, and John S. Fryberger. 1981. Manual of Ground-Water Quality Sampling Procedures. Robert S. Kerr Environmental Research Lab, ORD, U.S. EPA, Ada Oklahoma. NWWA/EPA Series. DBS&A #1220/SCA/1991.

- Wehrmann, H. Allen. 1984. An Investigation of a Volatile Organic Chemical Plume in Northern Winnebago County, Illinois. SWS Contract Report 346. ENR Document No. 84/09. Illinois Department of Energy and Natural Resources, State Water Survey Division, Champaign, IL. DBS&A #940/WEH/1984.

Prepared by: Joanne

Approved by: Daniel B. Stephens
Daniel B. Stephens

Reviewed by:
Quality Assurance Manager

Reviewed by:
Systems Operations Manager

Section 13.5.5

Collection of Surface Water Samples

Procedure

Collection of Surface Water Samples

1. PURPOSE

The following SOP defines activities to be completed for the collection of surface water samples.

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors when collecting surface water samples.

3. PROCEDURES

A site-specific water sampling plan shall be prepared to define surface water sampling locations and procedures that are unique to each site. The following general procedure shall be followed for collection of surface water samples:

1. Select the water sampling location. Collect spring samples as close to the source as possible. Do not collect spring or stream samples from stagnant pools; collect these samples from free running locations if possible. The selection of the optimum sampling locations should be based on the objectives of the site-specific sampling plan.

2. Whenever possible, make a discharge measurement at the time of water sampling. If it is not possible to gauge the surface water discharge (see Section 13.9 of the DBS&A Operations Manual), make an estimate, and describe the procedure used to estimate the discharge in the field logbook.

3. Collect surface water samples as "grab" samples unless a depth integrated sampler or other procedure is required in the site specific sampling plan.

4. If the surface water is frozen, ice samples should not be taken in lieu of water samples.

5. Select the appropriate container as described in Section 13.5.6 of the Operations Manual.

6. For non-volatile analytes, dip a clean unpreserved container directly into the surface water, and partially fill the container. Swirl and rinse the container, and then discard the water.

7. Rinse the container two more times.

8. Fill the container with surface water.

9. Collect samples in decreasing order of volatility, i.e. collect samples to be analyzed for volatile organic compounds (VOCs) first, followed by semi-volatile organic compounds (SVOC), PCBs and pesticides, and inorganics. The preferred order of sampling according to the TEGD is VOCs, SVOCs, purgeable organic halogens (POX), total organic halogens (TOX), total organic carbon (TOC), extractable organics, total metals, dissolved metals, phenols, cyanide, sulfate and chloride, turbidity, nitrate and ammonia, and radionuclides.

10. Make sure that no air is entrapped in the sample vials to be analyzed for volatile organics. Take the sample by holding the vial at an angle so that aeration is minimized. Avoid touching the lip of the vial or the Teflon liner. If the sample cannot be collected directly from the water source, use a clean stainless steel cup. Direct the water stream against the inside surface of the vial. Allow a convex meniscus to form across the mouth of the filled vial. Carefully cap the vial, then invert and tap the vial to insure that no entrapped air is present. If entrapped air is present, recollect the sample.

11. If filtering of any samples is required by the site specific sampling plan, use the filtering procedure described in Section 13.5.7 of the Operations Manual.

12. Either add preservatives directly to the container as described in Section 13.5.6 of the Operations Manual, or transfer the sample to a pre-preserved container. If transferring the sample between containers, pour the water slowly from the glass bottle or cubitainer to the sample container.

13. Fill a clean beaker or other appropriate container with surface water for field parameter measurement as discussed in Section 13.5.3 of the Operations Manual. Temperature, electrical conductivity, and pH generally will be measured at all locations. Alkalinity, dissolved oxygen, and Eh will be measured only as required by the site-specific sampling plan.

14. Carefully document the surface water sampling location. Photographs of the sampling location should be taken from several locations if possible. Describe each photograph along with the photo number in the log book (e.g., photo #5-Upstream (south) view of location # SPG-014, taken from the west bank). Also include the time, date, and the name of the photographer in the log book, and transfer this information to the back of photograph when it is received. In addition, provide a detailed written description of the sample location in the log book.

15. Record all pertinent information in the field notebook. Data to be recorded include the date and time of collection, climatic conditions at the time of sampling, well sampling sequence, types of sample containers used, sample identification numbers, field parameter data, name(s) of collector(s), deviations from established sampling protocol (e.g., equipment malfunctions), purpose of sampling (e.g., surveillance, compliance), and collection of quality control samples. Also note any obvious stress to vegetation, which may be a result of contamination.

Prepared by: Joanne ______________

Approved by: Daniel B. Stephens
Daniel B. Stephens

Reviewed by: ______________
Quality Assurance Manager

Reviewed by: ______________
Systems Operations Manager

Section 13.5.6

Sample Preservation

DANIEL B. STEPHENS & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Procedure
Sample Preservation
SECTION 13.5.6

1. PURPOSE

The following SOP defines activities to be completed to properly preserve a water sample for shipment to an analytical laboratory for analysis.

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors when preserving water samples in the field.

3. PROCEDURES

Table 13.5.6-1 of this SOP lists recommended containers, preservatives, and holding times for individual analytes or analytical methods. The suggestions for sample storage and preservation presented are intended to serve as general guidelines. The analytical laboratories shall be consulted for the proper preservation and storage procedure for the analytical methods that will be used (e.g., this guideline recommends preservation of volatile organic samples with hydrochloric acid (HCl), but some laboratories require preservation with mercuric chloride).

Samples for volatile organics analysis (EPA 602, 624 or 8020) shall be collected in pre-cooled, pre-acidified, certified-clean 40 ml borosilicate vials with teflon septum caps supplied by the analytical laboratory. Samples to be analyzed for other constituents should be collected in appropriate containers as listed in Attachment 1 to this SOP.

4 ATTACHMENTS

- Table 13.5.6-1, Container/Preservative Reference Chart (5 sheets)

Prepared by: Joanne Hilton

Approved by:
Daniel B. Stephens

Reviewed by:
Quality Assurance Manager

Reviewed by:
Systems Operations Manager

TABLE 13.5.6-1. CONTAINER/PRESERVATIVE REFERENCE CHART
General/Inorganic Chemistry

Analysis	*Container*	*Preservative (Chill to 40°C)*	*Container*	*Holding Time (From Sampling Date)*	
	Water	Water	Soil	Water	Soil
Alkalinity	4 oz. Plastic	Unpreserved	N/A	14 days	N/A
Ammonia (NH_3)	4 oz. Plastic	.25 ml H_2SO_4[A]	4 oz. jar	28 days	28 days
BOD	16 oz. Plastic[B]	Unpreserved	N/A	48 hr.	N/A
Boron	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Bromide	16 oz. Plastic	Unpreserved	8 oz. jar	28 days	28 days
Chloride	4 oz. Plastic	Unpreserved	8 oz. jar	28 days	28 days
COD	4 oz. Plastic	.25 ml H_2SO_4[A]	4 oz. jar	28 days	28 days
Color	4 oz. Plastic	Unpreserved	N/A	48 hr.	N/A
Cyanide (total and/ or amenable)	4 oz. Plastic	2 ml 1.5N NaOH[B]	4 oz. jar	14 days	No Specified Time
Electrical Conductivity	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Flashpoint	8 oz. Amber Glass w/Septum[B]	Unpreserved	8 oz. jar	28 days	28 days
Fluoride	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Formaldehyde	1 L Glass	1% Methanol	4 oz. jar	28 days-Pres. 7 days-Unp.	28 days
General Minerals • General Minerals • NO_3 • Metals	 1 L Plastic 4 oz. Plastic 16 oz. Plastic	 Unpreserved .25 ml H_2SO_4[A] 1 ml HNO_3[A]	 16 oz. jar	 28 days	 28 days
Gross Alpha/Beta	1 L Plastic	2 ml HNO_3[A]	4 oz. jar	6 mo.	6 mo.
Hardness	4 oz. Plastic	Unpreserved	N/A	28 days	N/A
Hexavalent Chromium (CR^{+6})	16 oz. Plastic	Unpreserved	4 oz. jar	24 hr.	28 days

A - Typical volume needed to bring the pH to <2
B - Headspace free
C - Typical volume needed to bring the pH to >12
D - Typical volume needed to bring the pH to >9

TABLE 13.5.6-1. CONTAINER/PRESERVATIVE REFERENCE CHART (CONTINUED)
General/Inorganic Chemistry

Analysis	***Container***	***Preservative (Chill to 40°C)***	***Container***	***Holding Time (From Sampling Date)***	
	Water	**Water**	**Soil**	**Water**	**Soil**
Iodide	4 oz. Plastic	Unpreserved	4 oz. jar	24 hr.	28 days
Nitrate/Nitrite (NO_3/NO_2)	4 oz. Plastic	.25 ml $H_2SO_4^A$	4 oz. jar	28 days	28 days
• NO_3	4 oz. Plastic	Unpreserved	4 oz. jar	48 hr.	28 days
Odor	4 oz. Glass	Unpreserved	N/A	48 hr.	N/A
Oil & Grease	1 L Glass	2 ml $H_2SO_4^A$	4 oz. jar	28 days	28 days
418.1 (TPH by IR)	1 L Glass	2 ml $H_2SO_4^A$	4 oz. jar	28 days	28 days
pH	4 oz. Plastic	Unpreserved	4 oz. jar	immediately	14 days
Phenolics	4 oz. Amber Glass	.25 ml $H_2SO_4^A$	4 oz. jar	28 days	28 days
Phosphorus • Total (P)	4 oz./8 oz. Plastic	.25 ml/.5 ml $H_2SO_4^A$	4 oz. jar	28 days	28 days
Phosphorus • Ortho (PO_4)	4 oz./8 oz. Plastic (Filtered)	Unpreserved	4 oz. jar	48 hr.	28 days
Silica	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Solids (Residue) • Total dissolved	16 oz. Plastic	Unpreserved	N/A	7 days	N/A
• Total suspended	16 oz. Plastic	Unpreserved	N/A	7 days	N/A
• Total settleable	1 L Plastic	Unpreserved	N/A	48 hr.	N/A
• Total solids	16 oz. Plastic	Unpreserved	N/A	7 days	N/A
Specific Gravity	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Sulfate	4 oz. Plastic	Unpreserved	4 oz. jar	28 days	28 days
Sulfide	4 oz. Plastic	6 drops-2N Zn acetate & 8 drops 6N $NaOH^D$	N/A	7 days	N/A
Sulfite	4 oz. Plastic	1 ml EDTA	N/A	28 days-Pres. 6 hr.-Unp.	N/A

A - Typical volume needed to bring the pH to <2
B - Headspace free
C - Typical volume needed to bring the pH to >12
D - Typical volume needed to bring the pH to >9

TABLE 13.5.6-1. CONTAINER/PRESERVATIVE REFERENCE CHART (CONTINUED)
General/Inorganic Chemistry

Analysis	***Container***	***Preservative (Chill to 40°C)***	***Container***	***Holding Time (From Sampling Date)***	
	Water	**Water**	**Soil**	**Water**	**Soil**
Surfactants (MBAS)	1 L Plastic	Unpreserved	N/A	48 hr.	N/A
Total Coliform	8 oz. Glass or Polypropylene (Sterilized)	0.008% $Na_2S_2O_3$	N/A	6-8 hr.	N/A
TKN (Kjeldahl Nitrogen)	4 oz. Plastic	.25 ml H_2SO_4[A]	4 oz. jar	28 days	28 days
Total Organic Carbon (TOC)	4 oz. Amber Glass w/Septum[B]	.25 ml H_2SO_4[A]	4 oz. jar	28 days	28 days
Total Organic Halide (TOX)	8 oz. Amber Glass w/Septum[B]	.5 ml H_2SO_4[A]	4 oz. jar	7 days	No Specified Time
Total Radium	1 L Plastic	2 ml HNO_3[A,C]	4 oz. jar	6 mo.	6 mo.
Turbidity	4 oz. Plastic	Unpreserved	N/A	48 hr.	N/A

A - Typical volume needed to bring the pH to <2
B - Headspace free
C - Typical volume needed to bring the pH to >12
D - Typical volume needed to bring the pH to >9

TABLE 13.5.6-1. CONTAINER/PRESERVATIVE REFERENCE CHART (CONTINUED)
Organic Chemistry

Analysis	***Container*** *(Glass- and Teflon-lined caps only)*	***Preservative*** *(Chill to 40°C)*	***Container*** *(Glass- and Teflon-lined caps only - Chill to 40°C)*	***Holding Time*** *(From sampling date)*	
	Water	**Water**	**Soil**	**Water**	**Soil**
8010/8020	3X VOA[A]	3 drops HCl[B]	4 oz. jar	14 days-Pres., 7 days-Unp.	14 days until Analysis
• 8010	3X VOA[A]	3 drops HCl[B]	4 oz. jar	14 days	14 days until Analysis
• 8020	3X VOA[A]	3 drops HCl[B]	4 oz. jar	14 days-Pres., 7 days-Unp.	14 days until Analysis
• BTXE	3X VOA[A]	3 drops HCl[B]	4 oz. jar	14 days-Pres., 7 days-Unp.	14 days until Analysis
Modified 8015 (TPH)	4 oz. Amber Glass w/Septum[A]	.25 ml HCl[B]	4 oz. jar	14 days until Analysis	14 days until Analysis
• Gasoline Range	2X VOA	3 drops HCl[B]	4 oz. jar	14 days until Analysis	14 days until Analysis
• Diesel Range	4 oz. Amber Glass w/Septum[A]	.25 ml HCl[B]	4 oz. jar	14 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8240	2X VOA	3 drops HCl[B]	4 oz. jar	14 days-Pres., 7 days-Unp.	14 days until Analysis
EDB	1 L Glass	Unp.	8 oz. jar	28 days until Analysis	28 days until Analysis
8040	1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8080	2 x 1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8100/8310	1 L Amber Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8140	1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8150	1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
Modified 619	1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
8270	2 x 1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
Modified 632	1 L Glass	Unp.	4 oz. jar	7 days until Extraction 40 days after Extraction until Analysis	14 days until Extraction 40 days after Extraction until Analysis
TCLP					
• Volatiles (zero headspace extraction)	N/A	N/A	4 oz. jar	N/A	14 days until Extraction 14 days after Extraction until Analysis
• Non-Volatiles	N/A	N/A	16 oz. jar	N/A	14 days until TCLP Leaching

A - Headspace free
B - Typical amount to bring the pH to <2

TABLE 13.5.6-1. CONTAINER/PRESERVATIVE REFERENCE CHART (CONTINUED)
Metals

Analysis	***Container***	***Preservative***	***Holding Time*** *(From Sampling Date)*
WATER			
Metals (1 or more metals)			
• Total	16 oz. Plastic	l-ml HNO_3^A	6 mo. (28 days-Hg)
• Dissolved • Filtered in Field	16 oz. Plastic	l-ml HNO_3^A	6 mo. (28 days-Hg)
• Not Filtered	16 oz. Plastic (Specify "To be lab filtered")	Unpreserved	6 mo. (28 days-Hg)
• Organic Lead	8 oz. Amber Glass (Glass Only) w/Septum (Headspace Free)	Unpreserved Chill to 4°C	14 days until Analysis (laboratory recommended)
• Hexavalent Chromium (Cr^{+6})	16 oz. Plastic	Unpreserved	24 hr.
SOIL			
Metals (1 or more metals)			
• Total	4 oz. jar		6 mo.
• Soluble			
• EP Toxicity	8 oz. jar		6 mo.
• WET	8 oz. jar		6 mo.
• TCLP (see also Organic Chemistry)	8 oz. jar		6 mo.
• Hexavalent Chromium (Cr^{+6})	4 oz. jar		28 days
• Organic Lead	4 oz. jar	Chill to 4°C	14 days until Analysis (laboratory recommended)

A - Typical amount to bring the pH to <2.

Section 13.5.7

Sample Filtration

Procedure
Sample Filtration
SECTION 13.5.7

Effective 06/01/93 • Supersedes n/a • Page 1 of 2

1. PURPOSE

The following SOP defines activities to be completed to properly filter water samples in preparation for analysis by an analytical laboratory.

2. SCOPE

This procedure is applicable to all DBS&A employees and its contractors and subcontractors when filtering water samples.

3. PROCEDURES

Recent research indicates that if samples are obtained correctly, field filtration for metals may not be necessary (Puls and Powell, 1992). However, filtration of samples to be analyzed for dissolved metals may be required in some cases. If filtration is required, it shall be outlined in the site specific sampling plan.

If filtration is required, filter the samples in the field if possible. If field filtering is not possible, preserve the sample by chilling to 4°C (i.e. do not add acid), and immediately ship the sample via overnight delivery to the laboratory. Indicate on the chain of custody that laboratory filtration and preservation are required.

Vacuum filtration of ground water samples is not recommended (Barcelona et al., 1985, pg. 65). Samples to be analyzed for TOC, VOCs or other organic compounds should not be filtered. Filtration may be performed on samples collected for analysis of dissolved metals, however.

The following procedure shall be followed to filter samples in the field with the GeoPump:

1. Connect the GeoPump to an automobile cigarette lighter or outlet if electricity is available.
2. Replace the tubing for the GeoPump at the beginning of each sampling round. If the samples are collected in any order other than most contaminated to least contaminated, or if very high levels of contamination are suspected or observed, then replace the tubing between each sample or as necessary.
3. If the tubing is not replaced between each sample, flush the lines with Liquinox followed by at least three flushes with distilled water.
4. Collect an unfiltered water sample as discussed in Sections 13.5.4 and 13.5.5 of the DBS&A Operations Manual.
5. Place the intake line in the unfiltered sample.
6. Pump at least a few hundred milliliters of the sample through the GeoPump prior to sample collection in order to flush the line. Set the GeoPump at the lowest rate possible in order to minimize aeration. Dispose of this water appropriately.

7. Place a disposable 45 micron filter on the output line. Direct the output stream below the filter into the pre-acidified sample container, as outlined in Section 13.5.6 of the DBS&A Operations Manual

4. REFERENCES

- Barcelona, Michael J., James P. Gibb, John A. Helfrich and Edward E. Garske. 1985. Practical Guide for Ground-Water Sampling. Prepared in cooperation with RSKERL, Ada, Oklahoma. SWS Contract Report 374. DBS&A #560/BAR/1985.

- Puls, Robert W. and Robert M. Powell, R.S. Kerr Environmental Research Laboratory (RSKERL). 1992. Acquisition of Representative Ground Water Quality Samples for Metals. *Ground Water Monitoring Review, Summer 1992.*

Prepared by: ______________________

Approved by: ______________________
Daniel B. Stephens

Reviewed by: ______________________
Quality Assurance Manager

Reviewed by: ______________________
Systems Operations Manager

Section 13.5.8

Quality Assurance/ Quality Control (QA/QC)

Section 13.6.1

Ground-Water Level Measurement

Procedure
Ground-Water Level Measurement

1. PURPOSE

The purpose of this procedure is to provide DBS&A personnel with the information necessary to collect accurate water-level data from ground-water wells. Water level measurements provide the fundamental data needed to determine aquifer characteristics; therefore, it is crucial that the appropriate methods are used to meet the data requirements of an aquifer investigation.

2. SCOPE

The following procedures are applicable to all DBS&A employees and subcontractors engaged in the measurement of ground-water levels in wells. Several methods are available for determining the depth to water (DTW); this SOP briefly describes methods used to measure water levels manually, and automatically with the help of data recorders. This information is intended to help DBS&A personnel determine the appropriate equipment to collect water levels for background trend analysis and aquifer tests.

3. PROCEDURES

Immediately following well construction (see Section 13.4.1 of the DBS&A Operations Manual), a measuring point shall be clearly labeled "MP" with a permanent marker at the top of the casing. The designated MP shall be located at a point which is unlikely to change in elevation during the life of the well. This will prevent repeated surveys to determine the reference elevation of the measuring point. If the MP does change, it shall be clearly re-marked and referenced to the original elevation or a new survey will be necessary. Water levels will be measured in accordance with ASTM D 4750, Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).

The water level measurement (depth to water; DTW) shall be recorded on the Water Level Measurement Form included as Attachment 1 to this SOP (DBS&A Form No. 120). In addition, the following information shall be recorded on the form: the person making the measurement, the measuring device, the surveyed point from which the measurement is made, the time of day (military time), the date, the wellhead condition, and any measuring point (MP) changes.

Ground-water level data may also be recorded in the field log and on other applicable DBS&A forms including but not limited to those used for water sampling and drilling/soils logging.

The following subsections will describe the most commonly used techniques for obtaining water-level data in the field.

3.1 Steel Tape

Graduated steel tapes provide accurate measurements to within approximately 0.01 foot of the actual DTW for depths of 100 feet or less. The rigidity of the tape allows it to hang straight in the well. Steel tapes should generally not be used when many measurements must be made in rapid succession, such as during an aquifer test. Measurements with a steel tape are relatively time consuming.

When using a steel tape the lower 2 to 3 feet is wiped dry and coated with carpenters chalk or water finding paste before being lowered down the well. The tape is then lowered into the well to the estimated DTW. The tape should be held on a foot marker at the well-head measuring or reference point (MP). After removing the tape, the wetted end is read and subtracted from the previous reading; the difference is the actual DTW. If tape graduations are greater than 0.1 foot apart, a separate engineering tape or scale shall be used to accurately determine the wetted end measurement.

The steel tape should not stretch more than 0.05% under normal use and should not cause more than an 0.05-foot perceived rise in water level during measurement. If more than a 0.05-foot rise in water level occurs during measurement, a correction shall be made for the displacement. Steel tapes shall be calibrated against a surveyor's reference tape annually by the DBS&A Environmental Equipment Coordinator. Information from these calibrations shall be kept on hand at the DBS&A equipment supply facility.

The main disadvantage of the steel tape method is that the approximate depth to water must be known prior to the measurement. In addition, interferences such as cascading water, smearing, and/or evaporation may compromise the accuracy of the wetted-end measurement. However, steel tapes are relatively inexpensive and generally more durable than electrical instruments for measuring water levels.

3.2 Electrical Sounders

Electrical sounders operate by completing a circuit when the probe contacts the water level. Upon completion of the circuit a light, buzzer, or ammeter needle indicates that the probe is in contact with the water table. The probe is connected to a graduated tape, usually made from plastic and fiberglass. Batteries supply the necessary current through electrical wires contained in the graduated tape. Measurements are commonly made to within 0.01 foot with electrical sounders.

Electrical sounders are the most commonly used ground-water level measuring device on DBS&A projects. The major advantage of electrical sounders is that many measurements can be made rapidly and accurately without removing the probe from the well. Field personnel should position themselves near the MP so the DTW can be read at eye level. A second check reading should be taken before withdrawing the electric tape from the well. Most DBS&A sounders are marked every 0.02 foot.

The length of the electric line shall be calibrated annually with an engineers tape by the DBS&A Environmental Equipment Coordinator. Information from these calibrations shall be kept on hand at the DBS&A equipment supply facility.

Potential disadvantages of the electrical sounder devices include: the expense of an accurate sounder; inaccurate measurements that may be made due to stretching or kinking of the tape; electrical shorts that may be caused by broken or corroded wires; false readings due to cascading water; snagging of the sounder tip on pump columns and cables; or incomplete circuits due to low concentrations of total dissolved solids in the water.

3.3 Automated Water Level Measurements

To determine background water level trends, the most economic approach is to set up a continuous data recorder capable of making many measurements automatically. Driscoll (1986) discusses the application and installation of such systems in detail. The most common recorders produce a graphical chart or store the data electronically for future retrieval. Continuous water level records are quite useful for determining daily and seasonal fluctuations resulting from recharge and discharge periods, evapotranspiration and tidal stress, and during aquifer tests when there are not enough field personnel to collect all the necessary data. The following paragraphs briefly review equipment used with continuous recorders to measure water levels.

Automated pressure transducers are useful for collecting large quantities of water-level data rapidly during labor intensive aquifer tests. DBS&A owns an electronic data logging system consisting of a Campbell Scientific 21X data logger and DRUK pressure transducers which can be calibrated to output feet of water above the transducer. Refer to Section 13.6.4 of the Operations Manual for detailed information on using the system. The system can be programmed to collect data on arithmetic and logarithmic time scales. Measurements are accurate to approximately 0.01 foot providing there is no turbulence in the well.

Airline bubblers are commonly used by the U.S. Geological Survey for measuring stream stage and water levels in wells over periods of several years. Airline bubblers usually operate on nitrogen gas. The device works on the principal that the gas pressure required to push all the water out of the submerged portion of the tube equals the water pressure of a column of water equal to that height. Measurements are accurate to within 0.01 foot.

Float sensors can also be used to determine long term variation in background water levels. Float sensors consist of a tape or cable passing over a pulley with a float attached to one end and a counterweight attached to the other. The float follows the rise and fall of the water level. A graphic or electronic recorder is attached to the calibrated pulley to store the water level data. Float sensors work best in large diameter wells (4 inches or greater). The greatest disadvantage of this method is the potential for the float to stick on the side of the casing or jump the pulley resulting in a "stair stepping" record or no record at all. Measurements are accurate to 0.1 foot or greater depending on the precision of the recorder and pulley calibration.

4. ATTACHMENTS

1. Water Level Measurements (DBS&A Form No. 120)

5. REFERENCES

ASTM. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. Standard D 5092-90. Philadelphia, PA.

Driscoll, F.G. 1986. Groundwater and Wells. Johnson Division. St. Paul, MN. 1089 p.

Prepared by: Bob Marley

Approved by: ______
Daniel B. Stephens

Reviewed by: ______
Quality Assurance Manager

Reviewed by: ______
Systems Operations Manager

DANIEL B. STEPHENS & ASSOCIATES, INC.

Water Level Measurements

Project Name ______________________________ Measurement Date ______________

Project Number ______________ Field Staff ______________________________

Measuring Points and Datum Used ______________________________

Observations ______________________________

Well Number	Time	Elevation of Measuring Point (feet, mean sea level)	Depth Below Measuring Point (feet)	Water Level Elevation (feet, mean sea level)

Signature ______________________________ Date ______________

DBS&A Form No. 120 5/93

Section 13.6.2

Slug Testing

Guideline
Slug Testing
SECTION 13.6.2

1. PURPOSE

The following SOP describes procedures for performing various types of aquifer slug tests in the field.

2. SCOPE

The procedures listed below are applicable to all DBS&A employees, its contractors and subcontractors, for performing aquifer slug tests. The procedures for obtaining the necessary data in the field are described herein; the procedures for analyzing the data to calculate aquifer hydraulic properties are described in Section 14 of the DBS&A Operations Manual.

3. PROCEDURES

The procedures described below for performing slug tests are applicable to all aquifer types. Where a variation in methodology occurs with a particular aquifer type, it will be noted. These procedures are in accordance with ASTM D 4044-91, Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers. Additional references which may be helpful in planning and performing slug tests are Groundwater and Wells (Driscoll, 1986), and Analysis and Evaluation of Pumping Test Data (Kruseman and de Ridder, 1992).

3.1 Slug Testing

The slug test method involves creating a sudden change in head in a well and measuring the resulting water level response. Head changes are induced by suddenly removing or adding a known quantity of water in the well. This can be accomplished by removing a bailer full of water from the water column, placing a mechanical slug into the water column, or increasing/decreasing the air pressure in the well casing. From these measurements, the aquifer's transmissivity or hydraulic conductivity can be determined. Various analytical techniques allow for the estimation of coefficient of storage but should be considered less reliable than the estimate of transmissivity.

Slug tests are an inexpensive and rapid method of obtaining estimates of aquifer properties. No pumping is required in the slug test and no piezometers are required to be monitored. The main limitation of this test is that this method is only capable of determining the characteristics of a small volume of aquifer material surrounding the well. This material may have been disturbed during well drilling and construction and, as a result, may have a large impact on the results of the test. Additionally, only slug withdrawal test methods should be used for unconfined aquifers.

3.1.1 Required Preliminary Hydrogeologic Information

All available information pertinent to the slug test should be reviewed prior to the start of the test. This information will aid in preparing design specifications for the test. This information includes aquifer properties, such as aquifer type (confined, unconfined, etc.), aquifer thickness, aquifer boundaries, and any previous estimates of hydraulic properties, if available. Information on well construction details are also needed prior to the test. This includes geologic logs, well construction logs, screen interval and size, sand pack interval and size, borehole diameter, and casing diameter.

3.1.2 Water Level Measurements

Water levels should be measured immediately prior to the test, and throughout the test until water levels in the test well reach approximately 95% of the pre-test level. Water level response during the slug test will be measured as described in Section 13.6.1 of the DBS&A Operations Manual. Because water levels are dropping fast immediately after slug emplacement, measurements should be taken at brief intervals during this time. As recovery continues, the intervals can be gradually lengthened. Readings collected during the slug test should be recorded on Form No. 124, Slug Test Measurements.

3.1.3 Slug Test by Water Withdrawal

Water can be rapidly removed from a test well with the use of a bailer. In this method, a bailer of known volume is lowered below the water level in the test well. After it has been determined that the water level in the control well has recovered to within 95% of static, the bailer is rapidly removed from the water column. Water level recovery within the well is then measured and recorded until the water level has recovered to 95% of the background level. The bailer should be of sufficient size to ensure a proper water level response during removal from the water column.

A submersible pump can also be used to rapidly withdraw water from the test well. The pump will need to remove a sufficient volume of water from the test well in a matter of seconds. Care should be taken to ensure that water does not backflow into the well when the pump is shut off.

3.1.4 Slug Test by Mechanical Slug Injection

A mechanical slug constructed of nonporous material with a density greater than water can be rapidly lowered into the water column of the test well creating a nearly instantaneous rise in water level. The resulting water level recovery is then measured and recorded in the test well until the water level reaches approximately 95% of the background level.

3.1.5 Slug Test by Air Injection

Slug withdrawal can be simulated by injecting air into a well which has an airtight cap. This is accomplished with the use of an air pressure pump and regulator. In this method, the well is pressurized by the injection of air into the airtight test well. The injection of air into the well causes the water level in the test well to drop. Once the water level has stabilized, the pressure is released creating a sudden change in head. Water level recovery will need to be measured with the use of a pressure transducer connected to a data logger. This method requires that the test well be screened in the saturated portion of the aquifer.

3.1.6 Slug Test by Vacuum Withdrawal

The injection of a slug can be simulated by applying a vacuum to an airtight test well. This method requires the use of a vacuum pump and regulator. In this method, a steady vacuum is applied to the test well which creates a rise in water level. After the water level in the test well has stabilized, the vacuum is released which creates a sudden change in head. The water level recovery is then measured with the use of a pressure transducer connected to a data logger. This method requires that the test well be screened entirely in the saturated portion of the aquifer.

4. ATTACHMENTS

1. Slug Test Measurements (DBS&A Form No. 124)

5. REFERENCES

Driscoll, F.G. 1986. Groundwater and Wells, Second Edition. Johnson Filtration Systems, Inc., St. Paul, Minnesota.

Kruseman, G.P. and N.A. de Ridder. 1992. Analysis and Evaluation of Pumping Test Data, Second Edition. International Institute of Land Reclamation and Improvement.

Prepared by: ______________________

Reviewed by: ______________________
Quality Assurance Manager

Approved by: ______________________
Daniel B. Stephens

Reviewed by: ______________________
Systems Operations Manager

DANIEL B. STEPHENS & ASSOCIATES, INC.

Slug Test Measurements

Project Name ______________________ Test Date ______________

Project Number ______________ Field Staff ______________________

Well Number and Datum Used ______________________

Slug Type (material, volume, etc.) ______________________

Observations ______________________

Time	Depth Below Measuring Point (feet)	Change in Water Level (feet)

Signature ______________________ Date ______________

DBS&A Form No. 124 8/93