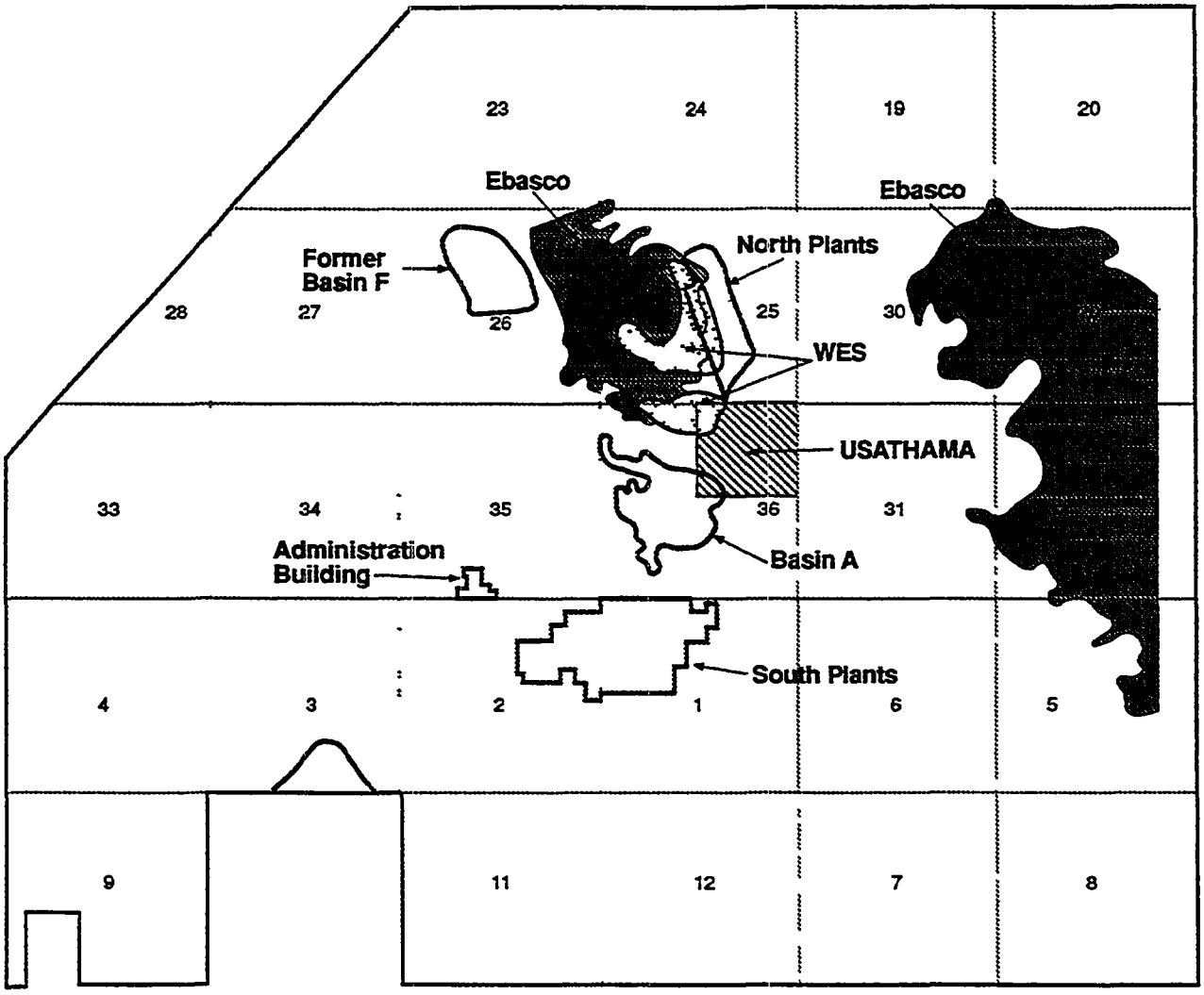


Explanation

2 Section Numbers

Section Lines

Waterways Experiment Station (WES) 1983

U S Army Toxic and Hazardous Materials Agency (USATHAMA), 1984

Ebasco Services Incorporated (EBASCO), 1988

N

0 1/2 1

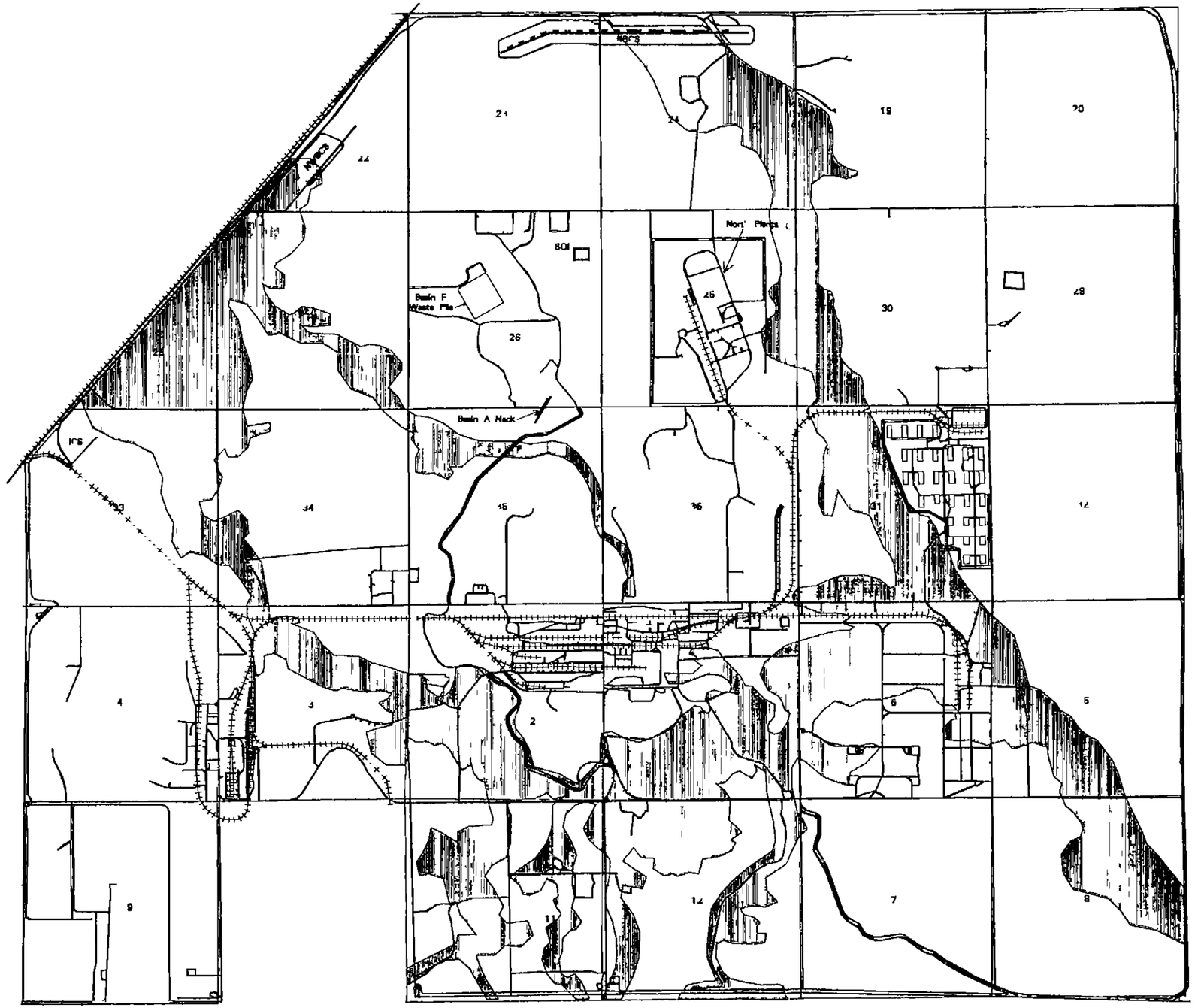
Scale in Miles

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
Harding Lawson Associates

Figure 4 1

Proposed Landfill Locations from
Previous Landfill Siting Studies



Explanation

- 100-Year Floodplain
- Road
- Railroad
- Section line
- 12 Section number
- NBCS North Boundary Containment System
- NWBCS Northwest Boundary Containment System
- ICS Irondale Containment System
- SQI Submerged Quench Incinerator

1000 0 2000 4000 FEET

N

Scale 1 36 000
One inch represents 3 000 feet

Prepared for
Program Manager for
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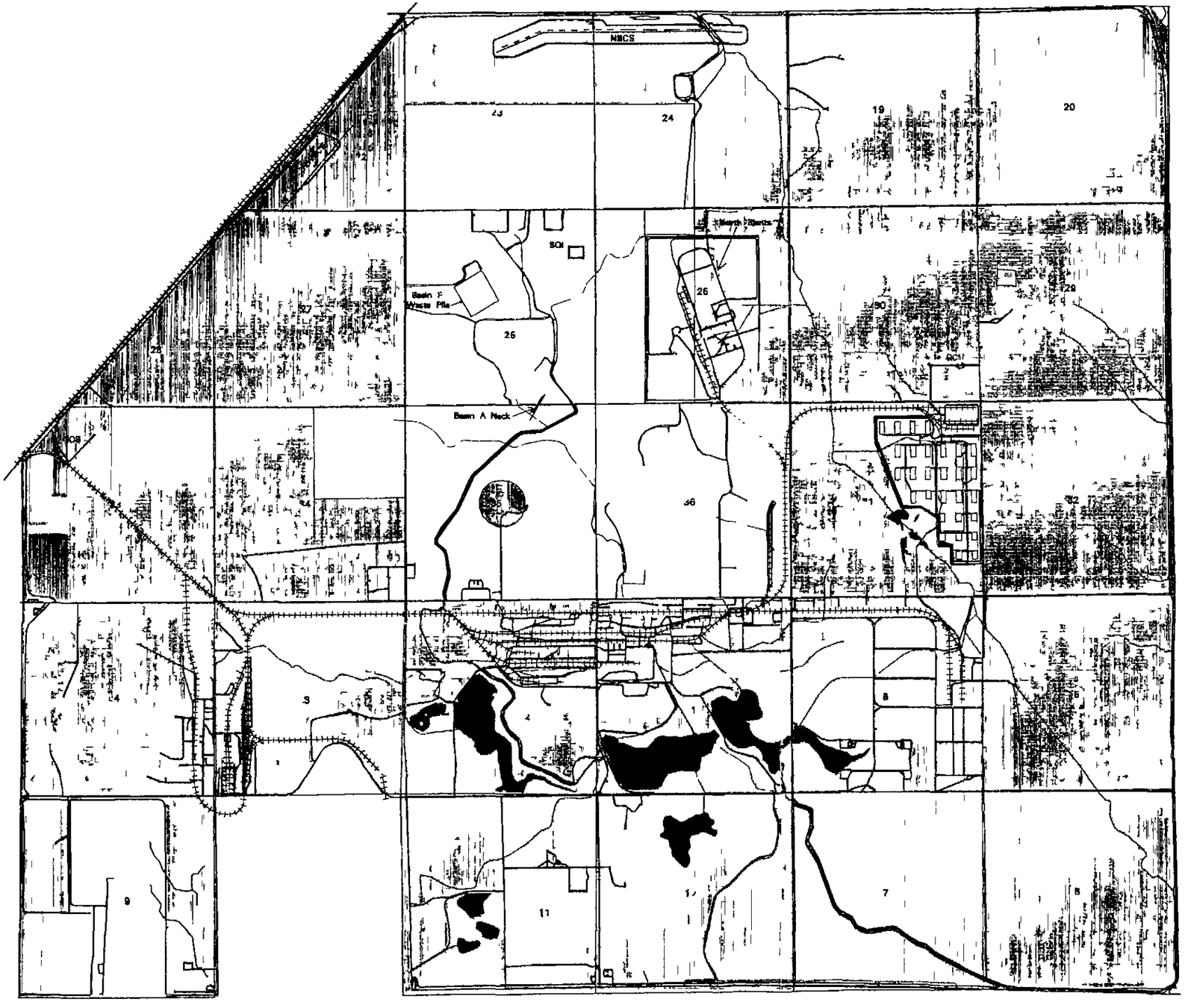
Commerce City, Colorado

Prepared by
Harding Lawson Associates

Figure 4-2

100-Year Floodplain Map

(U.S. Army Corps of Engineers, 1983)



Explanation

- United States Fish and Wildlife Service (USFWS) approved landfill sites
- Surface Water
- Stream
- Road
- Railroad
- Section line
- 12 Section number
- NBCS North Boundary Containment System
- NWBCS Northwest Boundary Containment System
- ICS Irondale Containment System
- SQI Submerged Quench Incinerator

1000 0 2000 4000 FEET

N

Scale 1 36 000
One inch represents 3 000 feet

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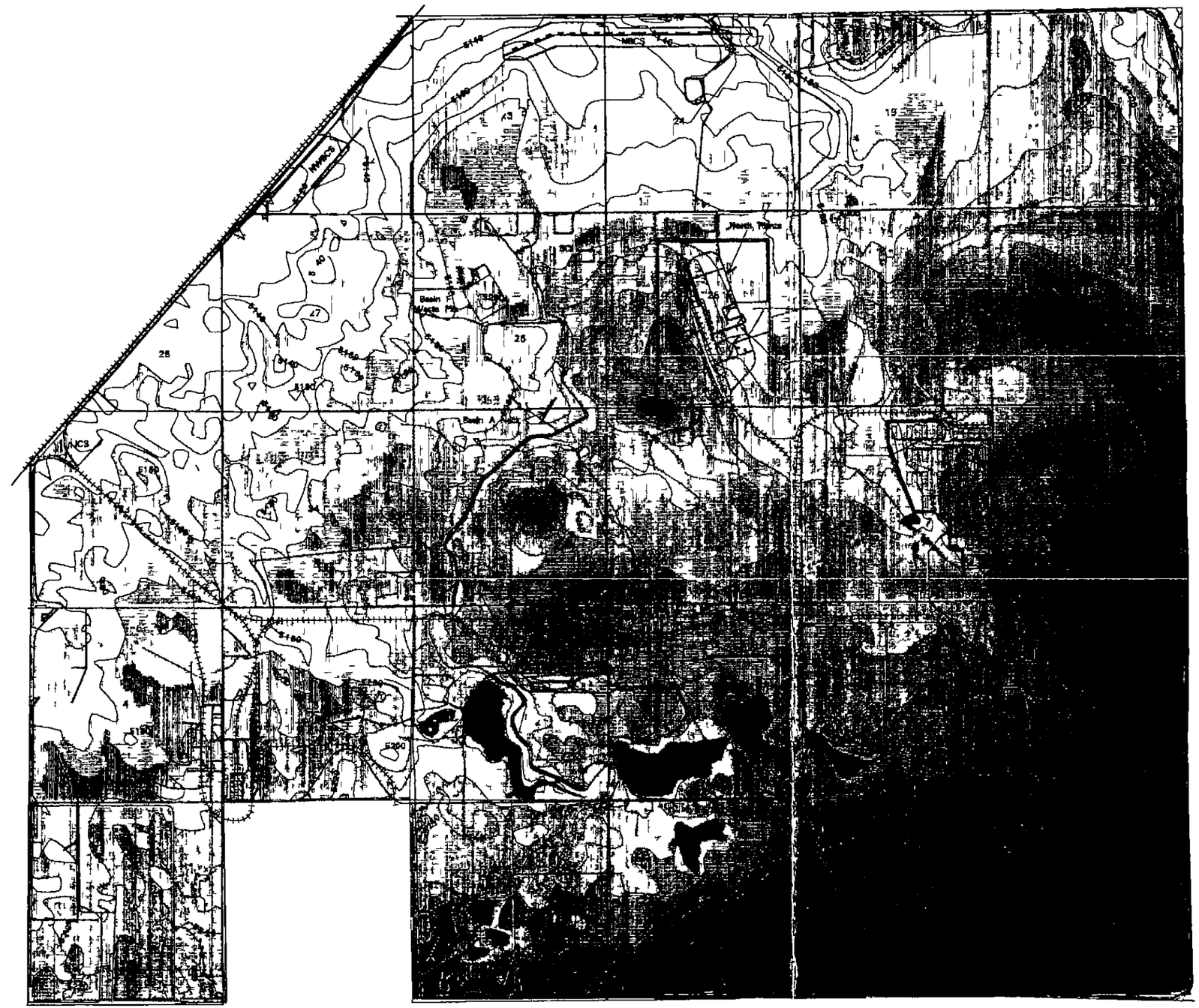
Figure 4 3

United States Fish and Wildlife Service
Approved Hazardous Waste Landfill Sites
(USFWS, 1994)



Explanation

5110 feet

5340 feet

10-foot contour interval

Surface Water

Stream

Road

Railroad

Section line

12 Section number

NBCS North Boundary Containment System

NWBCS Northwest Boundary Containment System

ICS Irondale Containment System

SQI Submerged Quench Incinerator

PMRMA Program Manager Rocky Mountain Arsenal

1000 0 2000 4000 FEET

N

Scale 1 36 000

One inch represents 3,000 feet

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Figure 4 4

Onpost Topographic Elevation Contour Map

(PMRMA, 1988)

Explanation

- Groundwater Contamination Plume
- Road
- Railroad
- Section line
- 2 — Section number
- NBCS — North Boundary Containment System
- NWBCS — Northwest Boundary Containment System
- ICS — Irondale Containment System
- SQI — Submerged Quench Incinerator

1000 0 2000 4000 FEET

N

Scale 1 36,000
One inch represents 3 000 feet

Prepared for
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Prepared by
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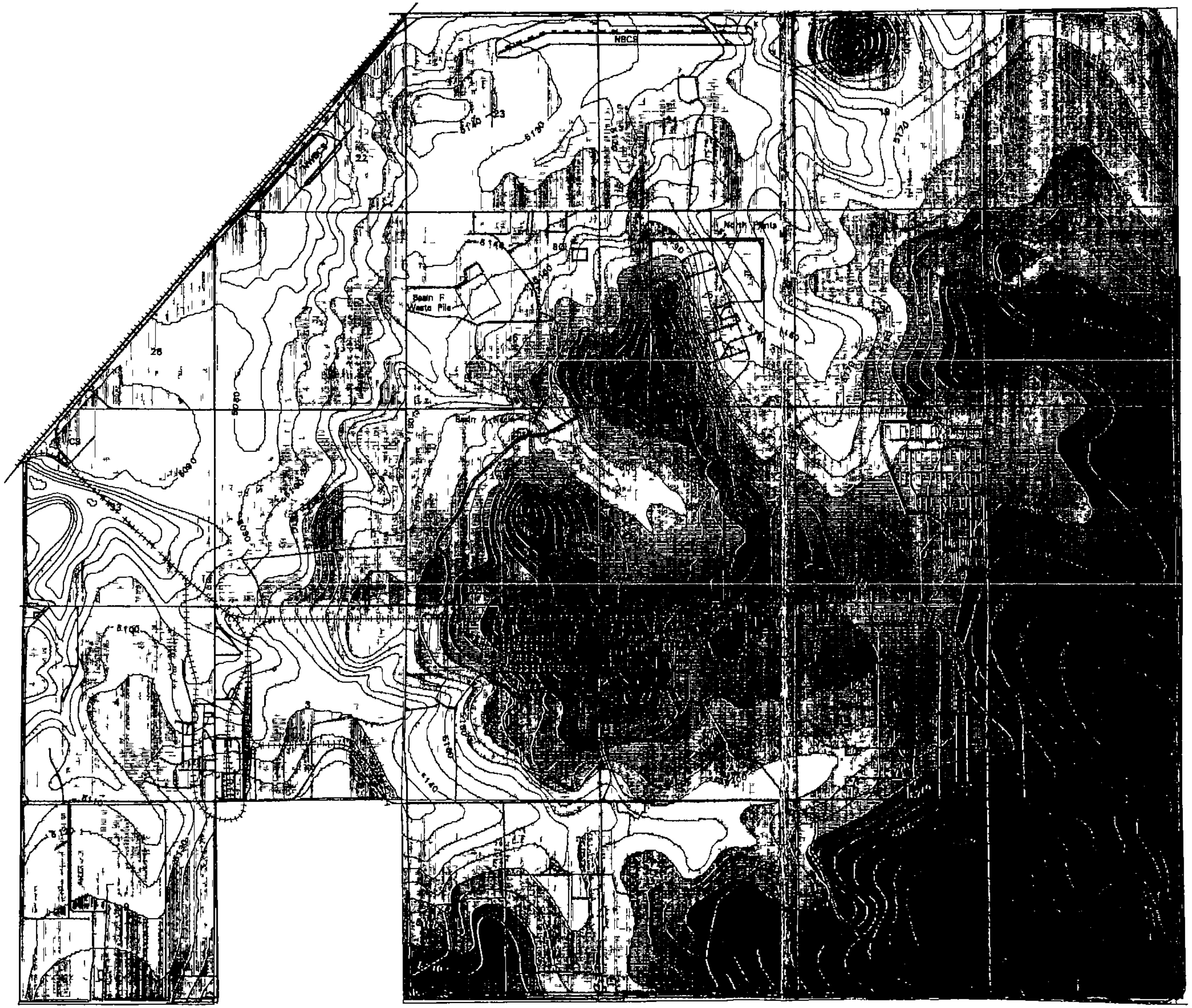
Figure 4 5

Groundwater Contamination Plume Map of RMA

(EBASCO, 1994)



Explanation

5040 feet

5310 feet

10-foot contour interval

Road

Railroad

Section line

12 Section number

NBCS North Boundary Containment System

NWBCS Northwest Boundary Containment System

ICS Irondale Containment System

SQI Submerged Quench Incinerator

HLA Harding Lawson Associates

1000 0 2000 4000 FEET

Scale 1 36 000
One inch represents 3 000 feet

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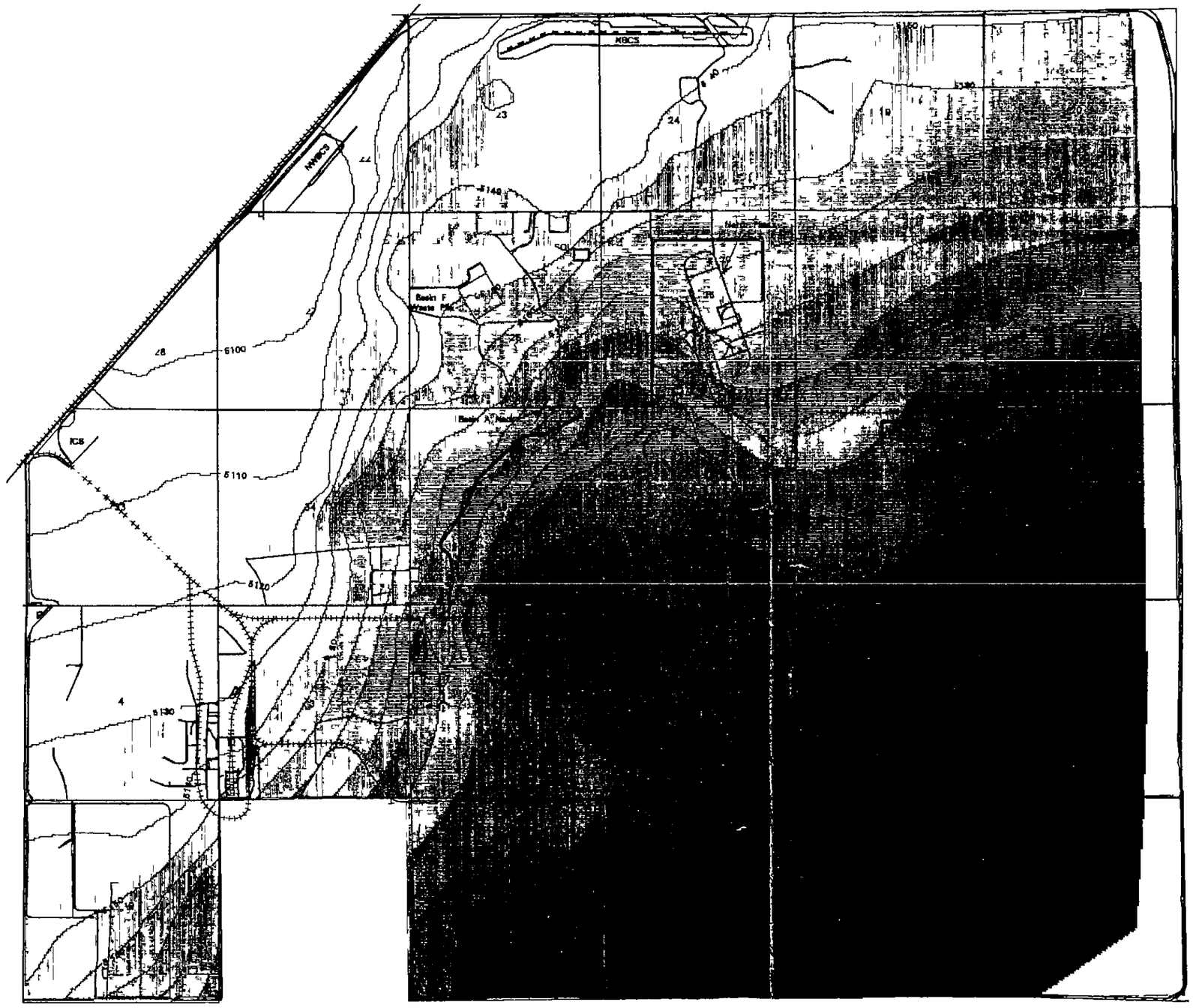
Figure 4 7

Onpost Bedrock
Elevation Contour Map
(HLA, 1992)



Explanation

5090 feet

5300 feet

10-foot contour interval

Road

Railroad

Section line

12 Section number

NBCS North Boundary Containment System

NWBCS Northwest Boundary Containment System

ICS Irondale Containment System

SQI Submerged Quench Incinerator

HLA Harding Lawson Associates

1000 0 2000 4000 FEET

N

Scale 1:36,000

One inch represents 3,000 feet

Prepared for

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Prepared by

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Figure 4-8

Onpost Winter 1991 Water-level Elevation Contour Map (HLA, 1992)

Explanation

0 feet

80 feet

10-foot contour interval

Road

Railroad

Section line

12 Section number

NBCS North Boundary Containment System

NWBCS Northwest Boundary Containment System

ICS Irondale Containment System

SQI Submerged Quench Incinerator

1000 0 2000 4000 FEET

N

Scale 1 36 000

One inch represents 3 000 feet

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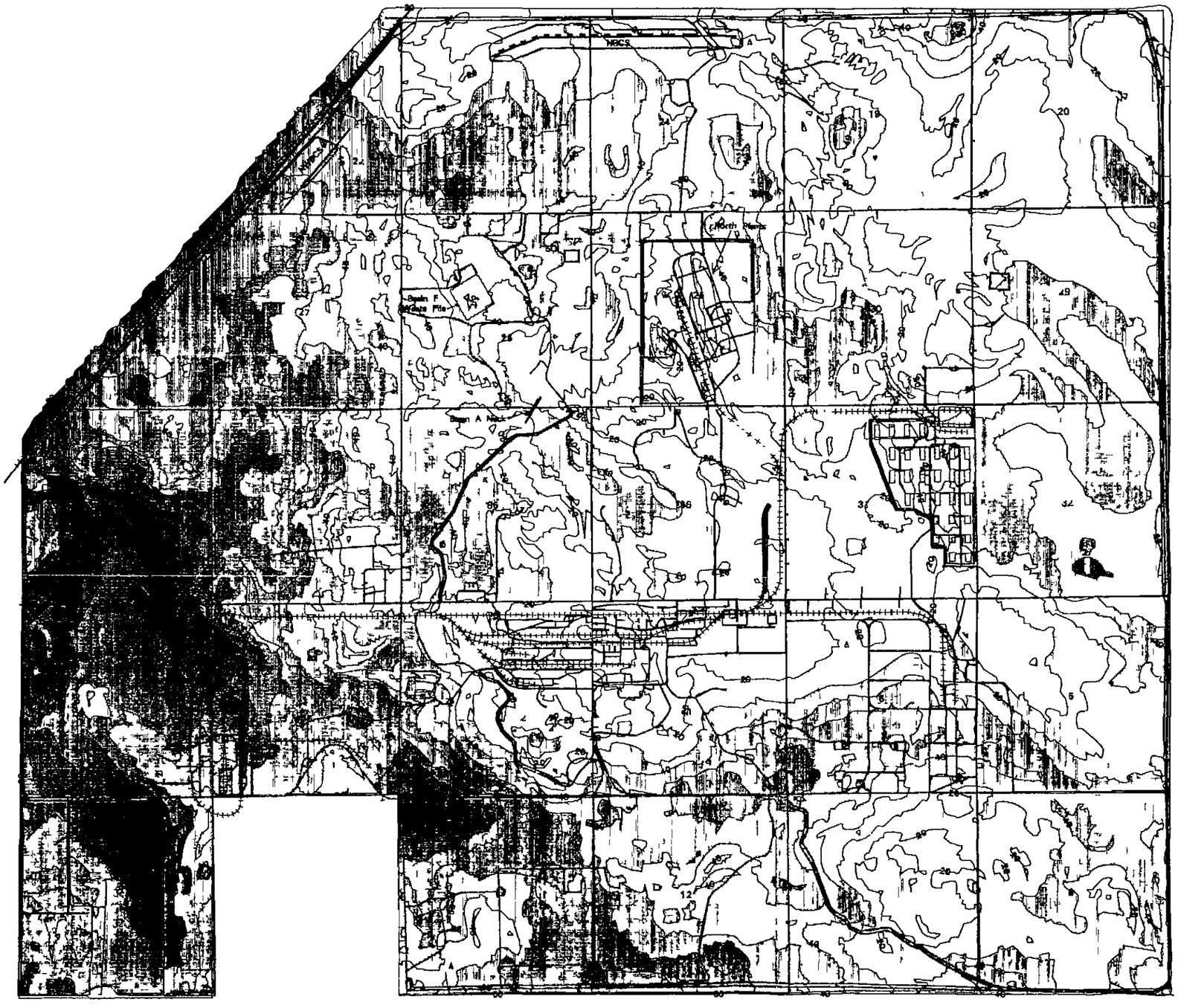
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by
Harding Lawson Associates

Figure 4-9

Onpost Approximate Depth to Groundwater Contour Map



Explanation

0 feet

140 feet

10-foot contour interval

Road

Railroad

Section line

12 Section number

NBCS North Boundary Containment System

NWBCS Northwest Boundary Containment System

ICS Irondale Containment System

SQI Submerged Quench Incinerator

1000 0 2000 4000 FEET

Scale 1:36,000

One inch represents 3,000 feet

Prepared for

Program Manager for

Rocky Mountain Arsenal

Commerce City, Colorado

Prepared by

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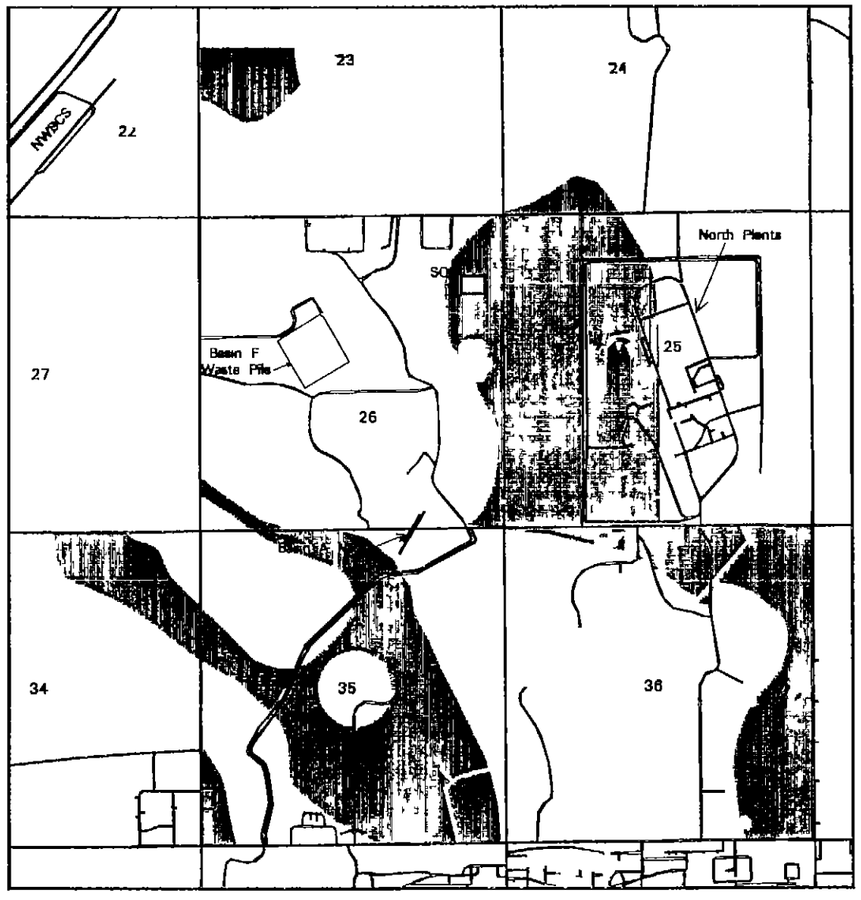
Figure 4-10

Onpost Approximate Depth to Bedrock Contour Map

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (in feet)

10 to 70 feet	Not suitable
70 to 90 feet	Suitable

Minimize
Depth to bedrock (in feet)

0 to 10 feet	Suitable
10 to 80 feet	Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

	Suitable areas based on primary landfill siting criteria
	Suitable areas based on secondary landfill siting criteria
	Road
12	Section number
NWBCS	Northwest Boundary Containment System
SQI	Submerged Quench Incinerator

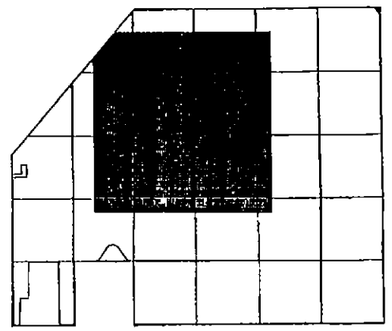
Total suitable acres based on primary and secondary landfill siting criteria 1

Maximum contiguous suitable acres 1

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2,500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to eliminate those areas at RMA deemed "unsuitable" with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands sensitive habitats, 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2 The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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Program Manager for
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Commerce City, Colorado

Prepared by
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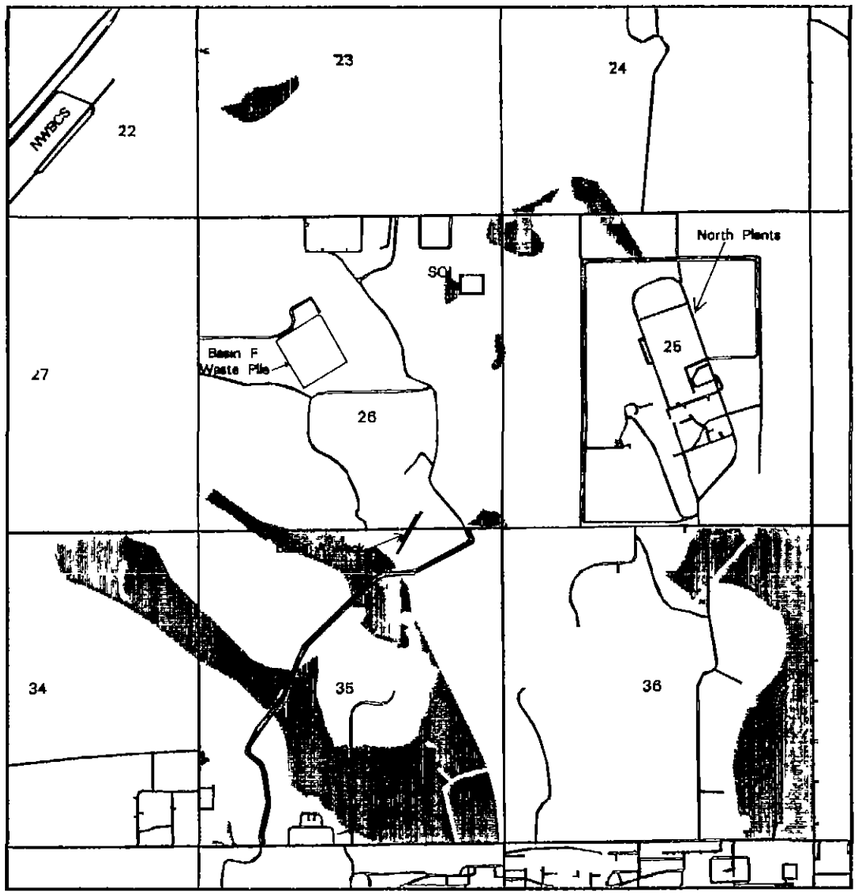
Figure 4 11 - Applied Selection Criteria - Depth to Groundwater Greater Than or Equal to 70 feet, and Depth to Bedrock Less Than or Equal to 10 feet

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (in feet)

10 to 40 feet	Not suitable
40 to 90 fee	Suitable

Minimize
Depth to bedrock (in feet)

0 to 40 feet	Suitable
40 to 80 feet	Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

Suitable areas based on primary landfill siting criteria

Suitable areas based on secondary landfill siting criteria

Road

12 Section number

NWBCS Northwest Boundary Containment System

SQI Submerged Quench Incinerator

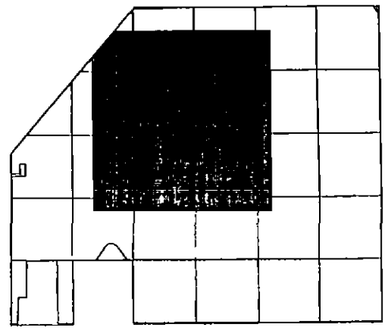
Total suitable acres based on primary and secondary landfill siting criteria. 469

Maximum contiguous suitable acres 371

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2 500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to elimnate those areas at RMA deemed "unsuitable" with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands sensitive habitats 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2 The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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Rocky Mountain Arsenal
Commerce City, Colorado

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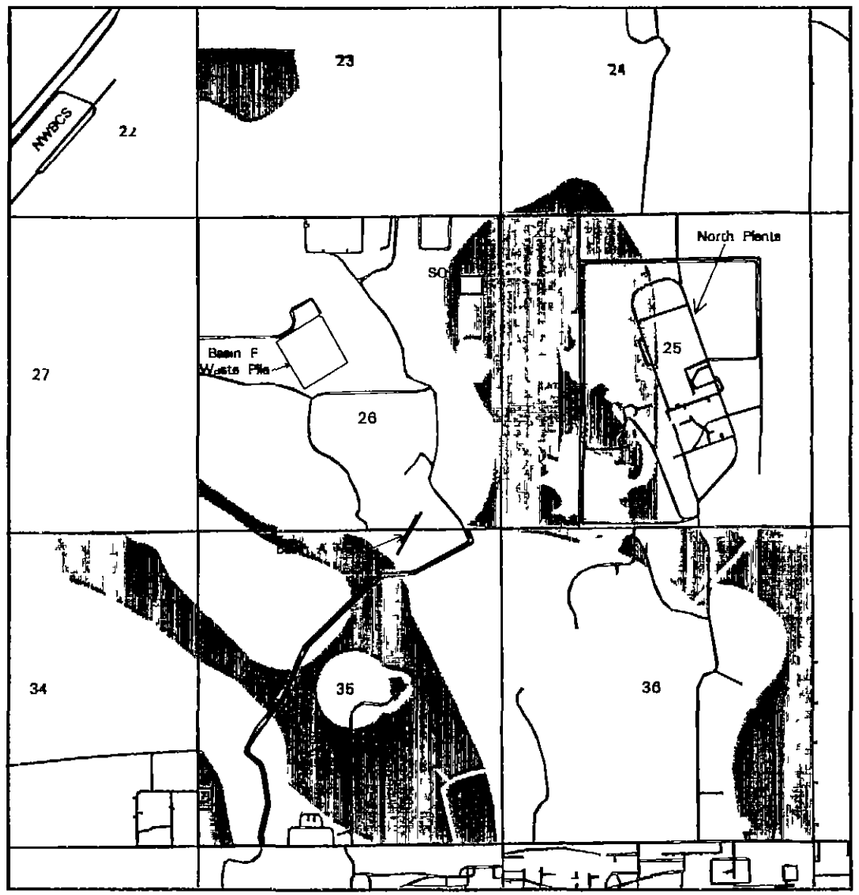
Figure 4 12 - Applied Selection Criteria - Depth to Groundwater Greater Than or Equal to 40 feet, and Depth to Bedrock Less Than or Equal to 40 feet

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (in feet)

10 to 60 feet — Not suitable

60 to 90 feet — Suitable

Minimize
Depth to bedrock (in feet)

0 to 20 feet — Suitable

20 to 80 feet — Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

Suitable areas based on primary landfill siting criteria

Suitable areas based on secondary landfill siting criteria

Road

12 — Section number

NWBCS — Northwest Boundary Containment System

SQI — Submerged Quench Incinerator

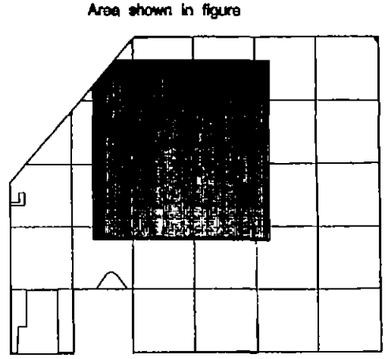
Total suitable acres based on primary and secondary landfill siting criteria 81

Maximum contiguous suitable acres 76

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2 500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to elminate those areas at RMA deemed "unsuitable" with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands, sensitive habitats 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2 The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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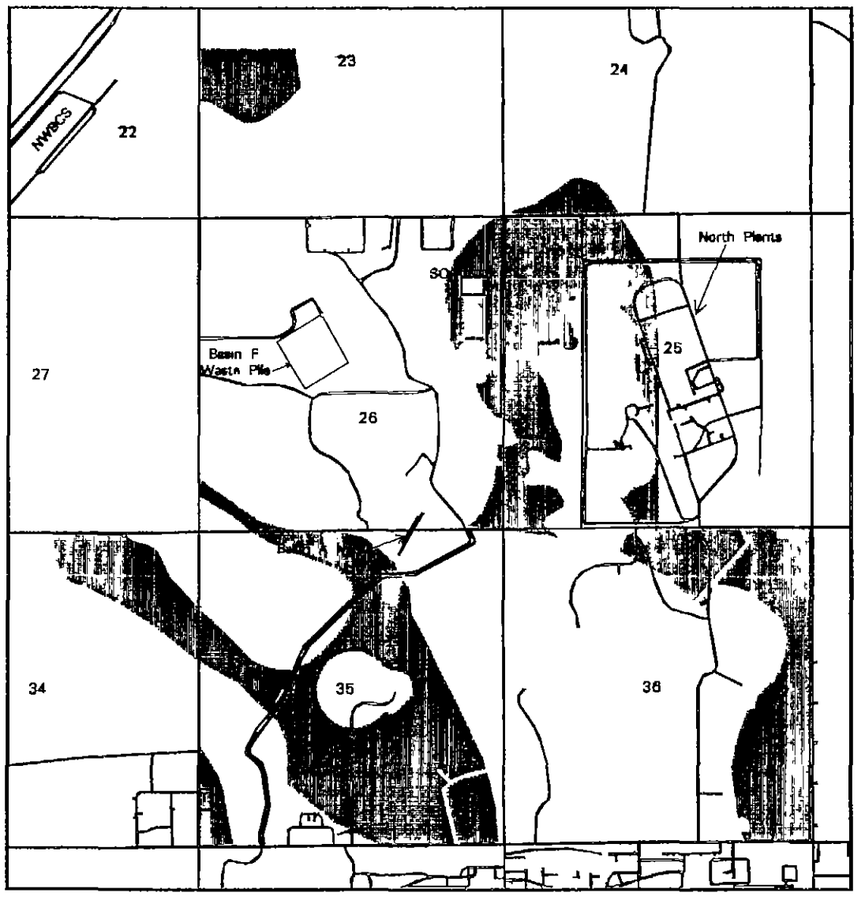
Commerce City, Colorado

Prepared by
Harding Lawson Associates

Figure 4 13 - Applied Selection Criteria - Depth to Groundwater Greater Than or Equal to 60 feet, and Depth to Bedrock Less Than or Equal to 20 feet

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (In feet)

10 to 60 feet	Not suitable
60 to 90 feet	Suitable

Minimize
Depth to bedrock (In feet)

0 to 40 feet	Suitable
40 to 80 feet	Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

	Suitable areas based on primary landfill siting criteria
	Suitable areas based on secondary landfill siting criteria
	Road
12	Section number
NWBCS	Northwest Boundary Containment System
SQI	Submerged Quench Incinerator

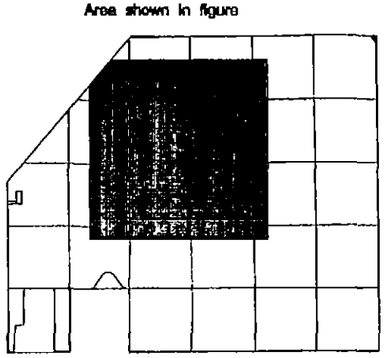
Total suitable acres based on primary and secondary landfill siting criteria. 147

Maximum contiguous suitable acres 138

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2 500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to eliminate those areas at RMA deemed "unsuitable with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands sensitive habitats 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2. The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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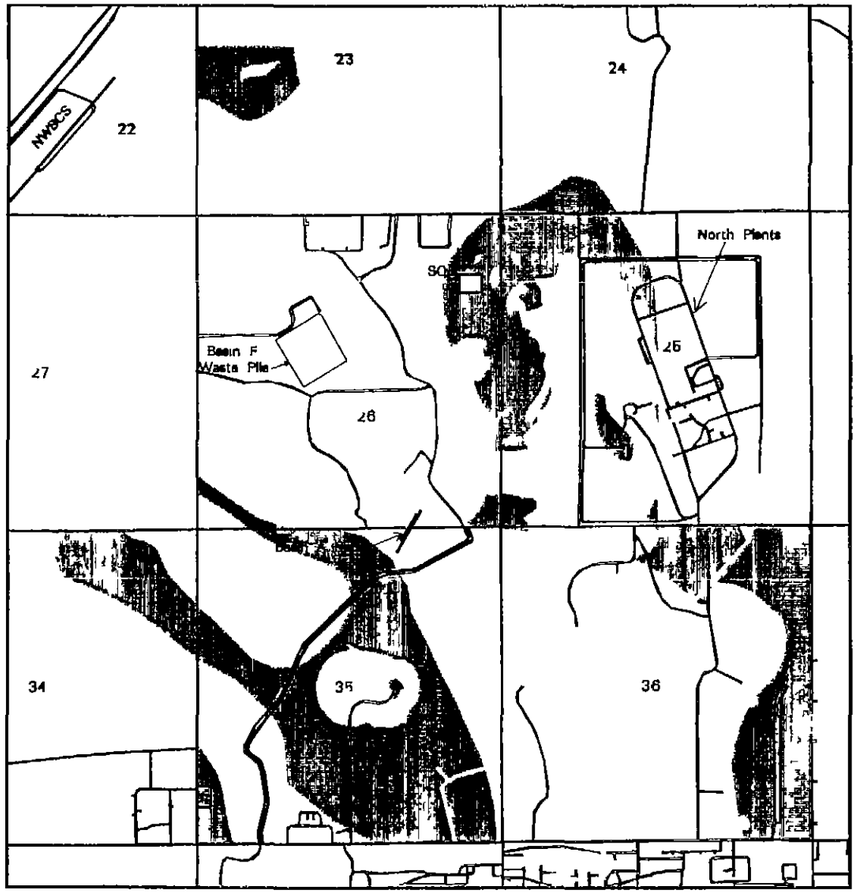
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by
Harding Lawson Associates

Figure 4 14 - Applied Selection Criteria - Depth to Groundwater *Greater Than or Equal to 60 feet*, and Depth to Bedrock Less Than or Equal to 40 feet

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (in feet)

10 to 50 feet — Not suitable

50 to 90 feet — Suitable

Minimize
Depth to bedrock (in feet)

0 to 30 feet — Suitable

30 to 80 feet — Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

Suitable areas based on primary landfill siting criteria

Suitable areas based on secondary landfill siting criteria

Road

12 — Section number

NWBCS — Northwest Boundary Containment System

SQI — Submerged Quench Incinerator

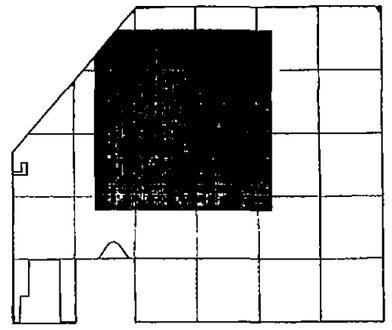
Total suitable acres based on primary and secondary landfill siting criteria. 233

Maximum contiguous suitable acres 217

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2 500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to elliminate those areas at RMA deemed "unsuitable" with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands sensitive habitats 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2 The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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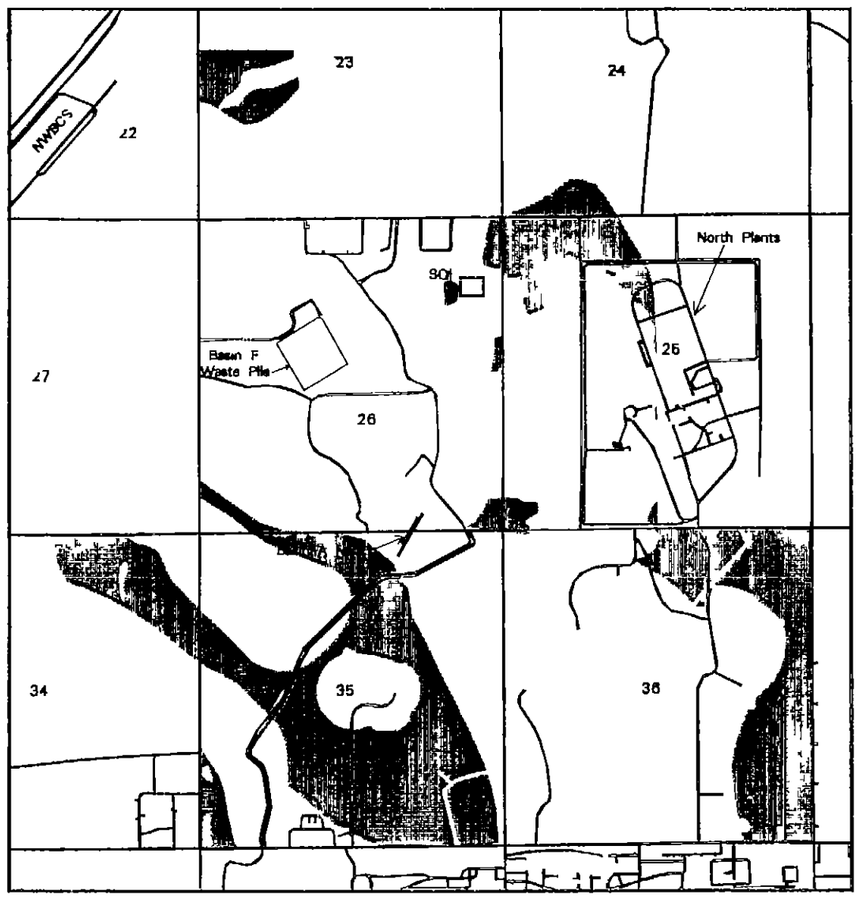
Figure 4 15 - Applied Selection Criteria - Depth to Groundwater Greater Than or Equal to 50 feet, and Depth to Bedrock Less Than or Equal to 30 feet

Potential Landfill Areas



Secondary Landfill Siting Criteria

The values listed below were used to determine siting potential based on depth to groundwater depth to bedrock and depth to saturated alluvium

Maximize
Depth to groundwater (in feet)

10 to 50 feet	Not suitable
50 to 90 feet	Suitable

Minimize
Depth to bedrock (in feet)

0 to 40 feet	Suitable
40 to 80 feet	Not Suitable

Note Secondary landfill siting criteria includes unsaturated alluvium

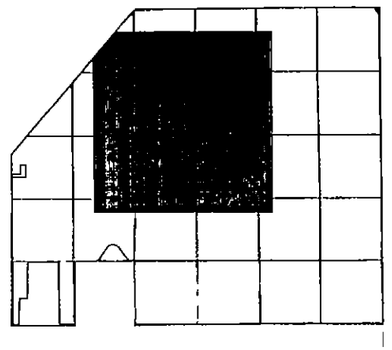
	Suitable areas based on primary landfill siting criteria
	Suitable areas based on secondary landfill siting criteria
	Road
12	Section number
NWBCS	Northwest Boundary Containment System
SQI	Submerged Quench Incinerator

Total suitable acres based on primary and secondary landfill siting criteria: 325
Maximum contiguous suitable acres 299

1000 0 2000 4000 FEET

Scale 1 30 000
One inch represents 2 500 feet

Area shown in figure



Rocky Mountain Arsenal

Note
The "Suitable Areas" identified in this figure are the result of a spatial analysis peformed to eliminate those areas at RMA deemed "unsuitable" with respect to the primary and secondary landfill siting criteria. The primary landfill siting criteria include avoidance of wetlands sensitive habitats 100-year floodplain organic groundwater contamination plumes, and human health exceedance areas as listed in Table 4 2 The secondary landfill siting criteria are identified in the box titled secondary landfill siting criteria.

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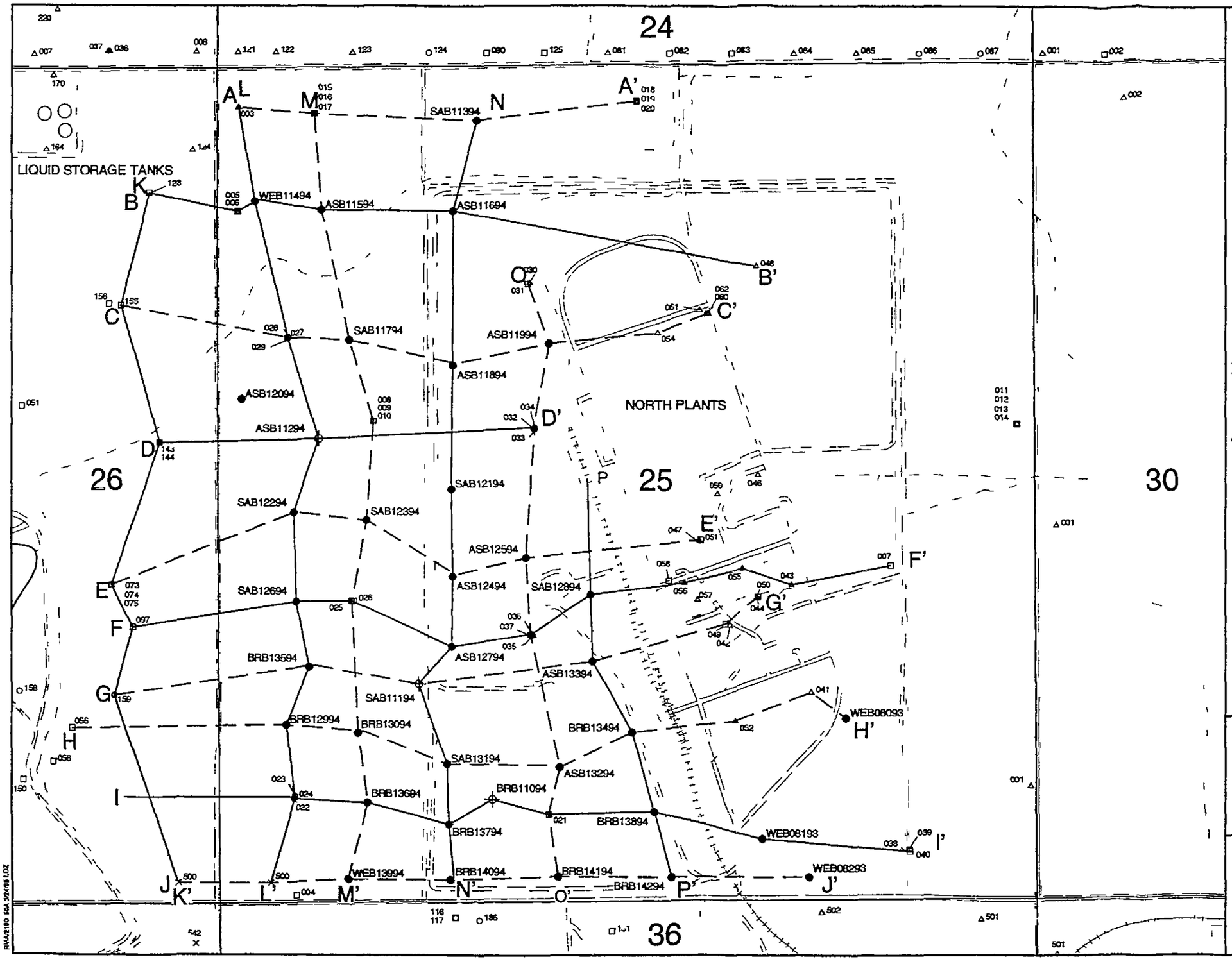
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by
Harding Lawson Associates

Figure 4 16 - Applied Selection Criteria - Depth to Groundwater Greater Than or Equal to 50 feet, and Depth to Bedrock Less Than or Equal to 40 feet



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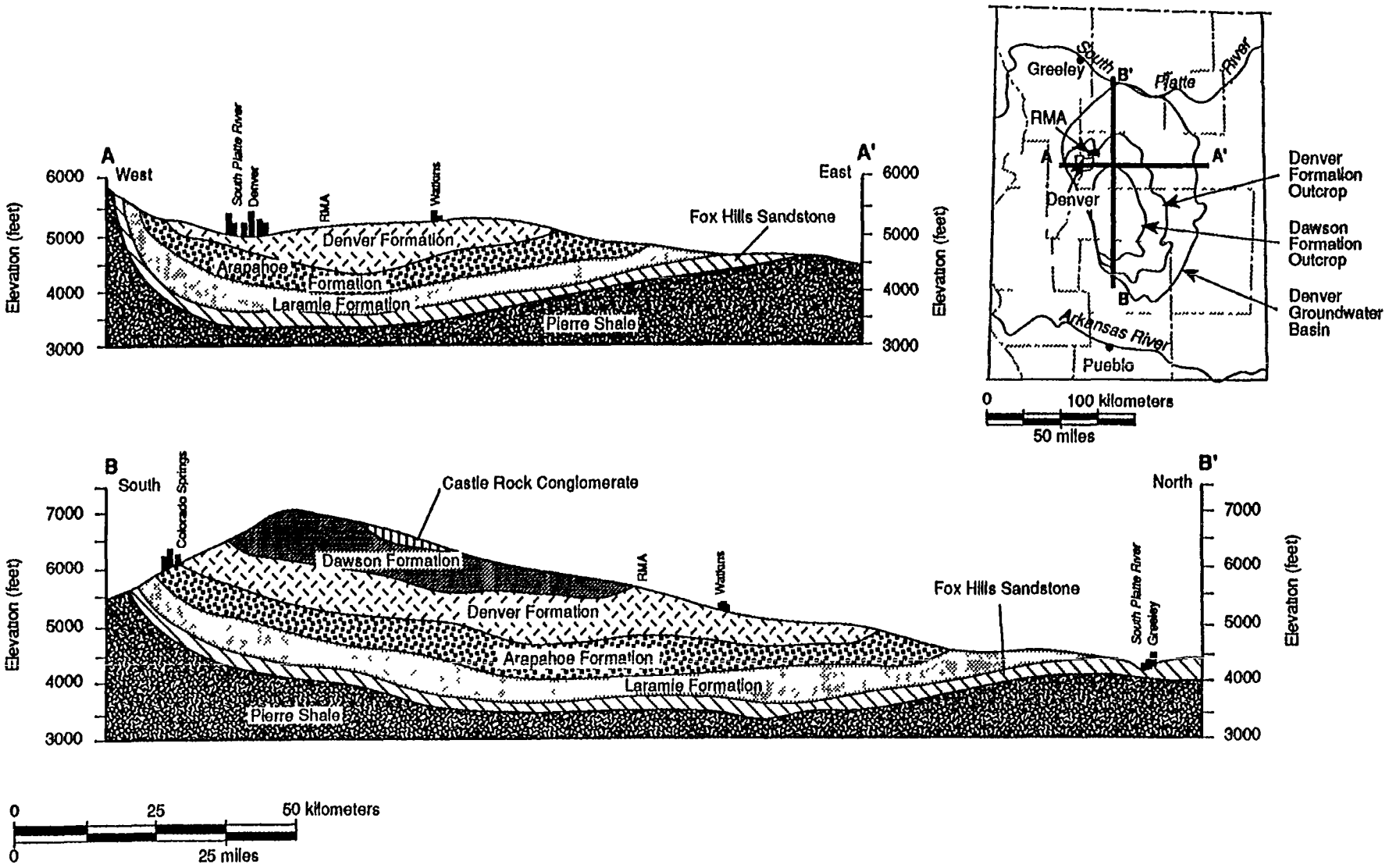
Rocky Mountain Arsenal
Commerce City Colorado

Prepared by:
Harding Lawson Associates

Figure 4-17

Boring and Cross-Section Location Map
Section 25



Source Robson and Romero, 1981

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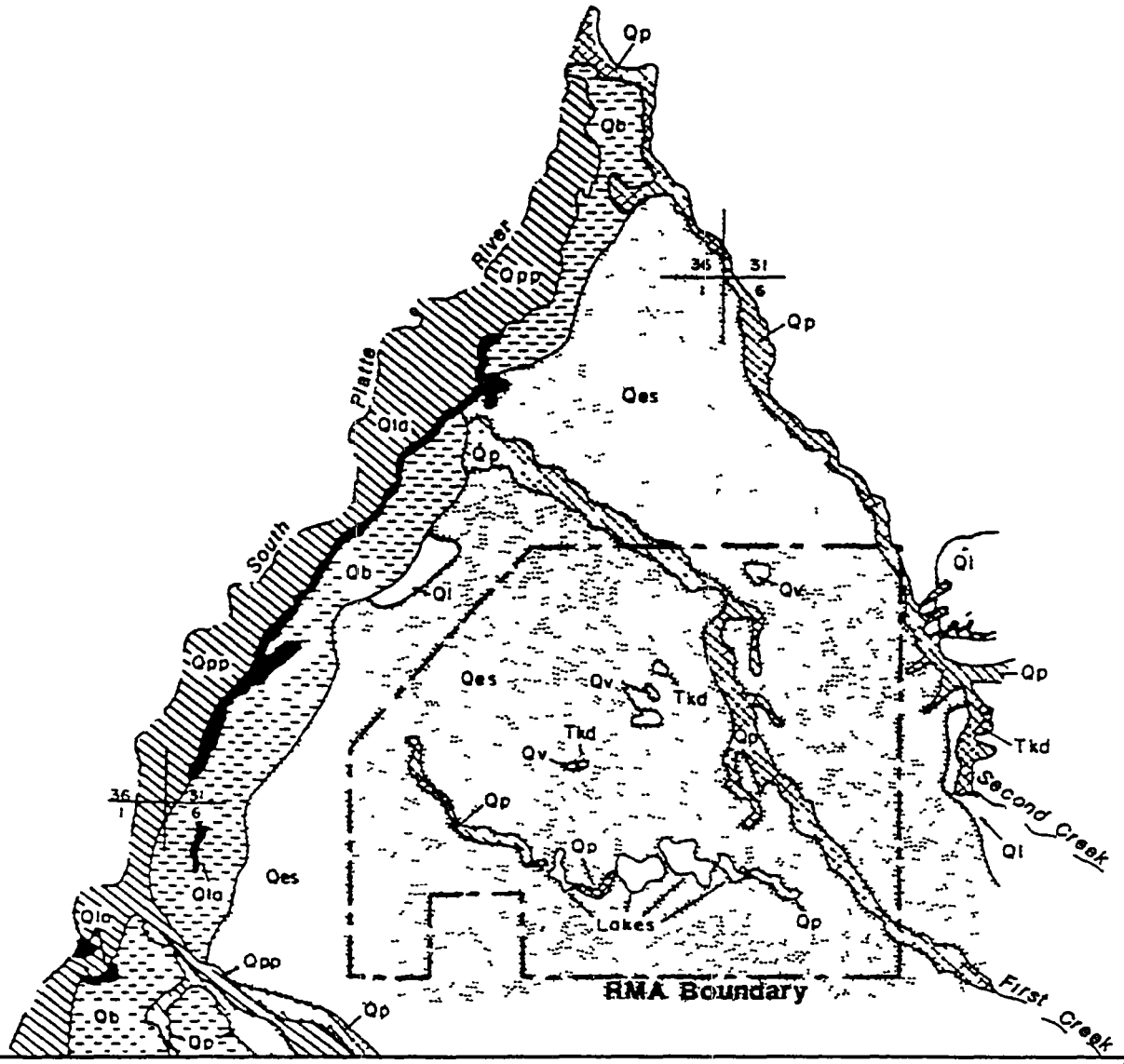
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
Harding Lawson Associates

Figure 4 18
Upper Stratigraphic Sections of the Denver Basin



EXPLANATION

- Qpp — Post Piney Creek Alluvium (Quaternary)
- Qp — Piney Creek Alluvium (Quaternary)
- Qes — Eolian Sand (Quaternary)
- Qi — Loess (Quaternary)
- Qb — Broadway Alluvium (Quaternary)
- Qlo — Louviers Alluvium (Quaternary)
- Qv — Verdos Alluvium (Quaternary)
- Tkd — Denver Formation (Upper Cretaceous & Tertiary)

N

0 1 2

Scale in miles

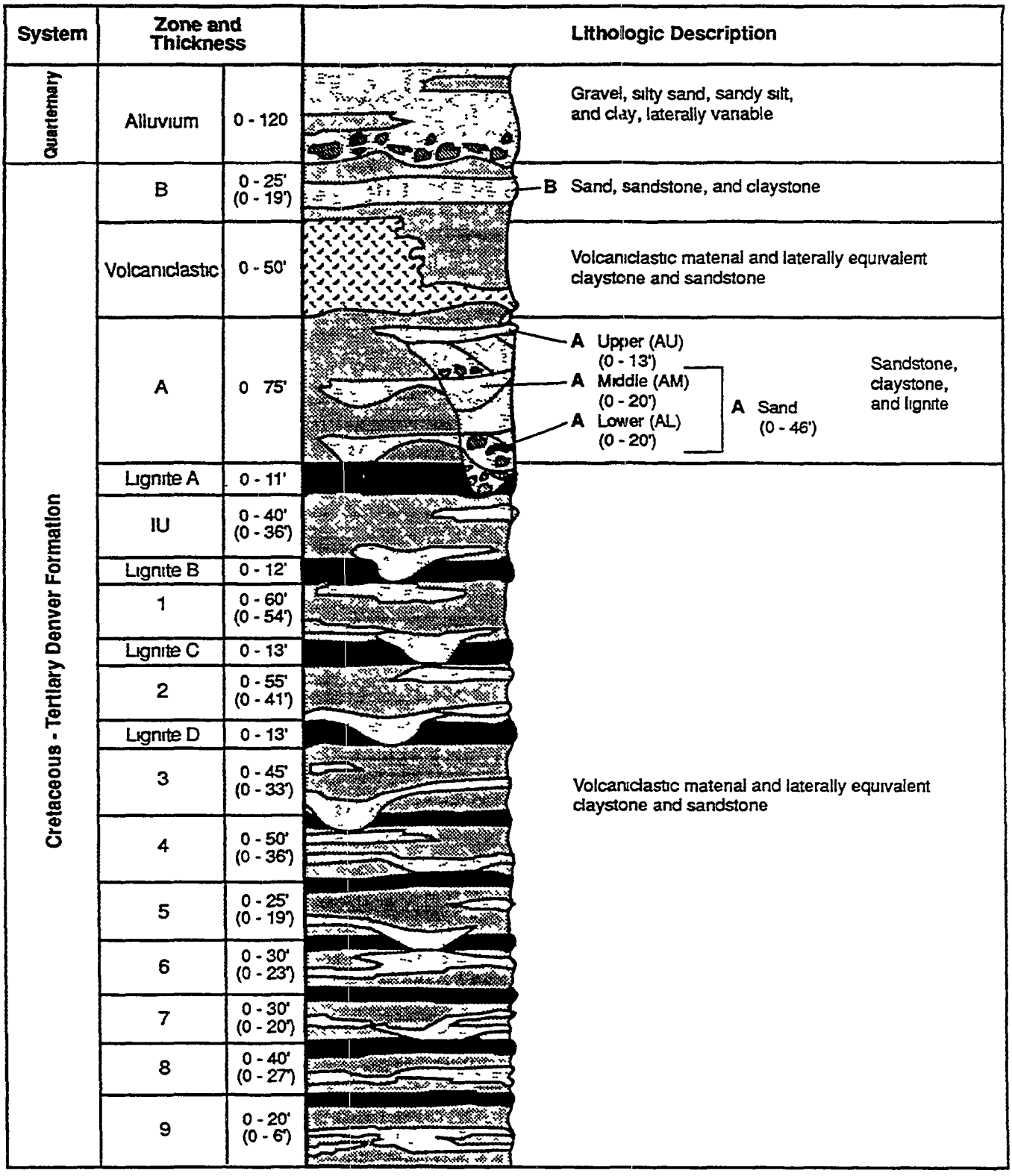
Source Lindvall 1980

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
Harding Lawson Associates

Figure 4-19

Surficial Geologic Map of the
Rocky Mountain Arsenal Area



Source Environmental Science and Engineering 1988

Note Thickness not to scale, net sandstone thickness shown in parentheses

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
Harding Lawson Associates

Figure 4 20

Denver Formation Stratigraphic Column

West

B

East

B'

5240
5220
5200
5180
5160
5140
5120
5100

Elevation in feet

26123 Tles K K
25005 25006
WEB11494 Tles L L
ASB11594 Tles M M
ASB1184 Tles N N'
Drainage
North Plant Road
Bunker
FM
25048
1U Sand
(123)
1 Sand
?
Datum Line

EXPLANATION

Alluvium:

- Clay sandy clay (CL,CH)
- Sand silty sand, clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

— — — Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone lignite, and claystone is unknown.

SAB11194 — Boring identification

29025 — Monitoring well(s) identification
101 — Sand pack
Screened interval with well number

TD = Total depth in feet

20
0
0
400
Scale in feet
Vertical exaggeration = 20x

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City Colorado
Prepared by
Harding Lawson Associates

Figure 4.21

Geologic Cross Section B-B

D

D'

East →

Elevation in feet

5280
5260
5240
5220
5200
5180
5160
5140
5120

26143 26144 Ties K K

ASB12094 (projected 170 ft.)

ASB11294 Ties L L

25008 25009 25010
Ties M M (projected 75 ft.)

Ties N N

25032 25033
25034 Ties O-O'

A Sand

Lignite A

U Sand

Lignite B

T Sand

TD = 145

Note. Screened interval for 25010 is 125 to 148 below ground surface

EXPLANATION

Alluvium:

- Clay, sandy clay (CL,CH)
- Sand,silty sand, clayey sand (SP, SM, SC, SW)
- Gravel

Bedrock (Denver Formation)*

- Lignite/Lignitic Claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

Top of weathered bedrock

Note*
In areas of no lithologic control, lateral extent of Denver Formation sandstone, lignite, and claystone is unknown.

SAB11184 — Boring identification

25025 — Monitoring well(s) identification

Sand pack

101 — Screened interval with well number

TD = Total depth in feet

20
0
0 400
Scale in feet
Vertical exaggeration = 20x

Prepared for
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by*
Harding Lawson Associates

Figure 4.22

Geologic Cross Section D-D'

F

F'

East

Elevation in feet

5290
5280
5260
5240
5220
5200
5180
5160
5140
5130

26097 Ties K K
SAB12694 Ties L L
25025 25026 Ties M M
ASB12794 Ties N N
25035 25036 25037 Ties O O
SAB12894 Ties P P
25058
25056
25055
25043
25007

A Sand
Lignite A?
Lignite A
1U Sand
Lignite B
1 Sand

TD = 102

EXPLANATION

Alluvium.

- Clay sandy clay (CL,CH)
- Sand, silty sand clayey sand (SP SM, SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone lignite and sandstone (see note)

Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone lignite, and claystone is unknown.

SAB11194 — Boring identification

29025 — Monitoring well(s) identification
101 — Screened interval with well number
Sand pack

TD = Total depth in feet

20
0
0
400
Scale in feet
Vertical exaggeration = 20x

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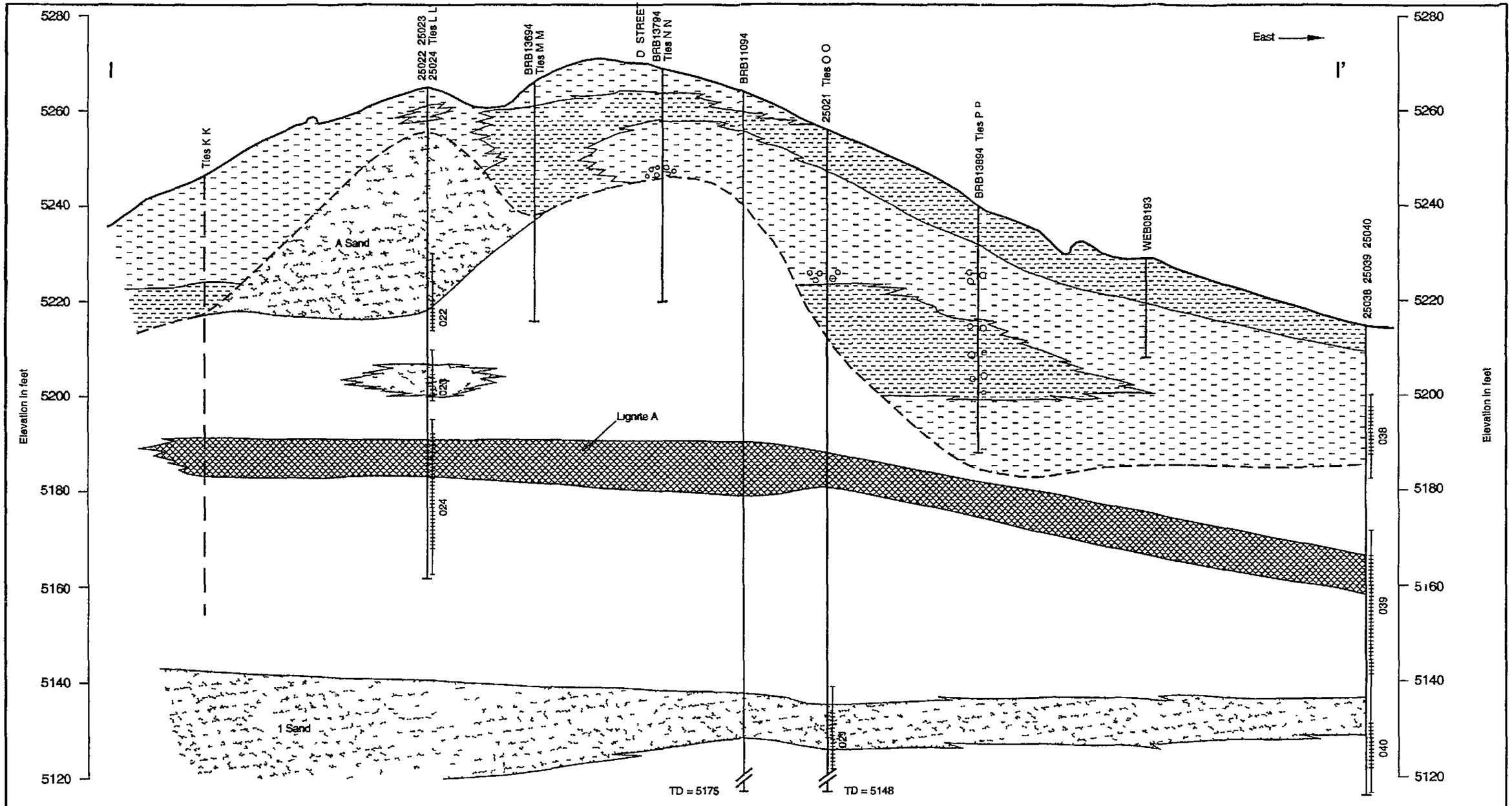
Commerce City Colorado
Prepared by
Harding Lawson Associates

Figure 4.23

Geologic Cross Section F F'



EXPLANATION

Alluvium:

- Clay, sandy clay (CL,CH)
- Sand, silty sand, clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation):

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone, lignite and claystone is unknown

SAB11194 — Boring identification

28025 — Monitoring well(s) identification
Sand pack
Screened interval with well number
101
TD = Total depth in feet

20
0
0
400
Scale in feet
Vertical exaggeration = 20x

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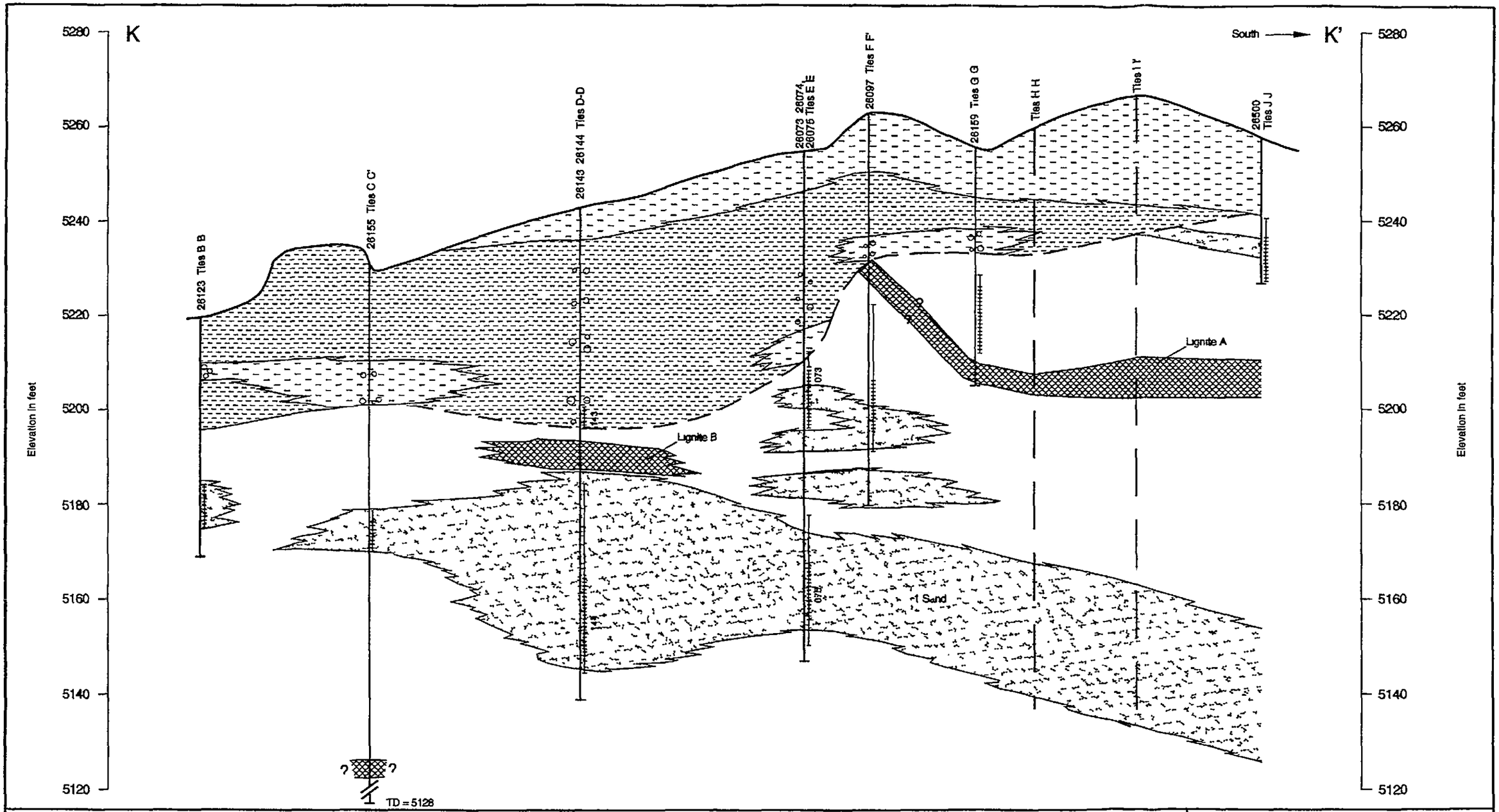
Figure 4.24

Geologic Cross Section I I'



EXPLANATION

Alluvium:

- Clay sandy clay (CL,CH)
- Sand silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)*

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone lignite, and sandstone (see note)

— — — Top of weathered bedrock

Note
In areas of no lithologic control lateral extent of Denver Formation sandstone, lignite, and claystone is unknown.

SAB11194 — Boring identification

29025 — Monitoring well(s) identification
Sand pack
101 — Screened interval with well number

TD = Total depth in feet

20
0
0 400
Scale in feet
Vertical exaggeration = 20x

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Figure 4.25

Geologic Cross Section K K'

L

L'

South →

Elevation in feet

5260
5240
5220
5200
5180
5160
5140
5120

25003 Tles A A
WEB11494 Tles B B
25027 25028 25029 Tles C C
ASB11294 Tles D D
SAB12294 Tles E E
SAB12694 Tles F F
BRB13594 Tles G G
BRB12994 ATles H H
25022 25023, 25024 Tles I I
25500 Tles J-J

1U Sand
A Sand
1 Sand
Lignite A
Lignite B
?

EXPLANATION

Alluvium:
- Clay sandy clay (CL,CH)
- Sand, silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)
- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone lignite, and claystone is unknown

SAB11194 — Boring identification

28025 — Monitoring well(s) identification
Sand pack
101 — Screened interval with well number

TD = Total depth in feet

20
0
0
400
Scale in feet
Vertical exaggeration = 20x

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Figure 4.26

Geologic Cross Section L-L

N

N' South

Elevation in feet

5290
5280
5260
5240
5220
5200
5180
5160
5140
5130

SAB11394 Tles A A
ASB11894 Tles B B
ASB11894 Tles C C
Tles D D
SAB12194
ASB12494 Tles E E
ASB12794 Tles F F
SAB11194 Tles G G
SAB13194 Tles H H
BRB13794 Tles I I
BRB14094 Tles J J

A Sand
Lignite A
1U Sand
Lignite A
Lignite B
1 Sand
1 Sand
TD = 170

EXPLANATION

Alluvium:
- Clay sandy clay (CL,CH)
- Sand, silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation):
- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone lignite, and claystone is unknown.

SAB11194 — Boring identification

28025 — Monitoring well(s) identification
101 — Sand pack
Screened interval with well number

TD = Total depth in feet

20
0
0
400
Scale in feet
Vertical exaggeration = 20x

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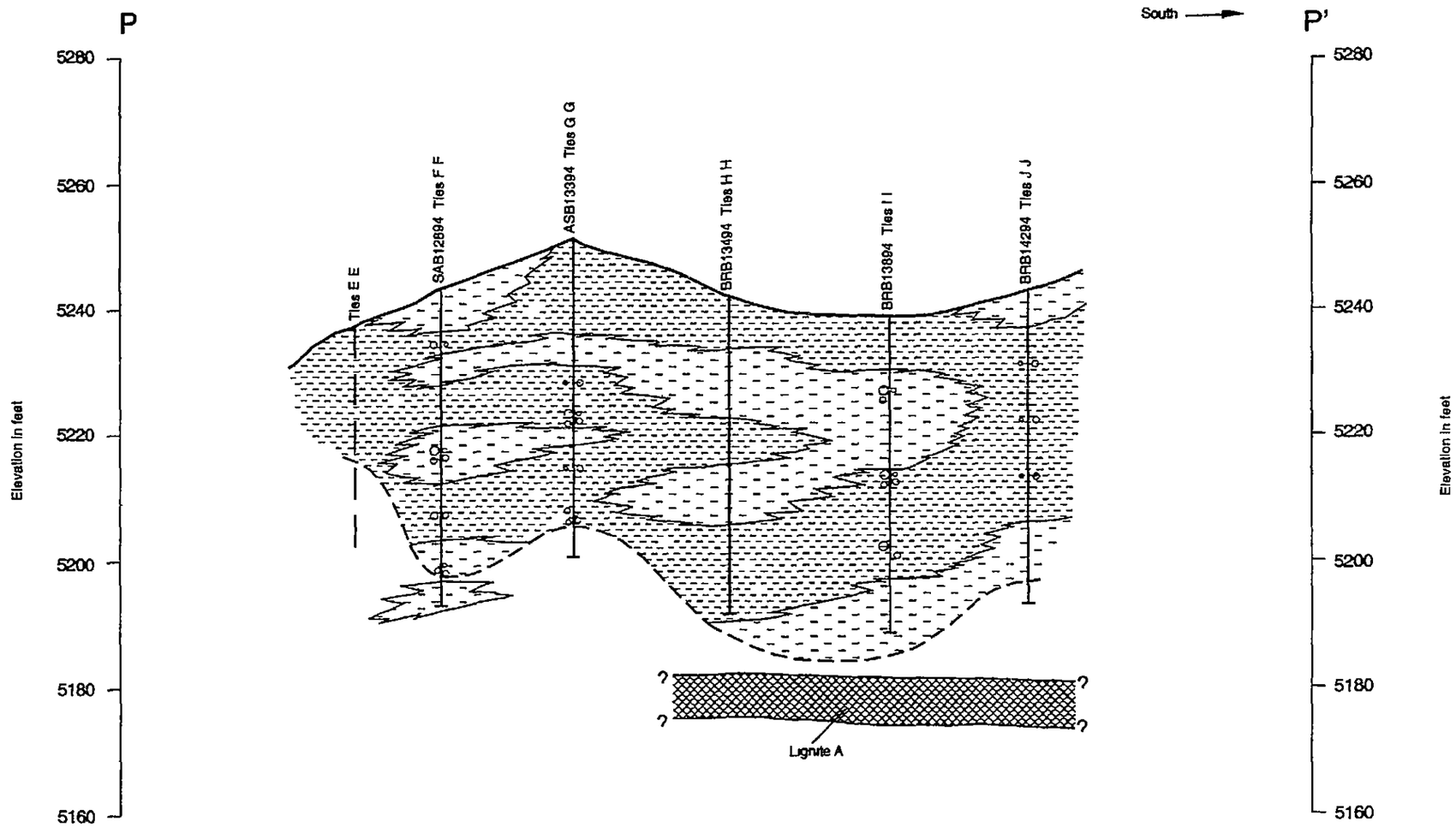
Figure 4.27

Geologic Cross Section N-N'



EXPLANATION

Alluvium:

- Clay sandy clay (CL,CH)
- Sand silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation):

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite, and sandstone (see note)

Top of weathered bedrock

Note:
In areas of no lithologic control lateral extent of Denver Formation sandstone lignite, and claystone is unknown.

SAB11194 — Boring identification

28025 — Monitoring well(s) identification
Sand pack
101 — Screened interval with well number

TD = Total depth in feet

20
0
0 40
Scale in feet
Vertical exaggeration = 20x

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Figure 4.28

Geologic Cross Section P P'

24

LIQUID STORAGE TANKS

SAB11394
WEB11494
ASB11594
ASB11694
SAB11794
ASB11994
ASB11894
ASB12094
ASB11294
NORTH PLANTS
SAB12294
SAB12394
ASB12594
SAB12694
SAB12894
BRB13594
ASB12794
ASB13394
SAB11194
BRB13094
BRB13494
WEB08093
SAB13194
ASB13294
BRB13694
BRB11094
BRB13894
BRB13794
WEB06193
WEB13994
BRB14094
BRB14194
BRB14294
WEB08293

26
25
30
36

Explanation

- Alluvial well with well number
- Unconfined Denver Formation well with well number
- Confined Denver Formation well with well number
- Shallow Soil Borings (30)
- Deep Bore Holes (3)
- Unpaved roadway
- Surface drainage
- Section number
- Thick sequence of A Sand
- Area where A Sand subcrops into the alluvium
- Study area boundary

N

0 600

Scale in feet

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Figure 4.29

A Sand Extent and Subcrop Map

RMA21907710.3/16/95 LDZ

24

26

30

36

LIQUID STORAGE TANKS

NORTH PLANTS

SAB11394

SAB12394

ASB12594

ASB12494

SAB12694

SAB12894

ASB12794

ASB13394

BRB13594

SAB11194

BRB12994

BRB13094

BRB13494

SAB13194

ASB13294

BRB13694

BRB11094

BRB13794

BRB13894

WEB13994

BRB14094

BRB14194

BRB14294

WEB08093

WEB08193

WEB08293

Explanation

- Alluvial well with well number
- Unconfined Denver Formation well with well number
- Confined Denver Formation well with well number
- Shallow Soil Borings (30)
- Deep Bore Holes (3)
- Unpaved roadway
- Surface drainage
- Section number
- Thick sequence of 1U Sand
- Area where 1U Sand subcrops into the alluvium
- Lateral extent of 1U Sand interbedded with claystone and siltstone
- Study area boundary

N

0 600

Scale in feet

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Figure 4 30

1U Sand Extent and Subcrop

24

LIQUID STORAGE TANKS

NORTH PLANTS

SAB11394

WEB11494

ASB11594

ASB11694

SAB11794

Note: 1 Sand extends to the east beyond the study area as illustrated in cross section H

ASB12594

SAB12894

ASB12794

ASB13394

SAB11194

BRB13094

BRB13494

SAB13194

ASB13294

BRB13694

BRB11094

BRB13794

BRB13894

WEB13994

BRB14094

BRB14194

BRB14294

WEB08093

WEB06193

WEB08293

26

25

30

36

Explanation

- Alluvial well with well number
- Unconfined Denver Formation well with well number
- Confined Denver Formation well with well number
- Shallow Soil Borings (30)
- Deep Bore Holes (3)
- Unpaved roadway
- Surface drainage
- 25 Section number
- Thick sequence of 1 Sand
- Areas where 1 Sand subcrops into the alluvium
- Lateral extent of 1 Sand interbedded with claystone and siltstone
- Study area boundary

0 600

Scale in feet

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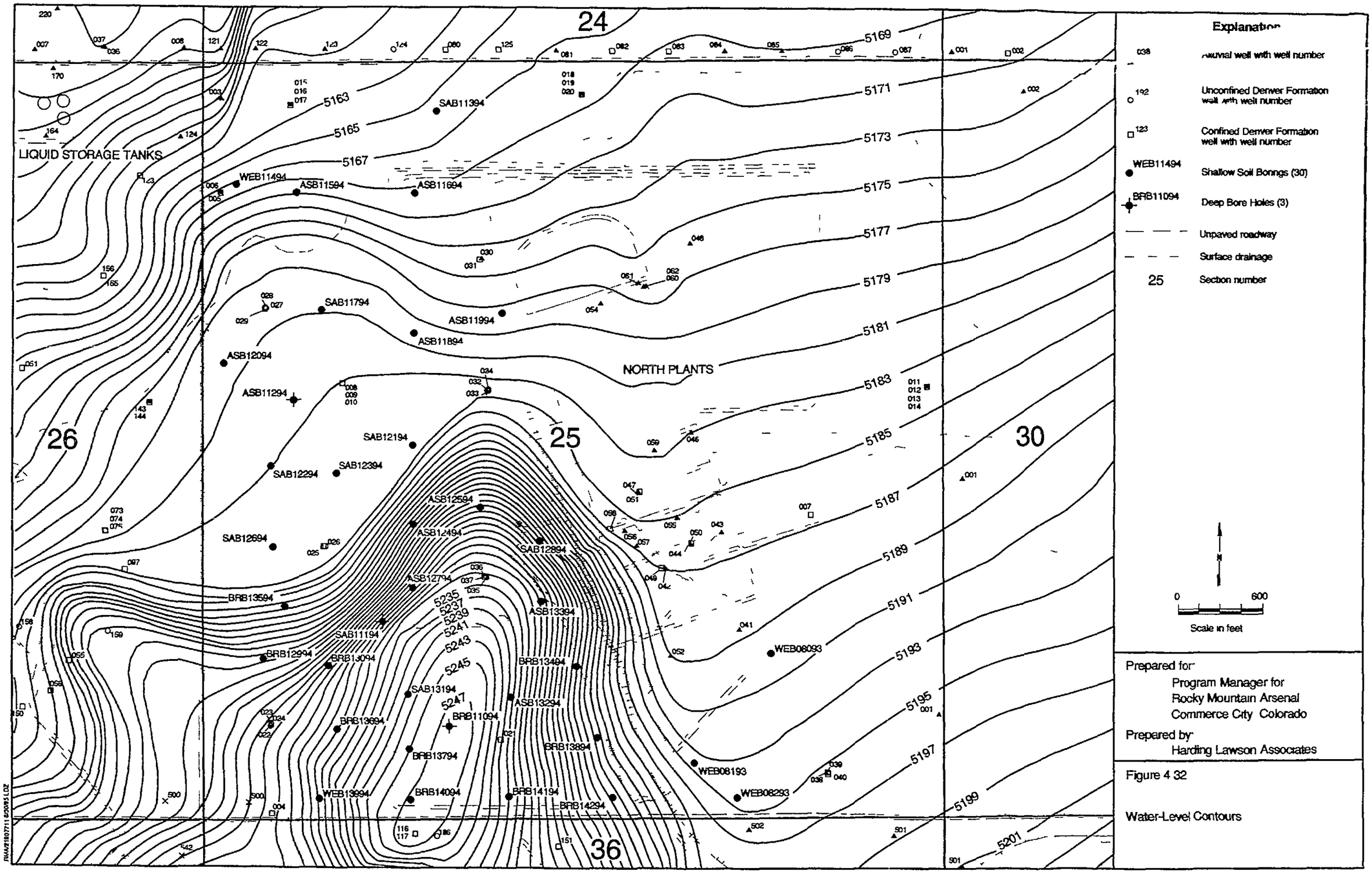
Figure 4 31

1 Sand Extent and Subcrop

RMA2180709 21MAR1.DGN


24
25
26
30
36
LIQUID STORAGE TANKS
NORTH PLANTS
5163
5165
5167
5169
5171
5173
5175
5177
5179
5181
5183
5185
5187
5189
5191
5193
5195
5197
5199
5201
5235
5237
5239
5241
5243
5245
5247
SAB11394
WEB11494
ASB11594
ASB11694
SAB11794
ASB11994
ASB11894
ASB12094
ASB11294
SAB12194
SAB12294
SAB12394
ASB12594
ASB12494
SAB12694
SAB12894
ASB12794
BRB13594
SAB11194
ASB13394
BRB12994
BRB13094
BRB13494
SAB13194
ASB13294
BRB11094
BRB13694
BRB13894
BRB13794
WEB13994
BRB14094
BRB14194
BRB14294
WEB08093
WEB08193
WEB08293
Explanation
038 Alluvial well with well number
192 Unconfined Denver Formation well with well number
123 Confined Denver Formation well with well number
WEB11494 Shallow Soil Borings (30)
BRB11094 Deep Bore Holes (3)
Unpaved roadway
Surface drainage
25 Section number
0
600
Scale in feet
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Prepared by
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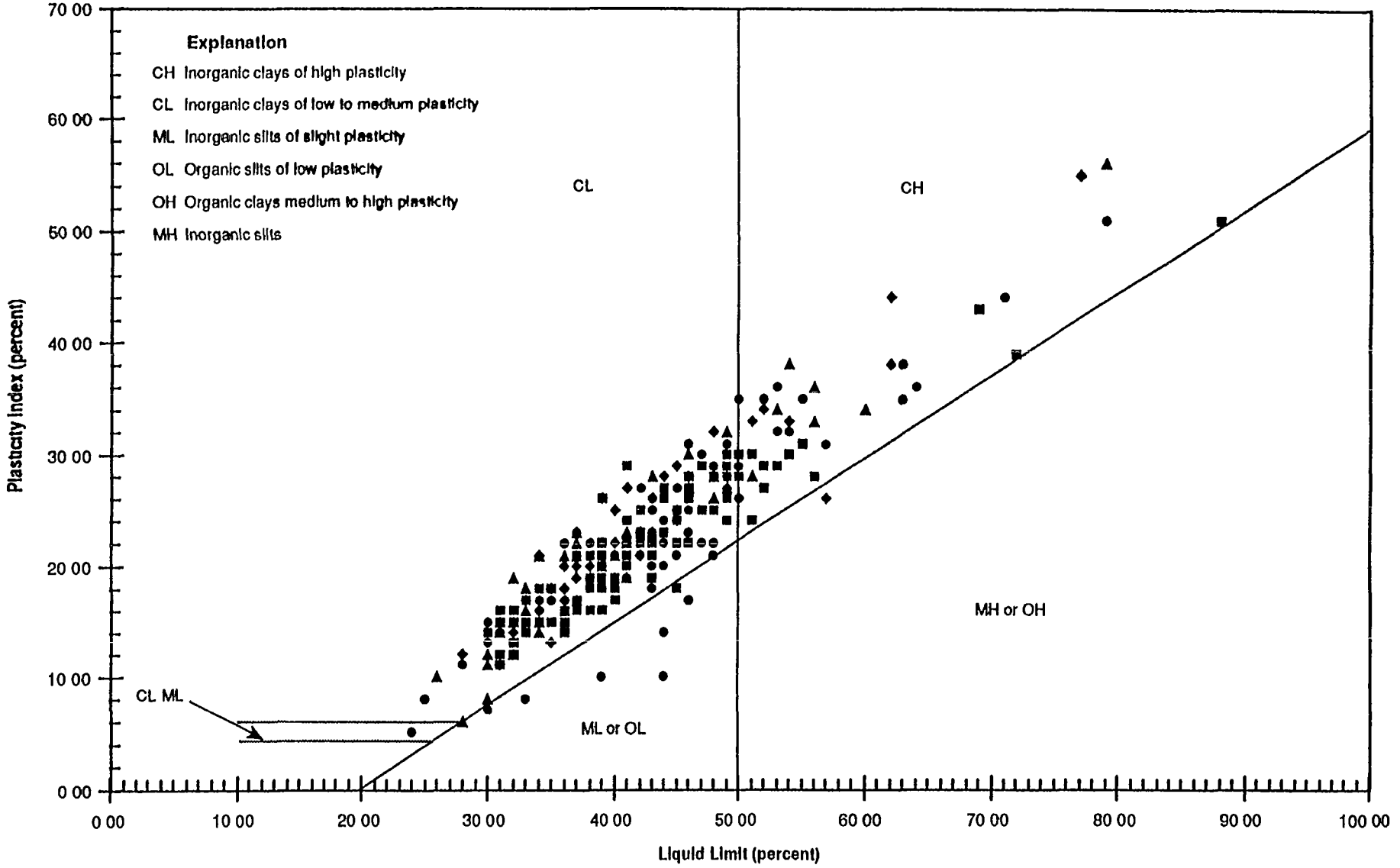
Figure 4 32
Water-Level Contours



RMAG 1049.B 3/17/94 NLM

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Figure 4 33

Plasticity Chart

5.0 SITE FEASIBILITY STUDY

This section presents the results of the Site Feasibility Study (FS) The primary objectives of the Site FS were to identify an appropriate landfill site within the area identified in the Area FS and to provide information on conceptual landfill models, design elements, construction costs, and schedules The Site FS links the data from the Material and Area Feasibility Studies to evaluate the site-specific requirements of an onpost landfill that will use onpost soils for the soil component of caps and liners, have sufficient capacity to dispose of anticipated waste volumes, and meet applicable federal, state, and local regulatory requirements

The study included a review and evaluation of the following criteria

- Waste types, volumes, and generation rates
- Regulatory criteria
- Specific site considerations and limitations
- Conceptual landfill design alternatives
- Evaluation and screening of alternatives
- Facility layout
- Material quantities and availability
- Construction cost estimates and schedules
- Operations and maintenance requirements

5.1 Waste Data

Waste data is a critical component of any landfill design. The amount of waste requiring disposal dictates the size of the landfill needed The type of waste impacts placement, compaction, and cover criteria. The rate at which the waste is generated effects operation and maintenance criteria and construction phasing The following section discusses

- Projected waste types that may be disposed of at an onsite hazardous waste landfill

- Estimated waste volumes
- Possible waste generation rates

The data presented are based on information obtained in the Proposed Final Detailed Analysis of Alternatives (DAA) (Ebasco, 1994) as summarized by RUST Environment and Infrastructure (RUST E&I, 1994)

5.1.1 Projected Waste Types and Characteristics

Based on information in the DAA, the potentially contaminated materials at the RMA that may be landfilled can be classified into three waste types hazardous and toxic materials, unexploded ordnance (UXO), and surety-contaminated materials The two major waste forms within these waste types include contaminated soils and building debris

The actual waste volumes generated for landfilling will be dependant on the selected remedial action alternative The alternatives define differing methods of treatment, storage, and disposal for contaminated material Contaminated materials that may be landfilled can be categorized as follows

- Contaminated soil
- Soil and debris treated by caustic washing
- Soil treated by thermal desorption
- Structural debris

The contaminated soil consists of excavated soil that is untreated. However, it is estimated that only a small portion of the soil will contain listed or characteristic hazardous waste Metallic debris and soil from UXO clearance operations are included in the contaminated soil category The second category includes soil and structural debris that has been treated by caustic washing to address agent contamination. The third category consists of soil treated by thermal desorption to remove organic contamination. The final category includes untreated debris from the demolition of structures

5.1.2 Projected Waste and Landfill Volumes

Table 5.1 summarizes the estimated volume of material to be landfilled for five different remedial alternatives presented in the DAA. It is estimated that between 440,000 cubic yards (CY) and 4,400,000 CY of waste materials will require landfilling depending on the selected remedial action alternative The preferred sitewide alternative in the DAA, Landfill/Caps Scenario, requires a waste volume of 2,300,000 CY

For the purposes of this report, the minimum and maximum waste volumes shown in Table 5 1 were increased to 1,000,000 CY and 6,000,000 CY to account for future adjustments in waste volumes Based on this projected minimum and maximum waste volume, three conceptual landfill models were developed to account for different waste volumes and to provide a total landfill capacity that accounts for the operational and intermittent cover materials that must be placed over the waste Conceptual Model 2 is the preferred sitewide alternative and meets the waste volume requirements of 2,300,000 CY The three models are as follows

Conceptual Model No	Total Landfill Volume (CY)	Waste Volume (CY)
1	1,200,000	1,000,000
2	2,760,000	2,300,000
3	7,200,000	6,000,000

For conceptual design purposes, the total landfill volumes presented above include a 20 percent volume increase over the needed waste volume to account for operational and intermittent waste cover material

5.1.3 Waste Generation Rates and Schedule

Waste generation rates at RMA will primarily be dependant on which of the five remedial action alternatives is selected and the duration of the remedial action. For this study, generation rates were estimated based on a schedule of 260 landfill operating days per year (5 operating days per week for 52 weeks) Additionally, two generation rates are estimated for each alternative in the DAA based on the development of remediation time frames with and without funding limitations The funding

limitation case assumes an annual funding limitation of $100 million for overall remediation activities, which lengthens the remediation period and decreases the generation rates The remediation time frame includes landfill design, construction, and final closure Table 5.2 presents the estimated waste generation rates for five different remedial alternatives presented in the DAA

Waste generation rates have been estimated to be in the range of 98,000 CY to 1,100,000 CY of material per year without considering a funding limit Assuming the $100 million annual funding limit, waste generation rates are estimated to be in the range of 37,000 CY to 280,000 CY of material per year

5.2 Regulatory Criteria

Section 4 2 of this report describes the regulatory criteria that apply to siting a landfill in Colorado A detailed review of all possible current requirements, such as a review of applicable or relevant and appropriate requirements (ARARs) under CERCLA and the Superfund Amendments and Reauthorization Act of 1986 (SARA) was not conducted as part of the current scope of work. The criteria listed in Section 4 2 will likely form the basis for siting a facility under a variety of regulatory scenarios, such as a permitted facility under RCRA, a corrective action management unit (CAMU) under RCRA, or as an interim response action (IRA) under CERCLA. The specific regulatory criteria can be more fully developed once the regulatory framework for siting the facility is better defined.

5.3 Site-specific Considerations and Limitations

Following development of the range of landfill volume (1,000,000 CY, 2,300,000 CY, 6,000,000 CY), the landfill conceptual models were further developed by reviewing and evaluating site conditions and characteristics that could impact the construction of a hazardous waste landfill. Existing site data was reviewed to identify specific limitations and considerations that may need to be addressed in

- The development of design alternatives
- The specific placement of the landfill within the preferred area

- Final design

5.3.1 Climate, Topography, and Surface Hydrology

The site's climate is semiarid with an average annual precipitation of 15 inches The majority of the yearly precipitation typically occurs between the months of March and August. The agricultural growing season is defined as the period between the last frost and the first frost, which averages about 150 days, however, soil temperatures are high enough to sustain plant growth for about 250 days of most years Therefore, selection of the vegetative cover for the final cover system at final design should take this into consideration to establish the necessary erosion protection year round

The ground surface in the vicinity of the preferred siting area generally ranges in elevation from about 5,280 feet above MSL to 5,225 feet above MSL and slopes towards the northwest. Figure 4.4 illustrates the onpost topography at RMA. In general, the area is a treeless plain. As illustrated in the 100-year floodplain map of RMA (Figure 4 2), there are no major drainage channels across the preferred landfill site First Creek is a well-defined channel crossing the RMA to the east of the study area.

The footprints for the three conceptual models should be placed such that run-on to the landfill will be minimized and runoff can be effectively managed As described in Sections 4.2 and illustrated in Figure 4 2, the site is not within the 100-year floodplain. Drainage can be designed to comply with regulations without any significant problems for any of the three proposed landfill volumes There is sufficient area for ditches and other drainage facilities, existing slopes are acceptable or can be amended without excessive amounts of cut and fill, and there is a receiving ditch north of the footprint areas

Run-on to the landfill can be prevented by constructing ditches and/or berms A landfill perimeter berm could serve this purpose

A more detailed description of the topography, and surface hydrology is included in Section 4 2.1 of this report.

5.3.2 Soil and Bedrock

The preferred landfill area is underlain by unconsolidated Quaternary alluvium and the Denver Formation The alluvial soils encountered in the preferred landfill siting area generally consist of the following two types of material (1) clay and sandy clay and (2) sand, silty sand and clayey sand with occasional gravel

The depth to weathered bedrock (Denver Formation) in general follows the surface topography in the study area and ranges from approximately 5 feet to 60 feet. The areas where depth to bedrock is shallowest correspond with areas of high topographic elevation The Denver Formation generally consists of three strata claystone with interbedded siltstone, lignite, and sandstone; sandstone, and lignite/lignitic claystone The alluvium is generally underlain by claystone; however, there are areas in the vicinity of the landfill siting area where Denver Formation channel sand units (sandstone) are in contact with the alluvium Geologic cross sections are presented in Figures 4.21 through 4.28 A more detailed description of the geological and geotechnical study is included in Section 4 4 2 1 of this report

Bedrock channel sands subcrop into the alluvium in three locations in the preferred landfill area, as was noted in Section 4 0 (see Figures 4 29 4.30, and 4 31) Although there are no regulatory siting criteria that require avoiding sand units, siting the landfill such that the base of the landfill were placed above or into the subcrop sands could be a preferential pathway for leachate migration away from the facility If possible, the specific siting should place the base of the landfill into claystone If it is not possible to avoid the sand subcrop areas, the following alternatives are available

- Apply appropriate landfill design technology to minimize the potential impacts associated with these features

- Include wet/dry sand subcrop monitoring points in the facility's monitoring program because the saturated sand units could provide preferential migration pathways

5.3.3 Groundwater

As described in Section 4 4 2.3, there are two groundwater flow systems (the unconfined flow system and the confined flow system) in the preferred landfill area. The unconfined flow system is the primary flow system of concern because it is the first groundwater system encountered beneath the site The unconfined flow system occurs at depths ranging from 20 to 70 feet below ground surface (bgs) The groundwater flow direction in the unconfined flow system is generally to the northwest. A groundwater surface contour map for the preferred area is presented in Figure 4 32 Figure 4 9 presents a contour map showing the depth to groundwater over the preferred area.

Hydrogeologic siting considerations at the preferred landfill site include maximizing the depth to groundwater and evaluating groundwater flow conditions with regard to the long-term groundwater monitoring At the preferred landfill location (western half of Section 25), the depth to groundwater is greatest in the center of the area (Figure 4 32) For long-term groundwater monitoring of the landfill, it is preferable to place the landfill away from areas where groundwater mounds occur because groundwater flows radially from these areas and monitoring for potential leakage is difficult. A groundwater mound exists that straddles the boundary between Sections 25 and 36 (Figure 4 32) For these two reasons, siting the landfill within the central portion of western Section 25 is preferred

5.3.4 Geologic Hazards

The location of the preferred landfill siting area was selected where no geologic hazards such as active faults, unstable areas, or poor foundation conditions are known to exist. Additional study may be required as a component of subsequent engineering design.

5.3.5 Environmentally Sensitive Areas

The location of the preferred landfill siting area was selected to avoid wetlands, floodplains, sites of historical significance, sensitive wildlife habitats, or other environmental sensitive areas

5.3.6 Slope Stability Considerations

Proposed preliminary excavation plans should be developed such that the landfill bottom will be located in or near a competent bedrock formation (Denver Formation) consisting of either shale, sandstone, lignite, or claystone Slope failure within these formations is unlikely, considering the slope geometry and proposed final elevations

5.3.7 Settlement Considerations

The field and laboratory data indicate the alluvial soils are generally medium dense/stiff to very dense/stiff. Assuming landfill geometry consisting of a 30-foot excavation and a 35-foot fill above grade, the net maximum additional surcharge on the subsurface soils will be on the order of 600 pounds per square foot (psf). This magnitude of surcharge may result in settlements on the order of 1/2 inch This estimate should be checked during final design.

5.4 Conceptual Design Alternatives

The conceptual design parameters of a hazardous waste landfill are intended to

- Provide waste containment by separating the waste from the environment
- Prevent contaminant migration by encapsulating the waste
- Confirm facility performance by planning, scheduling, and implementing a periodic site monitoring program

The primary features of a hazardous waste landfill containment system are a liner system and cover (cap) system that completely enclose the waste Containment system components and alternatives are discussed in detail in sections below and are as follows

- Liner Systems
- Leachate Collection and Removal Systems
- Gas Management Systems
- Final Cover Systems
- Performance and Environmental Monitoring System

5.4.1 Liner Systems

Liner systems include multiple layers consisting of a combination of geomembranes/flexible membrane liners (FML), compacted clay liners (CL) or geosynthetic clay liners (GCL), and granular soil or geosynthetic drainage layers The liner system is designed to minimize the release of hazardous waste or hazardous waste constituents to the environment.

Six liner systems were evaluated using EPA's Hydrologic Evaluation of Landfill Performance (HELP) Model, as shown below·

Landfill Liner System Alternatives

	Layer (Top to Bottom)	Liner System No. 1	Liner System No. 2	Liner System No. 3	Liner System No. 4	Liner System No 5	Liner System No. 6
1	Geomembrane	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE
2	Barrier	GCL	CL	GCL	GCL	CL	CL
3	Drainage	Geonet	Geonet	Geonet	Geonet	Geonet	Geonet
4	Geomembrane	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE
5	Barrier	GCL	GCL	CL	CL	CL	CL
6	Geomembrane	N.A.	N.A.	N.A	40-mil HDPE	N.A.	40-mil HDPE

HDPE High-density polyethylene
CL 3 feet of compacted clay
GCL Geosynthetic clay liner
N.A Not applicable

Cross sections of each liner system are presented in Figure 5 1 The purpose of the tertiary geomembrane included with Liner System Nos 4 and 6 is to provide a moisture barrier between the moisture-conditioned compacted clay liner and the drier in situ soils The results of the evaluation are presented in detail in Section 5.5.1 1