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CORRES. CONTROL
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00939 RF03

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ACTION

2003 OCT -9 A 9:43

CORRESPONDENCE
CONTROL

Department of Energy

ROCKY FLATS FIELD OFFICE
10808 HIGHWAY 93, UNIT A
GOLDEN, COLORADO 80403-8200

OCT 07 2003

03-DOE-01378

DIST.	LTR	ENC
BERARDINI, J. H.	X	X
BOGNAR, E. S.	X	X
BROOKS, L.	X	X
BUTLER, L.	X	X
CROCKETT, G. A.		
DECK, C. A.	X	X
DEGENHART, K. R.	X	X
DIETER, T. J.		
DIETERLE, S. E.		
FERRERA, D. W.	X	X
GIACOMINI, J. J.		
HIETT, S. B.	X	X
ISOM, J. H.		
LINDSAY, D. C.	X	X
LONG, J. W.		
LYLE, J. L.		
MARTINEZ, L. A.	X	X
NAGEL, R. E.	X	X
NORTH, K.	X	X
PARKER, A. M.	X	X
RODGERS, A. D.		
SHELTON, D. C.	X	X
SPEARS, M. S.		
TRICE, K. D.		
TUOR, N. R.	X	X
WILLIAMS, J. L.		
Zahm, C.	X	X
Nesta, S	X	X
Freiboth, C.	X	X

COR. CONTROL	X	X
ADMN. RECORD	X	X
PATS/130		

Reviewed for Addressee
Corres. Control RFP

10/9/03 — Date; LC — By

Ref. Ltr. #

DOE ORDER #
None

Mr. Steven H. Gunderson
Rocky Flats Cleanup Agreement Project Coordinator
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530

Dear Mr. Gunderson:

This letter constitutes Rocky Flats Cleanup Agreement Standard Operating Protocol for Facility Disposition Notification for Building 991 Tunnel and Vaults 996, 997, and 999, which were characterized as type 2 facilities. Work to decommission the tunnel has proceeded based on contact record; this letter documents the disposition for the record.

Questions may be directed to Steve Tower at (303) 966-2133.

Sincerely,

Joseph A. Legare
Assistant Manager
for Environment and Stewardship

Enclosure

cc w/o Encl.:
E. Schmitt, OOM, RFFO
S. Tower, AMP, RFFO
S. Nesta, K-H RISS Env.
C. Freiboth, K-H RISS D&D
T. Rehder, USEPA

cc w/Encl.:
Administrative Record

Reviewed for Classification/UCNI/OUO
By: Janet Nesheim, Derivative Classifier
DOE, EMCBC
Date: 10-14-08
Confirmed Unclassified, Not UCNI/Not OUO

1/55

DOCUMENT CLASSIFICATION
REVIEW WAIVER PER
CLASSIFICATION OFFICE

IA-A-001683

KAISER-HILL
COMPANY

September 19, 2003 03-RF-01436

Joe Legare
Assistant Manager for
Environment and Stewardship
DOE, RFFO

ROCKY FLATS CLEANUP AGREEMENT (RFCA) STANDARD OPERATING PROTOCOL (RSOP) FOR FACILITY DISPOSITION - NOTIFICATION LETTER FOR 991 TUNNEL FEG-029-03

The Facility Disposition RSOP requires that DOE notify the Lead Regulatory Agency (LRA) prior to implementing work activities pursuant to this document. The Rocky Flats Environmental Technology Site (RFETS) received concurrence from the Colorado Department of Health and Environment (CDPHE) that 991 Tunnel was a Type 2 facility (August 8, 2003).

The purpose of this Notification is to invoke this RSOP for demolition of the facility, based on the attached Contact Records between Kaiser-Hill, DOE-RFFO, and CDPHE. Documentation of the facility status is in the Pre-Demolition Survey Report (PDSR) submitted on September 10, 2003. Associated RSOP documentation is provided in attachments 1 through 4.

As stated in the Reconnaissance Level Characterization Report (RLCR), dated February 4, 2003, and approved by CDPHE on August 8, 2003, 991 Tunnel was characterized as a Type 2 facility. The Pre-Demolition Survey Report (PDSR) submitted to CDPHE on September 10, 2003 documents the condition of 991 Tunnel.

If you have any questions or require additional information, please contact Karen Wiemelt x9883.

Dennis Ferrera

Frank E. Gibbs
Deputy Project Manager
Remediation, Industrial D&D, and Site Services

Attachment:
As Stated

SMN:pvt

Orig. and 1 cc – Joe Legare

cc: Steve Tower

Kaiser-Hill Company, L L C
Rocky Flats Environmental Technology Site, 10808 Hwy. 93 Unit B, Golden, CO 80403-8200 ♦ 303-966-7000

991 TUNNEL RSOP NOTIFICATION FOR FACILITY DISPOSITION

This RSOP Notification for Facility Disposition addresses leaving the 991 Corridor C Tunnel and Vaults 996, 997, and 999 in place as final disposition of these structures. As discussed in Section 4 of the RSOP for Facility Disposition, tunnels will be addressed on a case-by-case basis. This notification discusses the physical condition of the tunnel and vaults along with the pre-demolition survey (PDS) results and environmental, structural, and groundwater analyses that have been conducted. The final section discusses the proposal for final disposition of the tunnel and vaults.

PHYSICAL DESCRIPTION

The following information is from the Building 991 Complex Facility Safety Analysis Report (FSAR), October 2001 and the current Land Configuration plans.

The 991 Corridor C tunnel extends from the 996 vault to the 997 vault with the 999 vault located approximately at the midpoint of the tunnel. The 991 tunnel is an underground, reinforced concrete structure with exterior dimensions of eight feet wide, 10 feet high, and approximately 660 feet long. The walls, roof and floor are 15 inches thick. The earth cover varies throughout the length of the tunnel and is estimated to be up to 21 feet in some locations. The 991 tunnel is, on average, 19.5 feet below grade. These depths are not anticipated to change based on the current Land Configuration plans.

The 996 and 997 vaults are underground vault structures located northwest of Building 991. The 996 vault is located at the western-most end of the 991 tunnel while the 997 vault is located at the eastern-most end. The structures were built to withstand exceptionally high blast pressures. The exterior walls are 14 feet, 6 inch thick reinforced concrete. The roof is 12 feet thick concrete. The floors are six feet thick concrete and the interior partitions are two feet thick concrete. The outside dimensions of the structure are 60 feet by 68 feet. Each vault has four main storage areas, which are 12 feet wide by 18 feet, 6 inches long by 10 feet high. The original design criteria of the vaults required the structure to support specific dead loads and to withstand the blast pressure of a semi-armor piercing 2000-pound bomb. The top of the 996 vault is 10 feet below existing grade while the top of the 997 vault is 6 feet below existing grade.

Vault 999, built in 1956, is an underground, reinforced concrete structure with outside dimensions of 49 feet by 33 feet and is accessed from Corridor C through a 10 foot 6 inch long by 13 foot wide vestibule. The vault is a box structure with three separate areas. The roof is 21 inches thick and is supported by 18 inch thick exterior walls and 24 inch thick interior walls. The walls are supported by continuous spread footings with a top of footing elevation of 12 inches below the floor slab. The floor slab is 6 inches thick and lightly reinforced. The floor to the bottom of roof slab height is 10 feet. The cross-section of the vestibule appears as a continuous box structure constructed of a 15 inch thick roof slab, 18 inch thick floor slab and 12 inch thick by 10 foot high walls. The top of the 999 vault is over 19 feet below existing grade.

PDS RESULTS

The PDS Report that presents the survey results from the 991 Tunnel and vaults 996, 997, and 999 was submitted to DOE on August 27, 2003 and to CDPHE on September 10, 2003. The surveys show the tunnel and vaults meet the unrestricted release criteria.

ENVIRONMENTAL ANALYSIS

The 991 Corridor C Tunnel and Vaults 996, 997, and 999 are part IHSS Group 900-1, 991 UBC. Samples were collected in accordance with SAP Addendum IA-03-03 to determine if contamination existed below these structures. No contamination was found that required an action. These data were presented to EPA and CDPHE on July 14, 2003. Based on the data collected and presented there is not an exceedance that would result in an ER action at the tunnel or vaults. A Contact Record was generated on July 21, 2003 to document this concurrence (Attachment 1). The data will be included in the IHSS Group 900-1 Closure Document once all IHSS sampling in complete (Building 991 UBC sampling is not complete).

STRUCTURAL ANALYSIS

In March 2003, a structural analysis was conducted for the 991 Corridor C tunnel and the 996, 997, and 999 vaults to predict the long-term condition of these structures if they were left in place. The analysis assumed the footing drains fail, allowing groundwater to enter the structures and corrode the steel rebar in the concrete. The conservative engineering estimate was that the 991 Corridor C tunnel (the weakest of the 4 structures) could continue to exist without failing for 500 years or longer. Once it eventually fails, the analysis predicted the volume of the tunnel to most likely be reduced by half, causing a depression 2 feet deep by 22 feet wide (Attachment 2).

GROUNDWATER ANALYSIS

Groundwater modeling was conducted for these structures in November 2002 (Attachment 3). This analysis assumed normal climatic conditions and footing drain failure. Under these conditions, no adverse effects were seen (i.e., no groundwater seeps in the vicinity of the tunnel). The modeling was updated in September 2003 to include more conservative wet conditions and a smaller grid size (Attachment 4). The modeling parameters were the same that were used for the 771 DOP and included the current Land Configuration plans for the 991 area.

Under wet conditions, the model predicts no adverse impact (i.e., groundwater is greater that 1 meter from the surface) on the eastern side of the tunnel. However, on the western side of the tunnel, the model predicts that groundwater could come within less than 1 meter of the surface during wet conditions. The model also shows this condition even with the tunnels removed, indicating it is caused by the shallow bedrock in the vicinity of the western edge of the tunnel. Further, the model shows no contaminated plumes migrating into the tunnel area during these wet conditions.

DISPOSITION PROPOSAL

Based on these results, final disposition of the 991 Corridor C tunnel and the 996, 997, and 999 vaults is proposed to include the following:

- All structures remain in place.
- The tunnel and vaults are emptied.
- All ductwork, conduit, lighting, vacuum pump, and asbestos insulated air and water lines are removed.
- Floor tiles, painted surfaces and vault doors will remain.
- The footing drain will not be interrupted and will remain in place. However, no efforts will be made to maintain the drain.
- A four-foot thick plug of foam will be place at the entrance to the 991 Corridor C tunnel.

The foam plug will be installed following completion of asbestos abatement (late September). The plug will be in place with the plywood forms and no additional cover from approximately

September/October 2003 until demolition of the remainder of the 991 Complex. During demolition of the remainder of the 991 Complex, final grading will cover the foam plug. The plug will be approximately 15 feet below and 20 to 30 feet horizontally from the final grade based on the current Land Configuration plans. The tunnel and vaults will be, on average, approximately 15 feet below grade with the shallowest depth at 6 feet at the top of the 997 vault and the deepest depth at 22.5 feet at the top of the tunnel near vault 996.

The area in the vicinity of the western edge of the tunnel requires engineered controls for slope stability. These controls will be designed using the consultative process in early FY04 and installed as part of final land configuration of the 991 complex. Final land configuration of this area is planned to occur in late second quarter/early third quarter FY04.

991 TUNNEL RSOP NOTIFICATION FOR FACILITY DISPOSITION

Attachment 1
CERCLA Administrative Record Index

CERCLA Administrative File

- RCLR (February 4, 2003) approved August 8, 2003
- RSOP for Component Removal, Size Reduction, and Decontamination Activities Notification Letter for 991 Tunnel (July 23, 2003) approved August 4, 2003
- PDSR for 991 Tunnel (submitted to CDPHE September 10, 2003)

Contact Record History

- April 17, 2002, Site contact C. Guthrie, CDPHE contact D. Kruchek
- February 4, 2003, Site contact R. DiSalvo, CDPHE contact D. Kruchek
- March 12, 2003, Site contact D. Parsons, CDPHE contact D. Kruchek
- March 21, 2003, Site contact R. DiSalvo, CDPHE contact J. Gunderson
- July 21, 2003, Site contact M. Broussard, CDPHE contact D. Kruchek, et.al.
- July 31, 2003, Site contact K. Wiemelt, CDPHE contact D. Kruchek
- August 4, 2003, Site contact J. Legare, CDPHE contact J. Gunderson
- August 8, 2003, Site contact J. Legare, CDPHE contact J. Gunderson
- September 5, 2003, Site contact F. Gibbs, CDPHE contact D. Kruchek
- September 10, 2003, Site contact J. Legare, CDPHE contact J. Gunderson

991 TUNNEL RSOP NOTIFICATION FOR FACILITY DISPOSITION

Attachment 2
Structural Analysis

CALCULATION/OTHER DOCUMENTS COVER SHEET

CALCULATION NUMBER CALC – 991 - BS - 00040 **Rev.** 0

Section 1: IDENTIFICATION

1. WCF or /Authorization Project Number	2. Project Title	3. Page
EFD58300	**B991 CORRIDOR-C TUNNEL STRUCTURAL ANALYSIS FOR THE PREDICTION OF LONG TERM CONDITION**	1 of 16

3. System Identification (See SX-164, Plant System and Component Identification and Labeling)	4. Other (Type of document, e.g., Studies, Conceptual Design Report, Design Criteria, etc.)
NA	**Capacity Analysis**
6. Natural Phenomena Hazard Performance Category (PC) Number ☒ PC-0 / NA ☐ PC-1 ☐ PC-2 ☐ PC-3	7. Building Number **B991**

8. Engineering Discipline(s) Involved with Calculation:

STRUCTURAL

Section 2: SIGNATURES FOR A CALCULATION

	Discipline	Print Name	Sign	Date
9. Designer(s)	Structural	Dennis Weingardt	[signature]	3-29-03
10. Checker(s)	Structural	Keith MacLeod	[signature]	3/29/03
11. Independent Verifier (for PC-0/NA and PC-1)	Structural	Keith MacLeod	[signature]	3/29/03
12. Peer Reviewer (for PC-2 and PC-3)	NA			
13. Responsible Engineering Manager	PCE	Tim Humiston	[signature]	4/1/03
14. Classification Review	DC	CJ FREIGON	[signature]	04/01/03

Section 3: SIGNATURES FOR OTHER DOCUMENTS

	Discipline	Print Name	Sign	Date
15. Preparer				

Section 4: REVISION SUMMARY

16. Description	17. Affected Pages

9

CALCULATION CONTROL NUMBER: CALC – 991 – BS – 00040 - (REV. 0)

1. **IWCP/Authorization Project Number:** EFD58300

2. **Calculation Title:** B991 CORRIDOR-C TUNNEL STRUCTURAL ANALYSIS FOR THE PREDICTION OF LONG TERM CONDITION

3. **Calculation Description:**

The site is considering leaving the concrete portions of Corridor-C Tunnel and the vaults in place and not removing them for the final site closure. This calculation addresses two factors that will be involved with this consideration, which are as follows:

   1. What is the projected number of years that the tunnel will remain standing before it begins to collapse.
   2. What will be the depression in the ground surface when the tunel does collapse.

Therefore, an analysis of the tunnel structure's present strength and condition is needed to determine what the future long term condition of the tunnel may be. From the analysis a projection can be made as to how many years before the tunnel begins to collapse. The analysis is based on the tunnel loaded only with the soil overburden that is presently on the tunnel now. The tunnel will not be subject to any vehicle traffic. The analysis is also based on the groundwater rising after the footing drains fail, and the tunnel will be exposed to the corrosive effects of water.

4. **Natural Phenomena Hazard Performance Category:** NA - it can be reasonably assumed that if an earthquake does occur it will not effect the tunnel, because the tunnel is buried and supported all around by soil.

5. **Calculation Objectives (List):**

The objective is to calculate the strength of the tunnel without steel rebar reinforcement with just the strength of the concrete. This will give an indication of whether the tunnel can support its own weight and overburden over a long period of time once the reinforcement has completely corroded. After closure the footing drains are likely to become inoperable over time and the natural groundwater flows are expected to rise. This will expose the tunnel to water and reinforcement will corrode.

The objective also is to model the effects on the ground surface after the tunnel has collapsed.

6. **List Methods used for Calculation:** Standard engineering design practice and by engineering methods of the (ACI) American Concrete Institute.

7. **List Assumptions used:** It is assumed that after a period of time the footing drains will fail and the groundwater will rise, which will expose most of the tunnel the corrosive effects of water. This is base on the report "Hydraulic Effects on Decommissioning Building 997" by Bob Prucha, Integrated Hydro Systems, November 25, 2002.

CALCULATION CONTROL NUMBER: CALC – 991 – BS – 00040 - (REV. 0)

8. Identify References:

1. ACI 318-89 American Concrete Institute 1989 Edition.
2. "Hydraulic Effects on Decommissioning Building 997" by Bob Prucha, Integrated Hydro Systems, November 25, 2002.
3. Drawings (attached): 30996-0001-02C, 13812-0003, 13812-0004, & 13812-0007.
4. Soil Overburden Survey Datum Drawing.

9. Identify Applicable Design Related AB Documents: NA

10. Body of Calculation: Refer to the following calculation pages.

11. Calculation Conclusion:

<u>Building B991 Corridor "C" Tunnel to B996, B999, & B997 Prediction of Long Term Condition of Tunnel</u>

<u>Present Strength & Condition of Corridor "C" Tunnel</u>

The Corridor "C" tunnel has been studied many time in the past, because the existing soil overburden is much greater than the tunnel was designed to support. I did a inspection and a review of the existing calculations of the tunnel in May 2000. My conclusion was that the overall condition of the tunnel was good, but there are many stress cracks and seepage of water with possible corrosion. Many cracks had stress gages placed in 1967 and the cracks did not show any further movement, which means the condition of the tunnel is not continuing to deteriorate. The studies and calculations of the tunnel all concluded that the tunnel has sufficient strength for the existing superimposed loads.

The calculations conclude the concrete of the tunnel roof has the strength support its own weight and the soil overburden after there is a total lose of reinforcement strength due to corrosion. The concrete strength is the ultimate rupture strength of the concrete just before it cracks. Once the concrete cracks the concrete loses all strength.

CALCULATION CONTROL NUMBER: CALC – 991 – BS – 00040 - (REV. 0)

11. Calculation Conclusion (continued):

Long Term Durability of the Corridor "C" Tunnel

Because, the concrete of the tunnel has the strength to support its own weight and the soil overburden the tunnel could remain intact for many years. Also, because the tunnel is narrow (8 ft. inside), once the roof of the tunnel begins to fail, the soil above the tunnel will arch over the roof to the side walls and the soil on each side of the tunnel.

Therefore, a conservative engineering estimate would be that the Corridor "C" tunnel could continue exist without failing for **500 years or longer**.

Depression in Soil After the Eventual Collapse of Corridor "C"

When the tunnel does eventually fail, the volume of the tunnel will most likely be reduced by approximately half. The depression in soil above the tunnel will have the approximate dimensions of **2 ft. deep x 22 ft. wide.** When the complete crushes and there is no interior volume left the approximate dimensions of the depression will be **4 ft. deep x 27 ft. wide.**

If there are any questions please give me a call.

Keith MacLeod, RFETS Material Stewardship Engineering
B460 C211- 09, phone 303-966-2067, pager 303-212-5674,
fax 303-966-7193, & e-mail keith.macleod@rfets.gov

CALC-991-BS-00040

Building 991 Tunnel - Problem Definintion

Givens Tunnel between Building 997 and 996

1. Tunnel runs between "Buildings" 997 and 996	Ref. - RISS "Rocky Flats Closure Project" Plan
2. Width (span of roof) of 991 tunnel is 8 feet.	Ref - Drawing 13812-0004
3. Floor elevation at the west end of the tunnel is 5946 ft	Ref - Drawing 13810-0003
4. Floor elevation at the east end of the tunnel is 5934 ft	Ref - Drawing 13810-0003
5. Height of tunnel from inside floor to top of roof is 10' + 1'-3"	Ref - Drawing 13810-0004
6. Grade elevation at Building 997 (west end of tunnel) is 5969.00 ft. (11.75 ft. soil over burden)	Ref - Survey Datums
7. Grade elevation at Building 997 (west end of tunnel) is 5960.00 ft. (14.75 ft. soil over burden)	Ref - Survey Datums
8. Concrete Strength is 4000 psi	Ref - Drawing 13812-0007

Find

1. Will tunnel withstand its own weight and overburden over a long period of time. In other words, will the tunnel remain structurally viable after many decades or centuries?
2. If tunnel does not remain structurally intact, what will be the effect of a tunnel collapse?

Assumptions

1. It is assumed that the reinforcing steel in concrete does not esist. This assumption is made in order to predict long term behavior of the tunnel after Rocky Flats Environmental Technology Site (RFETS) closure occurs. The "Buildings" 997 and 996 and the 991 Tunnel between them are located below groundand are currently kept relatively dry with footing drains. After closure the footing drains are likely to become inoperable over time and natual groundwater flows are expected to rise (Ref - "Hydraullic Effects of Decommissioning Building 997" - Bob Prucha, Integrated Hydro Systems, Monday, November 25, 2002). In fact, groundwater levels are expected to be higher than the original unbuilt hydrological state at the "upstream" ground water flow side of the structures.

Observation of the tunnel indicates that over the years water infiltration has existed (as evidenced by "stalactite"-type deposits along cracks in the tunnel walls and rusting of embedded steel items in the ceilng of the tunnel. Both cracks (due to localized settlements or shrinkage) and construction joints also exist, which usually are subject to water penetration.

Building 991 Tunnel - Problem Solution

1. Structural Viability of Tunnel without Reinforcing Steel

Load on Tunnel Roof

Earth Load

Refer to Figure 1. The maximum earth cover over the tunnel is 8.92 ft (say 9.00 ft)

For an assumed soil density of γ (simplifying assumption--actual soil will vary with water saturation), weight of soil on roof of tunnel is calculated as follows:

Height of soil column is $H_{soil} := 14.75$ ft

Density of soil is $\gamma_w := 120$ pcf(wet)

$\gamma_d := 100$ pcf(dry)

Assume average $\gamma := 110$ pcf

Load on tunnel roof due to soil is

$W_{soil} := H_{soil} \cdot \gamma$ pcf

$W_{soil} = 1622.5$ psf

Concrete Load

Height of concrete column is $H_{conc} := 1.25$ ft

Density of concrete is $\gamma_c := 150$ pcf

Load on tunnel roof due to ~~soil~~ CONCRETE is

$W_{conc} := H_{conc} \cdot \gamma_c$ pcf $W_{conc} = 187.5$ psf

Total Soil and Concrete Load on Tunnel Roof

Total load on tunnel roof is $W_{roof} := W_{soil} + W_{conc}$

$W_{roof} = 1810$ psf

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Bending Moment of Tunnel Roof

For a unit width of 1'

Bending span of tunnel roof is $l_{roof} := 8$ ft

Maximum bending moment on slab of tunnel roof is (assming roof sides fixed by walls (use fixed end moment):

$$M_{max} := \frac{W_{roof} \cdot l_{roof}^2}{10}$$

$$M_{max} = 11584 \quad \text{ft} - \text{lb}$$

Section modulus of unit 1' width of concrete, 1.25' is

$$S_{conc} := \frac{(H_{conc})^2}{6}$$

$$S_{conc} = 0.2604 \quad \text{ft}^3$$

$$S_{concin} := S_{conc} \cdot 1725 \quad \text{in}^3$$

$$S_{concin} = 449.2188 \quad \text{in}^3$$

For concrete strength (f_c) of 4000 psi:

and $f_c := 4000$ psi

$f_r := 7.5 \cdot \sqrt{f_c} \cdot 144$ psf $\qquad f_{rin} := \frac{f_r}{144}$ psi

$f_r = 68305$ psf $\qquad f_{rin} = 474.3416$ psi

Cracking moment of slab (unit width of 1') is $M_{cr} := f_r \cdot S_{conc}$

$$M_{cr} = 17788 \quad \text{ft} - \text{lb}$$

Since M_{cr} is greater than M_{max}

the tunnel roof would not collapse under the weight of the earth.

For a more conservative set of assumptions:

$H_{soil} := 12 \cdot ft$ $\gamma := 130 \cdot \frac{lb}{ft^3}$ $f_c := 2000$ psi

$f_r := 6 \cdot \sqrt{f_c} \cdot 144$ psf

$f_r = 38639$ psf

$M_{cr} := f_r \cdot S_{conc}$ $M_{cr} = 10062$ ft – lb

Compare this to the maximum moment on the roof slab:

$$W_{roof} := 187.5 \cdot \frac{lb}{ft^2}$$

$W_{soil} := H_{soil} \cdot \gamma$ $W_{soil} = 1560 \frac{lb}{ft^2}$

$W_{roof} := W_{roof} + W_{soil}$ $W_{roof} = 1747.5 \frac{lb}{ft^2}$

$M_{max} := \frac{W_{roof} \cdot l_{roof}^2}{10}$ $M_{max} = 11184 \frac{lb}{ft^2}$

Since M_{cr} is less than M_{max} in this case,

the tunnel roof would collapse under the weight of the earth.

As can be seen, whether the tunnel roof collapses is sensitive to the assumpltions made.

2. Effect on Ground Surface Due to Collapse of Tunnel

Sandy Soil over Collapsed Tunnel Roof

Assuming a sandy soil 8 ft deep with an angle of repose of 45 degrees, and a total loss of the tunnel roof, and total filling of the section of collapsed tunnel with the soil, the following depression in the ground may be estimated, where D is the depth of the depression and W is the width of the depression (1' unit length):

For $H_{soil} := 8 \cdot ft$ $\quad W := 2 \cdot (5.25 \cdot ft + H_{soil})$

$W = 26.5 ft$ $\quad Vol_T := 8 \cdot ft \cdot 11.25 \cdot ft$ $\quad Vol_T = 90 ft^2$

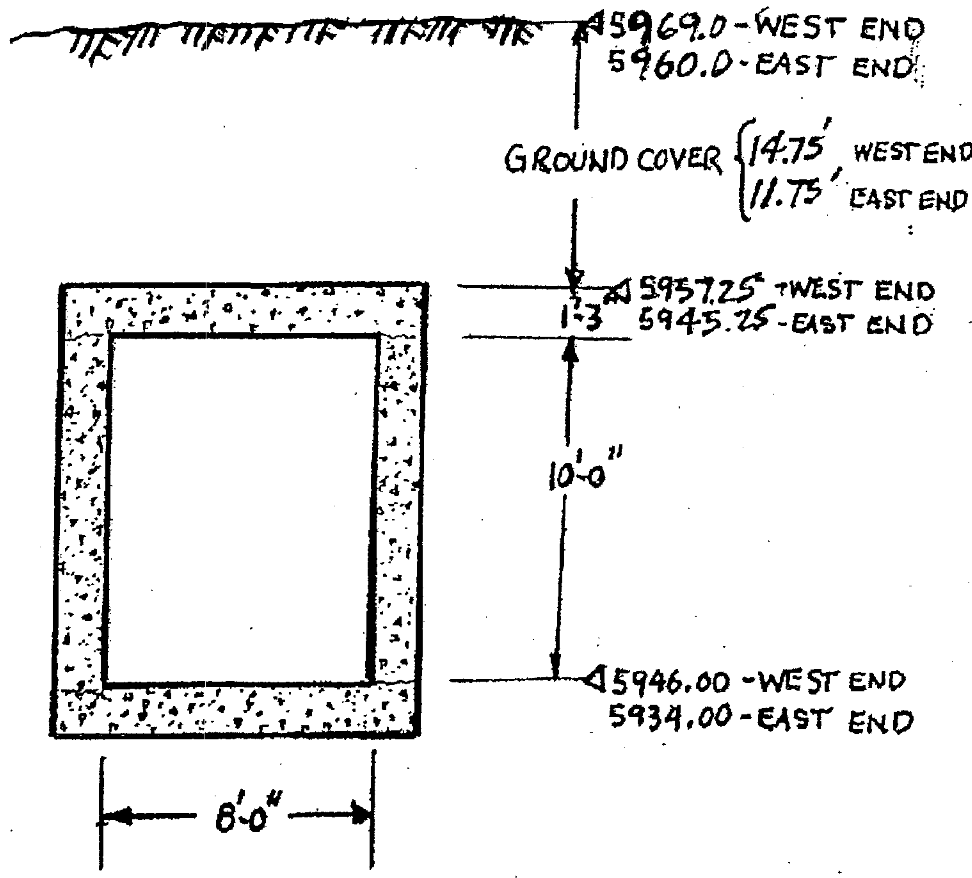
$Vol_D := D \cdot (W - D)$ $\quad$ For $\quad D^2 + WD + 90 := 0$

$$D := 0.5 \left(W - \sqrt{W^2 - 4 \cdot Vol_T} \right)$$

$D = 4 ft$

The collapse of the ceiling would cause a depression in the soil of 4 ft deep and 26.5 ft wide.

ROCKY FLATS	CALCULATION SHEET		CALC PAGE NO. Page 10 of 16
CALCULATION NO: CALC-991-BS-00040	REV.: 0	JOB #: EFD58300	
PREPARED BY: WEINGARDT	CHECKED BY:		
SUBJECT: BLDG 991 TUNNEL			

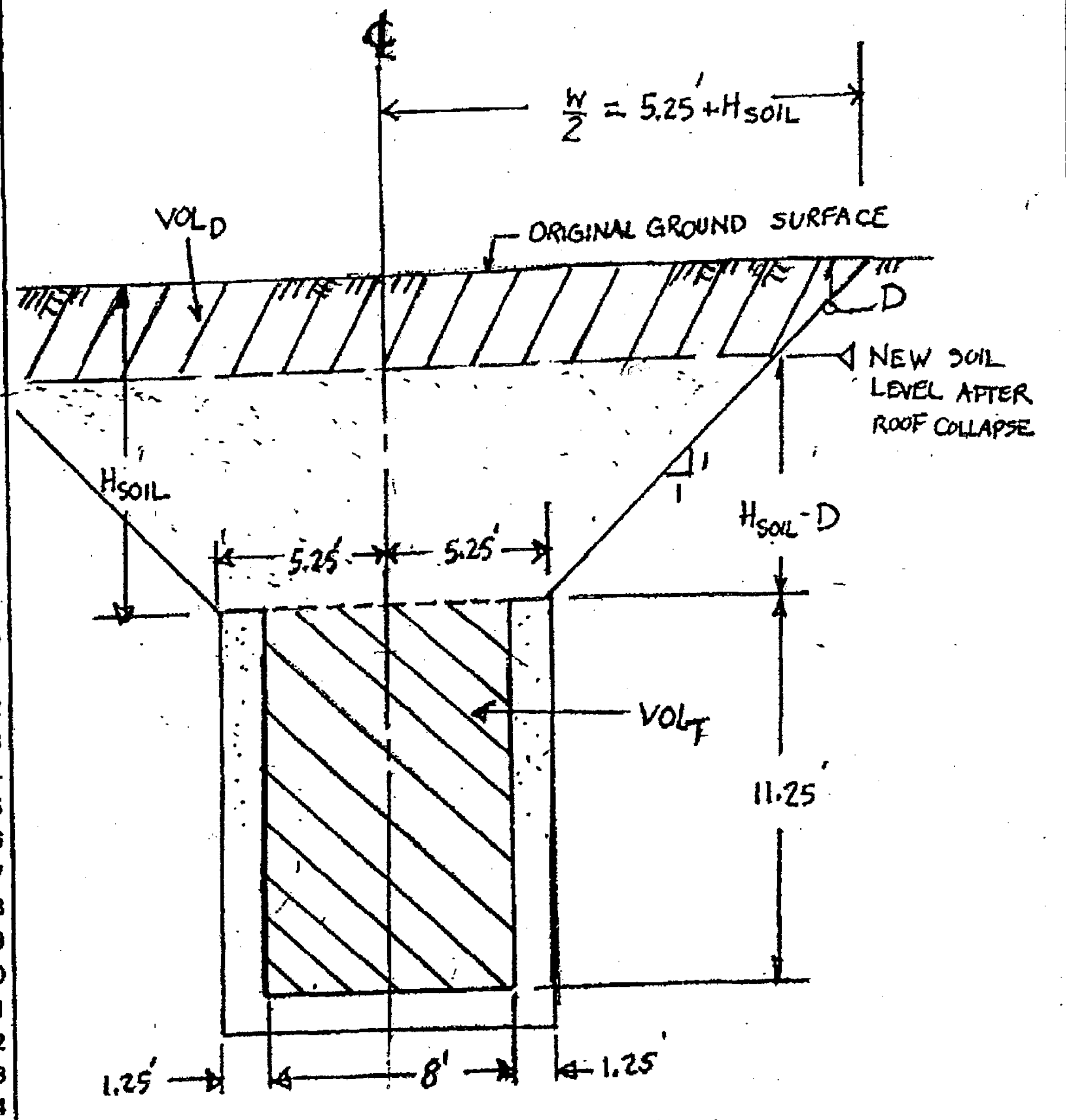


TYPICAL CROSS SECTION
THROUGH BUILDING 991 TUNNEL

FIGURE 1

18

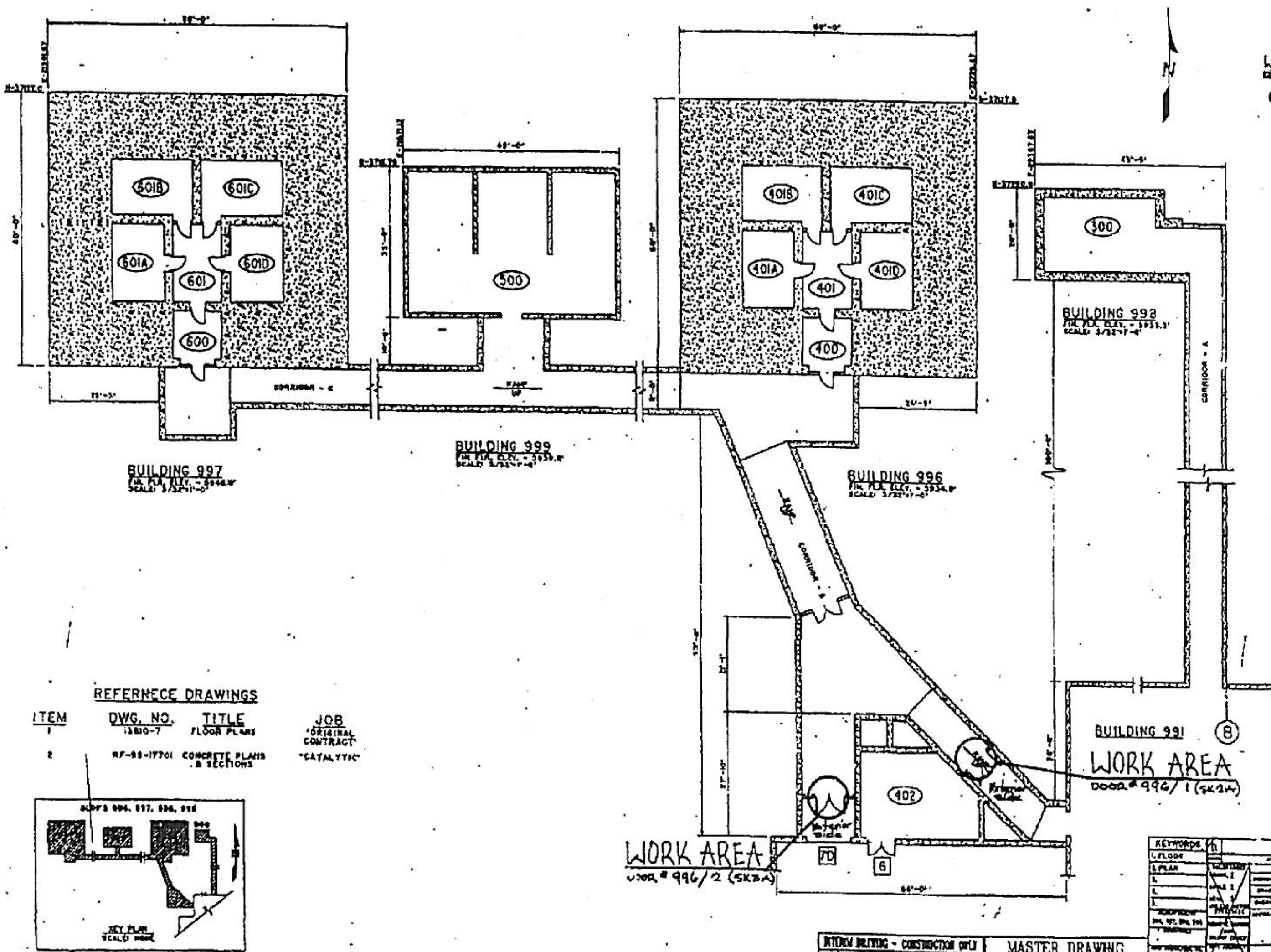
EG&G ROCKY FLATS	CALCULATION SHEET		CALC PAGE NO. Page 11 of 16
CALCULATION NO: CALC-991-BS-000410	REV.: 0	JOB #: EFD 58300	
PREPARED BY: WEINGARDT	CHECKED BY:		
SUBJECT: BUILDING 991 TUNNEL			



TYPICAL CROSS SECTION · 991 TUNNEL
-WITH ROOF COLLAPSE
(SANDY SOIL)

FIGURE 2

CAL-991-BS-000402 (PAGE 12 OF 16)



DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION

Reviewing Official: J. A. NESHEIM

Name: EMCBC Classn Officer

Date: 10-14-08

~~NOT FOR PUBLIC DISSEMINATION~~

FOR REFERENCE ONLY

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant

GOLDEN, COLORADO

BUILDINGS 996, 997, 998 & 999

FLOOR PLANS

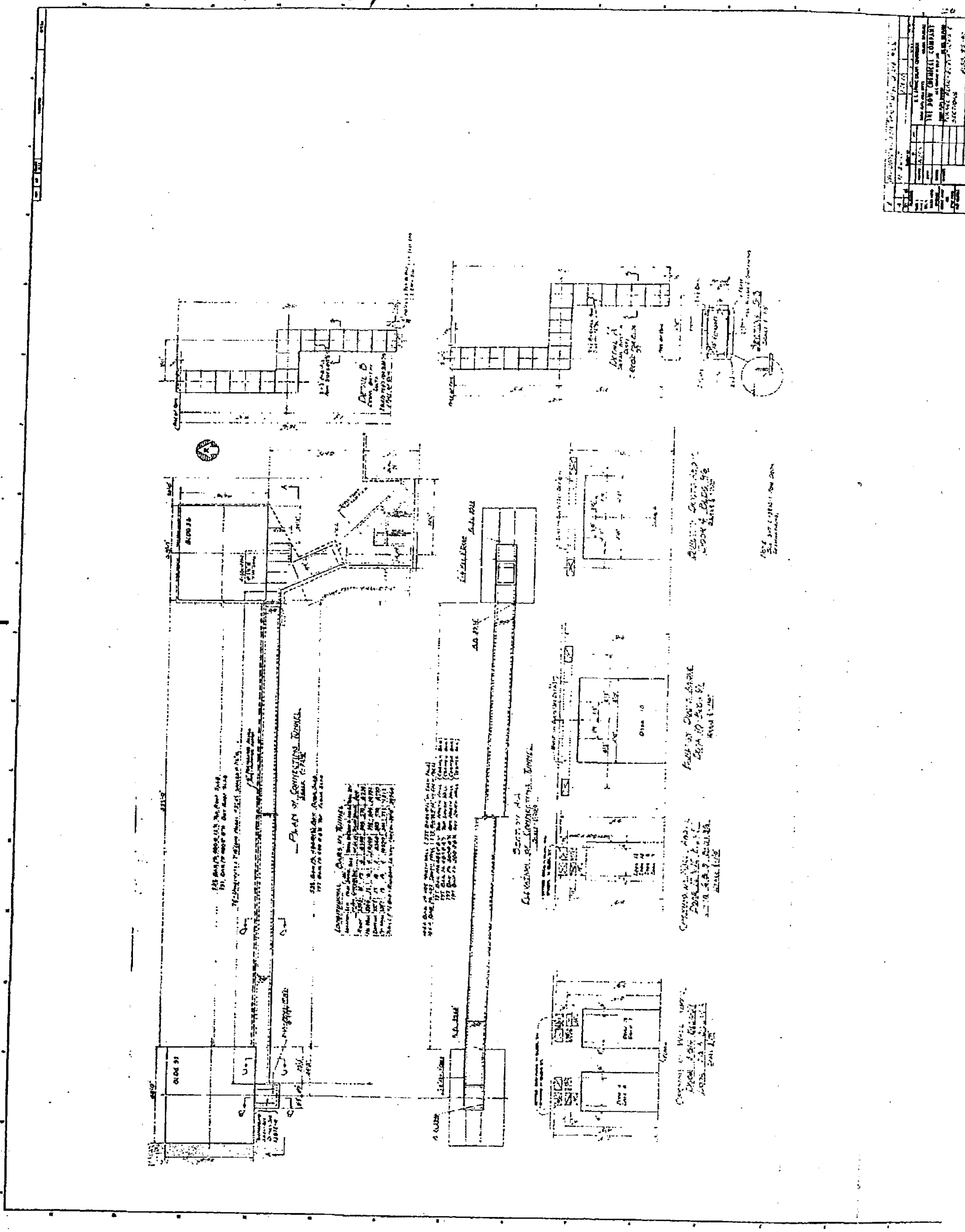
D 30996-1-002 A 1-2

INTERIM DRAWING - CONSTRUCTION ONLY

MASTER DRAWING

RETAIN COPY

COMPUTER GENERATED



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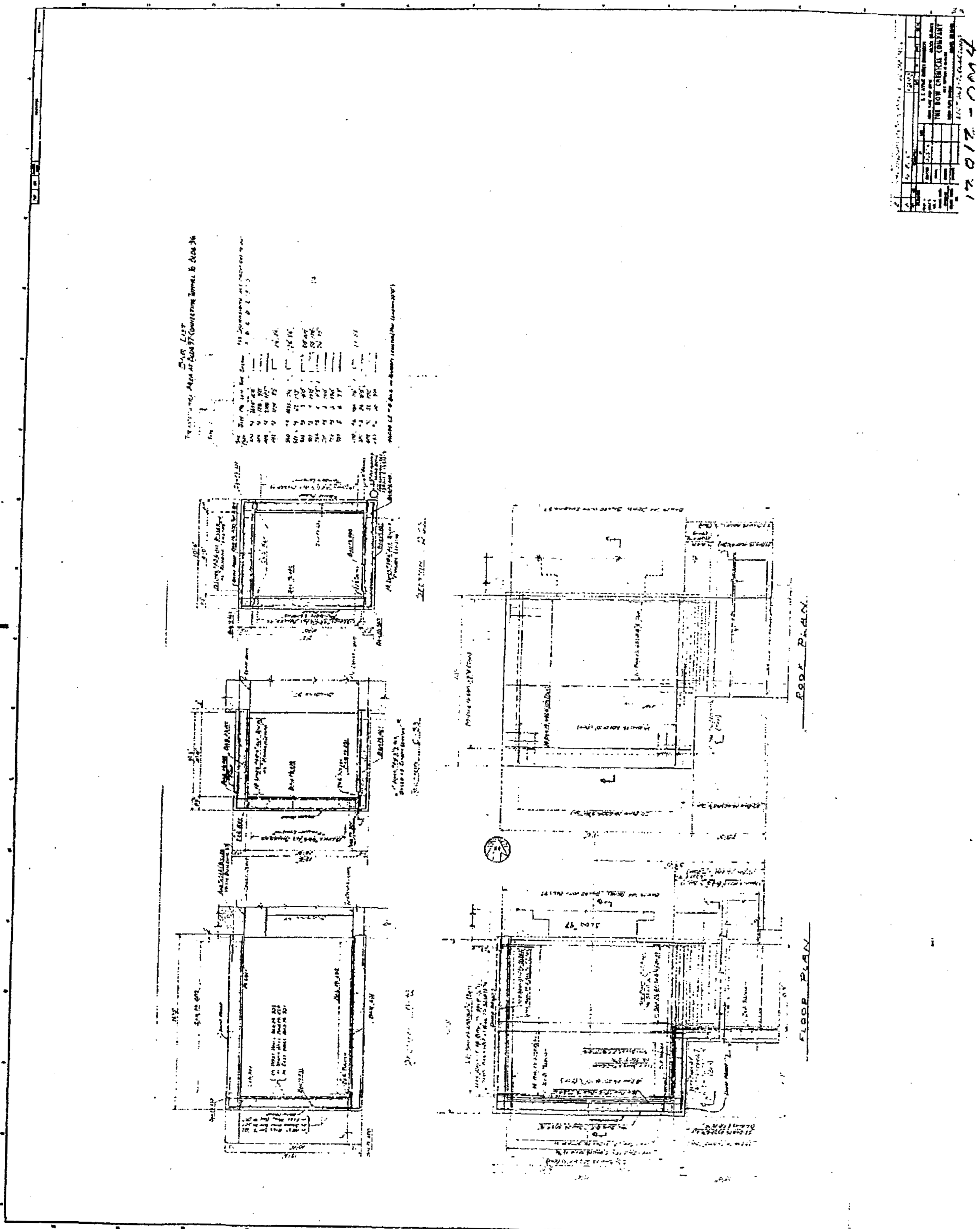

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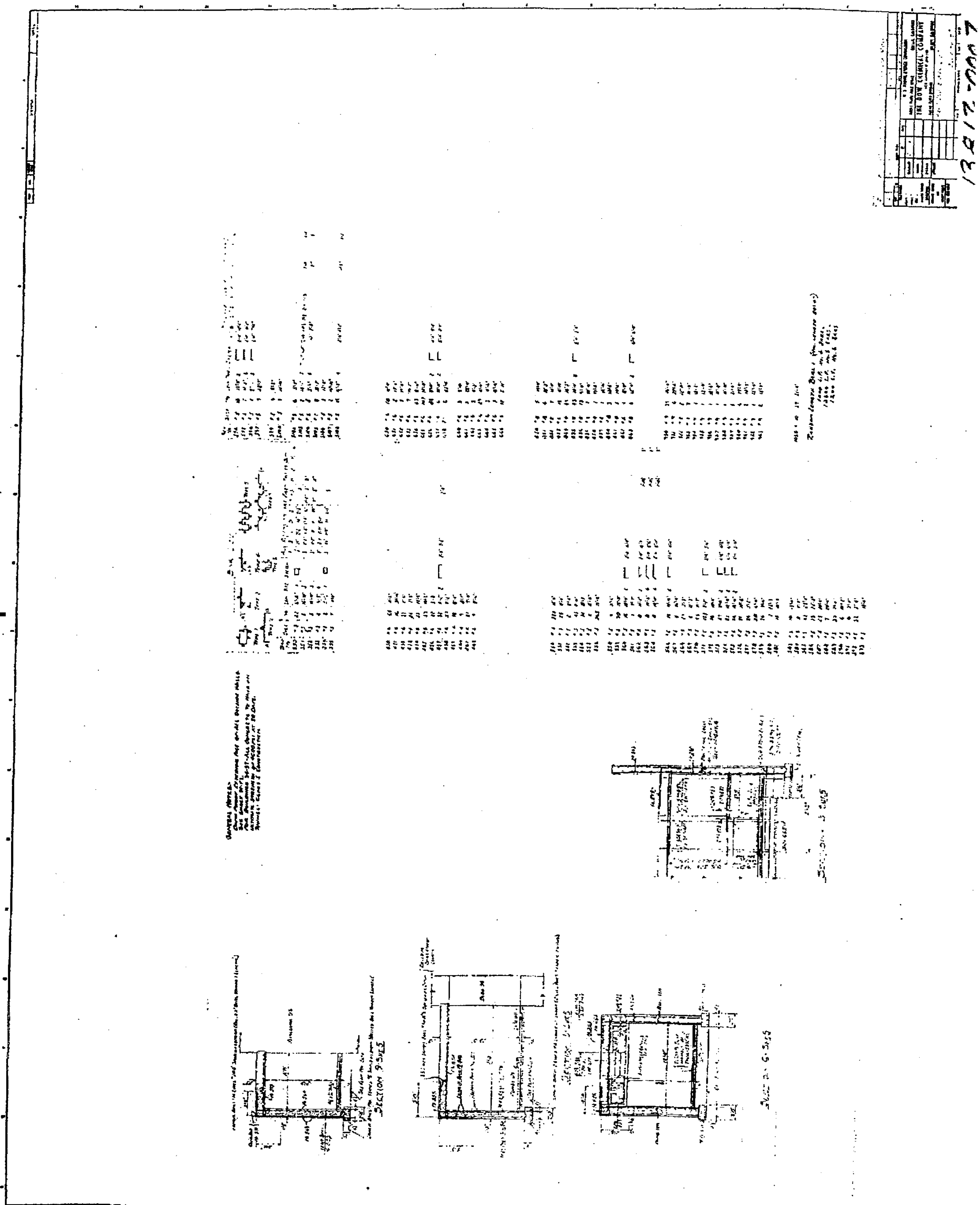

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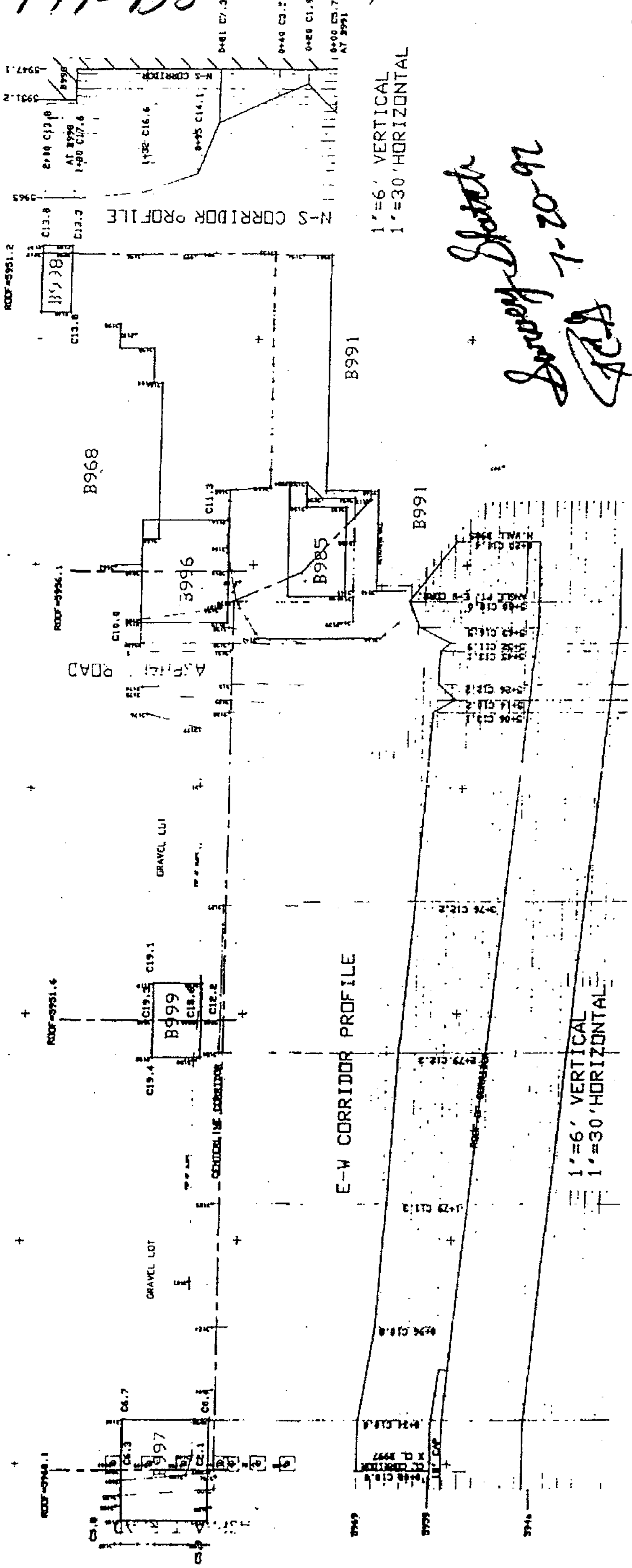

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FOR FACILITY DISPOSITION

Attachment 3
Original Groundwater Modeling Results

Hydraulic Effects
of
Decommissioning the 991 Tunnel

(Wednesday, February 19, 2003)

by Bob Prucha
Integrated Hydro Systems, LLC

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Purpose

This document summarizes possible surface and subsurface hydraulic effects, and potential contaminant transport impacts, due to decommissioning of the 991 Tunnel (buildings 996, 997, and 999 vaults). This evaluation was originally requested by Karen Wiemelt, on Thursday, November 14, 2002.

Two specific scenarios were considered in this evaluation:

a) The 991 Tunnel was left in place, as a void space, and
b) Discharge from the adjacent tunnel footing drain is eliminated.

Approach

A regional Site Wide Water Balance (SWWB) flow model (KH, 2002) was developed recently that compared present conditions to a hypothetical Site configuration where all pavement and above grade buildings were removed, and subsurface basement walls and slabs on most buildings were left in place and surrounding footing drains deactivated. Although the regional scale (200 by 200 foot grid) of this model doesn't allow accurate assessment of local changes in groundwater flow paths in areas like Tunnel 991, an improved level of understanding of the integrated system flow behavior was gained through this modeling. This provides a general basis for assessing the local current and hypothetical closure conditions in this study. Additionally, a substantial amount of hydraulic data (surface and subsurface hydrologic response data) were collected and evaluated as part of the SWWB model development. This provides additional information for evaluating local flow conditions around the 991 Tunnel. Most of this information was incorporated into a comprehensive GIS (Geographical Information System).

Current groundwater flow paths under present conditions are described first in Section 1. Key factors controlling groundwater flows in the vicinity of 991 Tunnel are then described in Section 2. Finally, expected system response to removing footing drains and leaving 991 Tunnel is described in Section 3. Possible effects on contaminant distributions are also assessed in both Sections 2 and 3 (considering current and possible future impacts to adjacent groundwater contamination).

Figure 1 depicts a 3D illustration of the 991 Tunnel area for reference. Although depicted at the groundsurface on Figure 1, the 991 Tunnel actually occurs entirely below grade. Its approximate location is depicted in yellow at the surface. It is important to recognize that it occurs along the upper portion of a hill slope, along the northern side of the South Walnut Creek headwater, located within the Industrial Area.

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1.0 Current Groundwater Flow Paths

Figure 2 shows contours depicting the shallow Upper Hydrostratigraphic Unit (UHSU) potentiometric surface (groundwater table) developed from available quarterly monitoring data (October 2000) for the area around 991 Tunnel. These levels are representative of current conditions in the vicinity. Each contour represents a constant groundwater table elevation. Groundwater flow arrows are drawn perpendicular to these constant elevation contours. The contours were developed by interpolating water level data from groundwater wells, most of which are shown on Figure 2. There are no wells in the immediate area of 991 Tunnel. However, the footing drains (shown by the dashed yellow line) located upgradient of 991 Tunnel cause surrounding groundwater levels to decrease around the building. This is confirmed because inflows do not occur in the building.

Groundwater, to the north of the 991 Tunnel area, likely flows toward the footing drain. Because wells are not located near the footing drain, there is no way to confirm what level of control the surrounding footing drains actually have on the groundwater flow direction pattern. Upstream flow directions and levels are likely more influenced than downstream given the placement of the building within the hillslope structure. Groundwater also likely flows parallel to the building on the downhill side (towards the east) as influenced by the headwater stream topography and bedrock.

2.0 Factors Affecting Groundwater Flow Directions

Several factors near the building likely affect groundwater flow directions and flow rates. As indicated above, the weathered bedrock surface contact is a significant factor. At RFETS, the majority of shallow groundwater flows through the UHSU compared to the LHSU (primarily low permeability Arapahoe Formation claystones). Within the UHSU, groundwater flows through both the unconsolidated material and the underlying weathered bedrock. Site data indicate that flow rates are lower within the weathered bedrock due to its comparatively lower permeability, except where sandstones are present.

The 991 Tunnel system occurs mostly within the weathered bedrock. It extends through much of the weathered bedrock thickness. The depth of unconsolidated material in the area of the 991 Tunnel only ranges from about 7 feet at the western end to about 16 feet below ground surface at the eastern end, while the thickness of weathered bedrock ranges from about 43 to 33 feet, from west to east. Groundwater level data indicate that a portion of the unconsolidated material in the area of the 991 Tunnel generally remains saturated throughout the year, though the majority of flow through the UHSU is through the weathered zone, because its saturated thickness is much greater than the unconsolidated material.

The contrast in saturated hydraulic conductivities between the unconsolidated material and weathered bedrock cause the bedrock surface to strongly control groundwater flow directions. Near the 991 Tunnel, the bedrock and topography slope mainly towards the south, causing groundwater to flow towards the upper South Walnut Creek. Vegetation, pavement and subsurface utilities also control local groundwater flows throughout the IA, but, their localized effect on subsurface flows near 991 Tunnel can't be accurately assessed due to the limited well coverage in the area.

Footing drains located upgradient (north-side) of the 991 Tunnel likely dominate the local groundwater flow paths around 991 Tunnel, though the specific discharge locations appear unclear (EG&G, 1992). The lack of wells in the location of the 991 Tunnel make it difficult to confirm drain influence on local groundwater levels, though, it is assumed that the footing drains are operational as groundwater inflow to the tunnel is not present and the tunnel void space is well below where natural groundwater levels would occur (ie within the unconsolidated material).

The spatial and temporal variability in both recharge and actual evapotranspiration can cause localized seasonal variations in water levels (head) that result in changes in the local groundwater paths. A review of available seasonal head changes and subsequent changes in groundwater flow directions (based on quarterly data for WY2000) suggest that adjustments to flow directions are limited. This is probably due to the strong local control imparted by the subsurface drains, which tend to dampen any seasonality, particularly near the building.

2.1 Contaminant Distributions

Figure 3 shows approximate extents of two TCE plume areas in the vicinity of the 991 Tunnel, which were developed based on available site data (SWD database). Approximate groundwater flow directions are also shown on Figure 3. These were estimated from available April 2000 groundwater data and footing drain inverts. The source of the plume area directly north of the 991 Tunnel appears to emanate from the western Solar Pond area. From this location, a plume area appears to diverge 180 degrees, from directly north to the southeast. The southern extent of the plume area is probably due mostly to the divergent groundwater flow in this area. Concentrations in the southern extent are very low, and of the ten most spatially frequent VOCs evaluated in this plume area, TCE appears to be most extensive. The direction of primary transport from this source area appears to be mainly east and north. Even under the current 991 Tunnel operation (with drains), detectable levels of VOCs are probably not likely from this source.

3.0 Expected Hydraulic Response at Closure

A possible scenario for decommissioning 991 Tunnel is to leave it in place as is, but to disrupt footing drain discharge. Three different hydraulic conditions can be considered in evaluating potential impacts of removing footing drains and leaving the building in place. Results of the SWWB regional integrated hydrologic modeling suggest runoff generally doesn't occur due to relatively high surficial soil permeabilities. As a result, little change in runoff is expected under the proposed change assuming existing soils are left in place (mostly comprised of Rocky Flats Alluvium fill material). Table 1 below summarizes subsurface hydrologic conditions associated with the three possible hydrologic scenarios.

Table 1

System Response	Natural System (no building/footing drains)	Current System (tunnel with footing drain discharge)	Closure Scenario (conduit, prevent footing drain discharge)
Groundwater Heads	~10 feet bgs	Footing drains strongly control local groundwater flows/levels. Basement walls exert no control.	Upgradient heads (north) increase, while heads in tunnel slowly increase to a level between natural and current system.
Groundwater Flow Paths	Follows bedrock/topo	Strong local control, though area of influence limited due to low K aquifer, shallow aquifer and strong vertical recharge/ET effects. TCE plume to the north – no current effects/minor future.	Upstream flows – routed west & east of tunnel compared to current and natural system. North TCE plume less likely to intercept 991 Tunnel than current or natural systems.
Surface water	Little runoff, mostly infiltration/ET	Little runoff, mostly infiltration/ET	Little runoff, but may be higher than other cases given potentially higher upgradient heads.

Figure 4 illustrates the three different hydraulic states in a vertical profile that indicates the subsurface extent of 991 Tunnel and its relation to groundwater levels and stratigraphic units (i.e., unconsolidated material, weathered bedrock and unweathered bedrock). The building is located near the upper edge of a hillslope.

The first state is the natural system. Under this condition, prior to 991 Tunnel construction, groundwater levels were likely within 10 feet of the ground surface in the vicinity of the building (ie within the unconsolidated material, ranging from 7

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to 16 feet depth, from west to east along the tunnel). Groundwater flow under this condition would have flowed from the uphill area (north) to the topographic low, or the upper South Walnut Creek area within the IA.

The second state shows the current system water level configuration. In this case, the effect of the footing drain on the upgradient side of the building strongly controls local groundwater heads. This configuration has the most notable impact on local groundwater hydraulics. The effect of the building basement has no effect on groundwater heads or flow directions. The footing drain dominates the local hydraulics surrounding the building.

The last case shows water levels that result when the footing drain is deactivated, but the building structure is left in place. Heads on the upgradient side are shown higher than the natural system, because the sub-grade building walls will impede groundwater flow, causing flows to buildup slightly behind the walls. This buildup will cause flows to be routed around the building. Downstream of the building, levels will drop to a level that occurs between the first two cases. Heads are not as high in this location as the natural state because inflow from uphill is routed east upgradient of the building.

Heads within the building occur at a level somewhere between the up- and downgradient sides of the building. It is likely that the levels will stabilize and will become a function of seasonal level variations and rates of inflow/outflow through building cracks, or joints. Levels within the building will not likely fluctuate at the same amplitude as levels outside which are subject to seasonal recharge/discharge processes because the slow inflow/outflow through cracks will damp seasonal variations. It can be expected that levels outside of the building are at seasonal lows, water within the building may discharge, while when levels outside are at seasonal highs, inflows may occur.

Because the building slopes from west to east, water will tend to reach a constant level within the building that is deeper in the east than the west. It is likely that the water level will reach a point where the entire building floor is submerged.

Surface water flow in the vicinity of 991 Tunnel are likely minimal for typical rainfall events. Surface water flows in each case will likely be similar, though, in the closure scenario, the anticipated increase in heads on the upgradient side of the building might result in a higher potential for ponding in this location. The likelihood of this occurring would also depend on the final surface grade and soil properties in this location.

A last consideration is that if, over time, the structure of the building fails, the void would be filled with material from directly above. In this case, a surface depression may result into which surface flows could be routed.

References

EG&G, 1992 "A Description of Rocky Flats Foundation Drains", SWD-012-92

Kaiser-Hill, 2002. Site-Wide Water Balance Model Report for the Rocky Flats Environmental Technology Site. May, 2002.

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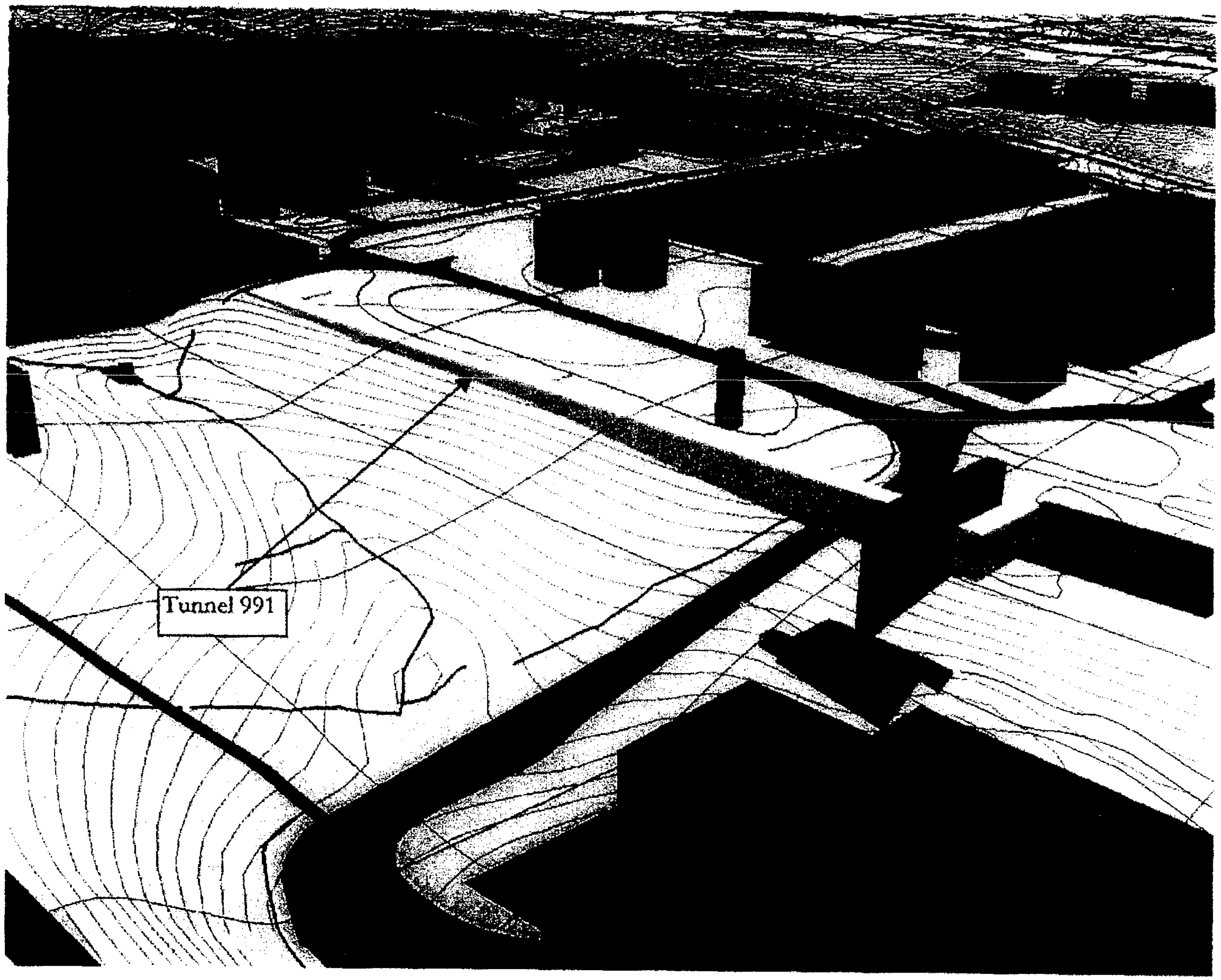
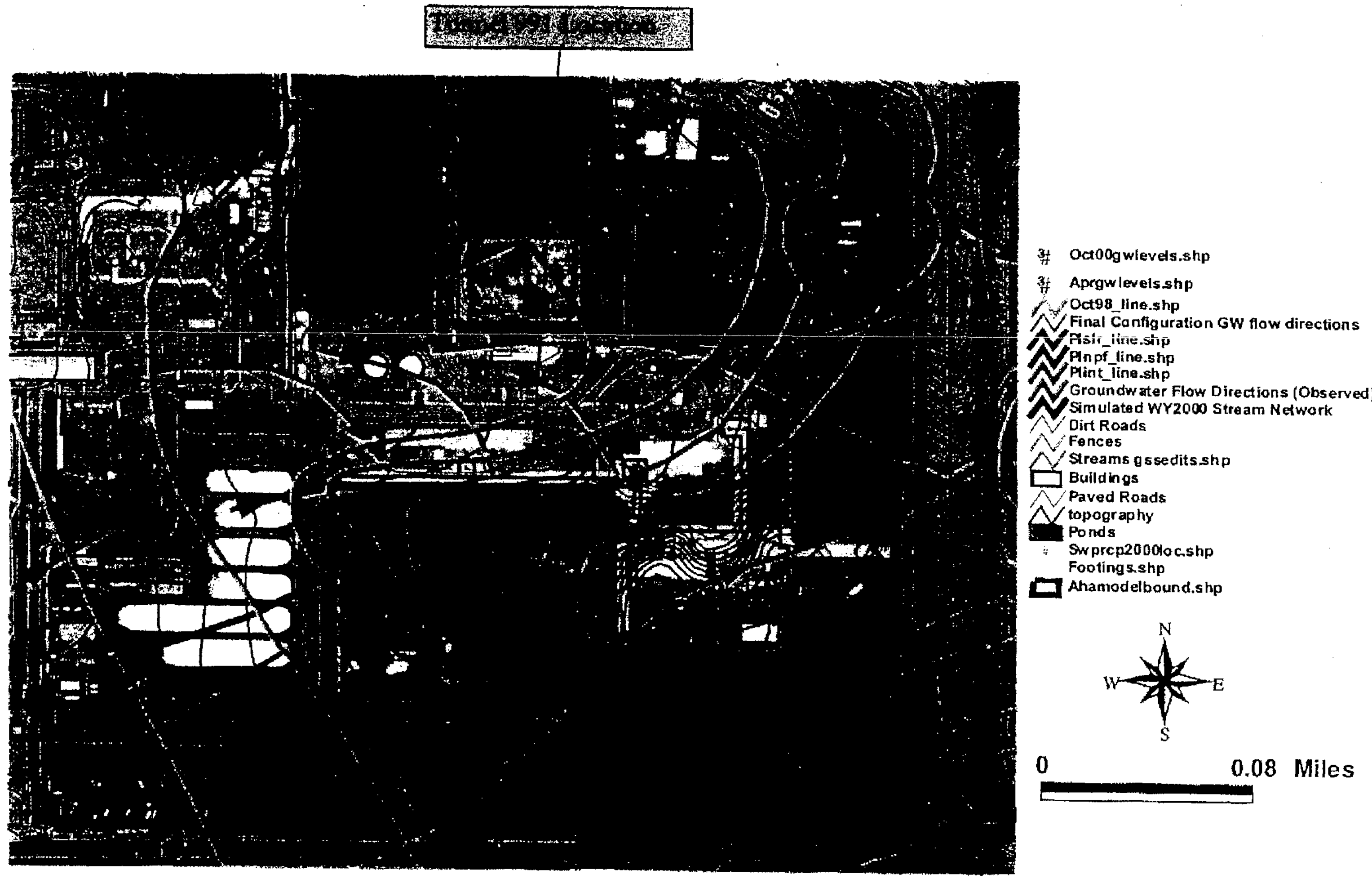


Figure 1. Tunnel 991 Site Location (Note: 991 is actually occurs entirely below grade)



Note: Yellow lines depict building footing drain locations.

Figure 2. Groundwater Potentiometric Surface and Approximate Groundwater Flow Directions

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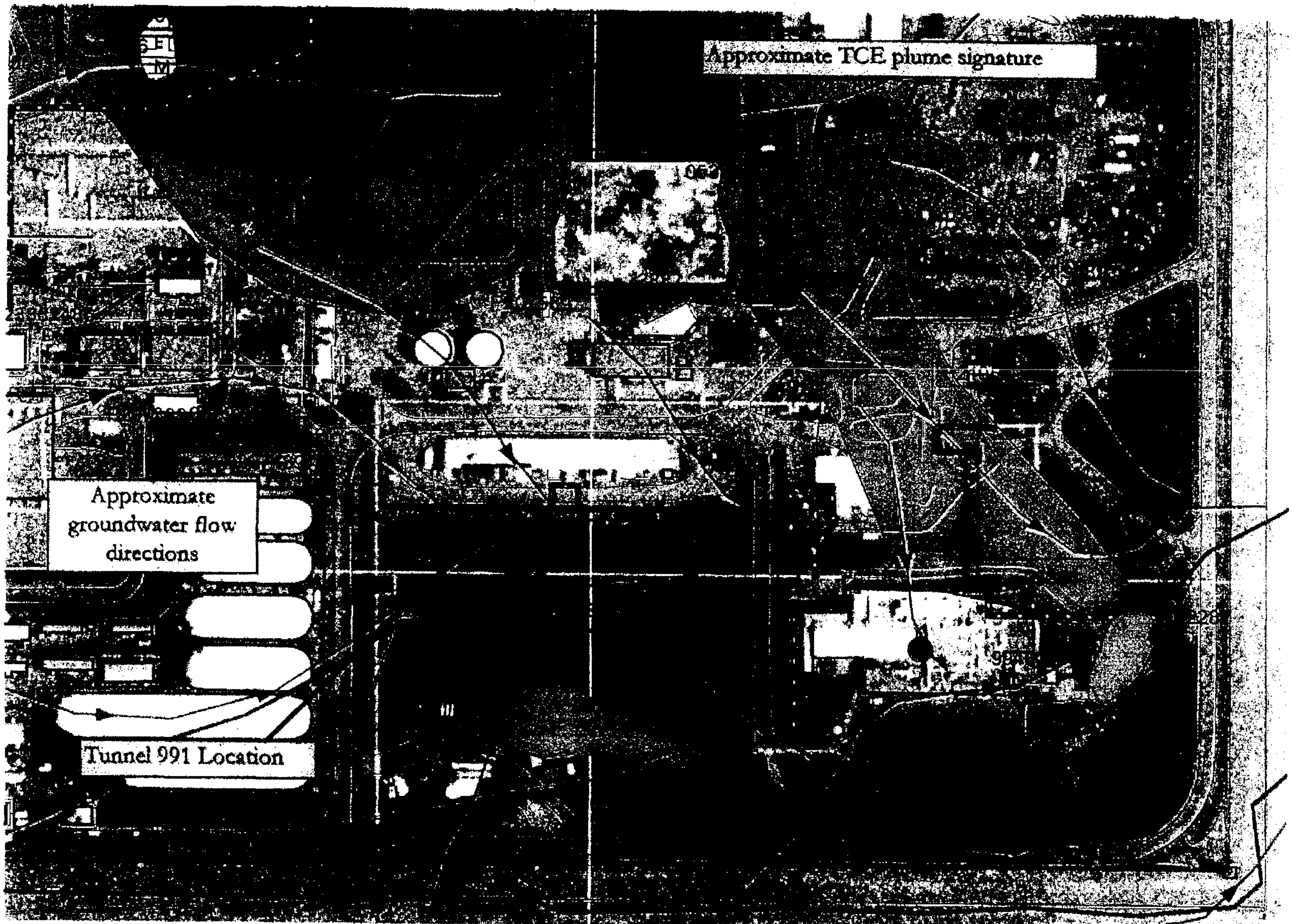

Figure 3. Approximate TCE plume signature area extents

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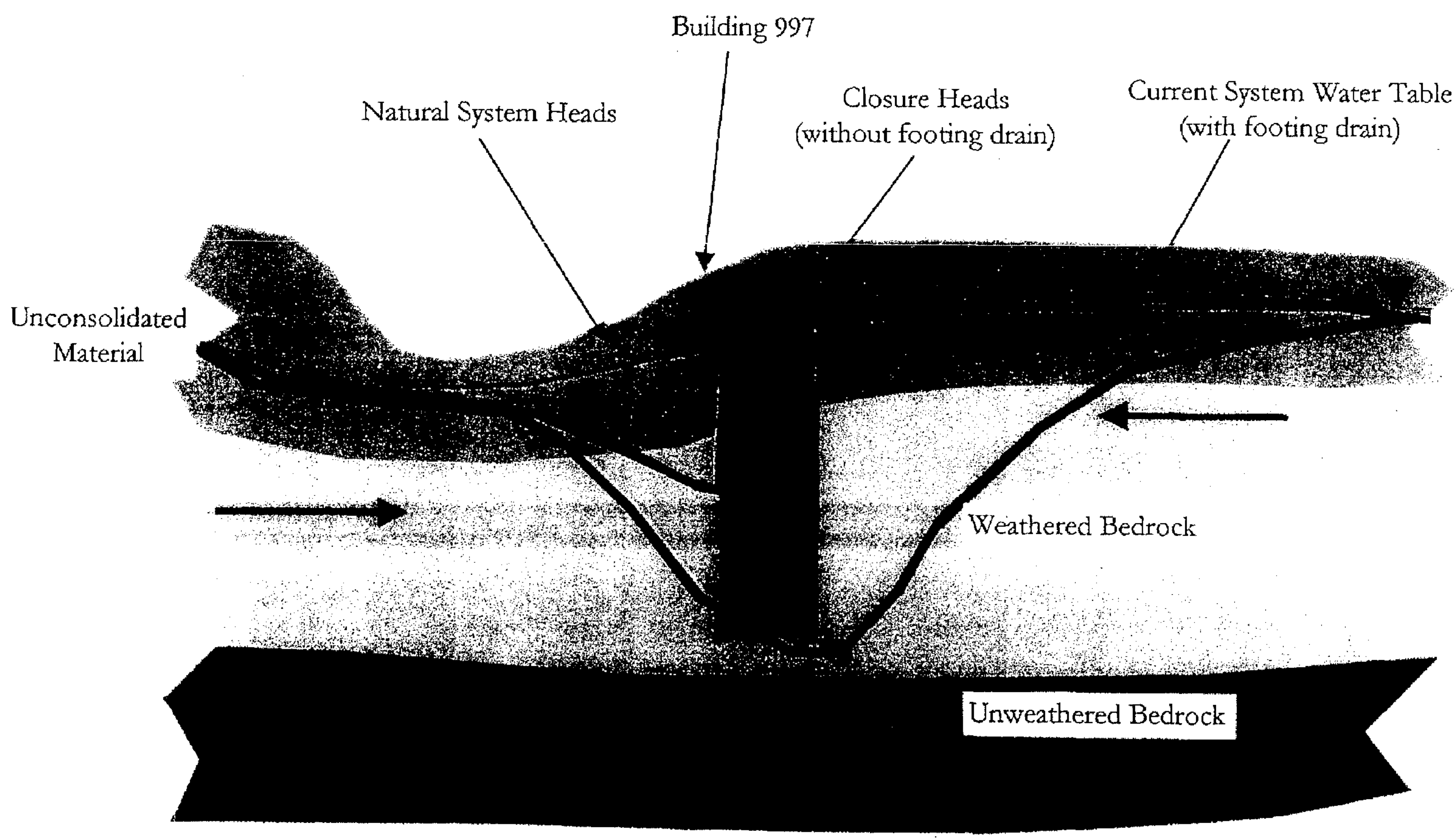

Figure 4. Conceptual Groundwater Flow Responses

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Attachment 4
Updated Groundwater Modeling Results

Additional Building 991 Modeling Simulations
(Bob Prucha, 9/18/2003)

A localized, high-resolution integrated flow model was developed for the area associated with the 991 Corridor C Tunnel and Vaults 996, 997, and 999. The purpose of the refined model was to better simulate localized hydraulic conditions surrounding the 991 Tunnel system proposed to be left in place under conservative conditions. The need to model the local conditions accurately was in response to concerns regarding the potential for groundwater to buildup at structures left in place, which in turn might cause increased potential for surface erosion and possible slumping. In addition, CDPHE comments to preliminary modeling required evaluating localized effects near the 991 tunnel system for wetter climate conditions.

A grid resolution of 25 feet was developed for the saturated, unsaturated and overland flow processes in the integrated model. Surface channel flow was not explicitly simulated in the model because it does not impact the hydrologic conditions within the 991 building area, and an appropriate set of overland flow (non-channelized) and saturated zone boundary conditions could be specified instead. The finer grid resolution permits explicit definition of the 991 Corridor C Tunnel and Vaults 996, 997 and 999. In addition, the integrated model also includes a specific numerical description of the 991 Building, 998 Vault, and Buildings 984 and 985.

Specific closure conditions regarding the 991 Building structures in addition to other land configuration modifications were provided by the ER group. For example, the entire subsurface structure associated with Building 984 was assumed removed for closure, while the 991 Tunnel, Vaults 996, 997 and 999, and the 998 Vault were to be left in place. Only those portions of basement walls and slabs Buildings 985 and 991 remaining at least 3 feet below a regraded topographic surface remain as well. Remaining portions of buildings 985 and 991 were included in the model to evaluate the collective impact of all structures left in place on the hydraulics surrounding the 991 Tunnel structures.

Hydraulic conditions surrounding the Tunnel system were evaluated using conservative conditions. In other words, any conditions that lead to higher groundwater levels in the area were considered. The two primary conservative conditions considered included assuming a wet year climate and that current drains in the area do not operate. The wet year climate is based on a 100 year climate sequence as described in the SWWB modeling report (KH, 2002). Current drains including storm, sanitary and footing drains, that generally lower groundwater levels, were assumed inoperable. The Tunnel structures were assumed to have a low hydraulic conductivity (1e-10 m/s) to simulate the effect of likely leakage through joints and cracks in the concrete.

Integrated model runs using the conservative assumptions were simulated for 3 years to allow the groundwater system to reach a state of dynamic equilibrium. In other words, it takes three years for initial conditions prescribed in the model to stabilize. In addition, an advective-dispersive transport simulation was performed using the AD module in the MIKE SHE software to evaluate the migration potential of the southern extent of a TCE plume to the north, into the 991 Tunnel area.

Results show that average annual groundwater depths during the wet year remain below 1 meter for the eastern portion of the 991 Tunnel, mostly due to increasing weathered bedrock depths to the east. Average annual groundwater depths in the western area of the Tunnel are near, or within 1 meter of ground surface on average. However, for larger precipitation events during a wet year, modeling shows that groundwater depths near the western end of the Tunnel system can reach ground surface, due mostly to the shallow bedrock in the area. This was further confirmed by simulating conditions without the Tunnel system. Virtually no difference occurs in simulated groundwater depths for larger precipitation events. Transport simulations showed that VOC plume movement from the north into the 991 Tunnel area does not occur, probably due to the strongly local northerly flow direction in the plume area.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Hydraulic Impacts – 991 Tunnel Decommissioning

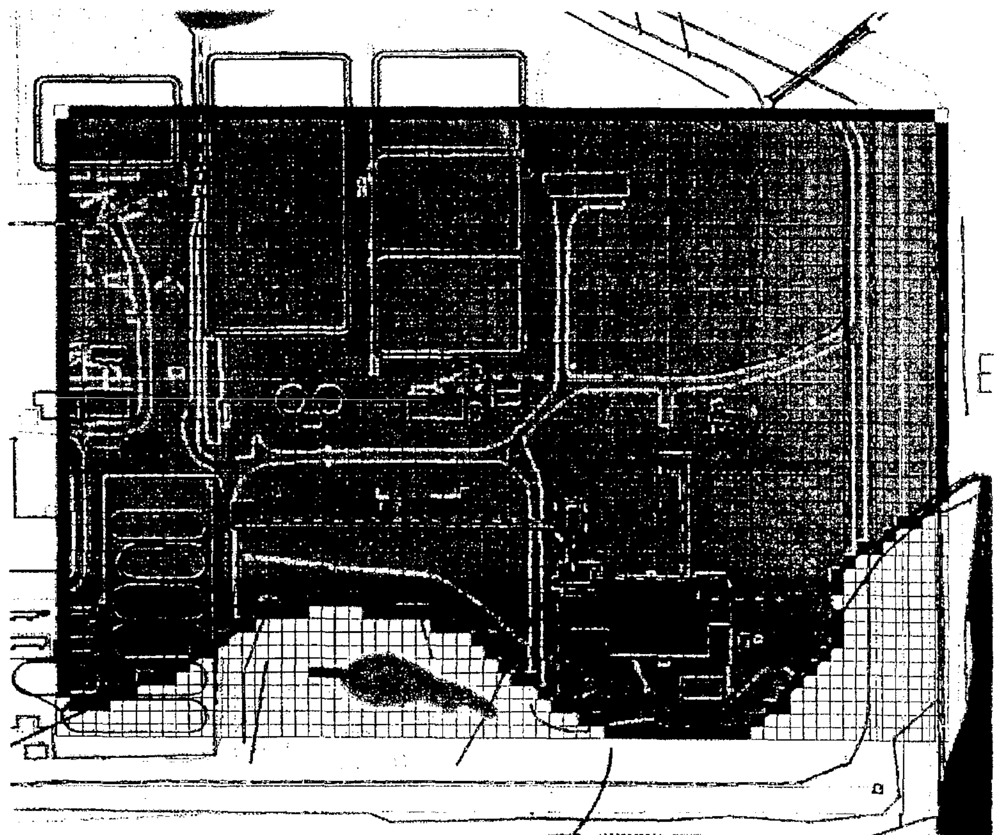
KAISER-HILL COMPANY, LLC

Overview

- Conservative Closure Conditions
  - Wet Year Climate
  - No Footing Drains
- Upgradient drain effects
- Transport Simulation
- Conclusions
- Recommendations

Refined Integrated Hydrologic Model
Building 991

- Fully integrated, surface, subsurface flow model.
- 25 foot grid consistent with Bldg771 model.
- 7-layer Saturated Zone model



Refined grid allows explicit definition of subsurface 991 tunnel and buildings

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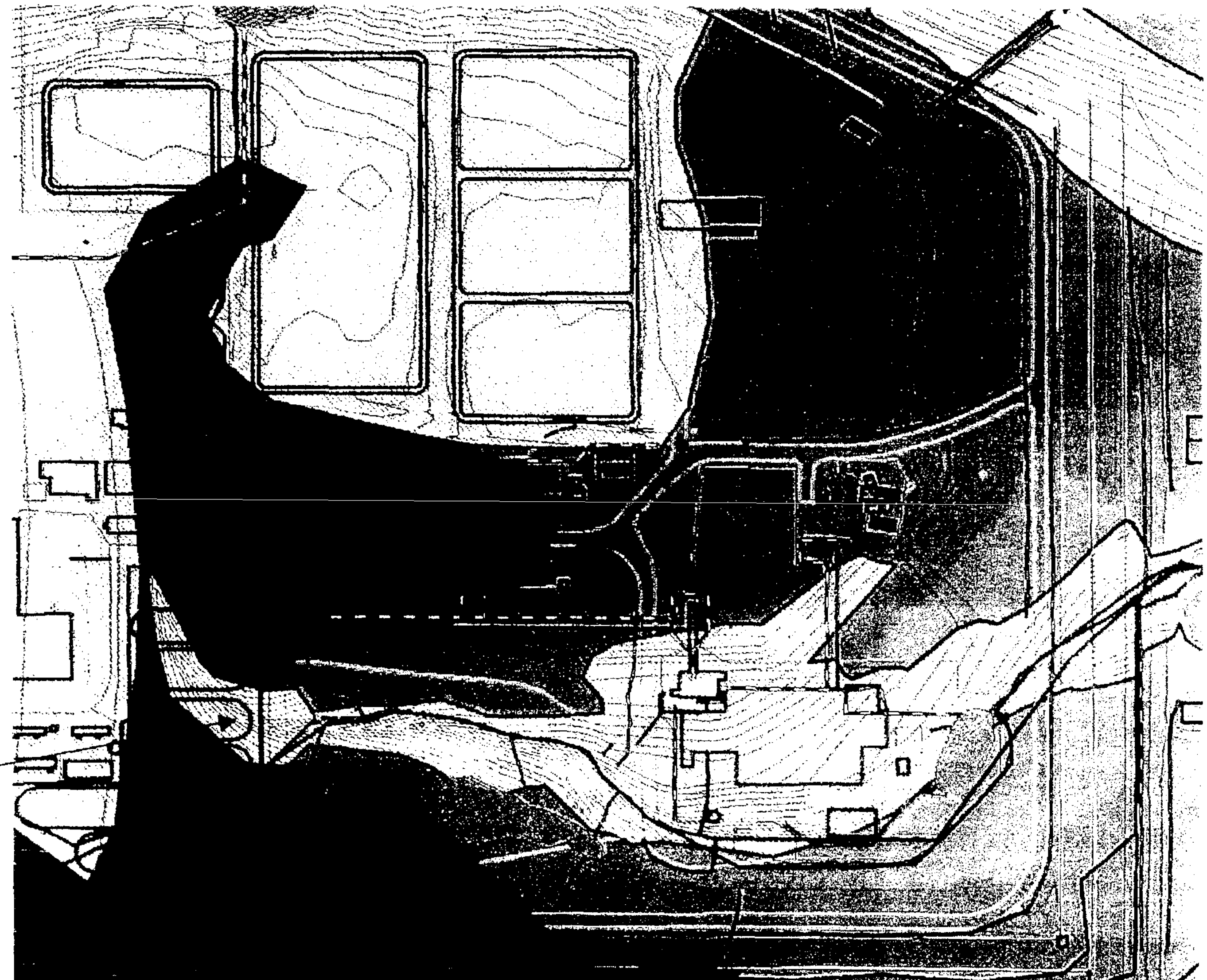
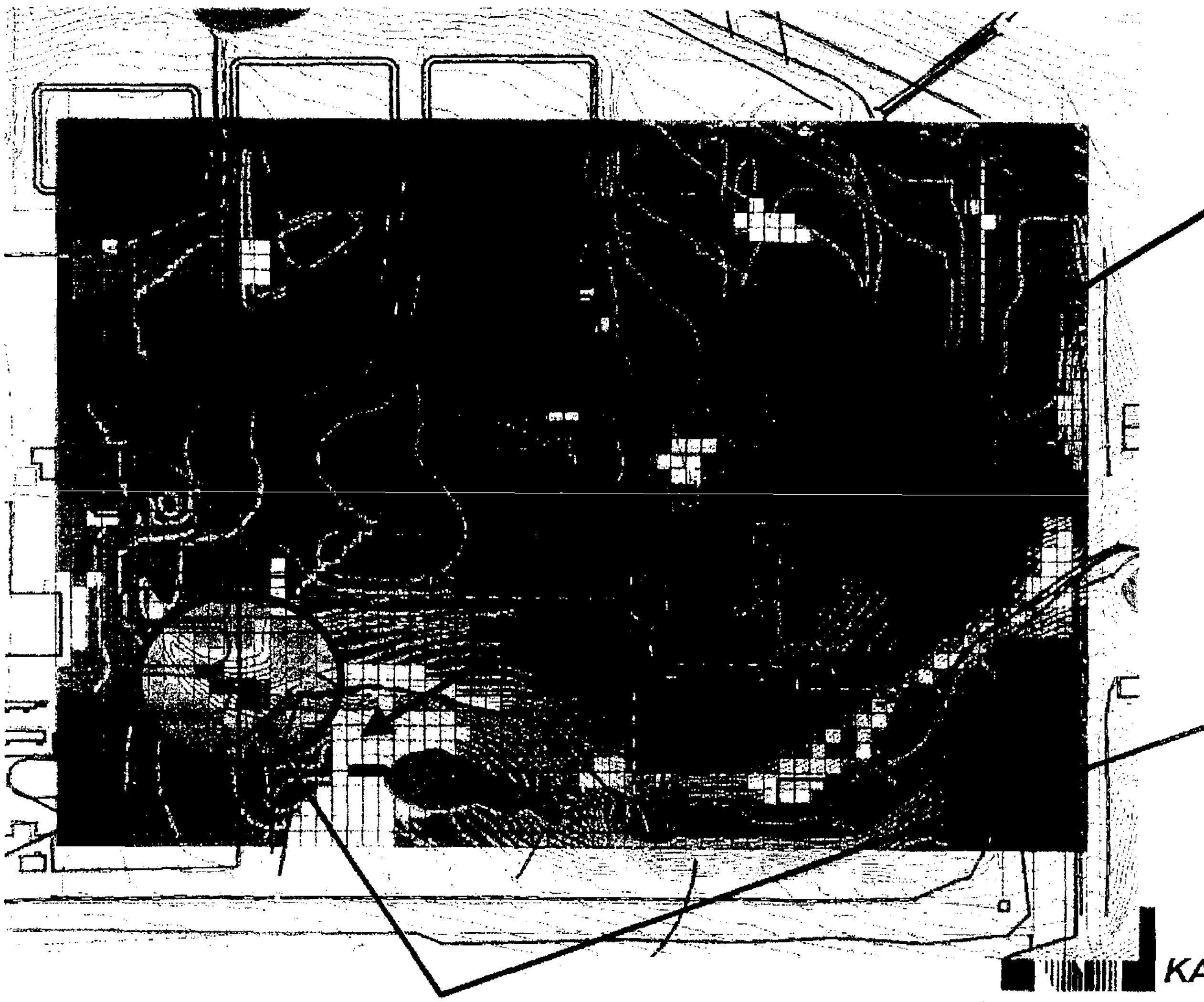
Regraded Area

Regraded areas shown in white with contours



Depth to Weathered Bedrock (ft)



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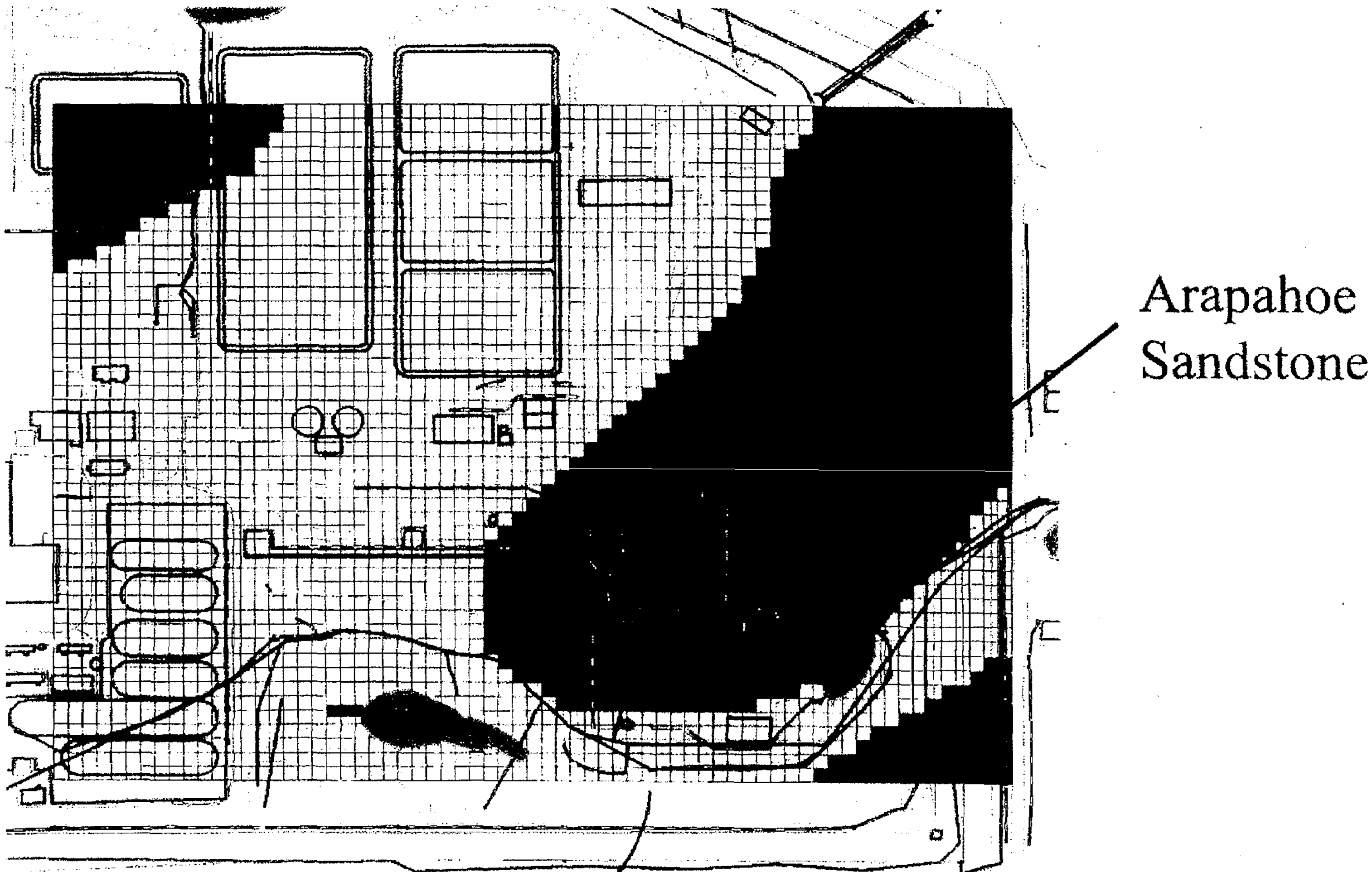
Arapahoe Sandstone Occurrence



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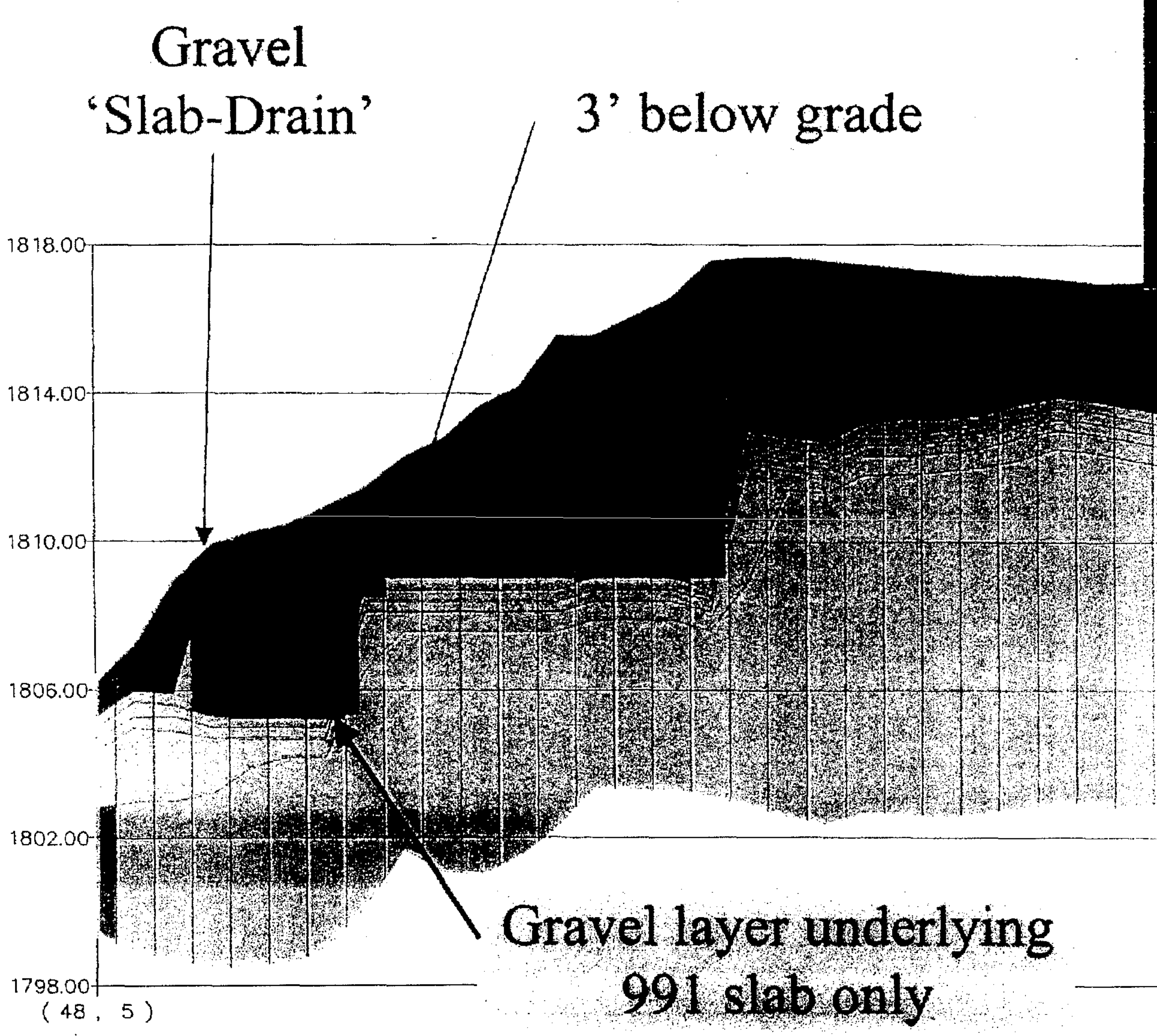
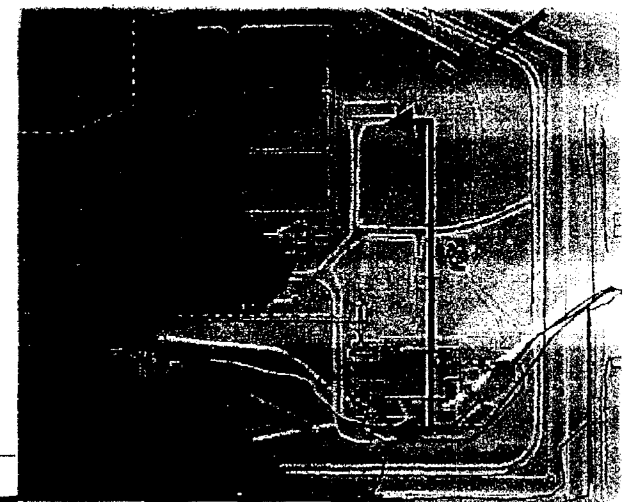
Section through Building 991





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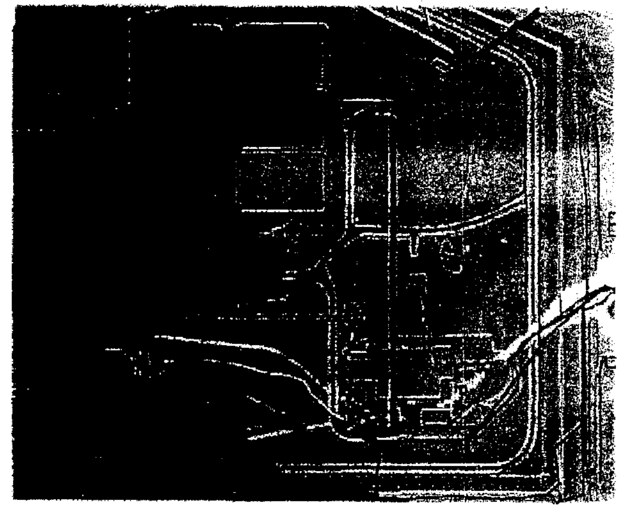
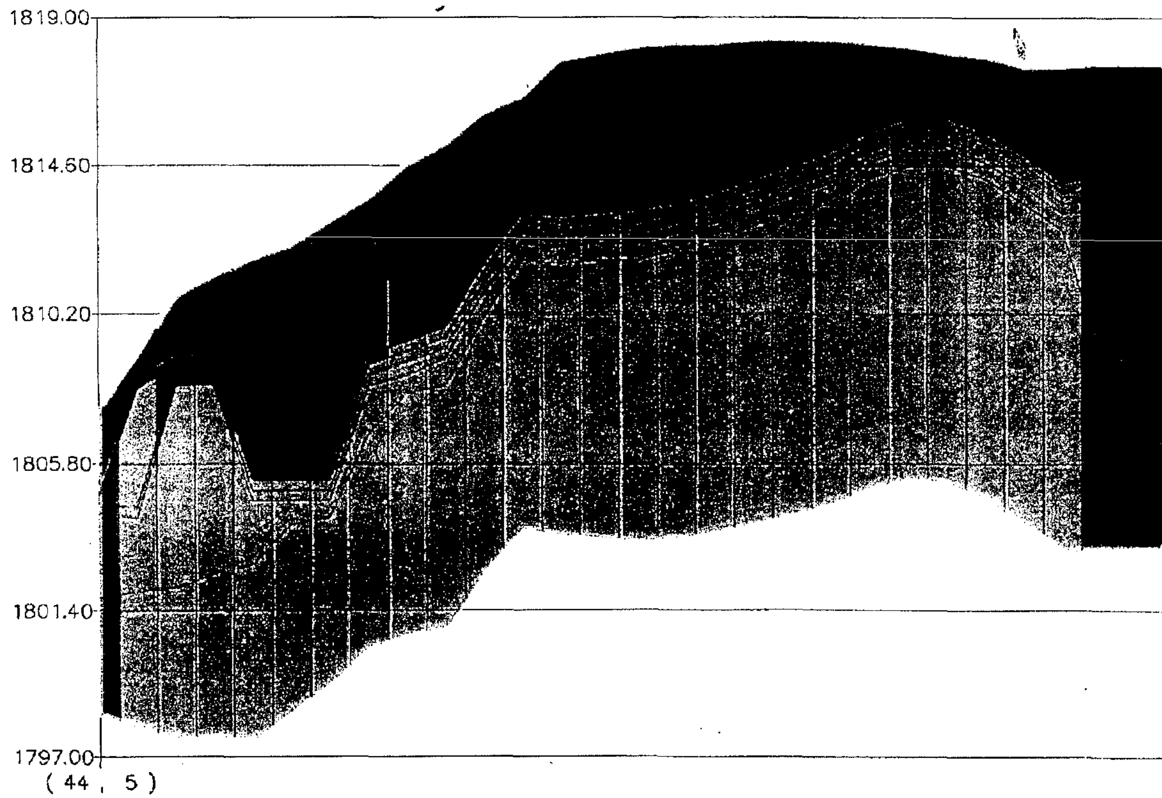
Section through Building 991





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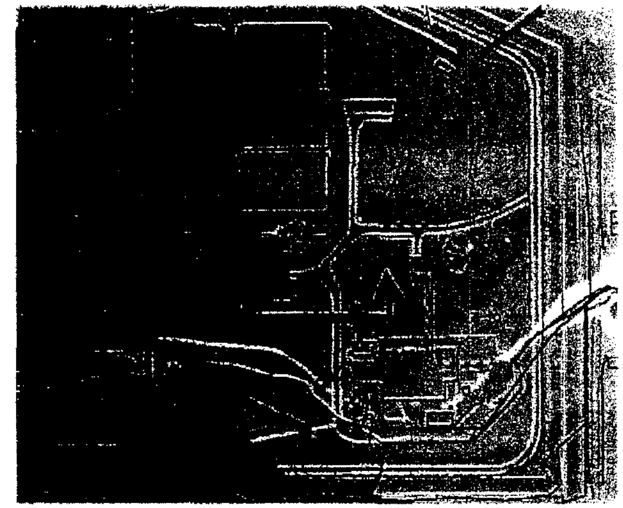
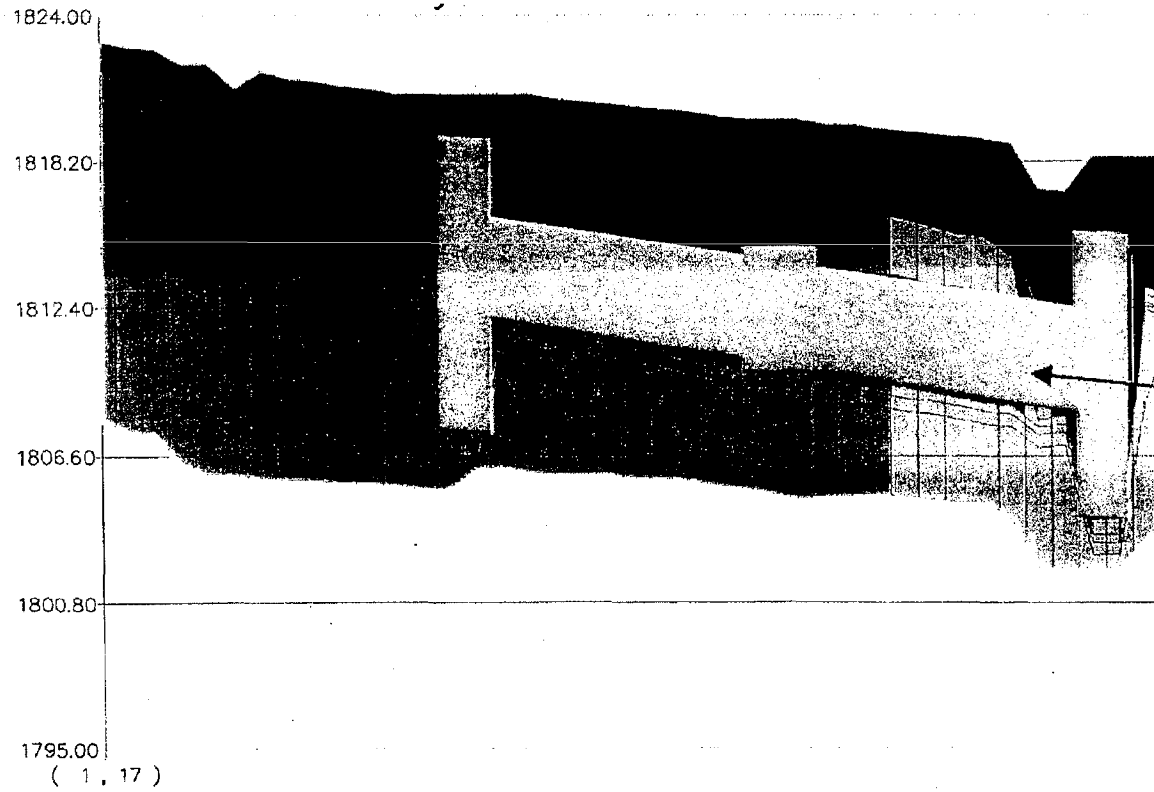
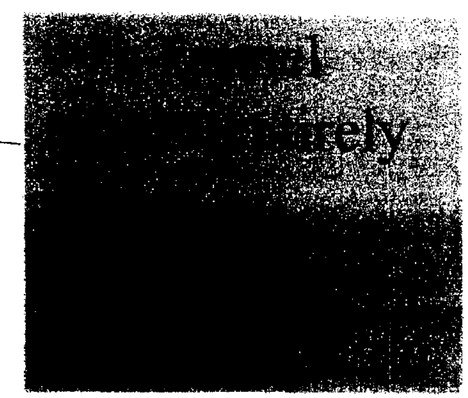
991 Tunnel Section







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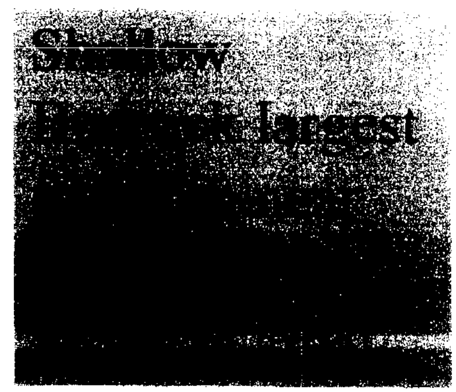
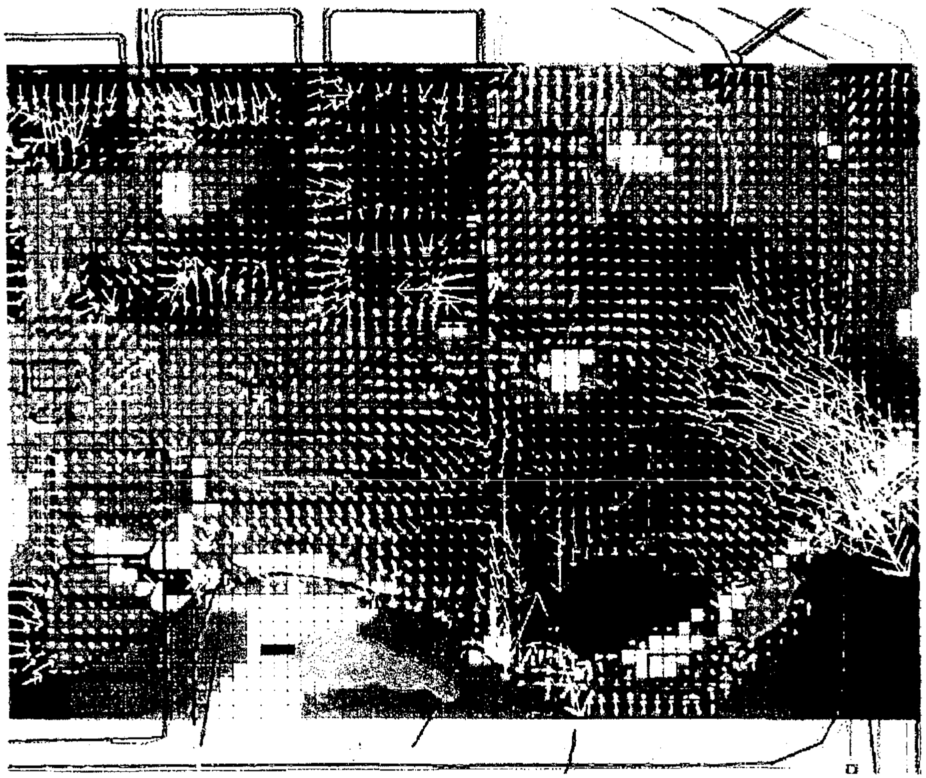
Minimum Annual GW Depths – No Tunnel

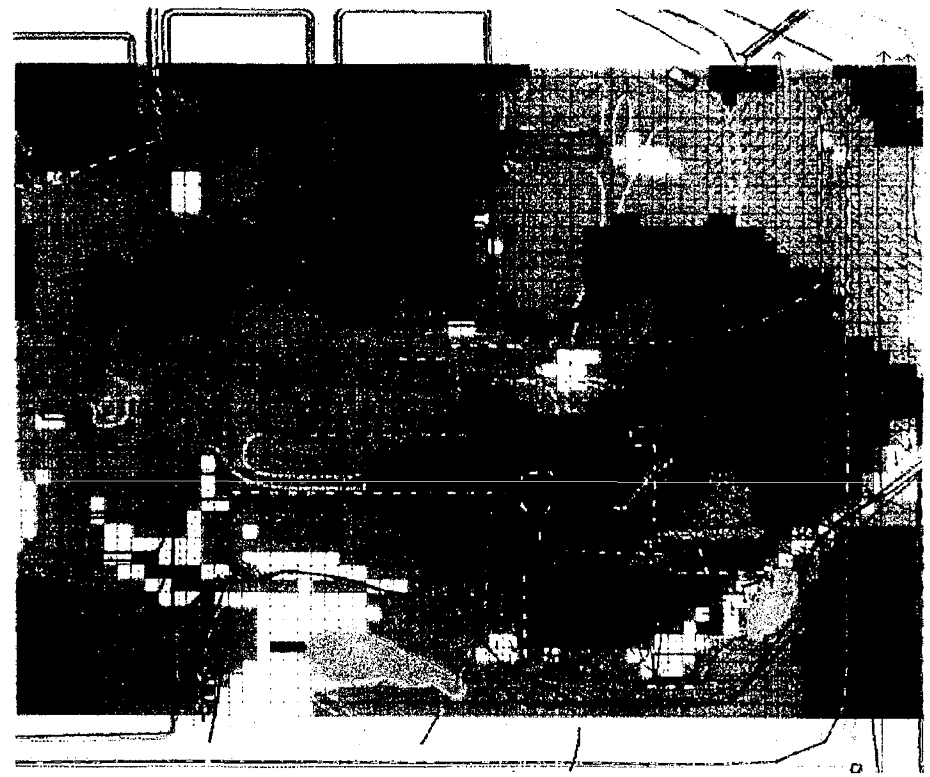
Results suggest tunnel has only small effect on minimum GW depths



Simulated - Groundwater Flow Directions



Layer 2



Layer 5 – Below all structures

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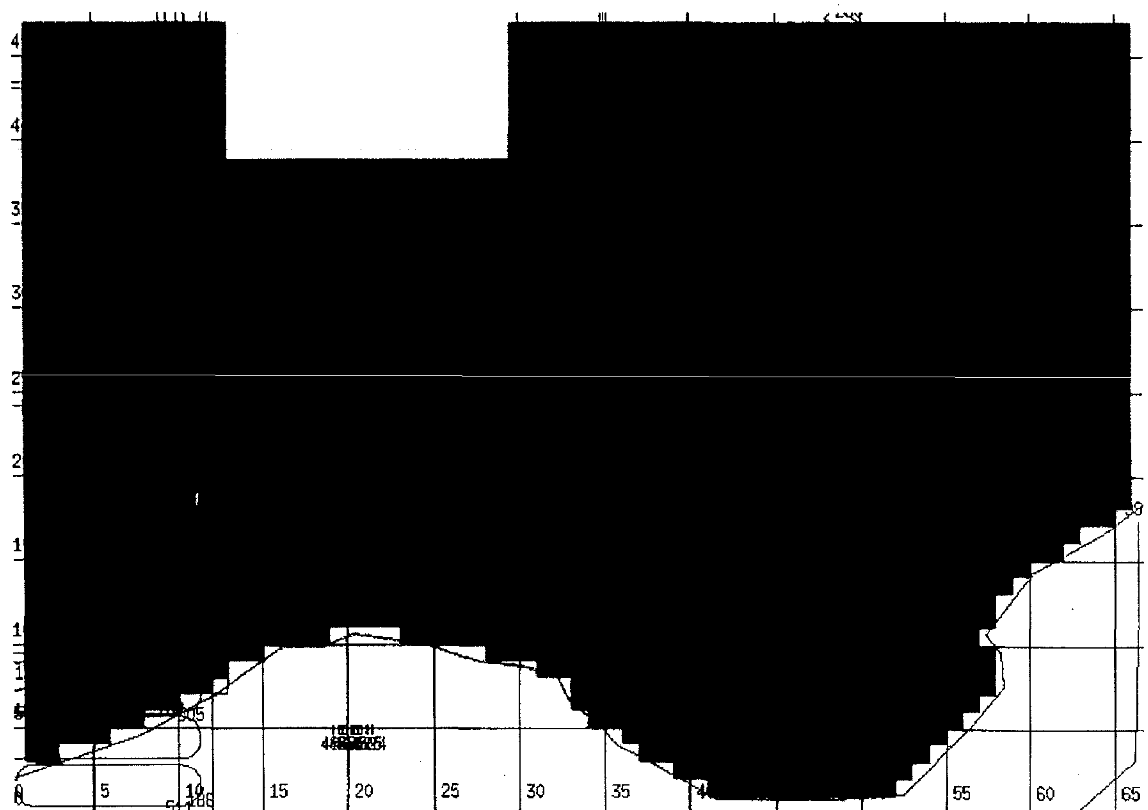
Drain Location



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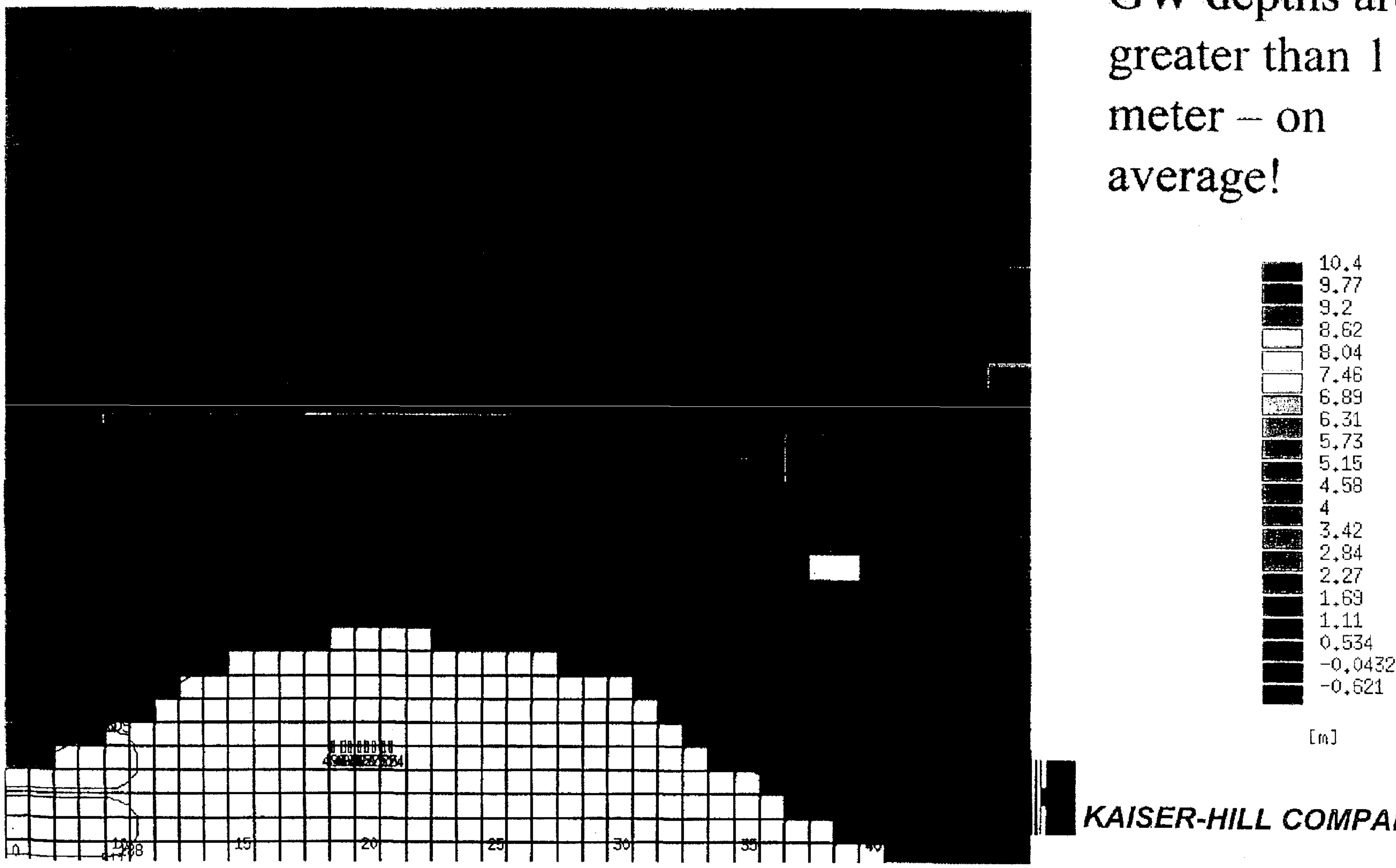
Mean Annual GW Depth – with drain (20 feet deep)

Wet Year, No Footing Drains



GW depths are greater than 1 meter – on average!

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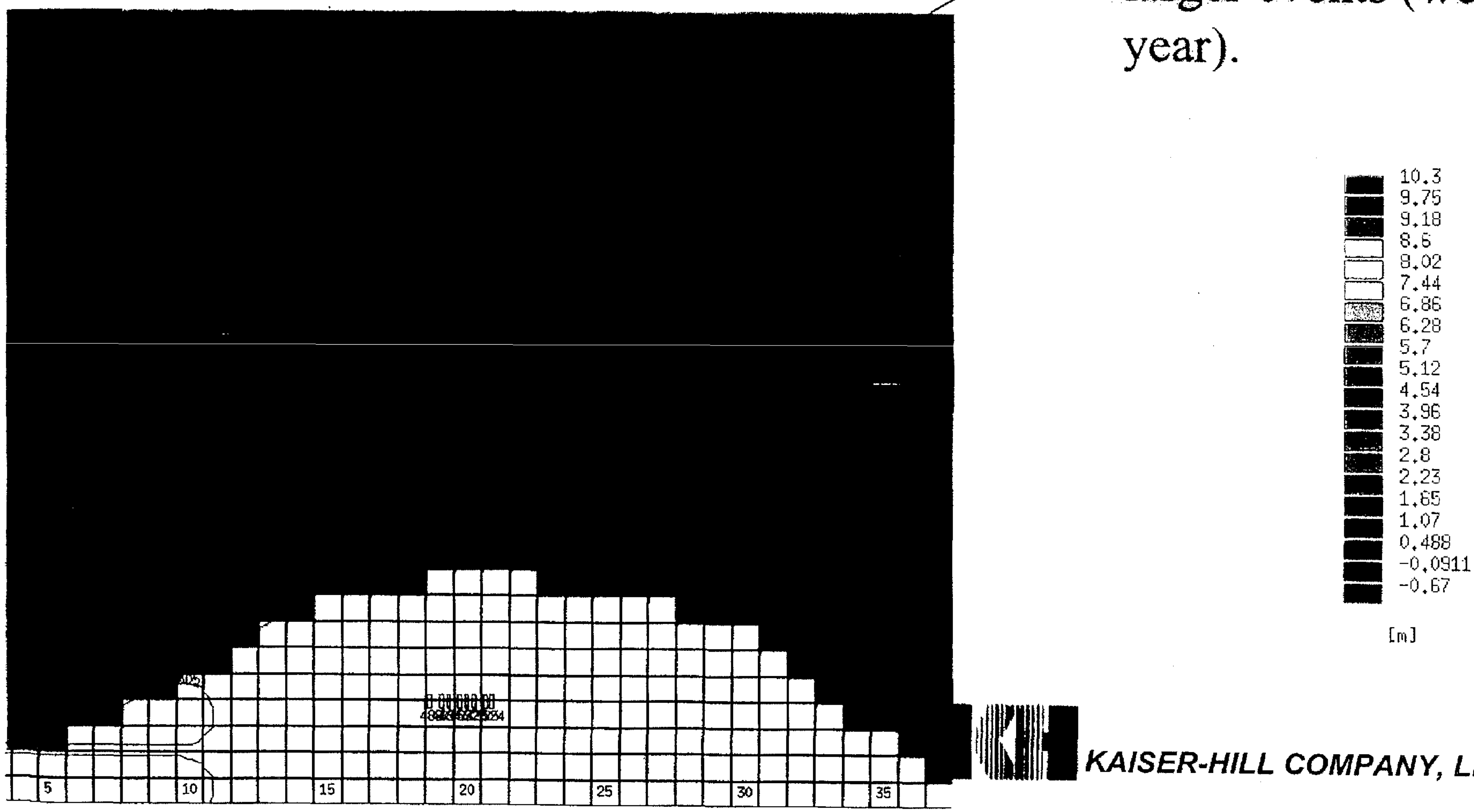
Minimum Annual GW Depth – with upgradient drain (20 feet deep)



Drain may be ineffective during larger events (wet year).

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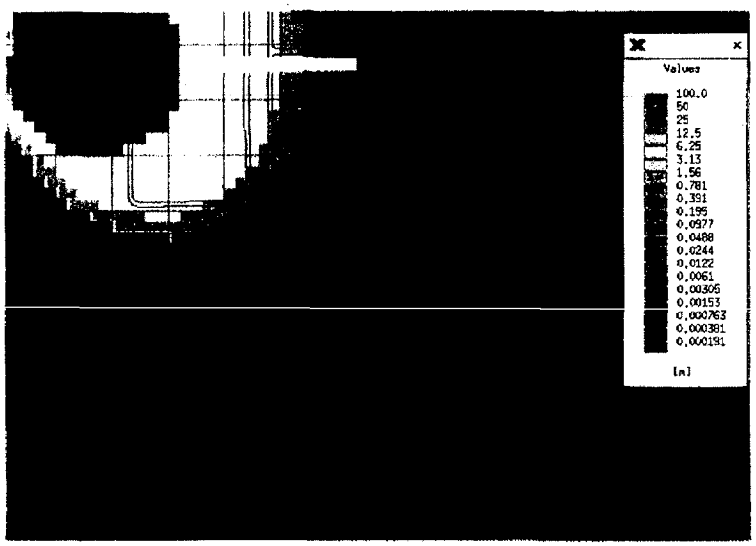
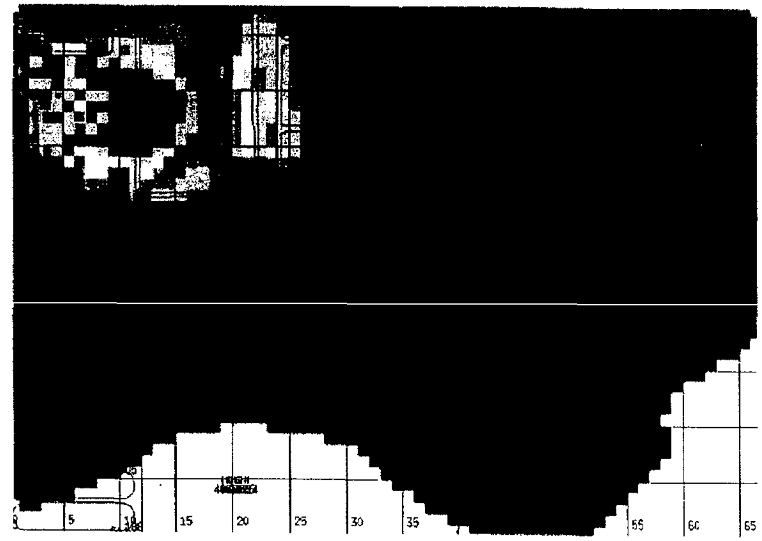
Transport Simulations



TCE – Current Distribution



TCE – Closure Condition – 30 Years

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Conclusions

Conservative Conditions – Wet Year, No Footing Drains

- East of mid-point of 991 tunnel - Minimum Annual Groundwater depths > 1 meter
- Western end of 991 tunnel –
  - Average annual groundwater depths < 1m
    - Upgradient, downgradient and above tunnel
    - Primarily caused by shallow bedrock depths in area,
    - Shallow tunnel (6' bgs) – only slight impact on groundwater levels in area
  - Minimum annual GW depths < 1 m over larger area
    - Adjacent to stream area (especially where bedrock exposed),
    - Western end of tunnel system
- Design drain upgradient of western 991 tunnel –
  - Average annual GW depths > 1 m in western tunnel area,
  - Larger events → GW depths < 1 m western tunnel area
  - May not be as effective as other alternatives
- Transport modeling show that VOC plume (north) → no impacts
- Vegetation response in wet year → groundwater levels may be lower.

Recommendations

- Control heads → only western tunnel area,
- Can use upgradient drains, but groundwater may still reach ground surface locally,
- Consider gravel layer over western end of tunnel → drain to South Walnut Creek
  - Reduces heads above tunnel – all events,
  - Reduces head upgradient of tunnel – all events
  - Depth of drain (generally 10 feet bgs)