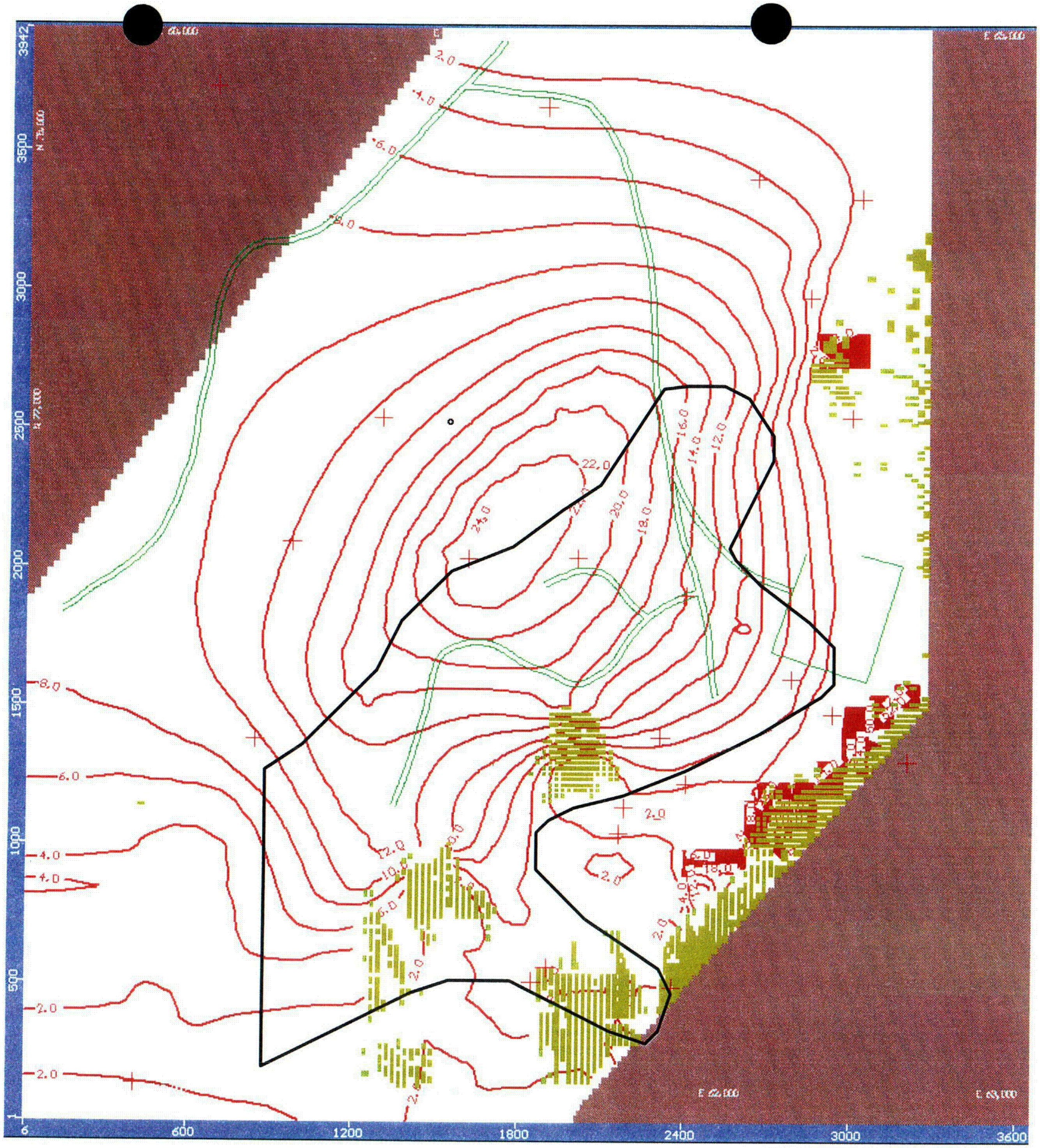


Figure 50
5G.Well Field
Drawdown
5 Years
(140 Wells
No Recharge)

Note: April 2002 plume outline shown by black outline

Pumps set to 3 ft above the base of Z3

Figure 51
5G. Well Field Additional Drawdown from 5 to 10 Years (140 Wells No Recharge)

(5-year simulation using output from 5 years of pumping as initial heads.)

Note: April 2002 plume outline shown by black outline

Pumps set to 3 ft above the base of Z3

C38

Figure 52
6. Cutoff Wells
With Particle Tracks
5 Years

Arrows are posted at 1-year intervals along particle tracks to indicate travel times.

Note: April 2002 plume outline shown by black outline

Pumps set to 5 ft above the base of Z3

Figure 53
7a. One Ranney Well Drawdown
1 Year

Note: April 2002 plume outline shown by black outline

Figure 54
7a. One Ranney Well
Drawdown
3 Years

Note: April 2002 plume outline
shown by black outline

C4H

Figure 55
7a. One Ranney
Well
Drawdown
5 Years

Note: April 2002 plume outline shown by black outline

Figure 56
7b. Two Ranney Wells Drawdown 1 Year

Notes:

1. No Recharge from Alluvium.
2. April 2002 plume outline shown by black outline.

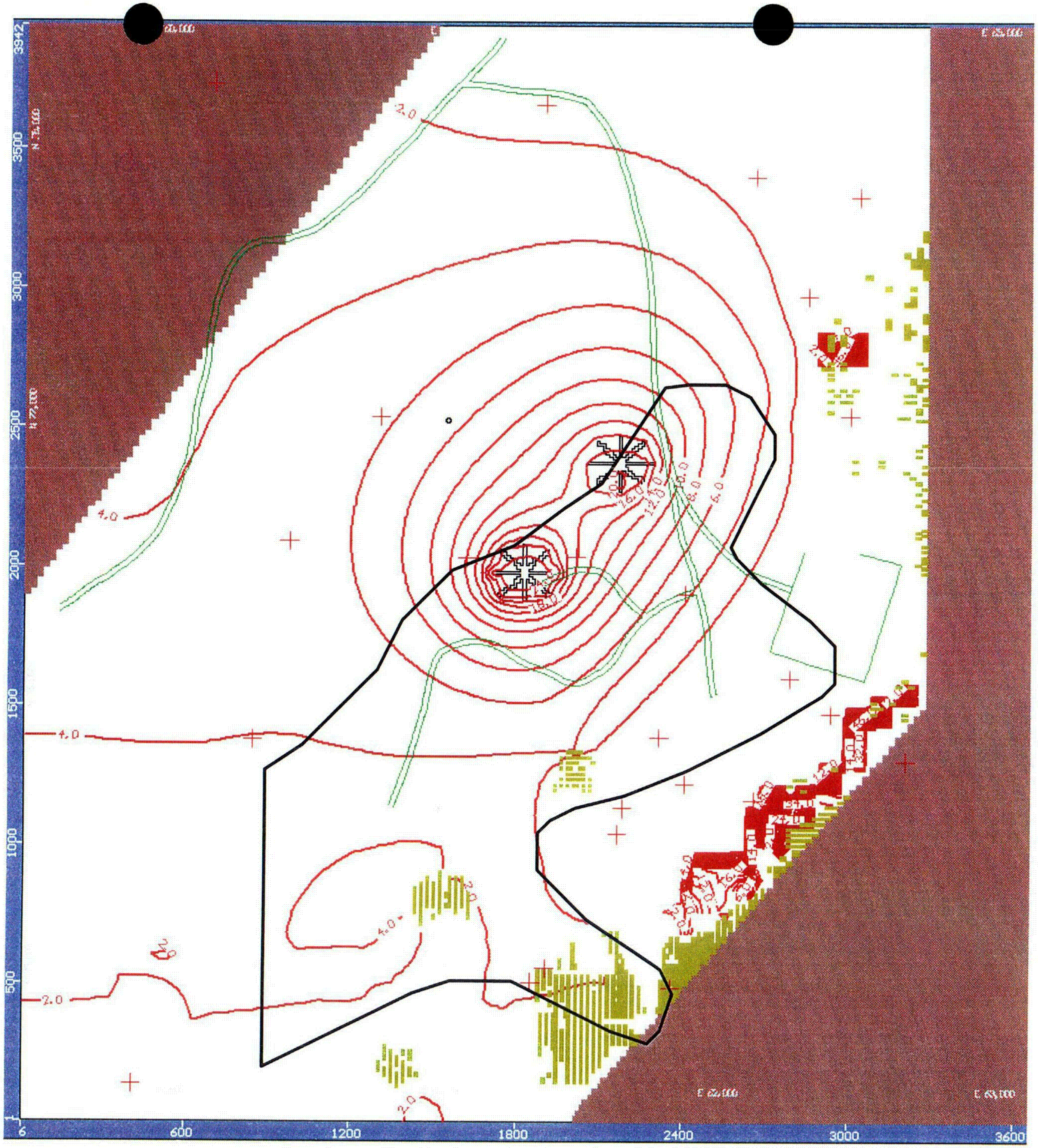


Figure 57
7b. Two Ranney Wells Drawdown 3 Years

Notes:

1. No Recharge from Alluvium.
2. April 2002 plume outline shown by black outline.

C44

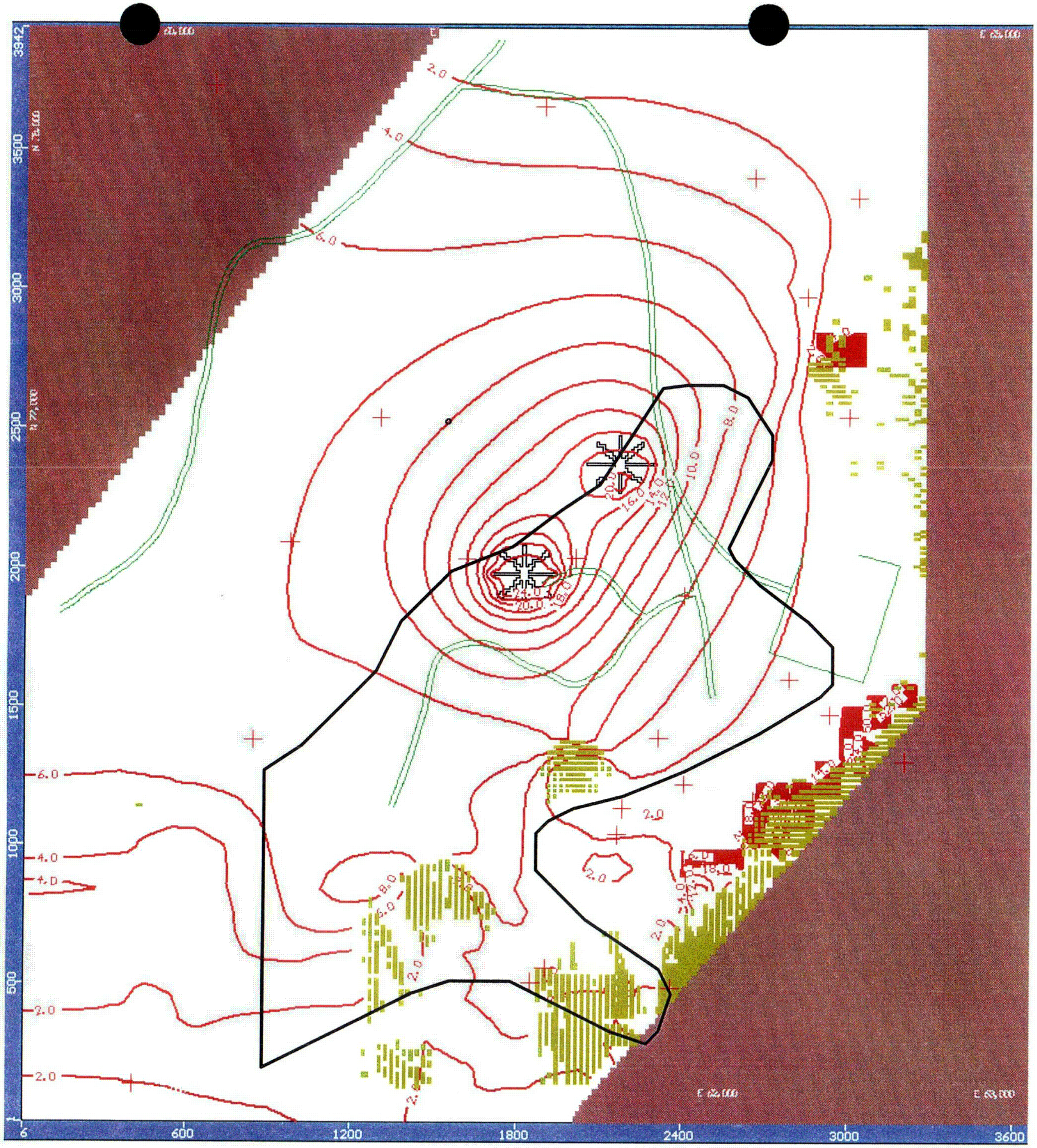


Figure 58
7b. Two Ranney Wells Drawdown 5 Years

Notes:

1. No Recharge from Alluvium.
2. April 2002 plume outline shown by black outline.

Figure 59
7c. Three Ranney
Wells
Drawdown
1 Year

Notes:

1. No Recharge from Alluvium.

2. April 2002 plume outline shown by black outline.

C46

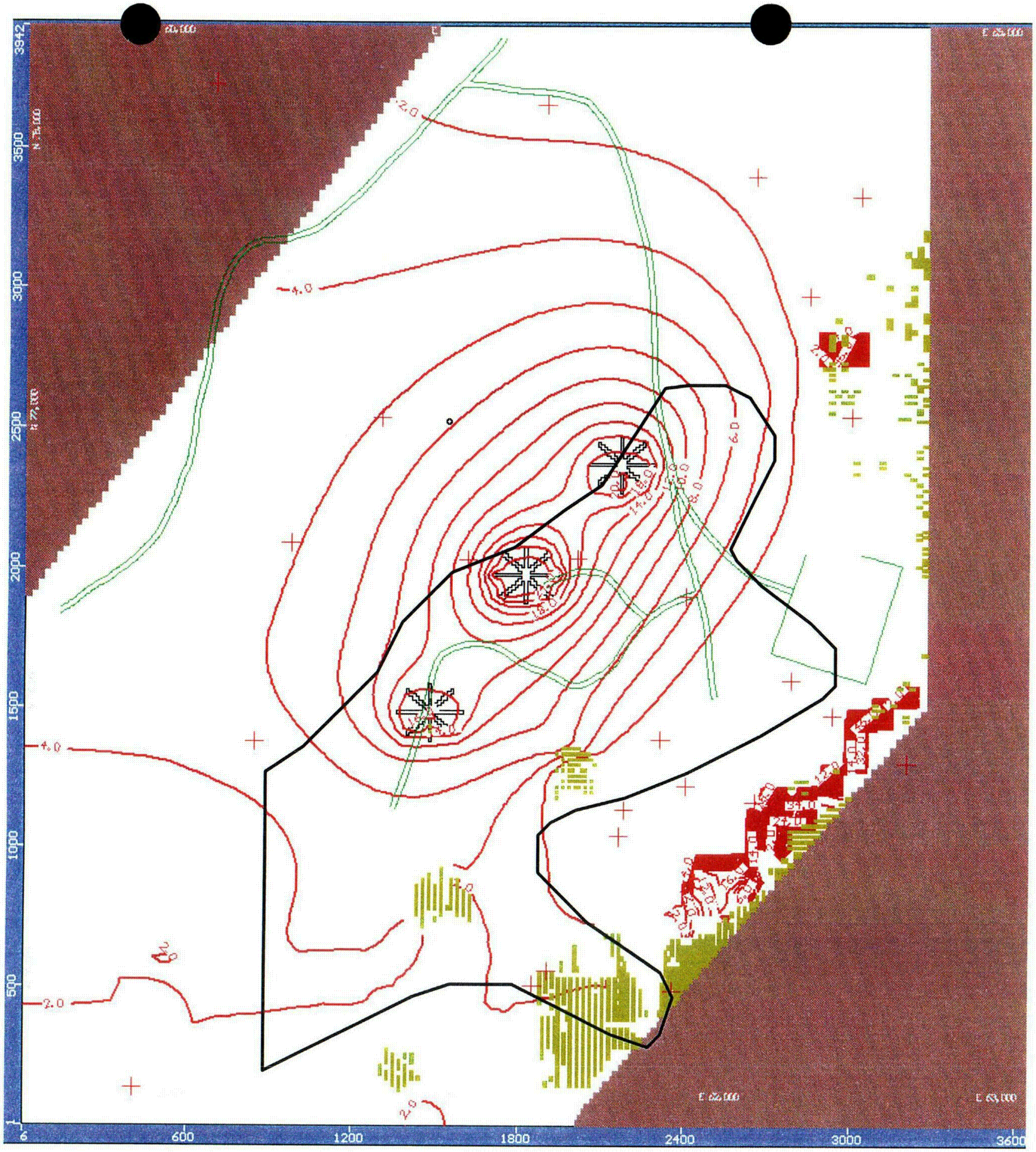


Figure 60
7c. Three Ranney Wells Drawdown 3 Years

Notes:

1. No Recharge from Alluvium.
2. April 2002 plume outline shown by black outline.

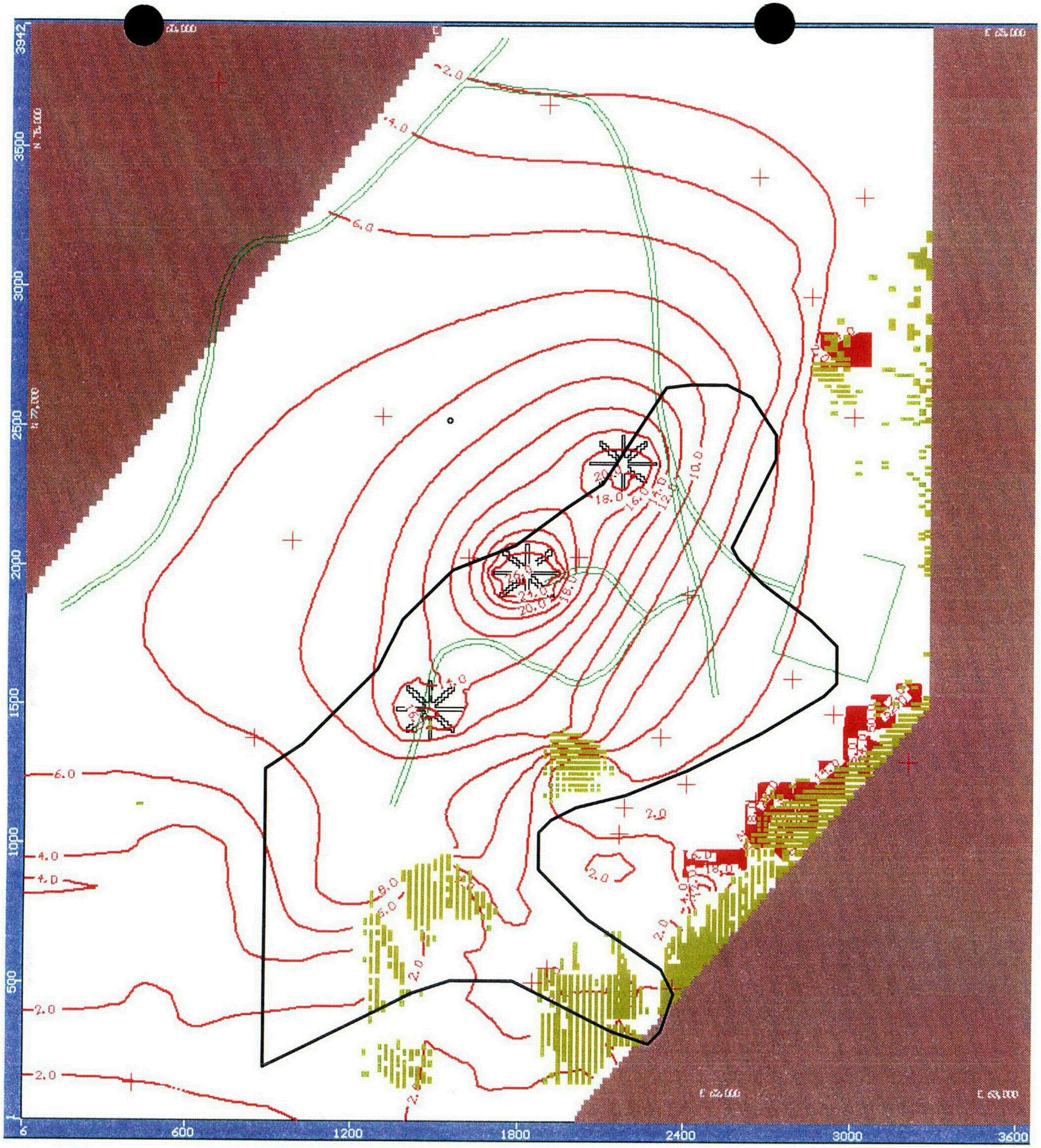


Figure 61
7c. Three Ranney Wells Drawdown 5 Years

Notes:

1. No Recharge from Alluvium.
2. April 2002 plume outline shown by black outline.

C48

Figure 62
8. Horizontal Well
Drawdown
1 Year

Note: April 2002 plume outline shown by black outline

Figure 63
8. Horizontal Well
Drawdown
3 Years

Note: April 2002 plume outline shown by black outline

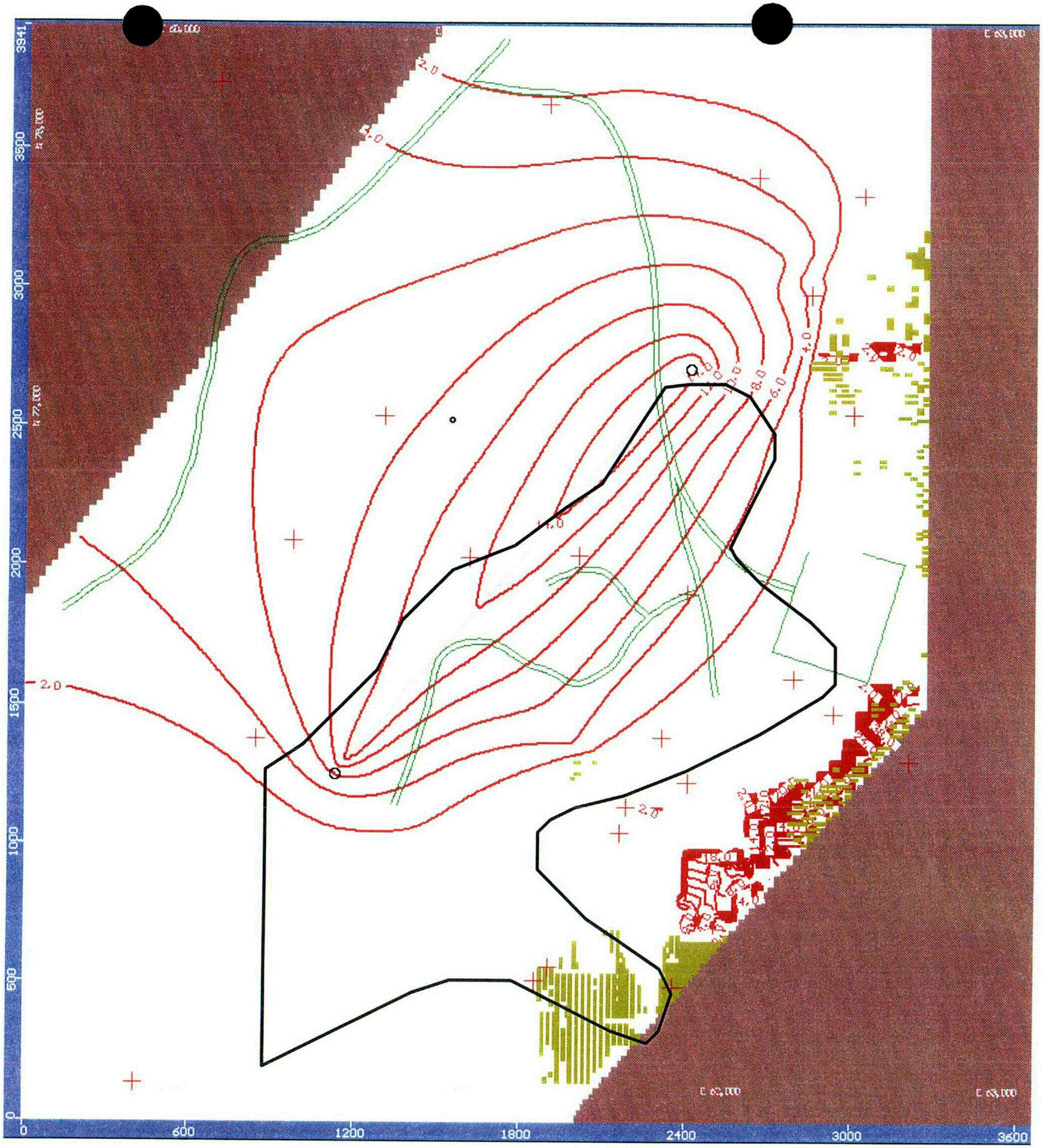


Figure 64
8. Horizontal Well Drawdown
5 Years

Note: April 2002 plume outline shown by black outline

Figure 65
5H. Well Field Drawdown
5 Years
(70 Wells)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.
2. Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

Figure 66
5H. Well Field
Additional
Drawdown
from
5 to 10 Years
(70 wells)
(5-year simulation using output from 5 years of pumping as initial heads.)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.

2. Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

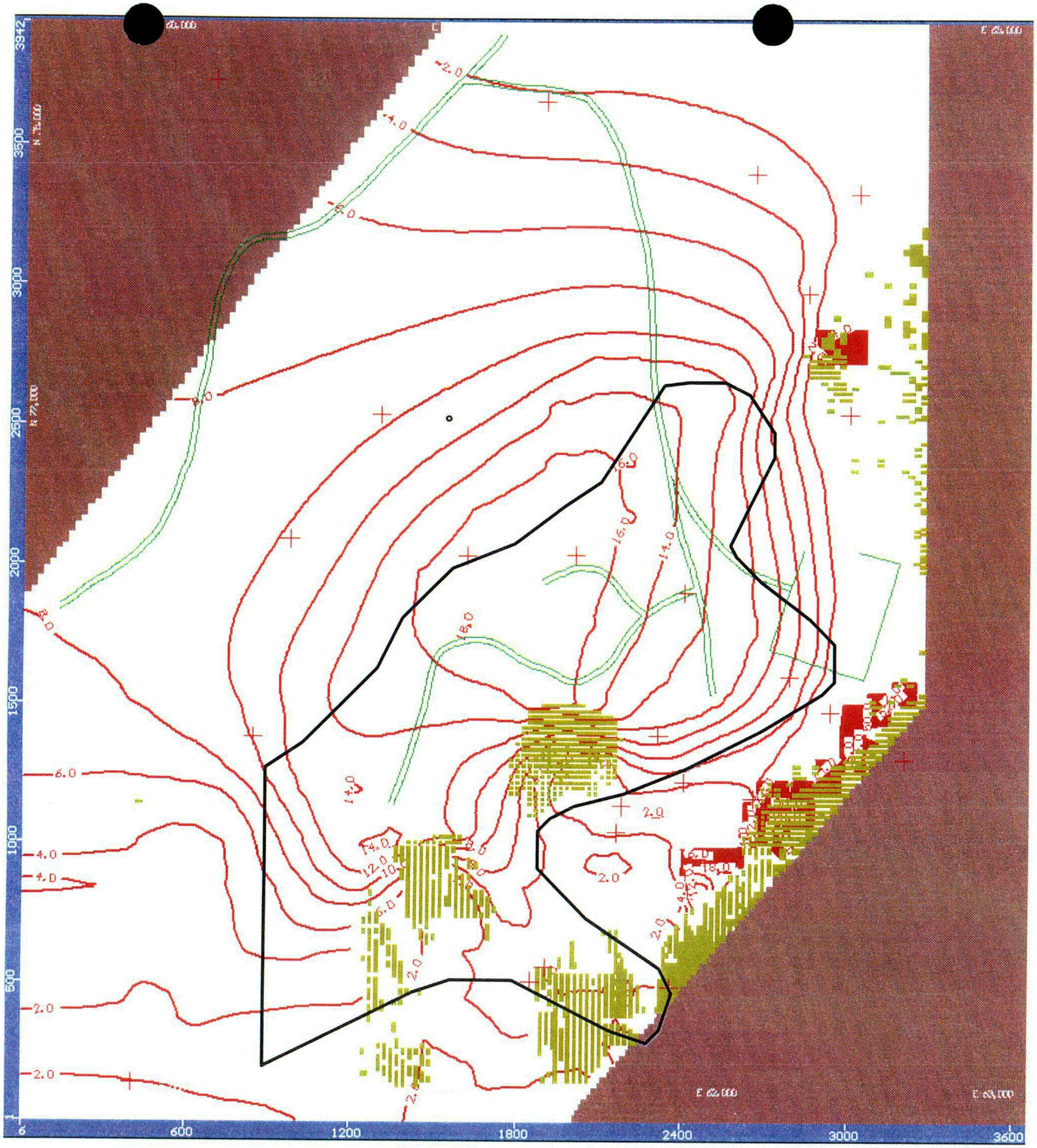


Figure 67
5I. Well Field Drawdown
5 Years
(70 Wells)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.

2. No Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

Figure 68 5I. Well Field Additional Drawdown from 5 to 10 Years (70 Wells)

(5-year simulation using output from 5 years of pumping as initial heads.)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.
2. No Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

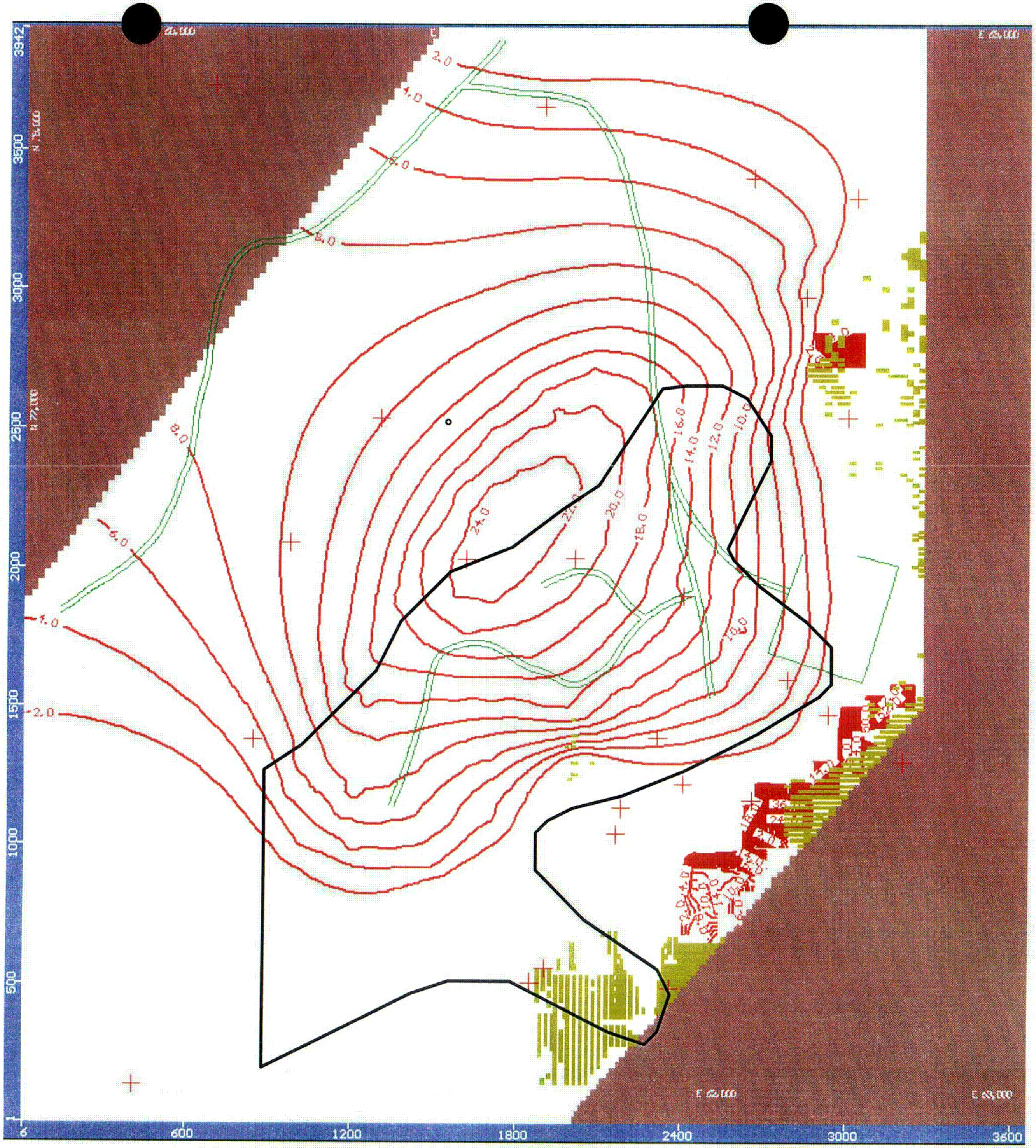


Figure 69
5J. Well Field Drawdown
5 Years
(140 Wells)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.
2. Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

C56

Figure 70 5J. Well Field Additional Drawdown from 5 to 10 Years (140 Wells)

(5-year simulation using output from 5 years of pumping as initial heads.)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.
2. Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

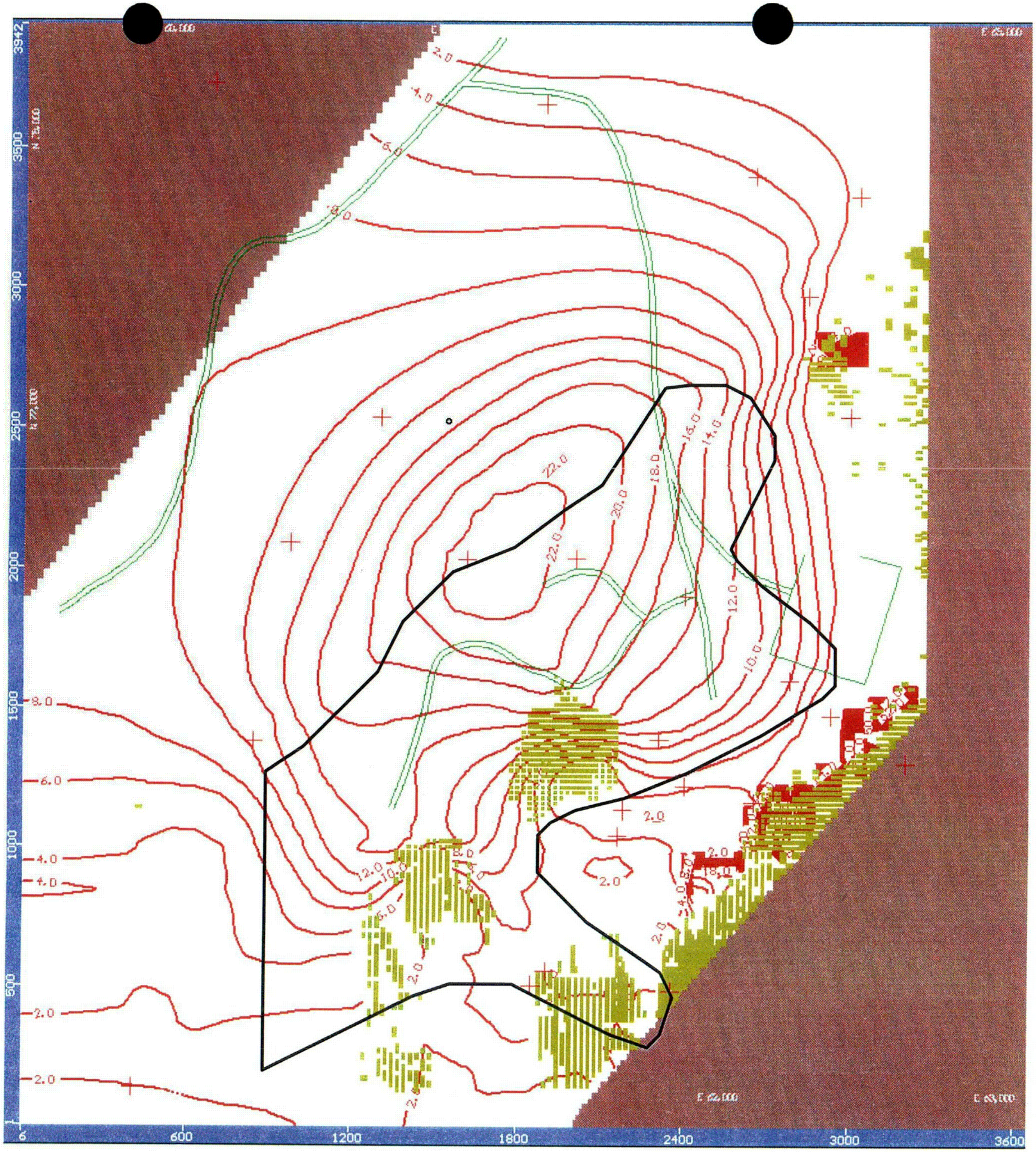


Figure 71
5K. Well Field Drawdown
5 Years
(140 Wells)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.

2. No Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

Figure 72
5K. Well Field
Additional
Drawdown
from
5 to 10 Years
(140 Wells)
(5-year simulation using
output from 5 years of pumping
as initial heads.)

Conditions:

1. Aquifer Hydraulic Conductivity Increased by a Factor of 2 in Well Field Area.

2. No Recharge from Alluvium.

Note: April 2002 plume outline shown by black outline

APPENDIX A

UNSATURATED MODEL PARAMETERS

APPENDIX A
UNSATURATED MODEL PARAMETERS

The figures presented within Appendix A include the following:

- Uniform Sand Volumetric Water Content and Conductivity Curve;
- Uniform Sand - Volumetric Water Content vs. Distance Graph;
- Heterogeneous Sand Volumetric Water Content and Conductivity Curve; and
- Heterogeneous Sand - Volumetric Water Content vs. Distance Graph.

The volumetric water content and conductivity curves shown were used as input parameters into the unsaturated SEEP/W model. These curves define each soil's conductivity and volumetric water content as a function of the soil pressure.

The two, volumetric water content vs. distance graphs are the output data generated by the SEEP/W model for both soil types. These graphs represent the volumetric water content at different locations throughout the modeled 10 meter tall soil column. The point at zero on the x-axis represents the bottom of the free draining soil column and the distance of 10 meters is the top of the soil column.

APPENDIX B

ALLUVIAL DEWATERING ANALYSIS

APPENDIX B
ALLUVIAL AQUIFER DEWATERING ANALYSIS

As shown on the Figure 3 surface geology map and in cross-sections on Figures 6 through 9, a substantial alluvium is present in the western portion of the study area. Extrapolation of water level contours on the April 2002 piezometric map (Figure 12) indicates that the lower portion of the alluvium is locally saturated with groundwater. The cross sections suggest that the saturated thickness of alluvial materials ranges from zero 30 feet, with an average saturated thickness of about 10 feet. The base of the alluvium is expected to follow the general surface topography with a slope of about 5.5 percent (5.5 feet vertical to 100 feet horizontal). The alluvium is likely to be transmissive due to the relatively high permeability of the sands and gravels that comprise the unit. Groundwater in the alluvium is in hydraulic communication with the underlying Z3 unit. Thus, if the water table in the Z3 unit is lowered, it is likely that the alluvial aquifer will provide downward recharge into the unit that would reduce the efficiency of dewatering activities.

To assess the feasibility for dewatering the alluvial aquifer, a two-dimensional (horizontal) transient flow analysis was developed using the finite-difference groundwater flow model, MODFLOW. The results of the model are considered preliminary and will be subject to revision following completion of a well installation and pump testing program, focussed on the alluvial aquifer, scheduled for September 2004. This field program will provide additional information on alluvium geometry, groundwater levels, and an estimate of in-situ hydraulic conductivity.

Details of the conceptual evaluation and model configuration are provided in the outline below. For this model, the aquifer material was assumed to be homogeneous and isotropic, with a hydraulic conductivity of 2×10^{-3} cm/sec and a specific yield of 0.20. Based on the conceptual model, dewatering wells (or drains) were simulated in the northeast portion of the saturated alluvium, along the axis of the alluvial trough where saturated thickness is currently greatest. Transient flow simulations were performed to evaluate alluvial aquifer dewatering. Based on the model simulations, the alluvial aquifer would be significantly dewatered in one year, leakage to the Z3 unit would cease after three years, and nearly complete dewatering would be achieved after five years. The initial pumping rate under this scenario would be approximately 50 gpm, and would decrease to approximately 12 gpm over three years.

APPENDIX C

COST EVALUATION DATA

APPENDIX C
COST EVALUATION DATA

Costing Approach

Capital cost estimates were developed for five dewatering alternatives as follows:

- Alternative 3 Tunnel
- Alternative 4 Open Pit
- Alternative 5 Enhanced Well Field
- Alternative 6 Cut-off/Containment Well
- Alternative 7 Large Diameter Hole with Radial Horizontal Collection Fan (1-3 Wells)
- Alternative 8 Directionally-drilled (horizontal) well

The following describes how each cost alternative was developed and assumptions made:

- Alternative 3 Tunnel: An 8 ft by 8 ft drift was assumed for construction. This size drift was used in case radial drainage holes would be installed at a later date to improve drainage to the drift. A concrete floor was assumed since it would be in use for a long period of time. A ventilation system was also assumed since there would be personnel needing access during construction and the operational life. A vertical shaft was also assessed with the associated costs for a headframe and elevator system. Costs for these options were developed by the Cowin Company and Redpath who both are specialty tunneling contractors.

- Alternative 4 Open Pit: This option assumed that an open pit would be developed downgradient of the existing plume and would act as a sump to collect any contamination. A conceptual pit plan was developed which estimated that approximately 500,000 cubic yards of material would have to be excavated. Costs were used from other open pit mining operations that we have been involved with on various projects. It was assumed that a 1/2 mile haul would be required to stockpile material that was excavated from the pit.

- Alternative 5 Well Field: This option assumed between 70 and 140 vertical dewatering wells would be installed in the location of the plume. The cost of hydraulic fracturing these wells was also included. These wells and the associated pumping and piping systems would be similar to the existing dewatering wells previously installed at the site. Extracted water would be routed to the existing evaporation system. Development costs for this option were obtained from Larry Bush of UNC who has installed the existing wells at the site.

- Alternative 6 Cut-off/Containment Wells: This alternative includes up to 32 wells to capture the seepage-impacted groundwater as it moves downgradient. The cost of hydraulic fracturing these wells was also included. These wells and the associated pumping and piping systems would be similar to the existing dewatering wells previously installed at the site. Extracted water would be routed to the existing evaporation system.

- Alternative 7 Large Diameter Hole with Radial Horizontal Collection Fan (Ranney-type Well): This option assumed that between one and three 15 foot diameter vertical shafts would be sunk to a depth of approximately 175 feet which would be at the base of the contamination plume. A total of 1,500 feet of radial drainage wells drilled out horizontally from the shafts were assumed for this project. The cost estimate for the Large Diameter Hole with Radial Collection Fan (Ranney-type Well) was developed for one installation. It was hoped that this cost could be developed with assistance from Layne Drilling, Ranney-type Well Division; however, this application is not suited to their normal installation methods (in unconsolidated sediments) and therefore they did not provide costing information. Therefore, the cost estimate for this alternative was developed based on shaft construction costing information developed during costing of the tunnel alternative.

- Alternative 8 Directionally-drilled (horizontal) well: A directional drillhole was assumed to be drilled approximately parallel down the middle of the current plume geometry. This drillhole would be started at the surface and decline to the bottom of the plume to intercept contamination. A 4,000 foot long drillhole was estimated to be required to intercept the current plume geometry. Costs from other jobs that MWH has completed were used to determine project development costs.

SUMMARY OF CAPITAL COSTS FOR ALTERNATIVES				
	Quantity	**Units**	**Unit Cost**	**Subtotal**
Alternative 3 Tunnel				
Item				
Decline and Drift	4,000	ft	$800	$3,200,000
Steel Sets	1	ls	$500,000	$500,000
Gunnite	1	ls	$300,000	$300,000
Fan System	1	ls	$110,000	$110,000
Concrete Floor	4,000	ft	$350	$1,400,000
Procure and Install Dewatering Pumps	3	*each*	$5,000.00	$15,000
Engineering (10% of Direct Cost)				$552,500
CQA (5% of Direct Cost)				$276,250
			Total	*$6,353,750*
Alternative 4 Open Pit				
Item	Quantity	Units	Unit Cost	Subtotal
Excavate and Load Material	500,000	yd³	$2.20	$1,100,000
Haul Material ½ mile and Dump	500,000	yd³	$0.40	$200,000
Doze Dumped Material	500,000	yd³	$0.20	$100,000
Procure and Install Dewatering Pumps	3	each	$5,000.00	$15,000
Revegetate Waste Stockpile	28,000	yd²	$ 0.60	$16,800
Mob/Demob (20% of Direct Cost)				$286,360
Engineering (10% of Direct Cost)				$143,180
CQA (5% of Direct Cost)				$71,590
Contractor OH&P (30% of Direct Cost)				$429,540
			Total	*$2,362,470*
Alternative 5 Well Field (70 Wells)				
Item	Quantity	Units	Unit Cost	Subtotal
Extraction Wells with Pumps	70	ea	$6,300	$441,000
Hydraulic Fracturing of Extraction Wells	70	ea	$12,000	$840,000
Extraction Wells (with Pumps) in Alluvium	15	ea	$6,300	$94,500
Collection System	1	ea	$50,000	$50,000
Engineering (10% of Direct Cost)				$58,550
			Total	*$1,484,050*
Alternative 5 Well Field (140 Wells)				
Item	Quantity	Units	Unit Cost	Subtotal
Extraction Wells with Pumps	140	ea	$6,300	$882,000
Hydraulic Fracturing of Extraction Wells	140	ea	$12,000	$1,680,000
Extraction Wells (with Pumps) in Alluvium	15	ea	$6,300	$94,500
Collection System	1	ea	$75,000	$75,000
Engineering (10% of Direct Cost)				$58,550
			Total	*$2,790,050*

SUMMARY OF CAPITAL COSTS FOR ALTERNATIVES

	Quantity	Units	Unit Cost	Subtotal
Alternative 6 Cut-off/Containment Wells				
Item	Quantity	Units	Unit Cost	Subtotal
Extraction Wells with Pumps	32	ea	$6,300	$201,600
Hydraulic Fracturing	32	ea	$12,000	$384,000
Collection System	1	ea	$50,000	$50,000
Engineering (10% of Direct Cost)				$58,550
			Total	*$694,150*
Alternative 7 Large Diameter Hole with Radial Horizontal Collection Fan (One Ranney-type Well)				
Item	Quantity	Units	Unit Cost	Subtotal
Shaft Excavation	175	ft	$1,200	$210,000
Headframe	1	ea	$1,500,000	$1,500,000
Radial Drillholes	1500	ft	$30	$45,000
Procure and Install Pump	1	each	$10,000.00	$10,000
Engineering (10% of Direct Cost)				$176,500
CQA (5% of Direct Cost)				$88,250
			Total	*$2,029,750*
Alternative 8 Directionally-drilled (horizontal) well				
Item	Quantity	Units	Unit Cost	Subtotal
Directional Drilling	4,000	ft	$300.00	$1,200,000
Procure and Install Pump	3	each	$5,000.00	$15,000
Mob/Demob (20% of Direct Cost)				$243,000
Engineering (10% of Direct Cost)				$121,500
CQA (5% of Direct Cost)				$60,750
Contractor OH&P (30% of Direct Cost)				$364,500
			Total	*$2,004,750*
(Unit Rates Include Other Indirect Costs)				

APPENDIX D

CRITERION DECISION ANALYSIS

APPENDIX D
CRITERION DECISION ANALYSIS

The remedial alternatives for the Z3 hydrostratigraphic unit were evaluated with a decision analysis software package, Criterium Decision Plus (CDP). This software facilitates the decision making process by utilizing a methodical approach to alternatives evaluation.

MODEL INPUTS AND ASSUMPTIONS

The relative importance of the individual criteria in the alternative evaluation is represented by assigning each criteria a weight value on a scale of 0 to 100, with 100 indicating the most important criteria. The criteria and their associated weights assigned for the evaluation are shown in the table below.

Criteria	Assigned Weight
Effectiveness	100
Cost	80
Environmental Impact	40
Regulatory Permitting	40
Public Acceptance	20

The sensitivity of these assigned weights is evaluated below as part of the analysis of the model results.

The quantitative ratings of each alternative for each criteria used in the alternatives evaluation are presented in the table below.

Criteria	Scale	Tunnel	Pit	Well Field-70	Well Field-140	Large Diameter Well(s)			Directional Drilling	Cutoff Wells
						1	2	3		
Effectiveness	0 - 100	49	33	76	85	36	52	59	10	0
Cost	0 - 100	97.7	36.3	22.8	42.9	31.2	62.4	93.7	30.8	10.7
Environmental Impact	0 - 100	100	60	100	100	100	100	100	100	100
Regulatory Permitting	0 - 100	60	60	100	100	80	80	80	100	100
Public Acceptance	0 - 100	100	80	100	100	100	100	100	100	100

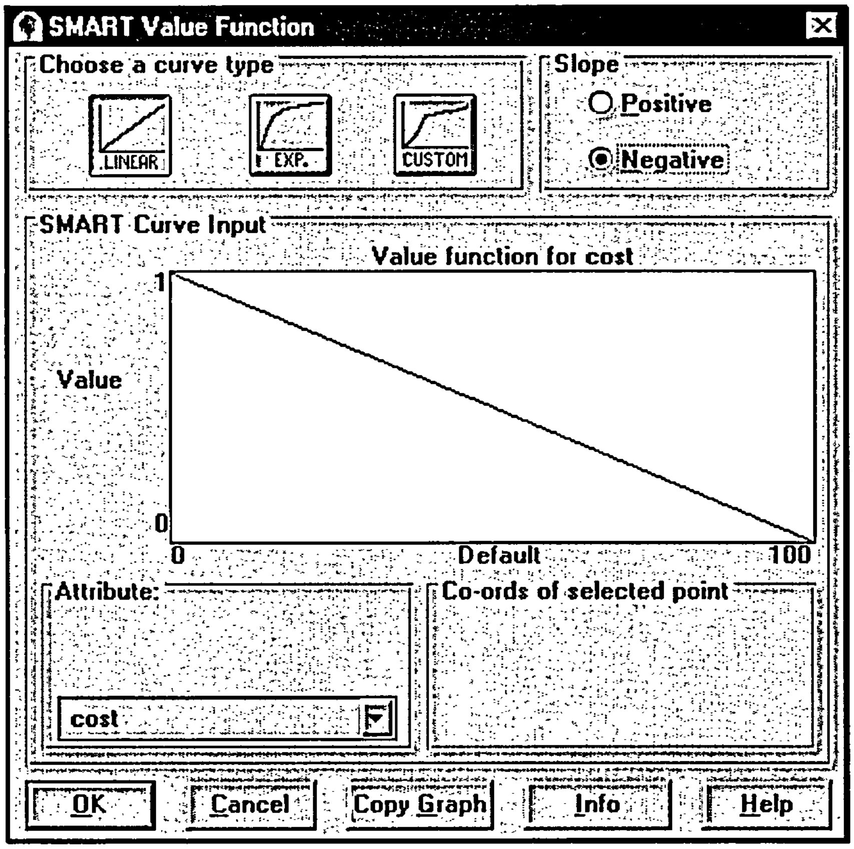
Cost ratings are based on actual estimates for each alternative normalized to a scale of 0 to 100, where each scale unit represents $65,000. Effectiveness ratings are based on modeling results. Effectiveness ratings represent the percentage of the plume volume extracted after five years assuming that the alluvium is dewatered, and represents whether the plume containment to support license transfer is able to be achieved within five years of implementation. The effectiveness value of Alternative 8, Directional (horizontal) drilling was reduced from 47 (percentage of plume volume extracted after five years) to 10 due to fact that failure of this horizontal well would be irreversible. Public Acceptance, Environmental Impact and Regulatory Permitting criteria relate to administrative implementability and are more subjective criteria that are assigned a relative rating on a scale of 0 to 100. As presented in Table D-1, *Summary of Alternatives and Criteria*, advantages and disadvantages of each alternative relative to the criteria assisted in the designation of the more subjective ratings.

TABLE D-1
SUMMARY OF ALTERNATIVES AND CRITERIA

	Alternative 3 Tunnel	**Alternative 4 Open Pit**	**Alternative 5 Enhanced Well Field**	**Alternative 6 Cutoff/ Containment Wells**	**Alternative 7 Large Diameter Vertical Well (Ranney-type)**	**Alternative 8 Directional Drilling**
Effectiveness	• Effective capture	• Ineffective capture • Freezing • Water balance • Unexpected climatic events	• Effective capture • Easily expanded as necessary	• Capture but does not dewater the plume	• Ineffective capture	• Ineffective capture • Possible collapse of borehole
Cost	• Potential variability in costs due to unexpected conditions • Additional costs for geotechnical analyses and design • Unknown waste handling/ disposal costs	• Additional costs for geotechnical analyses and design • Unknown waste handling/ disposal costs	• Variability in number of wells and pumping equipment is easily addressed	• Variability in number of wells and pumping equipment is easily addressed	• Expensive to expand • Additional costs for geotechnical analyses and design • Unknown waste handling/ disposal costs	• Expensive to expand • Additional costs for geotechnical analyses and design
Environmental Impact	• Limited environmental impact • Evaporation of water will have no environmental impact • Waste disposal requirements	• Wildlife Protection • Waste disposal requirements	• Limited environmental impact • Evaporation of water will have no environmental impact	• Limited environmental impact • Evaporation of water will have no environmental impact	• Limited environmental impact • Evaporation of water will have no environmental impact • Waste disposal requirements	• Limited environmental impact • Evaporation of water will have no environmental impact
Regulatory Permitting	• Health and Safety • Civil or mining project • Spoil disposal • Evaporation of water will not require a discharge permit	• Water quality • Biotic hazards • Spoil disposal	• Limited permitting • Evaporation of water will not require a discharge permit	• Limited permitting • Evaporation of water will not require a discharge permit	• Health and Safety • Civil or mining project • Spoil Disposal • Evaporation of water will not require a discharge permit	• Closure requirements • Spoil disposal • Evaporation of water will not require a discharge permit
Public Acceptance	• Viewed as a long-term feature	• Viewed as a mining property	• Expansion of current system	• Expansion of current system	• Viewed as a long-term feature	

The ratings input into CDP are transformed into scores ranging from 0 to 1 by applying a value function. The value function profile for the cost criterion is presented below. It shows a negative relationship between cost and score, i.e., the higher the cost, the lower the score value. All of the other criteria are represented by positive linear value functions (the higher the rating number, the higher the score value).

VALUE FUNCTION PROFILE



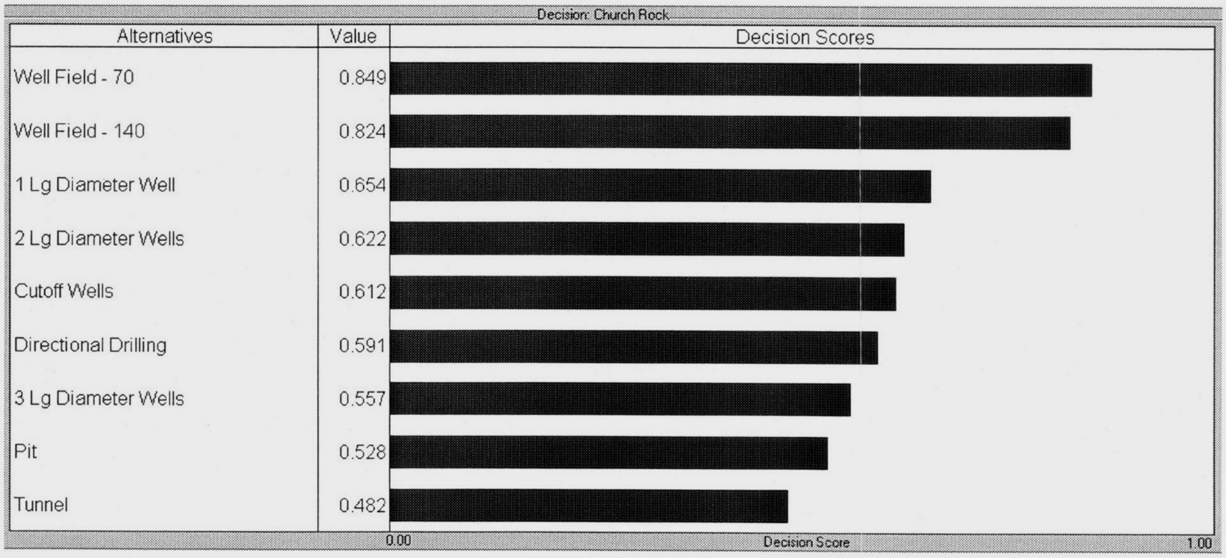
Slope
○ Positive
● Negative

Attribute: cost

MODEL RESULTS AND ANALYSIS

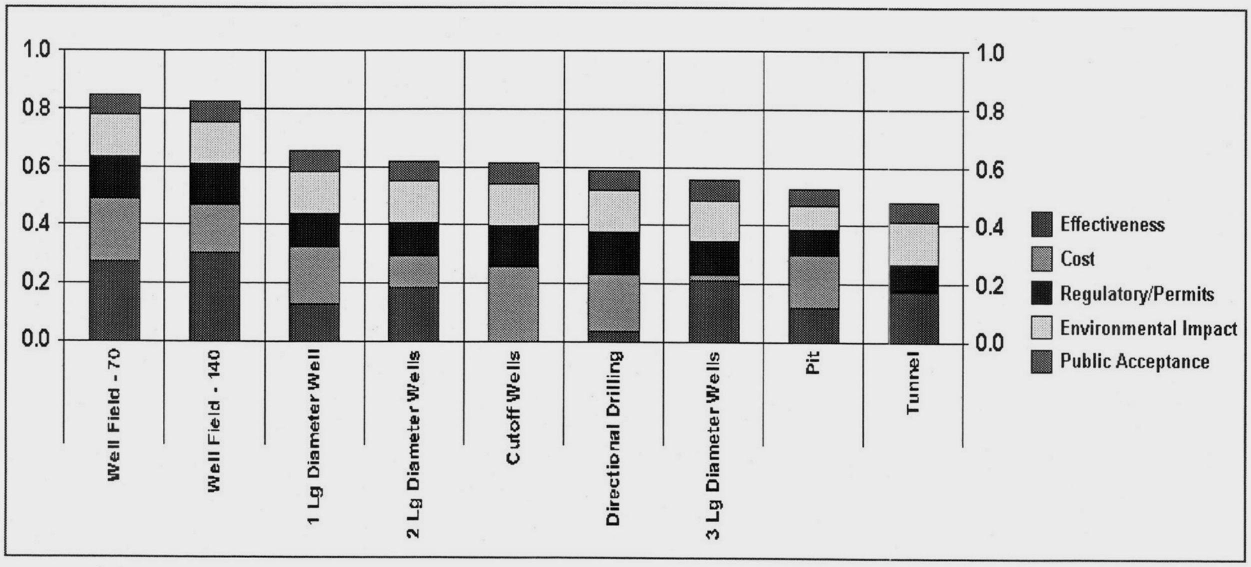
The overall score of an alternative is calculated based on the combination of its rating for each of the criteria and the relative importance of the criteria to the decision. The overall scores of each alternative are shown below, ranked in order of score.

DECISION ANALYSIS RESULTS



Further analysis of these scores can be accomplished through evaluating a breakdown of the overall score by each criteria. The contribution by criteria analysis illustrates how much effect each criteria is having on the overall score of the alternatives. This illustration is shown for each alternative in the figure below.

CONTRIBUTION BY CRITERIA



The above graph indicates that the differentiating factor between the two well field options is the trade-off established between the effectiveness and cost criteria. This is based on the relative weightings assigned for cost and effectiveness, which indicate that a 1% increase in effectiveness has equal value to over $80,000 (i.e. establishes a willingness to pay over $800,000 for each 10 percent of plume volume extracted within five years). Even though the 140 well option is able to manage 9% more of the plume volume than the 70 well option, it costs over an additional $1.3 million. Due to the level of savings, the 70 well option provides an acceptable trade-off worth the lower performance level and is an overall better option than the 140 well option.

CDP also provides information on how sensitive the alternative ranking is to the criteria weightings. A sensitivity analysis illustrates the robustness of the decision results and their sensitivity to changes in the criteria weights. It provides a snapshot of how much the weighting assigned to each criteria would have to be adjusted in order to generate a different top-ranking alternative. The most sensitive criteria in the model is cost, although the model results are relatively insensitive overall. The weight of the cost criteria would have to be reduced from the current weight of 80 to approximately 45 (56% as important as in the current model) in order for the 140 well option to become the preferred alternative. This would equate to an increase in the trade-off value to $144,000 per each percent of plume volume extracted within five years. The sensitivity analysis is illustrated in the graph below.

SENSITIVITY ANALYSIS