Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

87-GTB-111

SEP 10 1987

Mr. Russell Jim, Manager
Nuclear Waste Program
Yakima Indian Nation
P. O. Box 151
Toppenish, WA 98948

Dear Mr. Jim:

YAKIMA INDIAN NATION (YIN) HANFORD HYDROLOGY REVIEW MEETING SEPTEMBER 3, 1987

Enclosed for your information is a summary trip report regarding the recent meeting between the DOE and the Yakima Indian Nation held in Minneapolis on September 3, 1987.

We appreciated the opportunity to participate in the session and look forward to additional productive exchanges. If you have any questions please contact Dr. David Dahlem of my staff, on (509) 376-6406.

Sincerely,

O. L. Olson

for John H. Anttonen, Assistant Manager
for Commercial Nuclear Waste

BWI:AJK

Enclosure

cc: Correspondence Mailing List, w/encl.

RL F 1325.6 (5-87)

See Hr. Fm. Anttonen 9/10/87 101.4

United States Government | Department of Energy

memorandum

Richland Operations Office

DATE: SEP 8 1987

87-GTB-110

REPLY TO ATTN OF: BWI:DHD

SUBJECT: YAKIMA INDIAN NATION (YIN) HANFORD HYDROLOGY REVIEW MEETING 9/3/87

TO: John H. Anttonen, AMC

THRU: O. L. Olson, BWI

Messrs. Dahlem, Knepp, Thompson, and Clifton (Westinghouse) attended the above review, and discussed current program plans in Geohydrology relative to the attached agenda.

During the meeting, no recommendations were provided DOE and no actions were taken by DOE. The discussions were technical and involved work conducted by YIN consultants, primarily EWA. DOE expressed to the YIN that the results of their work and suggestions would be included in program planning where appropriate. It is our opinion that the program is aware of developments addressed in the technical presentations.

The YIN position is that DOE has not provided sufficient detail on the Geohydrology program to allow the YIN to back off their assessment that the testing program is not sufficient to reduce uncertainty in groundwater travel time estimates to acceptable levels.

Our feeling after the meeting is that we need to better address the problems of how the program is treating uncertainty in performance issues; the specific methods of closing issues, and schedule. The Geoscience Branch proposes to begin this discussion with Westinghouse in the near future.

Handouts from all technical presentations are attached.

A. Knepp for
David H. Dahlem, Chief
Geoscience and Technology Branch

Attachments

cc: M. Powell, AMC, w/o att.
J. E. Mecca, LES, w/o att.

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Assurance Division, RW-24

Ralph Stein, Director
Engineering and Geotechnology
Division, RW-23

DRAFT

YAKIMA INDIAN NATION/EWA, Inc.

LIST OF TOPICS FOR THE HANFORD HYDROLOGY REVIEW MEETING

Minneapolis, September 3-4, 1987
Ritz Hotel, 315 Nicollet Mall, 612/332-4000

I. Overview of Site Characterization Problems in Hydrology
(Mr. J. Wittman/YIN)

II. Stochastic Methods of Hanford Groundwater Travel Time Analysis
(Dr. G. Dagan/Dr. V. Nguyen)

III. Geostatistic Problems Associated with Head Fields and Hydraulic Conductivity Mapping in the Grande Ronde Basalt
(Dr. V. Nguyen/Dr. A. Djerrari/Dr. P. Kitanidis)

IV. Optimization of Monitoring Network for the Reduction of Site Characterization Uncertainty at RRL-2
(Dr. P. Kitanidis/Dr. G. Abi-Ghanem)

V. Three-Dimensional Analysis of Well and Tracer Tests in Layered and Fractured Basalts
(Dr. A. Calash/Dr. P. Huyakorn/Dr. E. Frind)

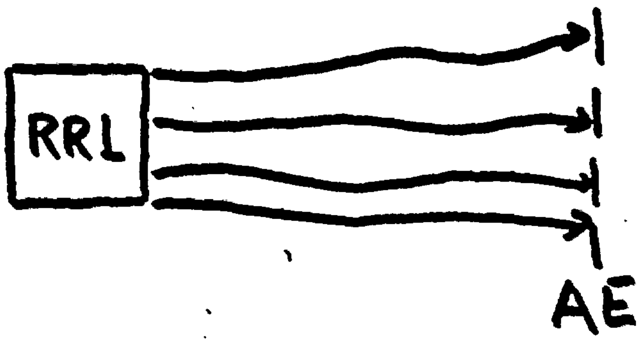
VI. Evaluation of Hydraulic Impact of Proposed Shaft Sinking on LHST
(Dr. V. Nguyen/Mr. J. Robertson)

Each subject will take 1-2hrs for presentation and discussion.

THE TOTAL TRAVEL TIME APPROACH

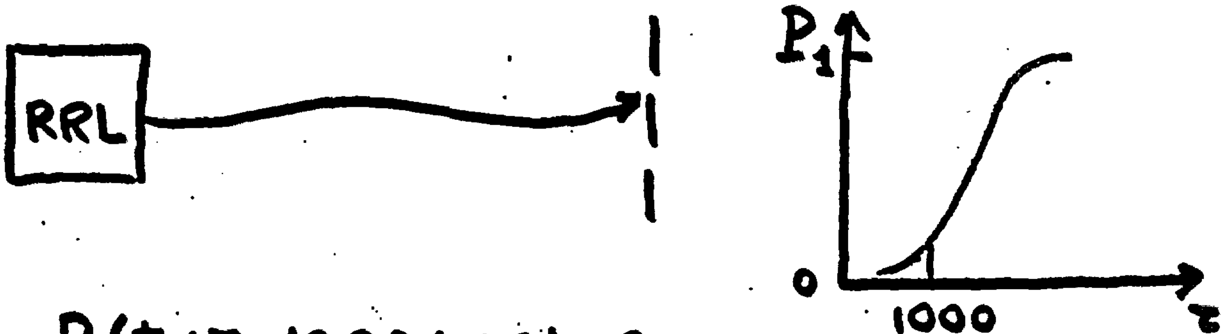
AIM: DERIVE PROBABILITY OF EXCEED. OF TT = 1000 YRS AS CRITERION OF ACCEPTANCE OF HANFORD SITE

I. CONCEPTUAL FRAMEWORK



THE PROBLEM: THE CONCENTRATION $C(\underline{x},t)$ OF RN IN GROUNDWATER SHOULD NOT EXCEED C_{ADM} AT AE AND FOR $t < \tau$.

FORMULATION BY GWT TOT:



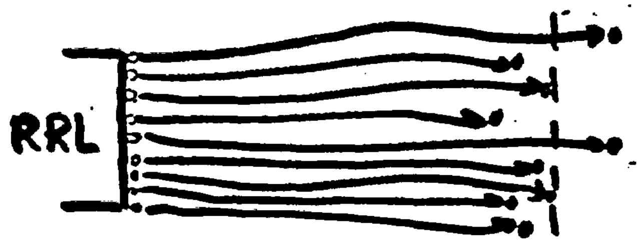
$P(t < \tau = 1000 \text{ YRS}) < \varepsilon$ OR $1-P > 1-\varepsilon$

CONCEPTUAL AND COMPUTATIONAL ADVANTAGES: (i) $C(\underline{x},t)$ DEPENDS ON INITIAL CONDITIONS, ON SPACE AVERAGING VOLUME. TOT IS A CLEAR-CUT FIGURE; (ii) C IS A RANDOM SPACE FUNCTION DUE TO UNCERTAINTY OF FACTORS. HENCE E(C), VAR(C). $P(\tau)$ LUMPS ALL UNCERTAINTY; (iii) $P(\tau)$ IS ROBUST (E.G. D &N, 1987)

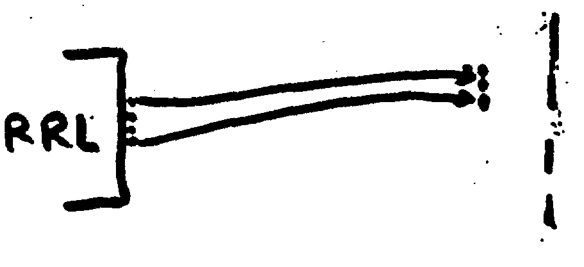
QUESTION MARK: ε = ? (EWA COMMENTS TO NRC).

WHAT IS THE RELATIONSHIP BETWEEN $P(\tau)$ FOR ONE PARTICLE AND ACTUAL DISTRIBUTION OF SWARM?

EXTREME CASES:



ERGODIC: P IS THE RELATIVE NUMBER $\frac{\bullet}{\circ + \bullet}$ IN ANY REALIZATION



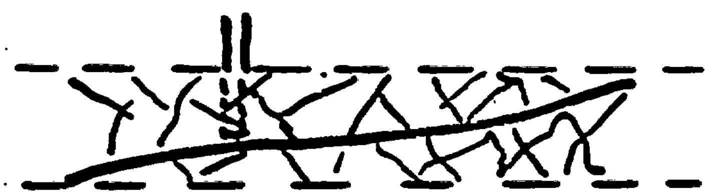
P IS THE PROBABILITY OF •

II COMPUTATION OF P(z).

PARTICLE IS CONVECTED BY GWT MODELED AS AN EQUIVALENT CONT. IS IT VALID FOR FRACTURED ROCK?

SCALES: ℓ = FRACTURE LENGTH SCALE
L = DISTANCE OF TRAVEL

YES FOR $\ell \ll L$



NO

MEASUREMENT OF CONTINUUM PROPERTIES (T, n_e) BY TESTS: LOCAL.

IF CONT. IS ADOPTED

$$\underline{V}_t = \underline{V} + \underline{u}_d$$

$\underline{V}_t$	$\underline{V}$	$\underline{u}_d$
TOTAL VELOCITY	CONVECTION BY GWT (DEPTH AVERAGED)	RANDOM "DIFFUSIVE" COMPONENT DUE TO 3D FRACTURES CONFIGURATION

LINEAR RESISTANCE → DARCY'S LAW

$$\underline{q} = -\frac{T}{b}\nabla\phi \; ; \; \underline{V} = \frac{\underline{q}}{n_e} = \frac{T}{b_e}\underline{G}$$

$$\frac{d\underline{x}}{dt} = \underline{V}(\underline{x},t) + \underline{V}_d$$

IF $\underline{V}$ IS DETERMINISTIC, τ IS RANDOM ONLY DUE TO $\underline{V}_d$ AND THE PROBLEM IS OF DISPERSION.

GENERALLY $\underline{V}$ IS UNCERTAIN.

SOURCES: (i) SPATIAL VARIABILITY OF T, n_e; (ii) ERRORS OF ESTIMATION OF PARAMETERS; (iii) UNCERTAINTY OF BOUNDARIES AND B.C.

SPATIAL VARIABILITY → $T(\underline{x})$. $Y = \ln T$

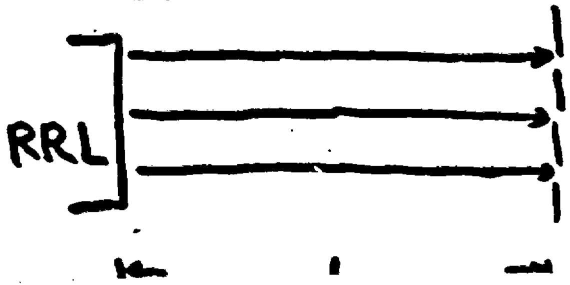
$E(Y) = m_Y$; σ_Y^2 ; I_Y.

EXTREME CASES:

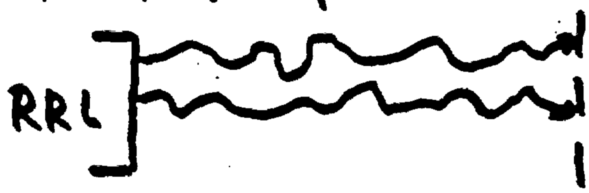
(i) $I_Y \gg L = 5$ km. $T \cong$ const → $\underline{V} = \frac{T}{b_e}\underline{G} \cong$ cons

$\tau \cong \frac{L b_e}{T G}$. UNCERTAINTY OF τ FROM <u>ESTIMATION</u> ERRORS OF T, G, b_e <u>ONLY.</u>

Modeling uncertainty



(ii) $I_Y \ll L$ → FICKIAN TRANSPORT



THESE TWO CASES ARE SIMPLE. FOR GIVEN m_Y, σ_Y^2 CASE (i) IS CONSERVATIVE

GENERALLY: m_Y, σ_Y^2, I_Y, $\bar{G}$, b_e ARE ESTIMATED AND $P(\tau)$ DEPENDS IN A COMPLEX MANNER ON THEM.

THE CONCEPTUALLY SIMPLE APPROACH MONTE CARLO SIMULATIONS + NUMERICAL SOLUTIONS. IMPORTANT LIMITATIONS:

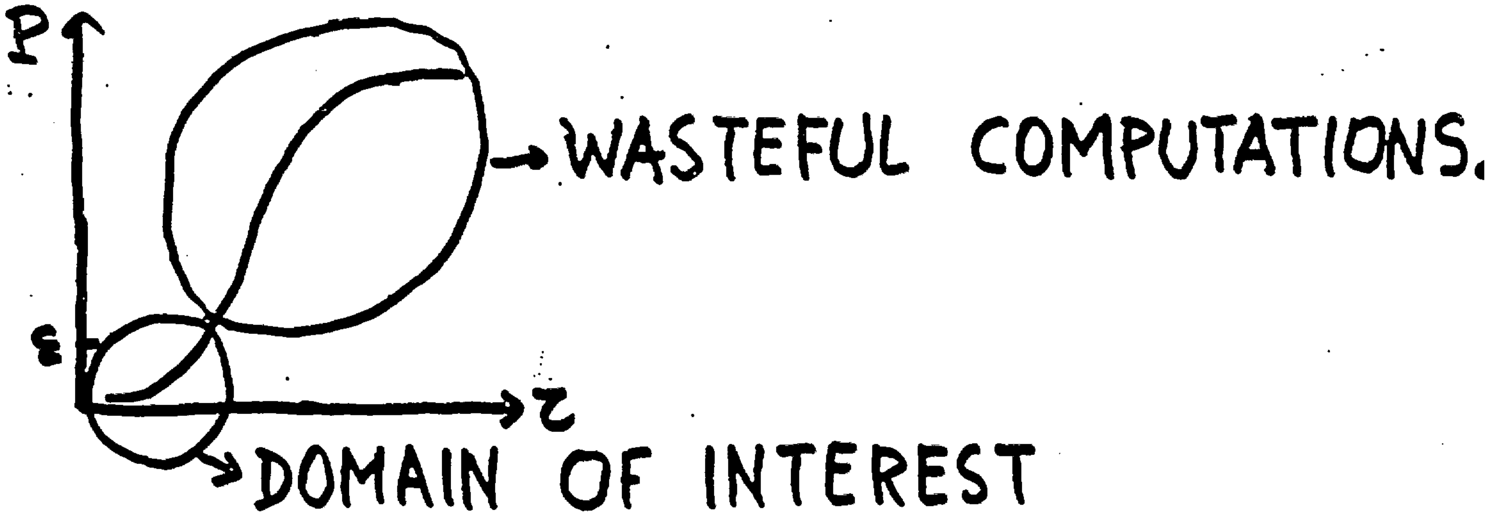
*** (i) ACCURACY OF NUMERICAL SCHEME FOR LARGE σ_Y^2 (ILLUSTRATION)

TASKS: - DEVLP. OF ADEQUATE SCHEMES
- DERIVATION OF BENCHMARK

(ii) COSTLY COMPUTATIONS

TASK: DEVLP. OF USEFUL APPROX.

(iii) DUE TO SPATIAL VAR. AND ESTIMATION ERRORS VERY LARGE NUMBER OF REALIZATIONS TO GET $P(\tau)$ ENTIRELY.



TASK: REDUCE NUMBER OF REALIZATIONS FULLY SOLVED.

(iv) DISTANT BOUNDARIES → LARGE NUMBER OF NODES IN REMOTE AREAS

TASK: SCHEMES TO IMPROVE TREATMENT OF BOUNDARIES.

THE IMMEDIATE TASK IS TO DEVELOP METHODOLOGY TO PROVIDE GUIDELINES FOR OPTIMAL DESIGN OF FIELD TESTS TO REDUCE UNCERTAINTY.

THE ESSENCE OF THE PROPOSED METHODOLOGY: COMBINATION OF GEOSTATISTICAL APPROACH + SIMPLIFIED TRANSPORT MODELS.

START WITH A-PRIORI CONSERVATIVE ESTIMATES OF PARAMETERS AND TRANSP. MODEL. DERIVE $P(\tau)$

↓

BY GEOSTATISTICAL METHODS INFER THE PARAMETERS DISTRIBUTION DUE TO ADDITIONAL MEASUREMENTS OF T, ϕ, n_e (ILLUSTRATION FOR WANAPUM).

↓

COMPUTE $P(\tau)$ BY APPROX. METHOD AND OPTIMIZE MEASUREMENTS TOWARD REDUCTION OF UNCERTAINTY

↓

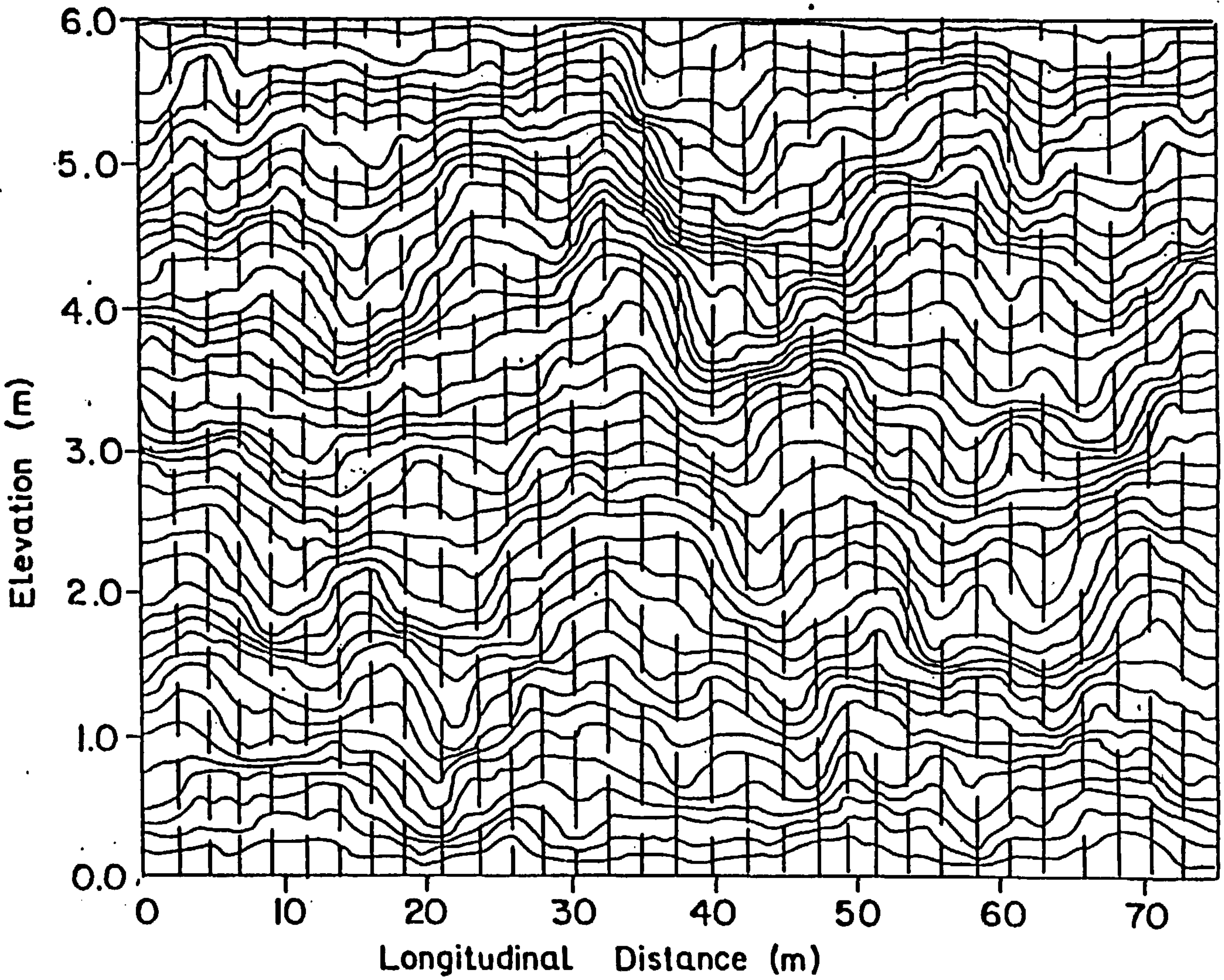
UPDATE PARAMETERS AFTER FIRST FIELD MEASUREMENTS ARE OBTAINED

↓

STOP IF FURTHER REDUCTION IS MARGINAL OR IF QUALIFYING CRITERION IS SATISFIED AMPLY

↓

USE FULL-BLOWN MONTE-CARLO SIMULATION TO VALIDATE COMPUTATIONS.


6.0
5.0
4.0
3.0
2.0
1.0
0.0
Elevation (m)
0
10
20
30
40
50
60
70
Longitudinal Distance (m)

SUMMARY OF PROPOSED STRATEGY FOR FUTURE INVESTIGATIONS

LONG RANGE

- DEVELOPMENT OF NUMERICAL SCHEMES TO TACKLE FLOW IN HETEROGENEOUS FORMATIONS OF LARGE σ_Y^2
- DERIVATION OF BENCHMARK FOR TRANSPORT
- DEVELOPMENT OF APPROX. SOLUTION OF TT COMPUTATION
- DEVLP. OF EFFICIENT MONTE CARLO PROCEDURES TAILORED TO TT

SHORT RANGE

- INTEGRATION OF GEOSTATISTICAL METH. OF PARAMETERS ESTIMATION AND SIMPLE EVALUATION OF $P(\tau)$
- DEVLP. OF PROCEDURE TO OPTIMIZE FIELD MEASUREMENT DISTRIBUTION TO REDUCE UNCERTAINTY OF τ
- APPLICATION TO HANFORD SITE PROGRAM

STOCHASTIC ESTIMATION OF TRANSMISSIVITY AND HEAD FIELDS

ISSUE: ARE AVAILABLE HEAD AND TRANSMISSIVITY FIELD MAPPINGS AT HANFORD RELIABLE?

<u>APPROACH</u>: SOLVE THE INVERSE PROBLEM

$$\frac{\partial}{\partial x}\left(T_x \frac{\partial \phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_y \frac{\partial \phi}{\partial y}\right) = 0 \qquad (1)$$

+ BOUNDARY CONDITIONS

GIVEN: $\phi(a_i)$ $i = 1,\ldots,m$

$T(b_j)$ $j = m+1,\ldots,n$

STOCHASTIC APPROACH

BASIC IDEAS

$\phi(\underline{x})$ AND $T(\underline{x})$ SPACE RANDOM FUNCTIONS

$\phi(a_i)$ AND $T(b_j)$ BELONG TO A REALIZATION OF $\phi(\underline{x})$ AND $T(\underline{x})$

TWO MAIN STEPS

1. SELECTION OF A GEOSTATISTICAL STRUCTURE AND ESTIMATION OF MODEL PARAMETERS

2. LINEAR ESTIMATION THEORY IS APPLIED TO PROVIDE MINIMUM VARIANCE AND UNBIAZED ESTIMATES OF HYDRAULIC HEAD AND TRANSMISSIVITY

SPECIFIC METHODOLOGY

1. IDENTIFICATION OF PARAMETERS OF SELECTED MODEL FOR GEOSTATISTICAL STRUCTURE

BASIC ASSUMPTIONS

(a) $Y = LnT$ SPACE RANDOM FUNCTION

FIRST MOMENT $E[Y_i] = F$

SECOND MOMENT

$$Cov(Y_i, Y_j) = \theta_1 \delta_{ij} + \theta_2 \exp(-d_{ij}/I) \qquad (2)$$

(b) A TWO-DIMENSIONAL MODEL OF A CONFINED AQUIFER UNDER STEADY FLOW CONDITION WITH NO LEAKAGE IS ASSUMED

(c) FIRST-ORDER APPROXIMATION OF THE FLOW EQUATION

$$Y = F + f$$

$$\phi = H + h$$

ZERO-ORDER EQUATION

$$\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2} = 0 \qquad (3)$$

SECOND-ORDER EQUATION

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = - \frac{\partial f}{\partial x} \frac{\partial H}{\partial x} - \frac{\partial f}{\partial y} \frac{\partial H}{\partial y} \qquad (4)$$

* PRIOR EXPECTED VALUE OF THE PIEZOMETR HEAD H OBTAINED BY SOLVING EQUATION (3), SUBJECT TO BOUNDARY CONDITIONS

* FOLLOWING A FINITE DIFFERENCE APPROACH, EQUATION (4) IS DICRETIZED AS

$$Ah = Bf + Ch_B$$

AND USED TO EXPRESS THE COVARIANCE MATRIX BETWEEN MEASUREMENTS

$$Q = \theta_1 \begin{bmatrix} R_{\phi\phi} & R_{\phi Y} \\ R_{Y\phi} & R_{YY} \end{bmatrix} + \theta_2 \begin{bmatrix} S_{\phi\phi} & S_{\phi Y} \\ S_{Y\phi} & S_{YY} \end{bmatrix} + \begin{bmatrix} P_{\phi\phi} & 0 \\ 0 & 0 \end{bmatrix} \qquad (2)$$

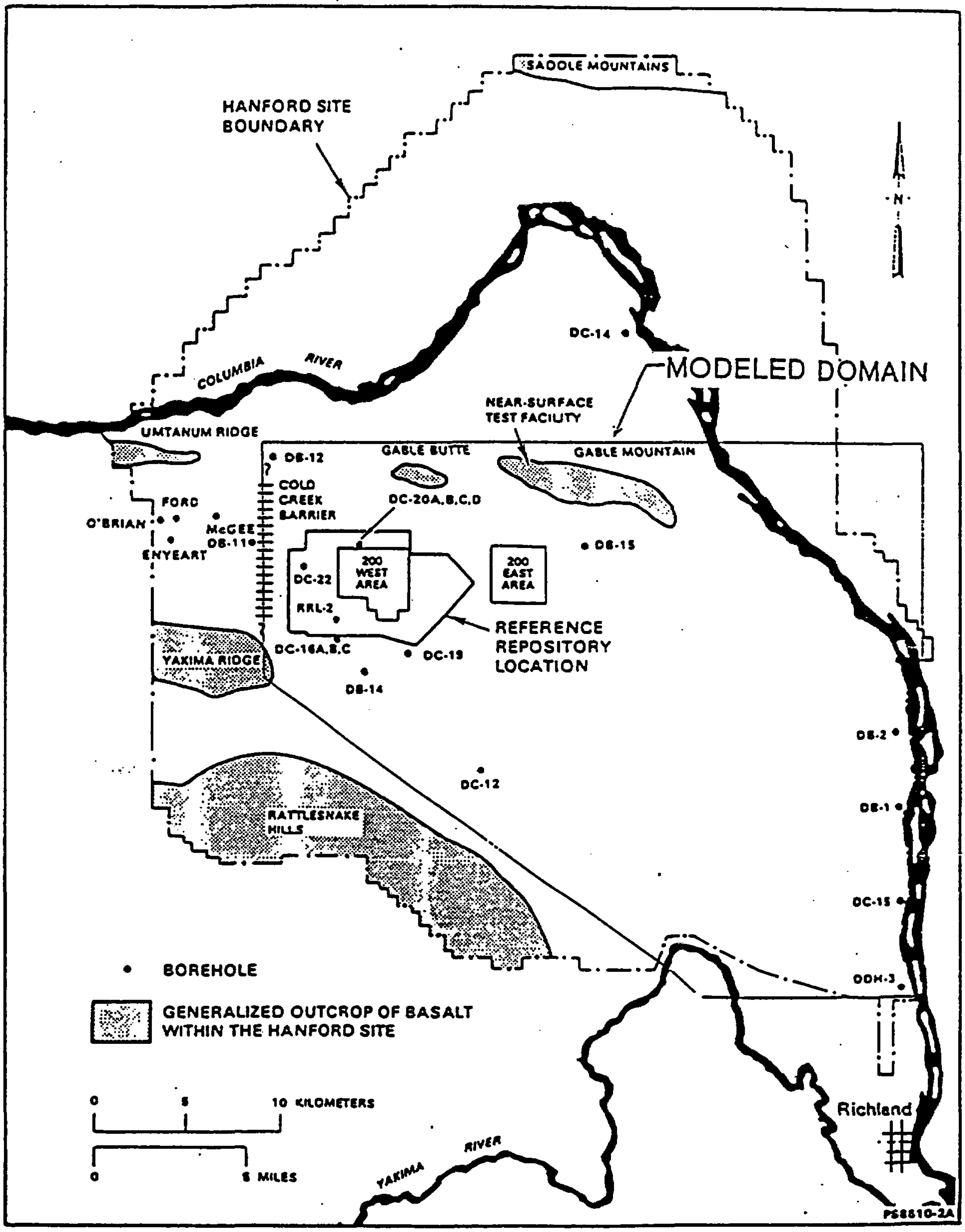
(d) MODEL PARAMETER ESTIMATION

MAXIMUM LIKELIHOOD PROCEDURE IS USED TO ESTIMATE θ_1 AND θ_2

2. ESTIMATION OF HYDRAULIC HEAD AND TRANSMISSIVITY

- LINEAR ESTIMATION THEORY (COKRIGING) IS APPLIED TO ESTIMATE HYDRAULIC HEAD AND TRANSMISSIVITY

FIGURE 1 : LOCATION MAP FOR SELECTED BOREHOLES



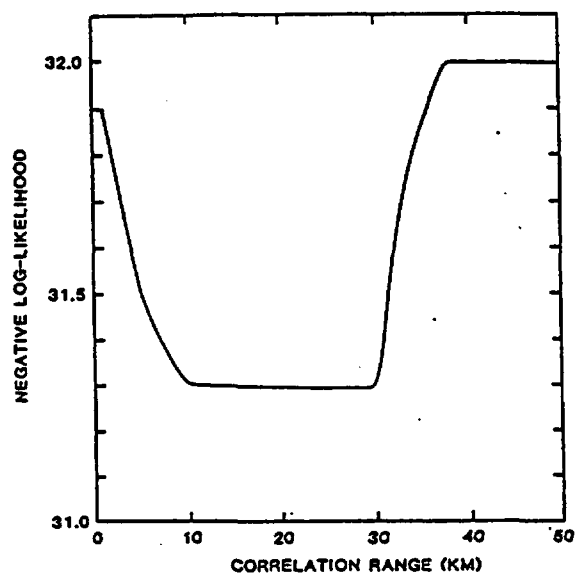
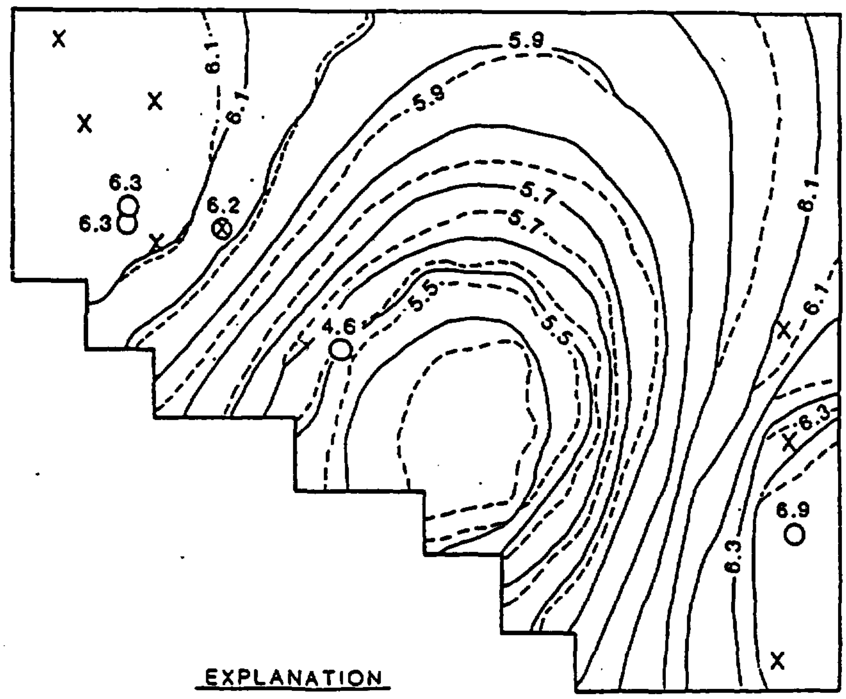


FIGURE 2 : NEGATIVE LOG-LIKELIHOOD OF PARAMETERS θ_1 AND θ_2 AS A FUNCTION OF THE TRANSMISSIVITY CORRELATION RANGE.

FIGURE 3 : PREDICTION OF LN TRANSMISSIVITY FIELD
(CORRELATION RANGE 30 AND 10 KM)



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

—— 6.1 —— LN(T) (l=10 KM) CONTOUR .

- - - 5.9 - - - LN(T) (l=30 KM) CONTOUR

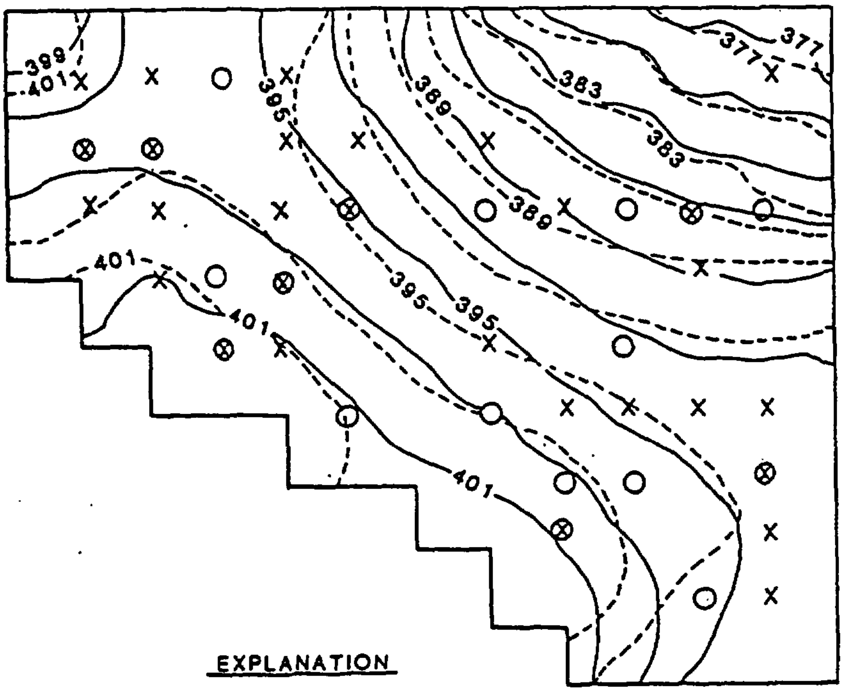
N

SCALE

0 5 10 15 MILES

0 5 10 15 20 KILOMETERS

FIGURE 4 : PREDICTION OF HYDRAULIC HEAD FIELD USING 30 HEAD AND 20 TRANSMISSIVITY MEASUREMENTS



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

-- 401 -- HYDRAULIC HEAD TO BE PREDICTED (FT)

— 395 — EXPECTED HYDRAULIC HEAD FIELD USING 30 HEAD AND 20 TRANSMISSIVITY MEASUREMENTS (FT)

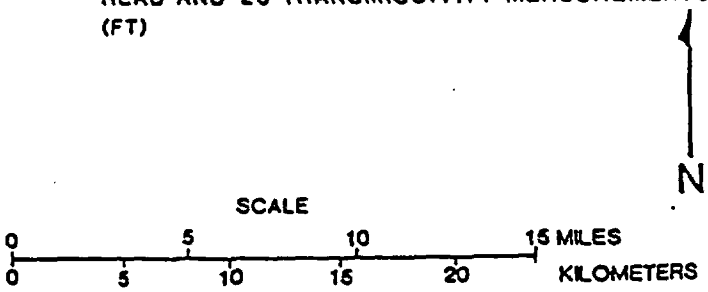


FIGURE 5 : PREDICTION OF HYDRAULIC HEAD FIELD USING
18 HEAD AND 12 TRANSMISSIVITY MEASUREMENT

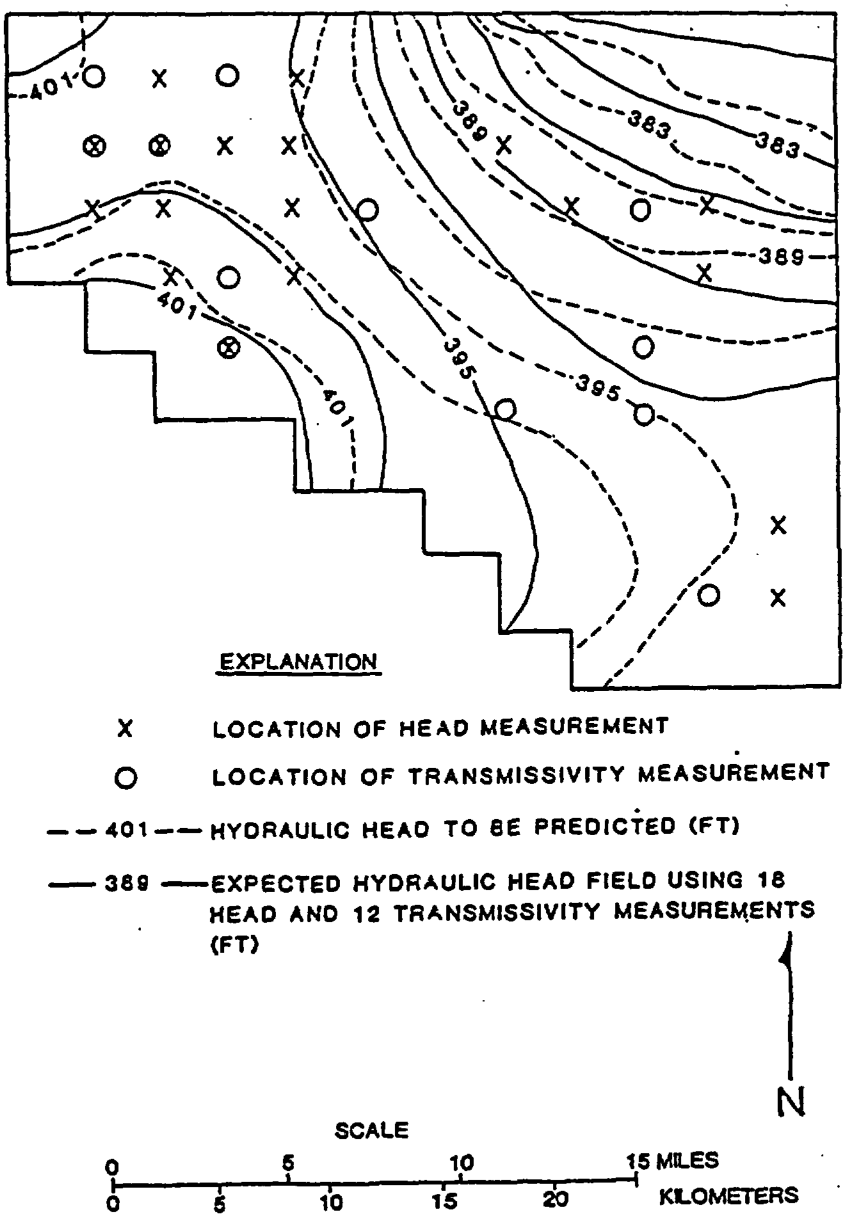
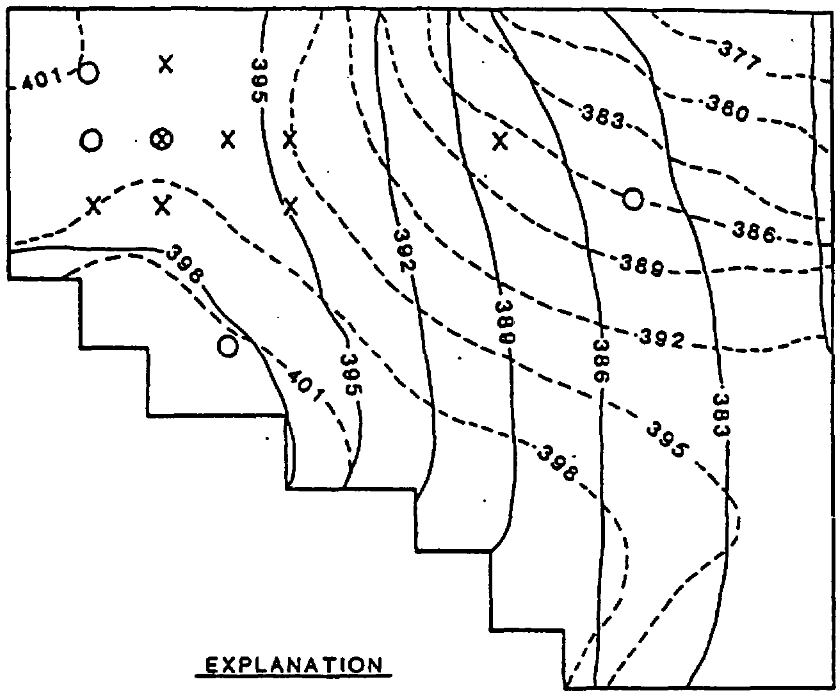


FIGURE 6 : PREDICTION OF HYDRAULIC HEAD FIELD USING 8 HEAD AND 5 TRANSMISSIVITY MEASUREMENTS



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

--- 401 --- HYDRAULIC HEAD TO BE PREDICTED (FT)

—— 397 —— EXPECTED HYDRAULIC HEAD FIELD USING 8 HEAD AND 5 TRANSMISSIVITY MEASUREMENTS (FT)

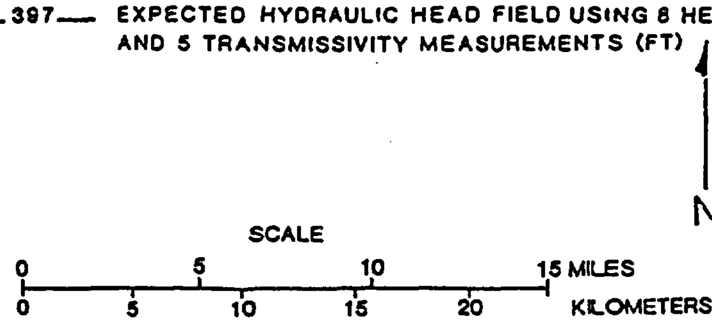
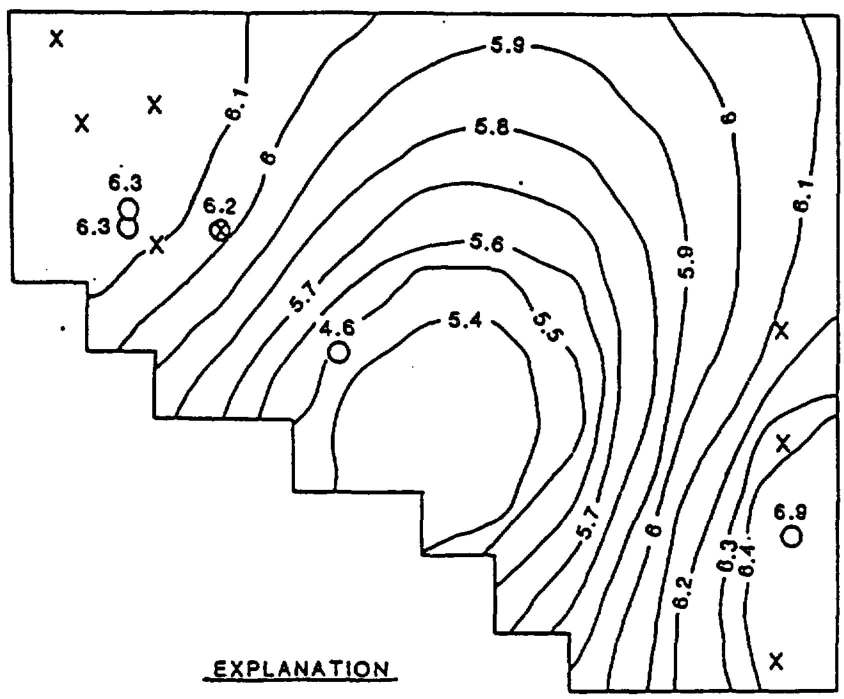


FIGURE 7 : PREDICTION LN TRANSMISSIVITY FIELD
(CORRELATION RANGE 30 KM)



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

—— 5.5 —— LN(T) (l=30 KM) CONTOUR

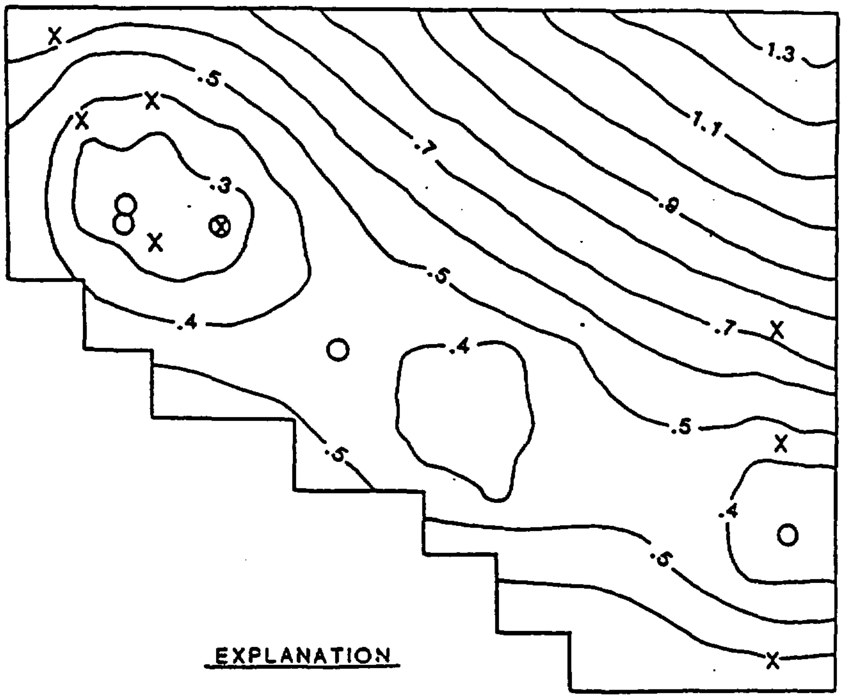
N

SCALE

0 5 10 15 MILES

0 5 10 15 20 KILOMETERS

FIGURE 8 : VARIANCE OF ESTIMATION ERROR FOR COKRIGED LOG TRANSMISSIVITY FIELD (CORRELATION RANGE 30 KM)



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

— .4 — CONTOUR OF VARIANCE OF ESTIMATION ERROR

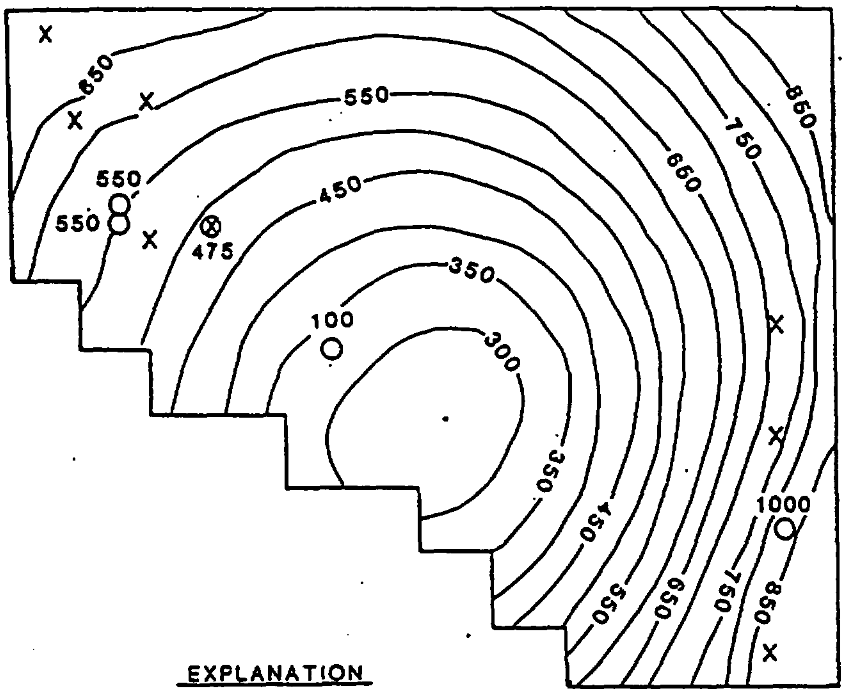
N

SCALE

0 5 10 15 MILES

0 5 10 15 20 KILOMETERS

FIGURE 9 : EXPECTED TRANSMISSIVITY FIELD (CORRELATION RANGE 30 KM)



EXPLANATION

X	LOCATION OF HEAD MEASUREMENT
O	LOCATION OF TRANSMISSIVITY MEASUREMENT
550	TRANSMISSIVITY MEASUREMENT (FT^2/DAY)
— 450 —	TRANSMISSIVITY CONTOUR (FT^2/DAY)

N

SCALE

0 5 10 15 MILES

0 5 10 15 20 KILOMETERS

FIGURE 10 : UPPER 95% TRANSMISSIVITY CONFIDENCE LIMIT
(CORRELATION RANGE 30 KM)

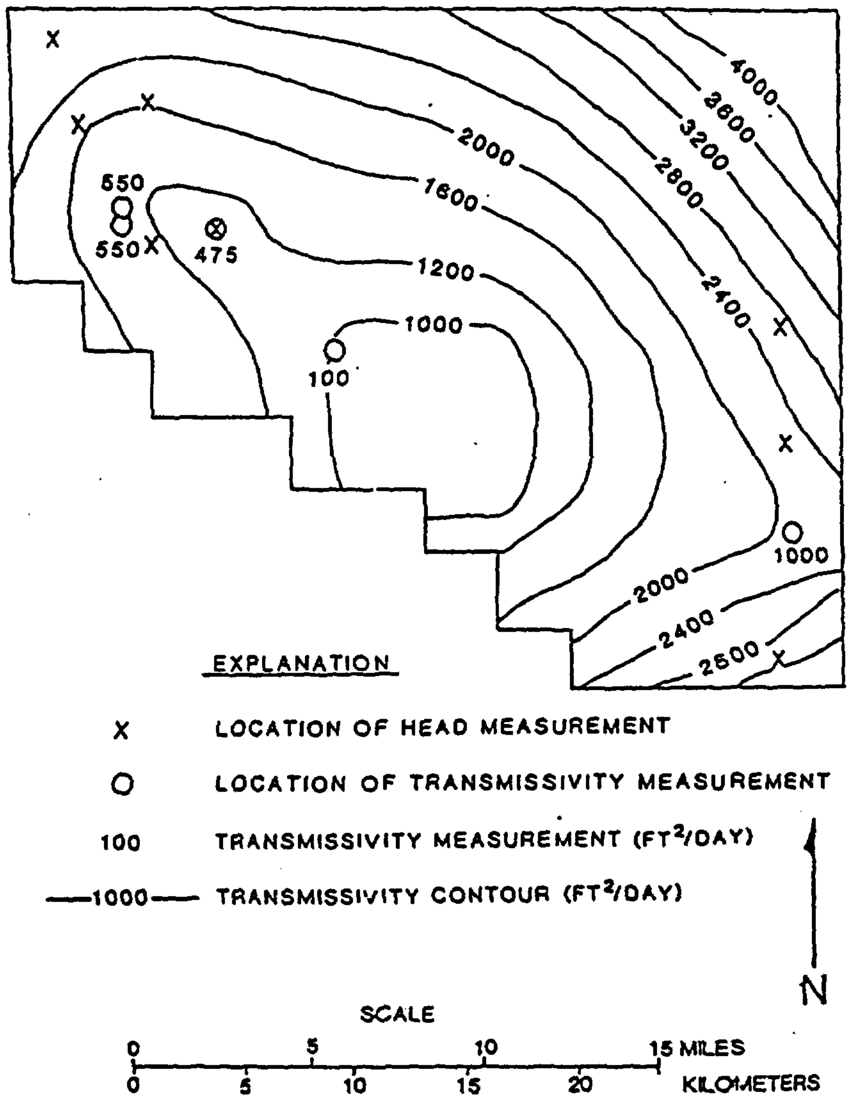


FIGURE 11 : LOWER 95% TRANSMISSIVITY CONFIDENCE LIMIT
(CORRELATION RANGE 30 KM)

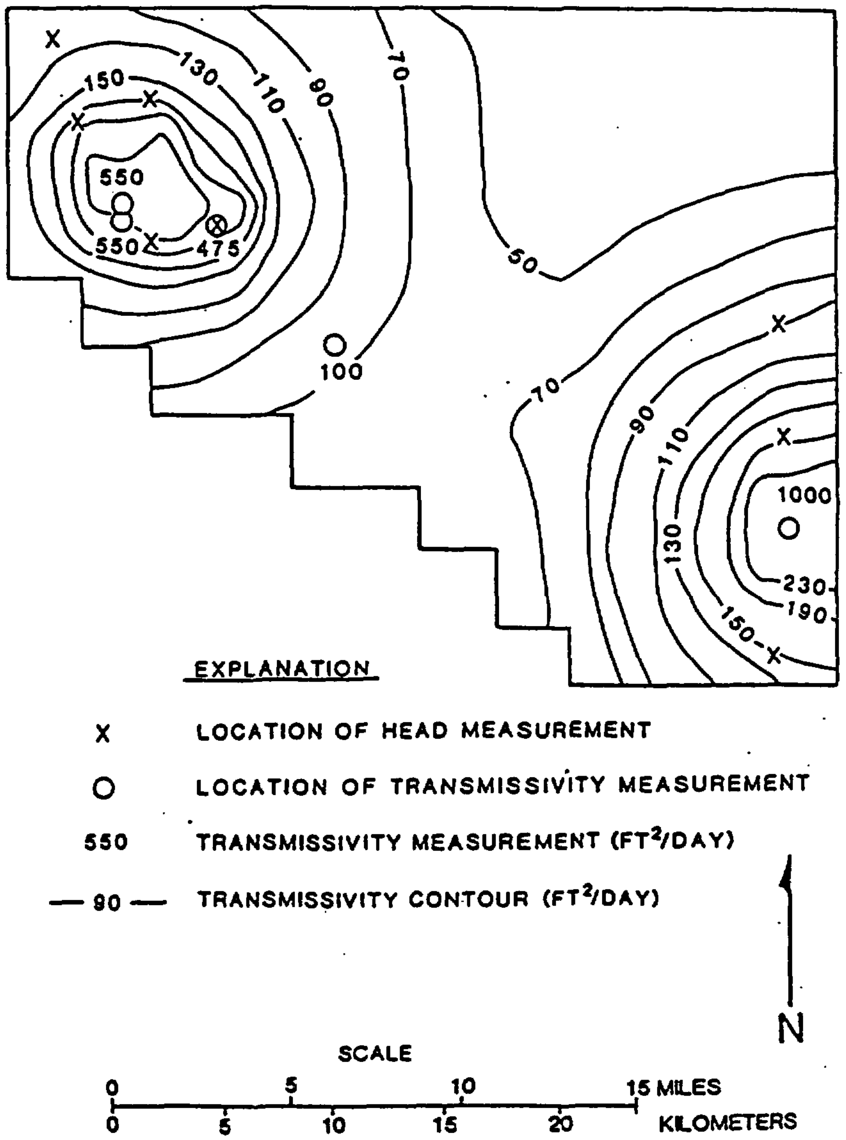


FIGURE 12 : EXPECTED HEAD FIELD (CORRELATION RANGE 30 KM)

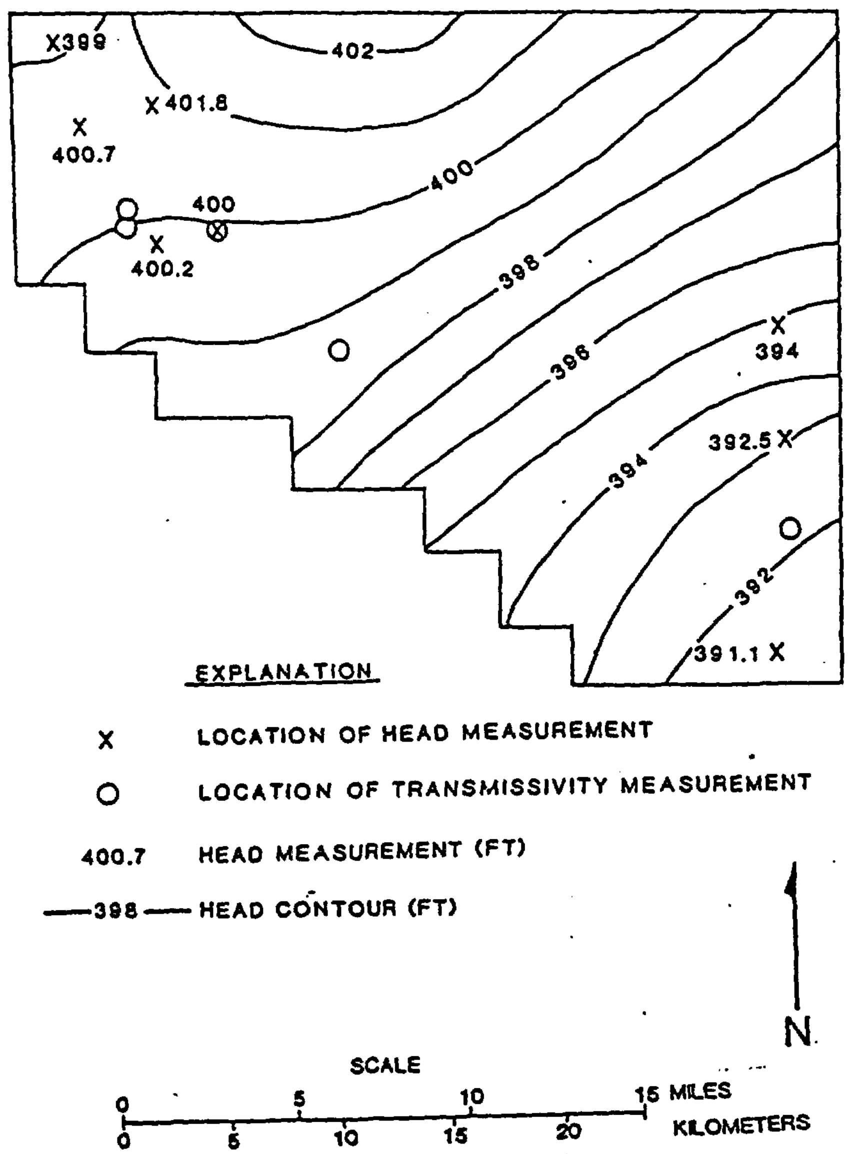
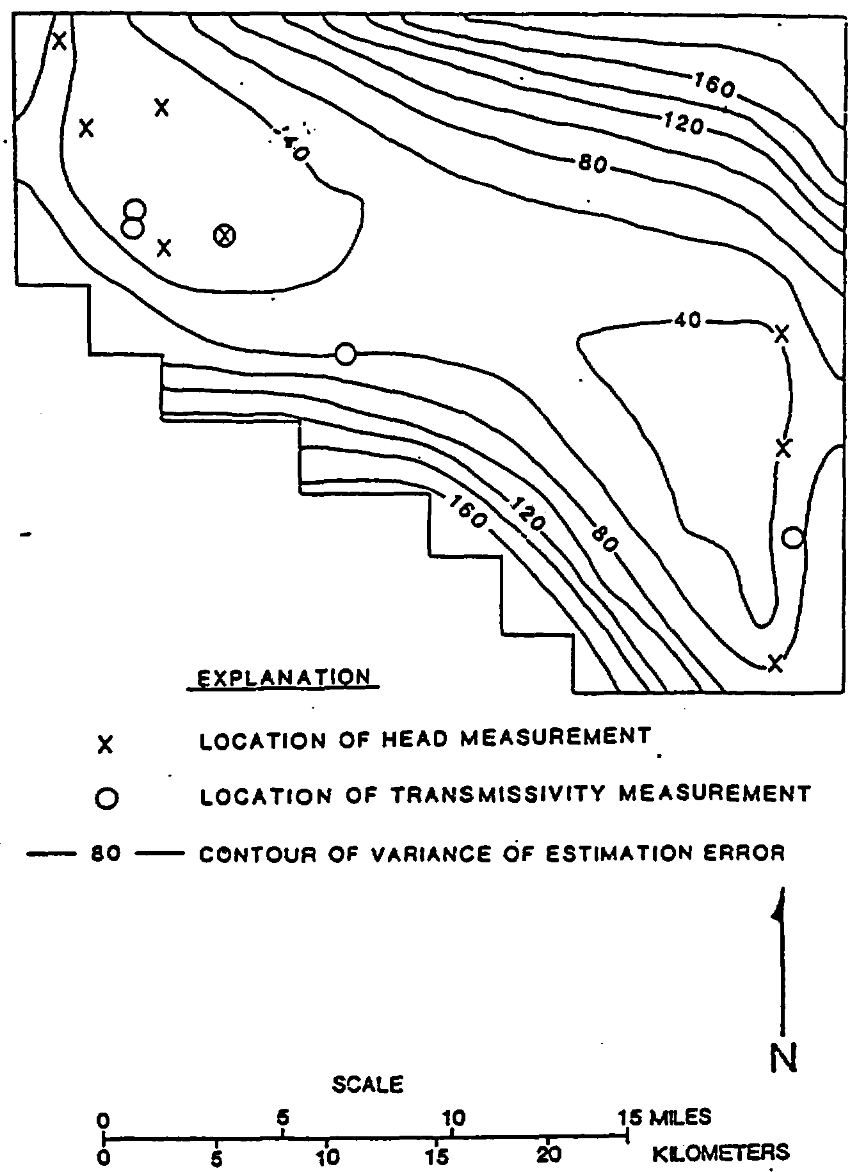


FIGURE 13 : VARIANCE OF ESTIMATION ERROR FOR COKRIGED HEAD FIELD (CORRELATION RANGE 30 KM).



SUMMARY OF POSITIONS

1. HEAD AND HYDRAULIC FIELD MAPPING AVAILABLE TO DATE IS NOT RELIABLE

2. THERE HAS NOT BEEN A SYSTEMATIC FRAMEWORK TO ANALYZE EXISTING DATA IN A MANNER WHICH QUANTIFIES UNCERTAINTY AND CONSEQUENTLY IMPROVE THE GROUNDWATER TRAVEL TIME ESTIMATES

3. LARGE-SCALE HYDRAULIC STRESS TEST AND THE SITE CHARACTERIZATION PLAN MUST TAKE INTO ACCOUNT THE NEED FOR MONITORING NETWORK OPTIMIZATION AND MEANINGFULL INTERPRETATION OF THE DATA BASE

4. THE DOE SHOULD SHOW THAT THE CURRENT HYDROGEOLOGIC PROGRAM AT HANFORD ULTIMATELY AIMS AT THE REDUCTION OF THE UNCERTAINTY IN THE EVALUATION OF THE DISQUALIFYING CONDITIONS

UNLESS NECCESSARY STEPS ARE TAKEN TO ADDRESS THE ABOVE, THE SITE CHARACTERIZATION ACTIVITIES WOULD NOT BE ABLE TO RESOLVE THE BASIC PROBLEM OF SITE SUITABILITY

ANALYSIS OF TWO WELL TRACER TESTS

ANALYSTS	TEST #1		TEST #2	
	α_L	EFFECT. POR.	α_L	EFFECT. POR.
HydroGeoLogic				
Using Gelhar's $T_{up}+T_{down}$	1.5 ft	4.2×10^{-4}		
Using our $T_{up}+T_{down}$	1.5 ft	2.9×10^{-4}	1.5 ft	1.5×10^{-4}
Gelhar#1/Rockwell#2	1.96 ft	2.1×10^{-4}	2.76 ft	1.2×10^{-4}
SAI	0.78 ft	4.3×10^{-4}	N.A.	N.A.

CONCLUSIONS

- TRAVEL TIME IN WELLS AND PIPING HAS CRITICAL IMPACT ON ANALYSIS OF BREAKTHROUGH CURVES
- ACCURATE MEASUREMENT OF FLOW RATES AND VOLUMES OF WELL BORES IS CRITICAL IN DETERMINING ACCURATE VALUES OF DISPERSIVITY AND EFFECTIVE POROSITY
- THE SECOND PEAK IS THE RESULT OF TRACER RECIRCULATION AND ITS TIME OF OCCURRENCE IS CONTROLLED PRIMARILY BY TRAVEL TIME IN THE WELL BORES
- TO ACCURATELY SIMULATE RECIRCULATION EFFECTS, A COMPOSITE (WELL BORE-FORMATION) MODEL IS NEEDED
- EFFECTS OF MATRIX DIFFUSION ARE PROBABLY INSIGNIFICANT FOR THE TWO TESTS ANALYZED BUT MIGHT BE SIGNIFICANT IN A LARGER SCALE, LONGER TERM TEST
- THE TWO TESTS ANALYZED WERE NOT DESIGNED AND CONDUCTED IN A MANNER WHICH WOULD REFLECT EFFECTS OF MATRIX DIFFUSION.
- LONGER TERM AND/OR LARGER SCALE TESTS ARE NECESSARY TO DETECT MATRIX DIFFUSION AND TO EVALUATE ITS CONTROLLING PARAMETERS
- VALUES OF DISPERSIVITY AND EFFECTIVE POROSITY DETERMINED FROM THE PRESENT NUMERICAL MODELING RESULTS
- THE PRESENT ANALYSIS OF THE TRACER TEST YIELDS DISPERSIVITY AND EFFECTIVE POROSITY VALUES THAT ARE MORE CONSISTENT BETWEEN THE TWO TESTS THAN PREVIOUS ANALYSES AND IN CLOSER AGREEMENT TO THE FIELD DATA

HYDROGEOLOGICAL ANALYSIS OF HEAD FIELDS

PURPOSE

* DELINEATION OF HORIZONTAL GROUNDWATER FLOW

* SUFFICIENCY OF DATA

* RELIABILITY OF EXTRAPOLATED INFORMATION

SCP (CHAPTER 3, p 3.9-20) :

"Currently, sufficient areal hydraulic head data are available to construct potentiometric maps for the Mabton interbed..."

METHODOLOGY

* USE GEOSTATISTICAL APPROACHES TO ANALYZE THE DATA AND INTERPOLATE AT LOCATIONS WHERE PROPERTIES HAVE NOT BEEN MEASURED

* TWO GENERAL STEPS

  - MODEL IDENTIFICATION

    + IDENTIFY THE GEOSTATISTICAL MODEL THAT REPRESENTS THE SPATIAL STRUCTURE OF THE DATA

  - INFERENCE

    + USE THE IDENTIFIED MODEL TO INTERPOLATE PROPERTIES AT LOCATIONS WHERE NO MEASUREMENT IS AVAILABLE

    + PROVIDE A MEASURE OF THE ERROR OF ESTIMATION (RELIABILITY OF PREDICTIONS)

GEOSTATISTICAL APPROACHES

* TWO GEOSTATISTICAL APPROACHES WERE USED TO CONSTUCT POTENTIOMETRIC MAP AT HANFORD

  - KRIGING

    + USE ONLY HYDRAULIC HEAD MEASUREMENTS FOR MODEL IDENTIFICATION AND INFERENCE

  - COKRIGING

    + USE BOTH HYDRAULIC HEAD AND TRANSMISSIVITY MEASUREMENTS, AS WELL AS MAKE USE OF THE FLOW EQUATIONS TO RELATE THE STATISTICS OF THESE TWO GEOSTATISTICAL FIELDS

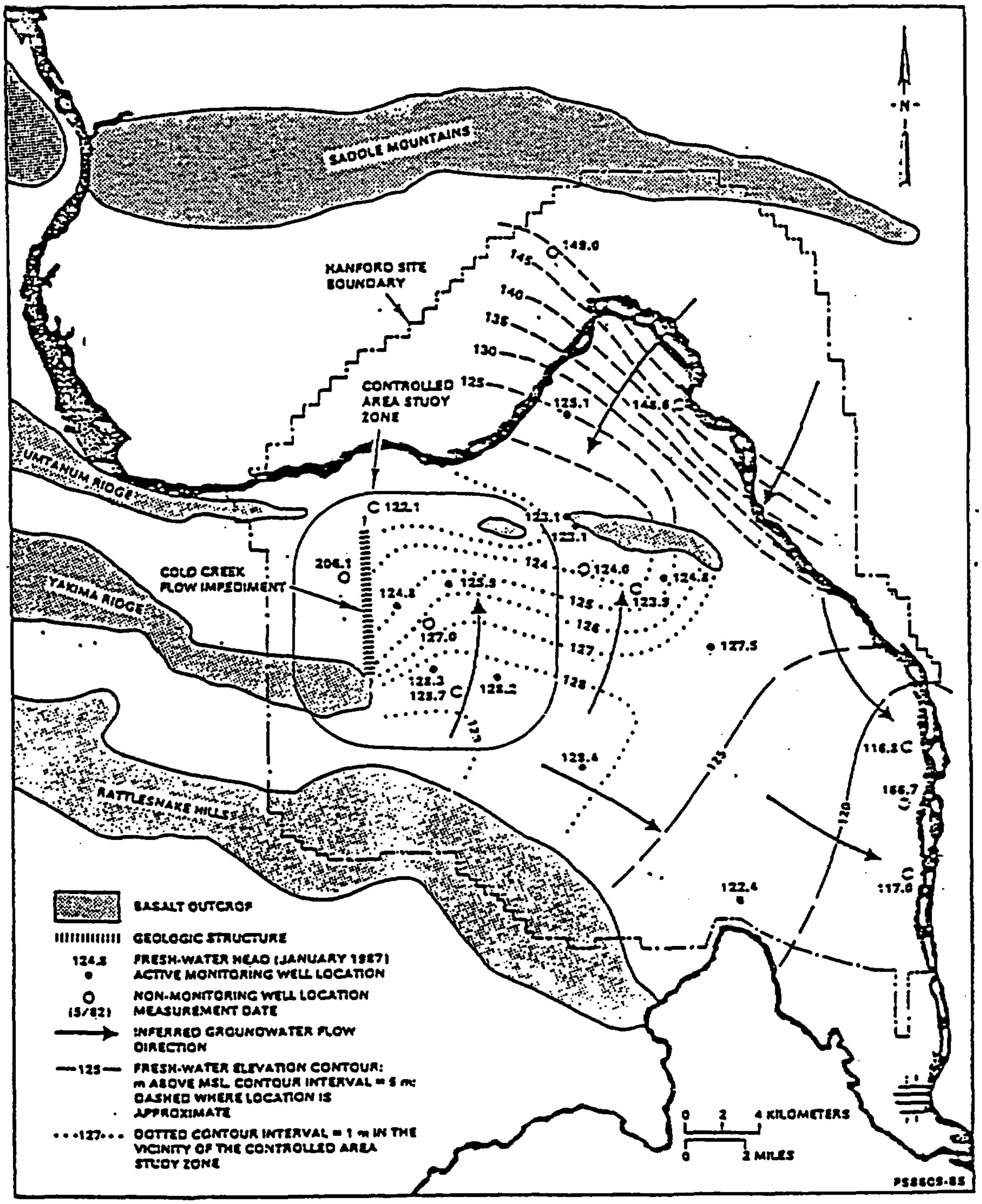


Figure 3.9-20. Freshwater potentiometric map for the Mabton interbed, Hanford Site (adapted from Spane, 1986c). PS8609-85

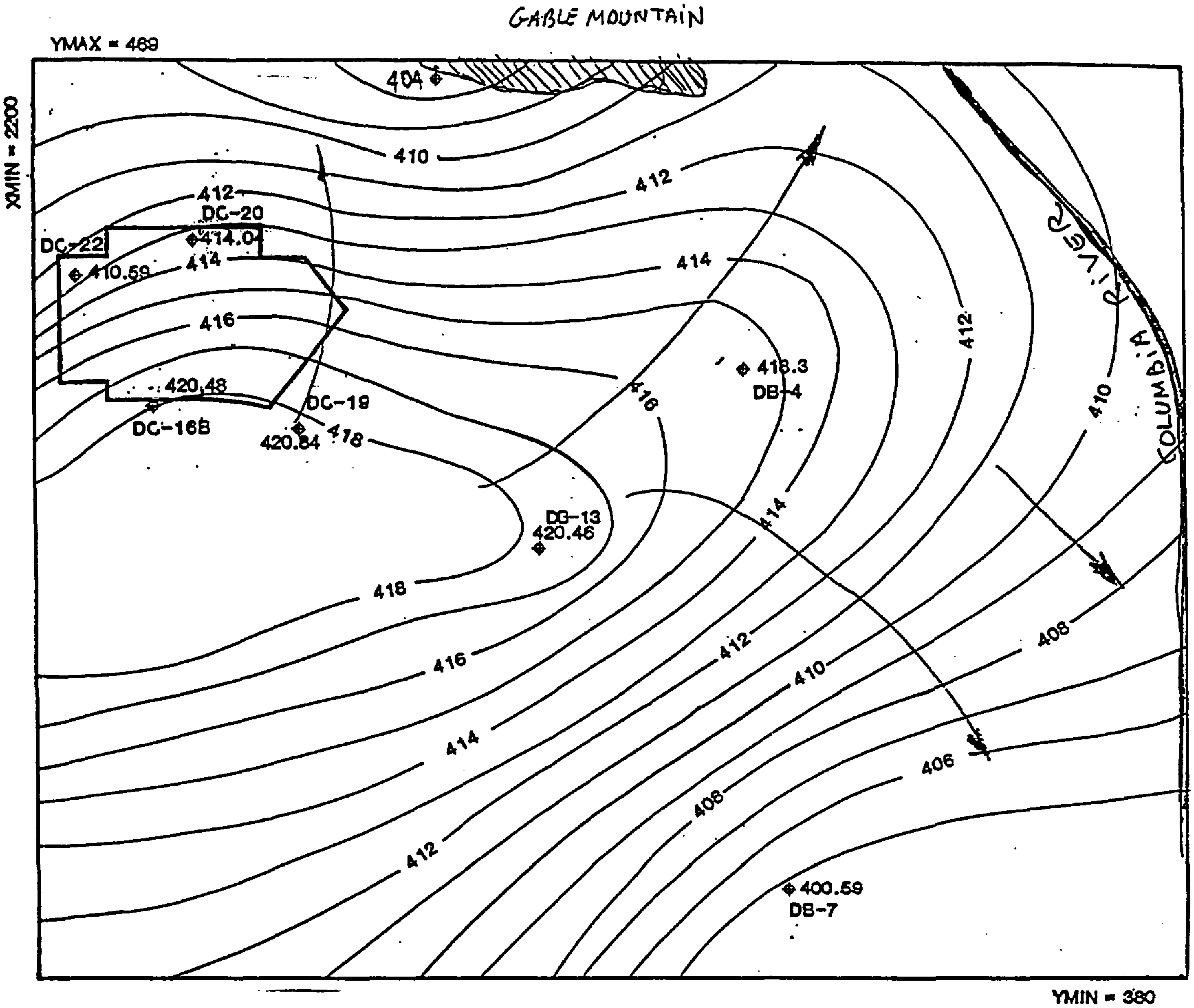


FIGURE 13: MABTON INTERBED
MAP OF HEAD ELEVATIONS

EWA

ENGINEERING FOR EARTH • WATER • AIR RESOURCES

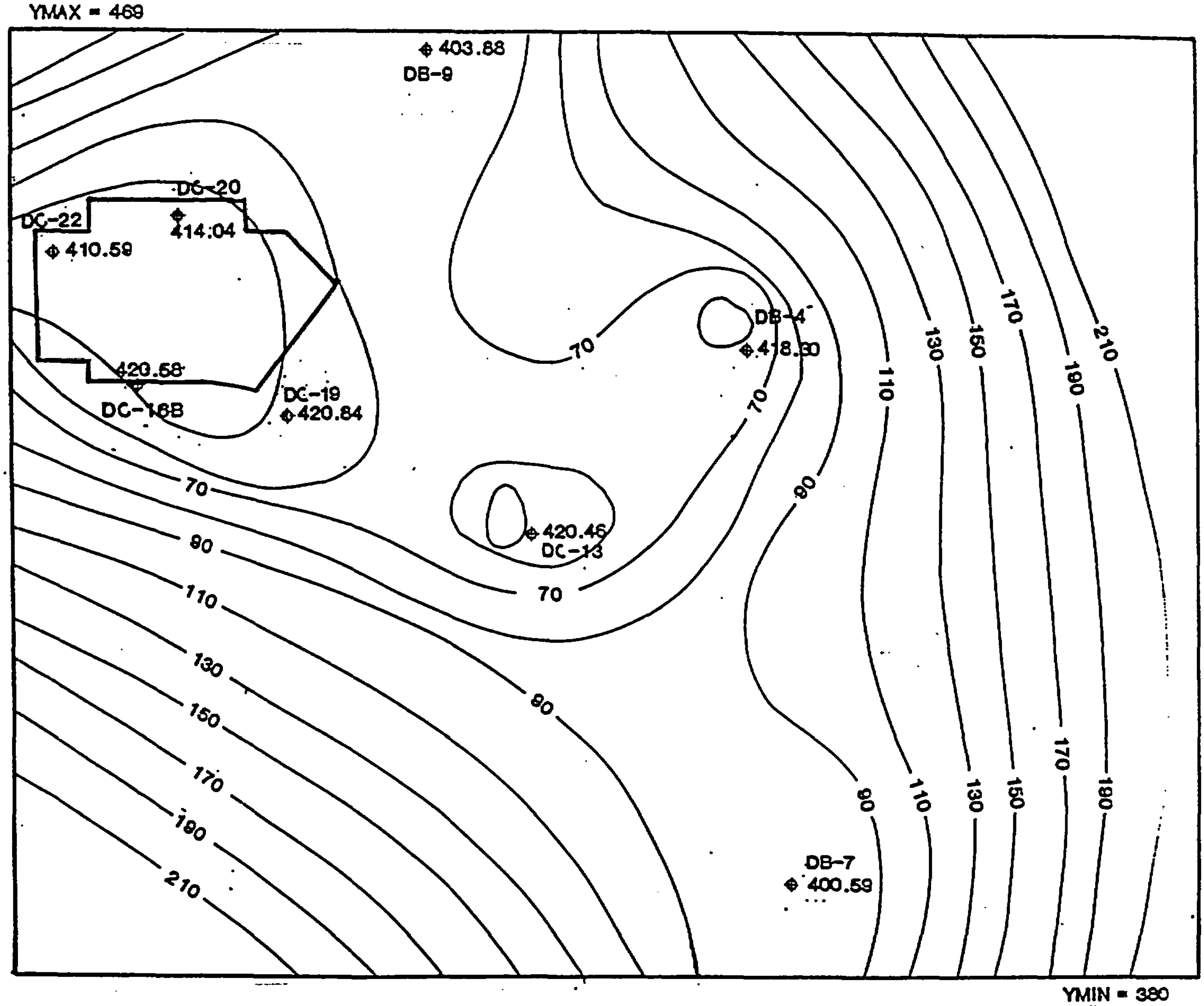


FIGURE 14: MABTON INTERBED

VARIANCE OF ESTIMATION ERROR

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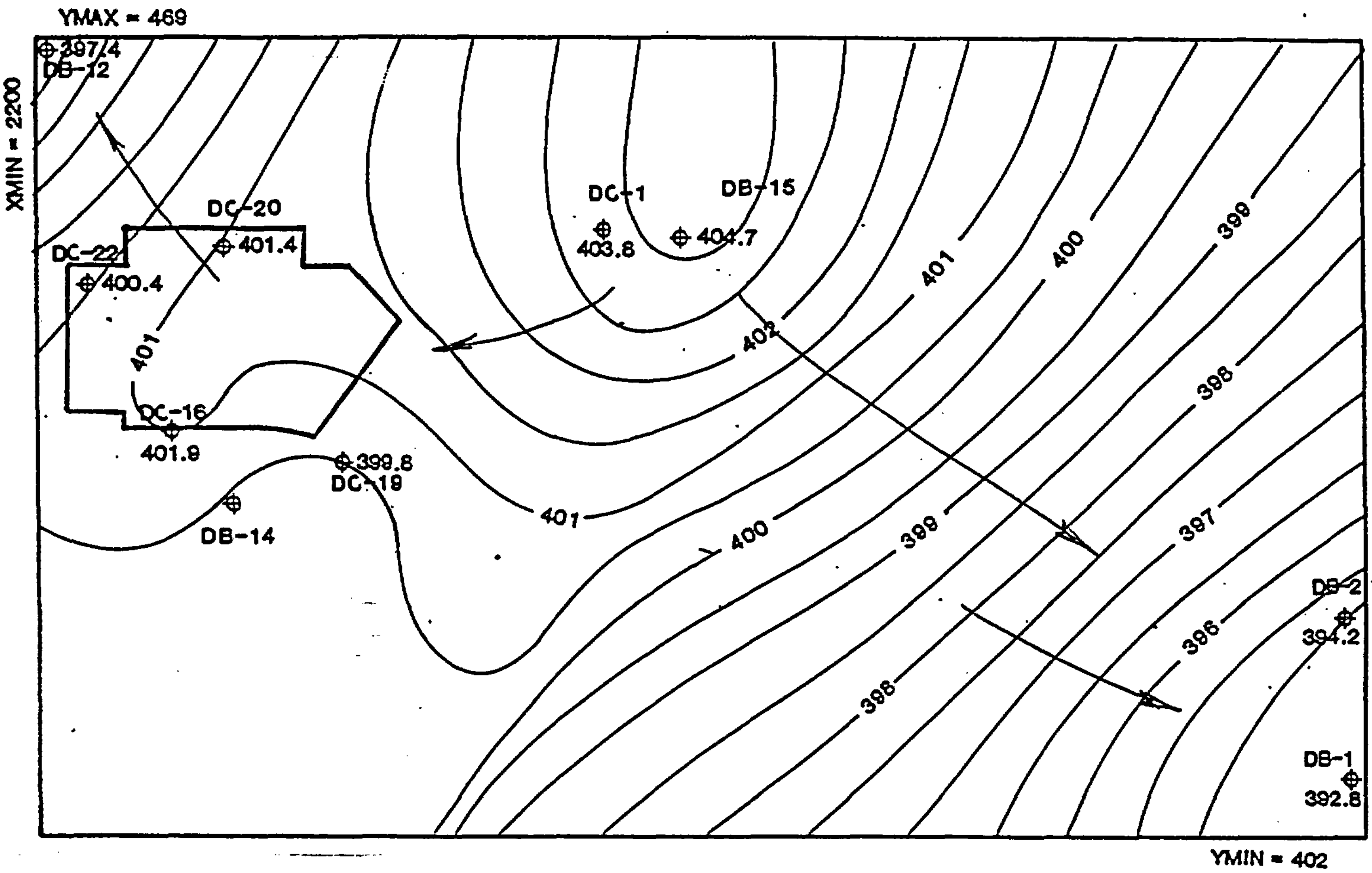

FIGURE 7: WANAPUM (MODEL 3)
MAP OF HEAD ELEVATIONS

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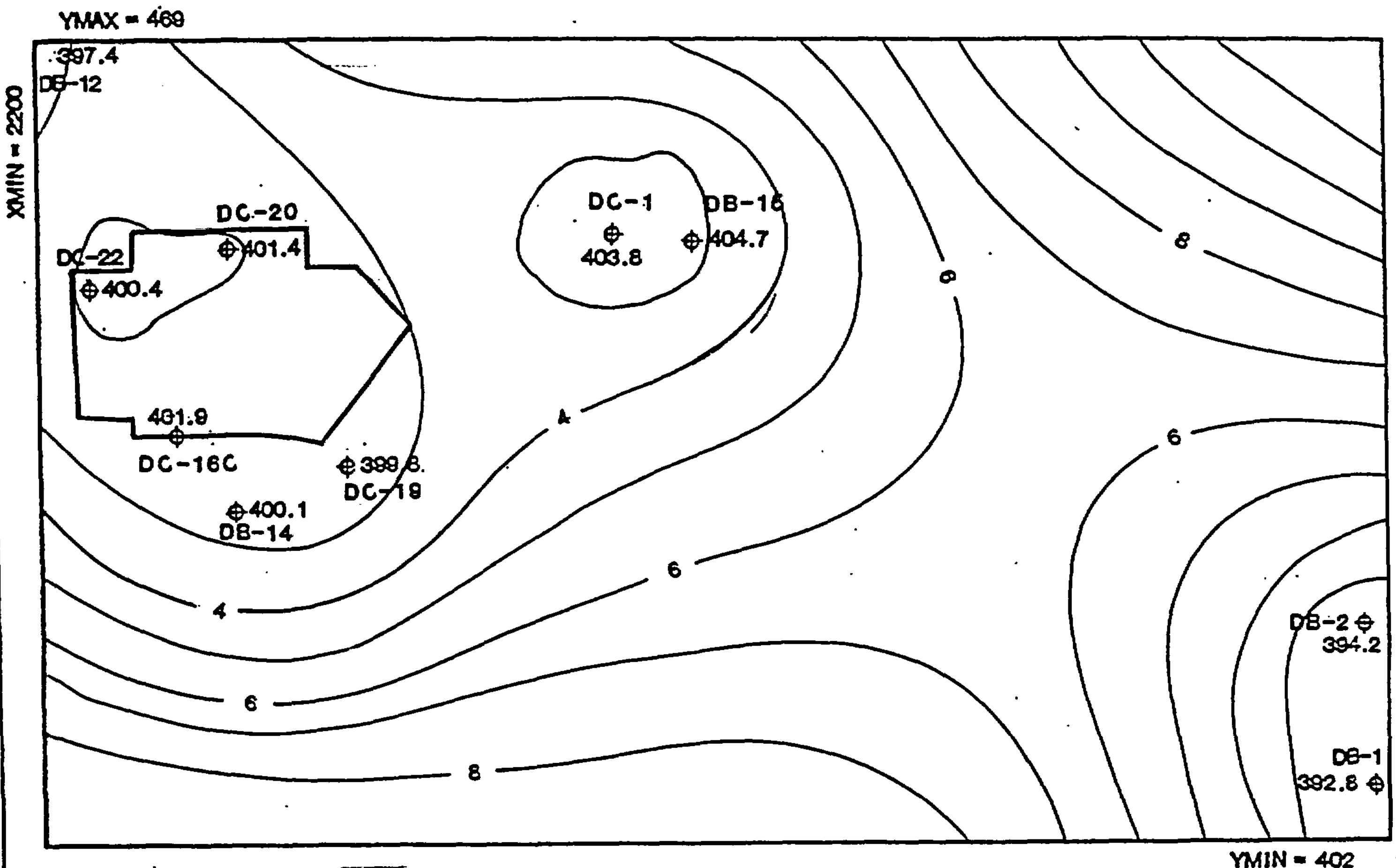


FIGURE 8: WANAPUM (MODEL 3)
VARIANCE OF ESTIMATION ERROR

ENGINEERING FOR EARTH • WATER • AIR RESOURCES

GEOSTATISTICAL APPROACH

USING HYDRAULIC HEAD AND TRANSMISSIVITY MEASUREMENTS

* GENERAL APPROACH: TWO STEPS

* FIRST STEP: IDENTIFICATION OF A GEOSTATISTICAL MODEL

  - SELECT A PARAMETRIC MODEL FOR THE STRUCTURE OF THE LOG-TRANSMISSIVITY RANDOM FIELD
  - RELATE THE RANDOM STRUCTURE OF THE HYDRAULIC HEAD FIELD TO THIS OF THE LOG-TRANSMISSIVITY FIELD USING THE GOVERNING FLOW EQUATIONS
  - ESTIMATE THE UNKNOWN PARAMETERS OF THE MODEL FOR THE LOG-TRANSMISSIVITY STRUCTURE (USING HYDRAULIC HEAD AND TRANSMISSIVITY MEASUREMENTS)
  - VALIDATE THE MODEL USING STATISTICAL TESTS

SECOND STEP: INFERENCE

  - ESTIMATE THE TRANSMISSIVITY AND HYDRAULIC HEAD FIELDS USING THE IDENTIFIED MODEL AND HYDRAULIC HEAD AND TRANSMISSIVITY MEASUREMENTS

FIGURE 1 : LOCATION MAP FOR SELECTED BOREHOLES

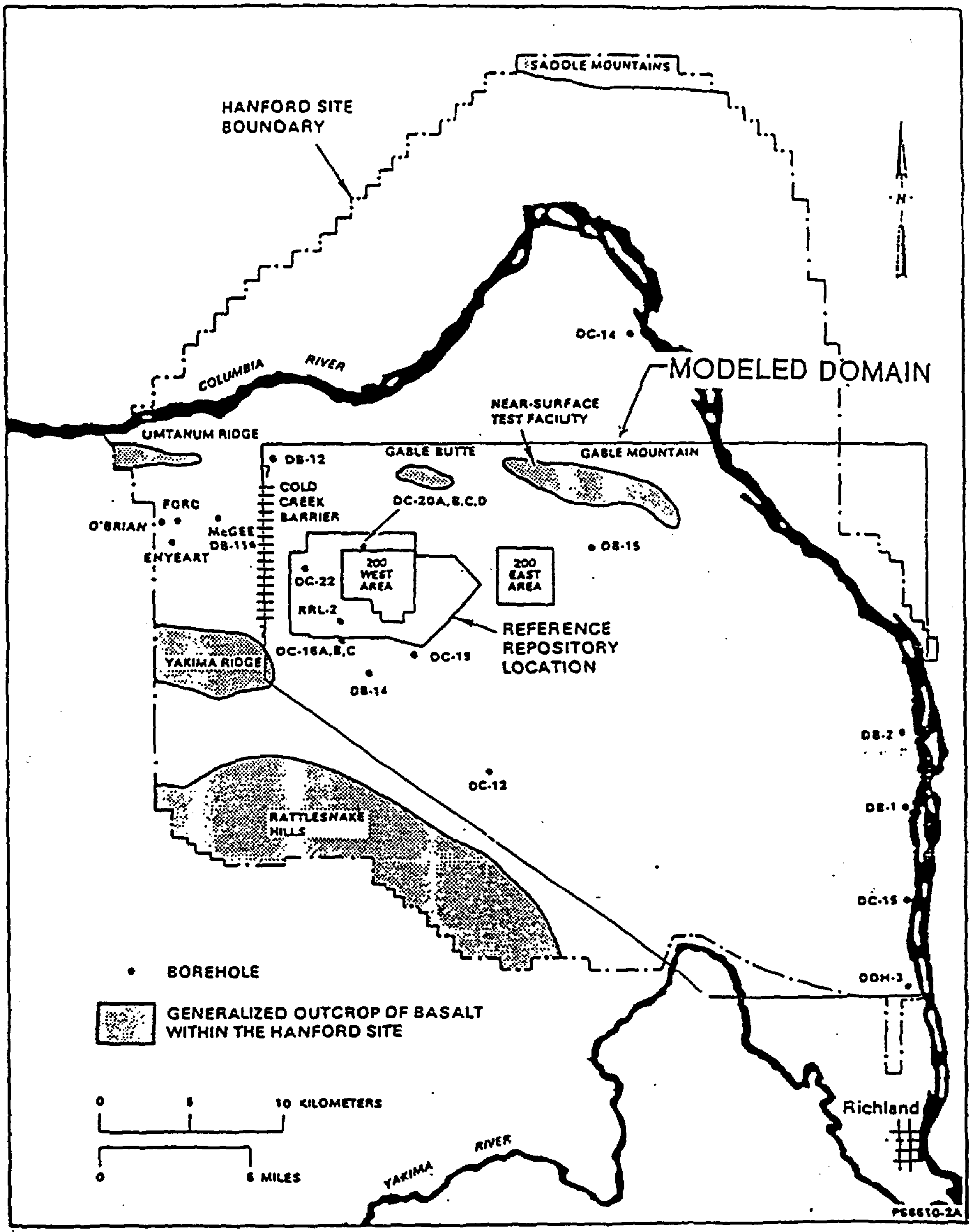


FIGURE 12 : EXPECTED HEAD FIELD (CORRELATION RANGE 30 KM)

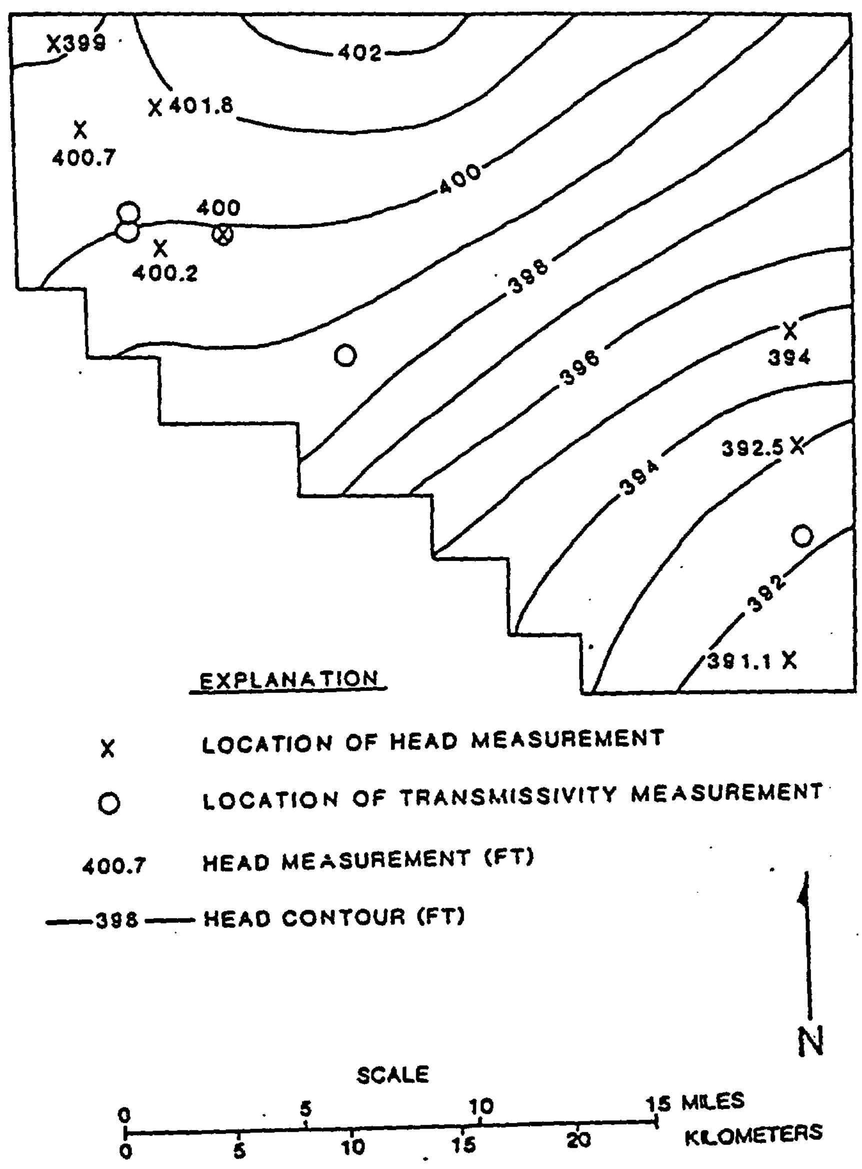
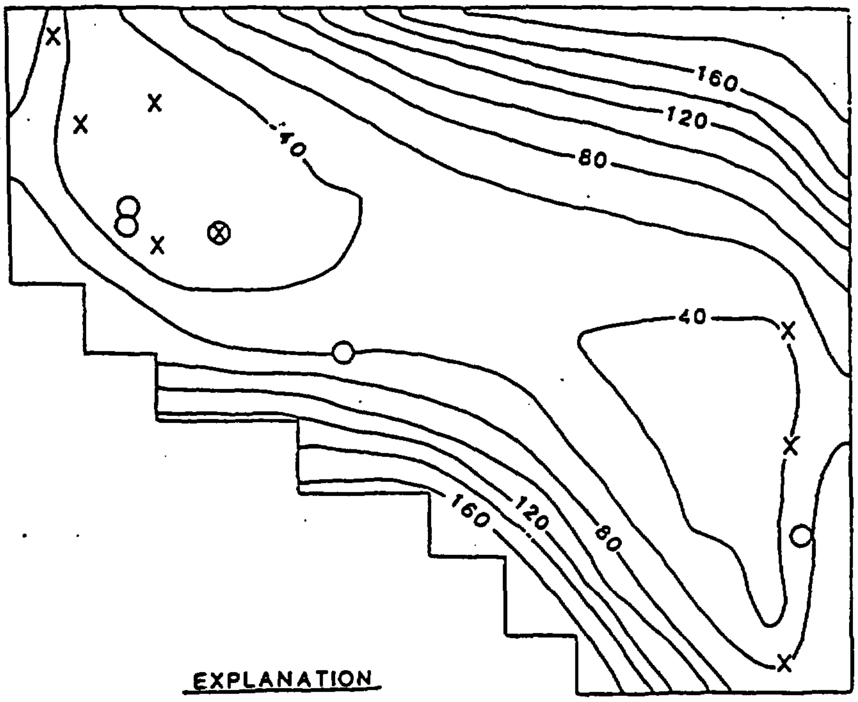


FIGURE 13 : VARIANCE OF ESTIMATION ERROR FOR COKRIGED HEAD FIELD (CORRELATION RANGE 30 KM)

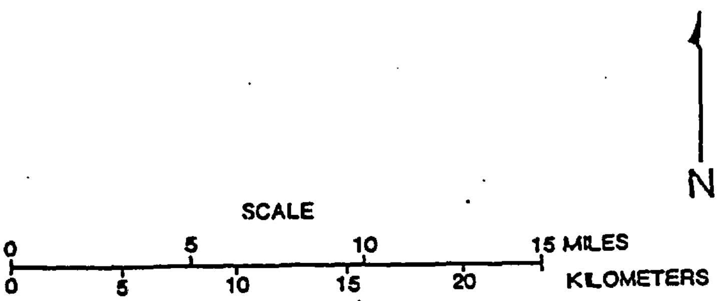


EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

— 80 — CONTOUR OF VARIANCE OF ESTIMATION ERROR



SENSITIVITY OF THE PREDICTED POTENTIOMETRIC MAP TO THE NUMBER OF AVAILABLE HYDRAULIC HEAD AND TRANSMISSIVITY MEASUREMENTS

GENERAL METHODOLOGY

* GENERATE TRANSMISSIVITY AND HYDRAULIC HEAD DATA AT EACH NODE OF A GRID OF THE MODELED DOMAIN. THESE DATA ARE USED TO CONSTRUCT A "KNOWN" HYDRAULIC HEAD FIELD

* USE DECREASING NUMBER OF RANDOMLY CHOSEN VALUES OF HEAD AND TRANSMISSIVITY (FROM THE COMPLETE DATA SET) TO ASSESS THE CAPABILITY OF REPRODUCING THE "KNOWN" HYDRAULIC HEAD FIELD

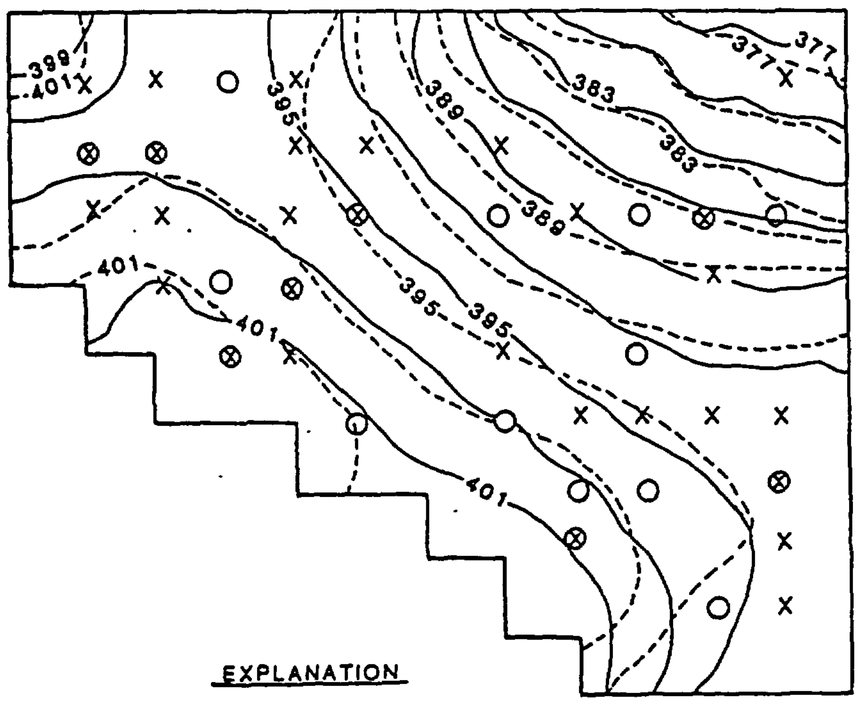
  - THREE CASES WERE CONSIDERED

    30 HEAD AND 20 TRANSMISSIVITY MEASUREMENTS

    18 HEAD AND 12 TRANSMISSIVITY MEASUREMENTS

    8 HEAD AND 5 TRANSMISSIVITY MEASUREMENTS

FIGURE 4 : PREDICTION OF HYDRAULIC HEAD FIELD USING 30 HEAD AND 20 TRANSMISSIVITY MEASUREMENTS



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

-- 401 -- HYDRAULIC HEAD TO BE PREDICTED (FT)

— 395 — EXPECTED HYDRAULIC HEAD FIELD USING 30 HEAD AND 20 TRANSMISSIVITY MEASUREMENTS (FT)

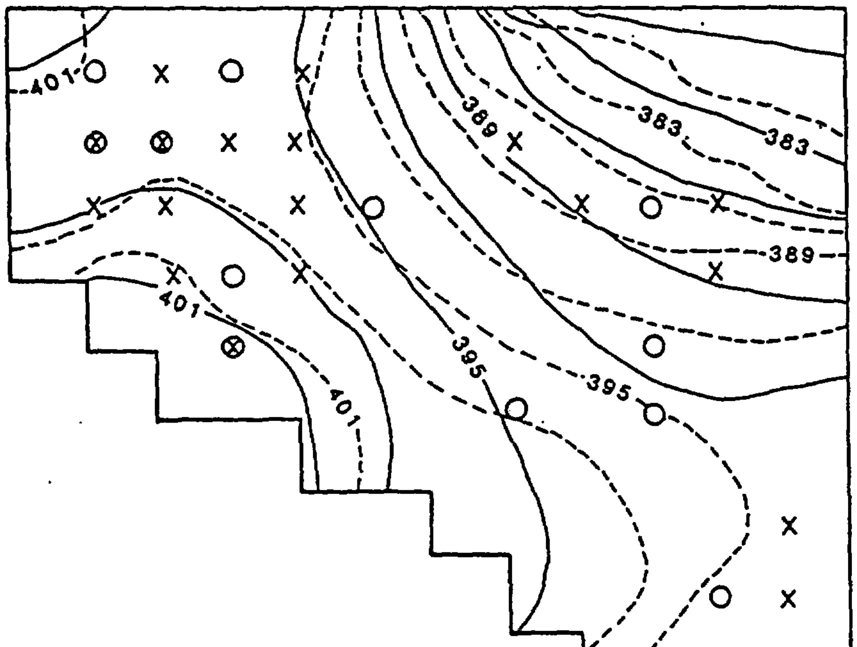
N

SCALE

0 5 10 15 MILES

0 5 10 15 20 KILOMETERS

FIGURE 5 : PREDICTION OF HYDRAULIC HEAD FIELD USING 18 HEAD AND 12 TRANSMISSIVITY MEASUREMENT



EXPLANATION

X LOCATION OF HEAD MEASUREMENT

O LOCATION OF TRANSMISSIVITY MEASUREMENT

— — 401 — — HYDRAULIC HEAD TO BE PREDICTED (FT)

—— 389 —— EXPECTED HYDRAULIC HEAD FIELD USING 18 HEAD AND 12 TRANSMISSIVITY MEASUREMENTS (FT)

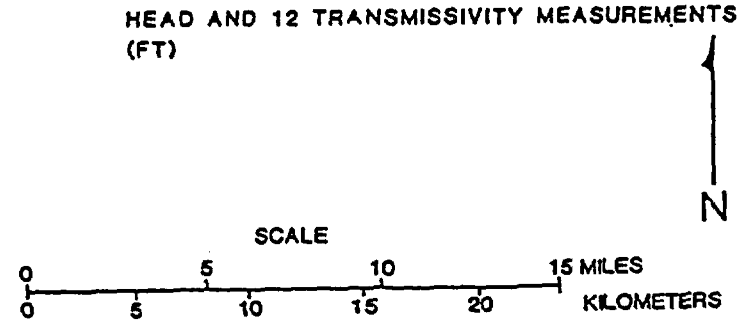
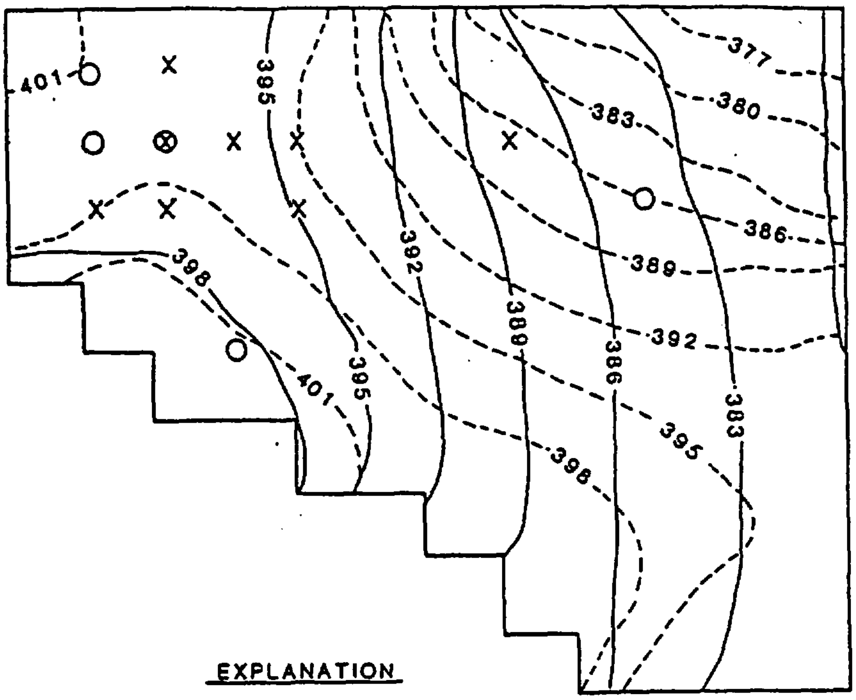


FIGURE 6 : PREDICTION OF HYDRAULIC HEAD FIELD USING 8 HEAD AND 5 TRANSMISSIVITY MEASUREMENTS



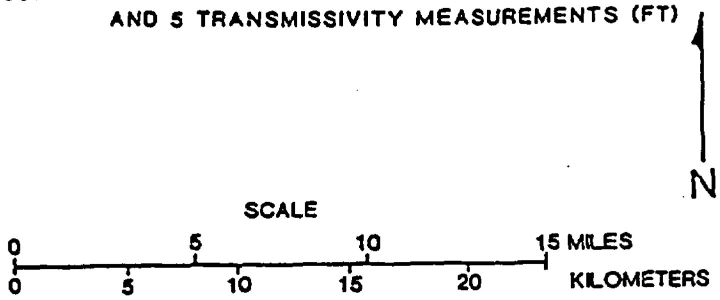
EXPLANATION

X — LOCATION OF HEAD MEASUREMENT

O — LOCATION OF TRANSMISSIVITY MEASUREMENT

--- 401 --- HYDRAULIC HEAD TO BE PREDICTED (FT)

—— 397 —— EXPECTED HYDRAULIC HEAD FIELD USING 8 HEAD AND 5 TRANSMISSIVITY MEASUREMENTS (FT)



CONCLUSIONS

* IMPORTANT UNCERTAINTY EXISTS IN HYDRAULIC HEAD FIELD INTERPOLATION

* WILL THIS UNCERTAINTY BE REDUCED TO AN ACCEPTABLE LEVEL ?

  SCP (CHAPTER 3, p 3.0-8)

  > "The field investigative approach .... involves the following:
  >
  > o Establishing baseline potentiometric surfaces before large-scale pumping tests and drilling of the exploratory shafts disturbs groundwater levels."

* WILL THIS GOAL BE REACHED JUST BY ADDING FIVE NEW BOREHOLES ?

  (DC-23, -24, -25, -32, 33)

DETAILED ANALYSIS OF TWO WELL TRACER TESTS AT BWIP SITE

OBJECTIVES

- TO REVIEW PREVIOUS ANALYSES OF DATA FROM TWO FIELD TESTS CONDUCTED BY SAI AND ROCKWELL (TESTS #1 AND #2)

- TO DEVELOP AN IMPROVED 3-DIMENSIONAL TRACER TRANSPORT NUMERICAL MODEL FOR COMPREHEHSIVE SIMULATION AND EVALUATION OF TRACER TEST RESULTS

- TO USE THE MODEL TO CONDUCT AN INDEPENDENT ANALYSIS OF DATA FROM BWIP TESTS #1 AND #2

- TO COMPARE RESULTS OF PARAMETER EVALUATION OBTAINED FROM PREVIOUS AND PRESENT ANALYSES

COMPARISON OF PREVIOUS AND PRESENT ANALYSES OF BWIP TRACER TEST DATA

PREVIOUS ANALYSES (GELHAR, 1982; LEONHART, 1982)

- USES GELHAR'S APPROXIMATE ANALYTICAL MODEL
- NO DETAILED ASSESSMENT OF EFFECT OF FLOW RATE CHANGES
- NO ACCOUNT OF TRACER RECIRCULATION EFFECT
- NO PARAMETER SENSITIVITY STUDY

PRESENT ANALYSIS (HGL, 1987)

- USES STACE3D NUMERICAL MODEL
- DETAILED ASSESSMENT OF EFFECT OF FLOW RATE CHANGES
- DETAILED ACCOUNT OF TRACER RECIRCULATION EFFECT
- PARAMETER SENSITIVITY ANALYSIS

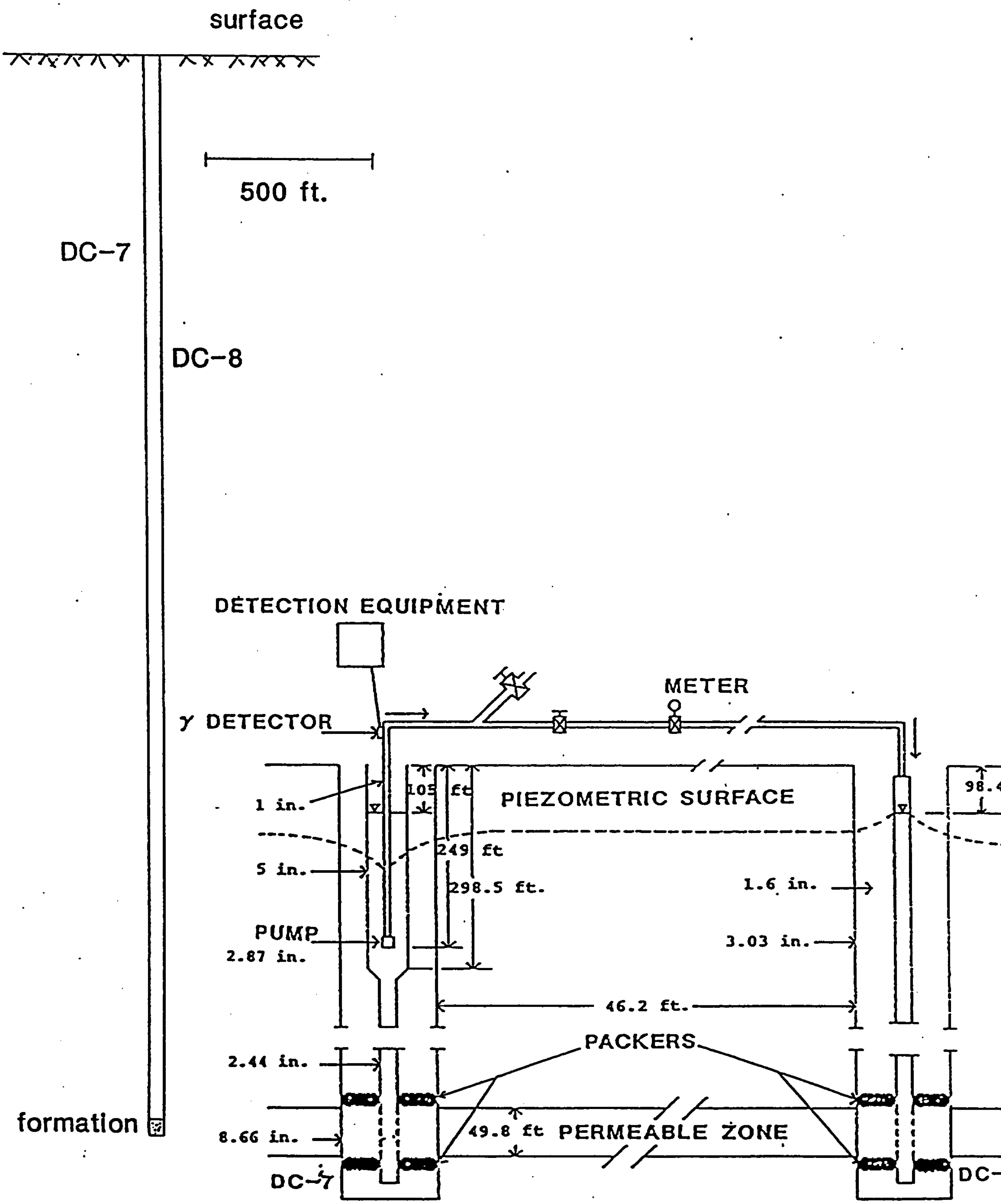
BWIP TRACER TEST DATA

TEST #1: DC-7/IF/Z9/Tt01, Dec. 8-12, 1979

- VARIABLE FLOW RATES $0.8 < Q_o < 8.4$ GPM
- UNEQUAL INJECTION AND WITHDRAWAL RATES, $Q_{in} \neq Q_o$
- SLUG INJECTION OF I^{-1} TRACER
- PRONOUNCED DOUBLE-PEAKED BREAKTHROUGH CURVE AT WITHDRAWAL WELL

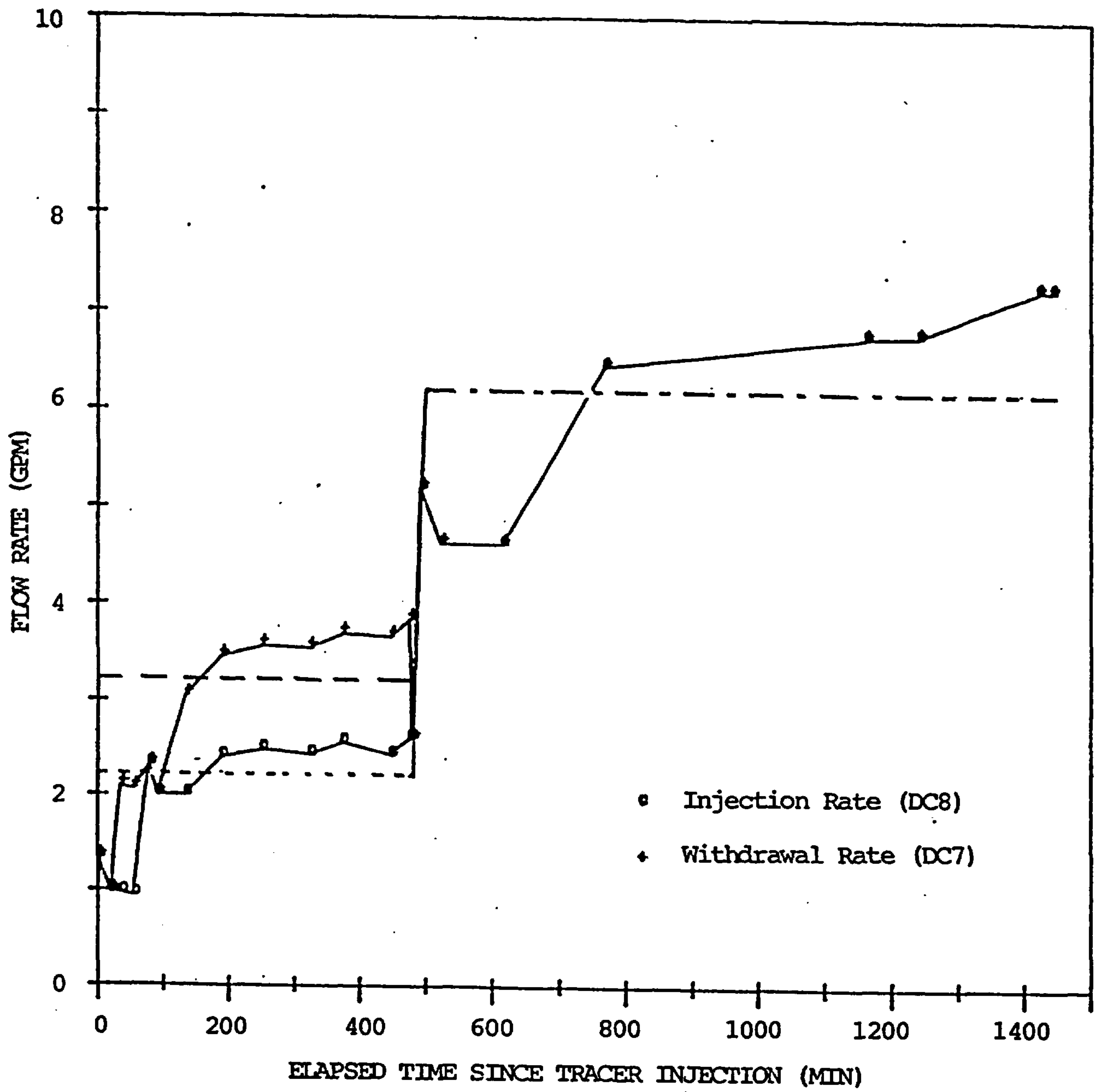
TEST #2: DC-7/IF/Z9/Tt02, January, 1982

- CONSTANT PUMPING RATES $Q_o = 1$ GPM
- EQUAL INJECTION AND WITHDRAWAL RATES, $Q_{in} = Q_o$
- SLUG INJECTION OF K^+ AND SCN^- TRACERS
- PRONOUNCED DOUBLE-PEAKED BREAKTHROUGH CURVES AT WITHDRAWAL WELL
- Na - K EXCHANGE REACTIONS



surface
500 ft.
DC-7
DC-8
formation
DETECTION EQUIPMENT
METER
γ DETECTOR
1 in.
105 ft
PIEZOMETRIC SURFACE
98.4
249 ft
5 in.
298.5 ft.
1.6 in.
PUMP
2.87 in.
3.03 in.
46.2 ft.
PACKERS
2.44 in.
49.8 ft
PERMEABLE ZONE
8.66 in.
DC-7

Measured flow rates versus time since tracer injection.

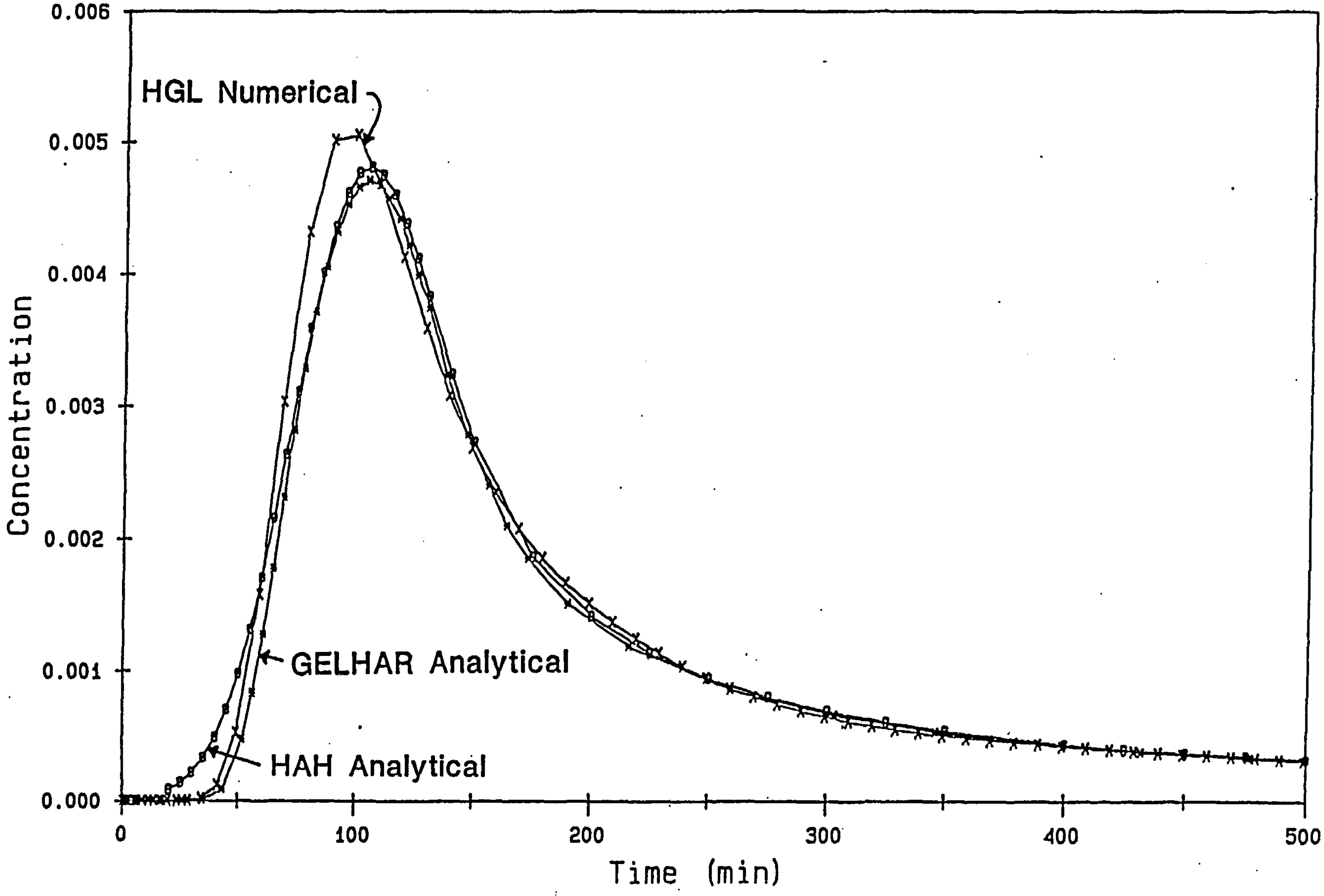


DATE	CLOCK TIME	REPORTED Q_o	CALCULATED Q_{in} FROM METER	REPORTED AVE. Q_{in}	Q_{in} USED BY GELHAR	Q_{in} USED BY SAI	Q_{in} USED BY HGL	REPORTED AVE. Q_{out}	Q_{out} USED BY GELHAR	Q_{out} USED BY SAI	Q_{out} USED BY HGL
12/11/79	13:55	1.33	--	--			--				
TRACER INJECTED	14:52	1.33	1.33	--			--				
	15:05	--	--								
	15:13	--	5.00	1.33			1.33	2.43			2.43
	15:16	--	--								
	15:24	0.98	1.64								
	15:34	0.97	1.00								
	15:39	--	--	0.95			0.95	2.05			2.05
	15:50	--	--								
	15:58	0.94	0.83								
	16:05	0.91	0.86	0.91			0.91	2.02			2.02
	16:22	2.31	2.06	2.31		2.25	2.31	2.31		3.31	2.31
	16:34	--	--								
	16:35	2.00	2.54								
	17:17	--	2.26						3.42		
	18:12	2.40	2.51		2.31						
	19:14	2.48	2.68								
	20:27	2.43	2.28	2.42			2.42	3.54			3.54
	21:17	2.56	2.50								
	22:32	2.43	2.60								
	23:00	2.61	2.61								
	23:05	--	--								
	23:17	5.20	3.47	--							
	23:47	4.62	6.10	--							
12/12/79	01:19	--	1.78	--							
	03:45	--	8.38	--		6.20	6.20	6.20		6.20	6.20
	03:53	6.45	--	--							
	10:21	6.76	6.75	--							
	11:47	6.78	6.78	--							
	14:45	7.26	7.26	--							

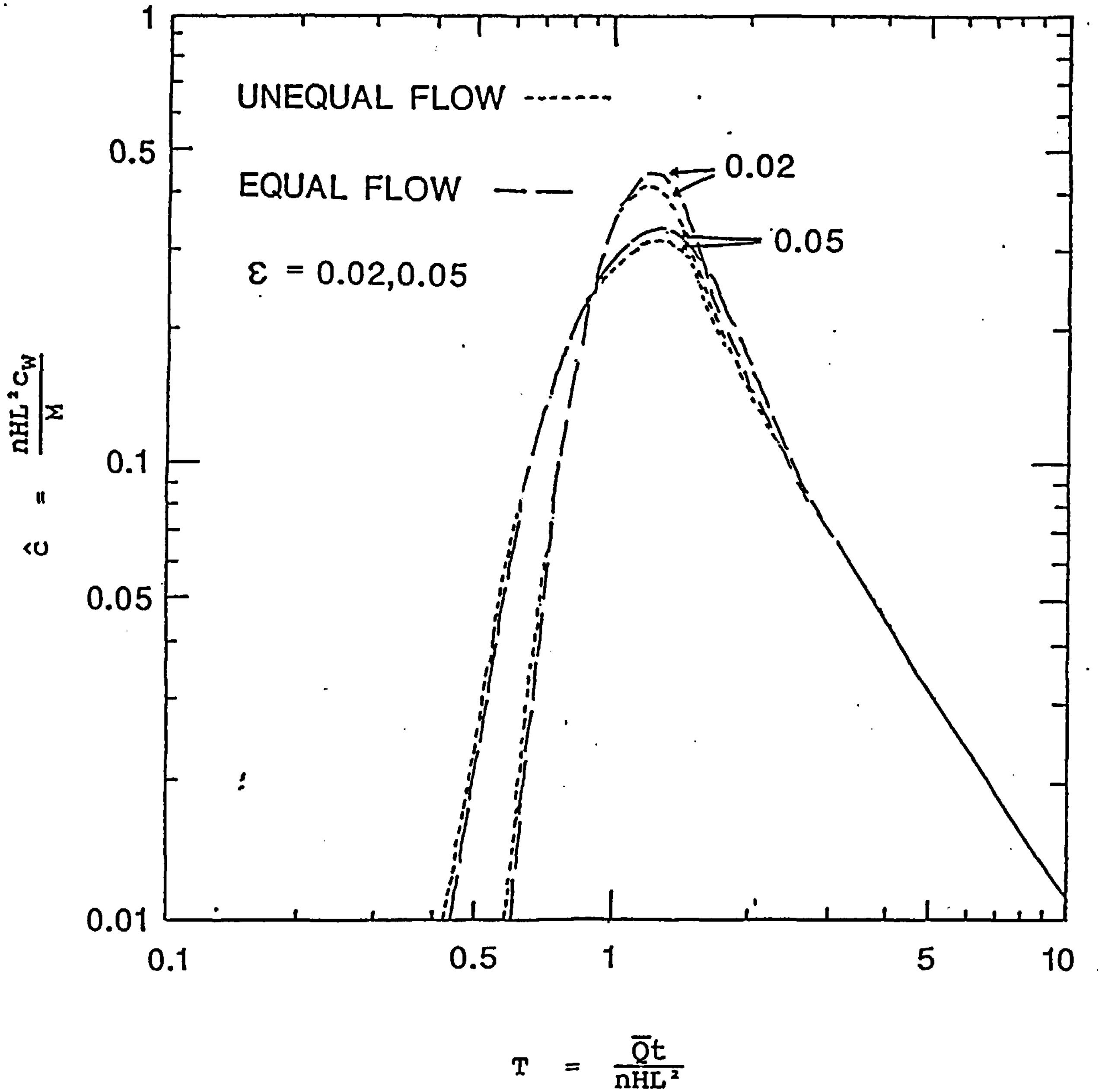
STACE3D

Solute Transport Analysis using Curvilinear Elements in 3 Dimensions

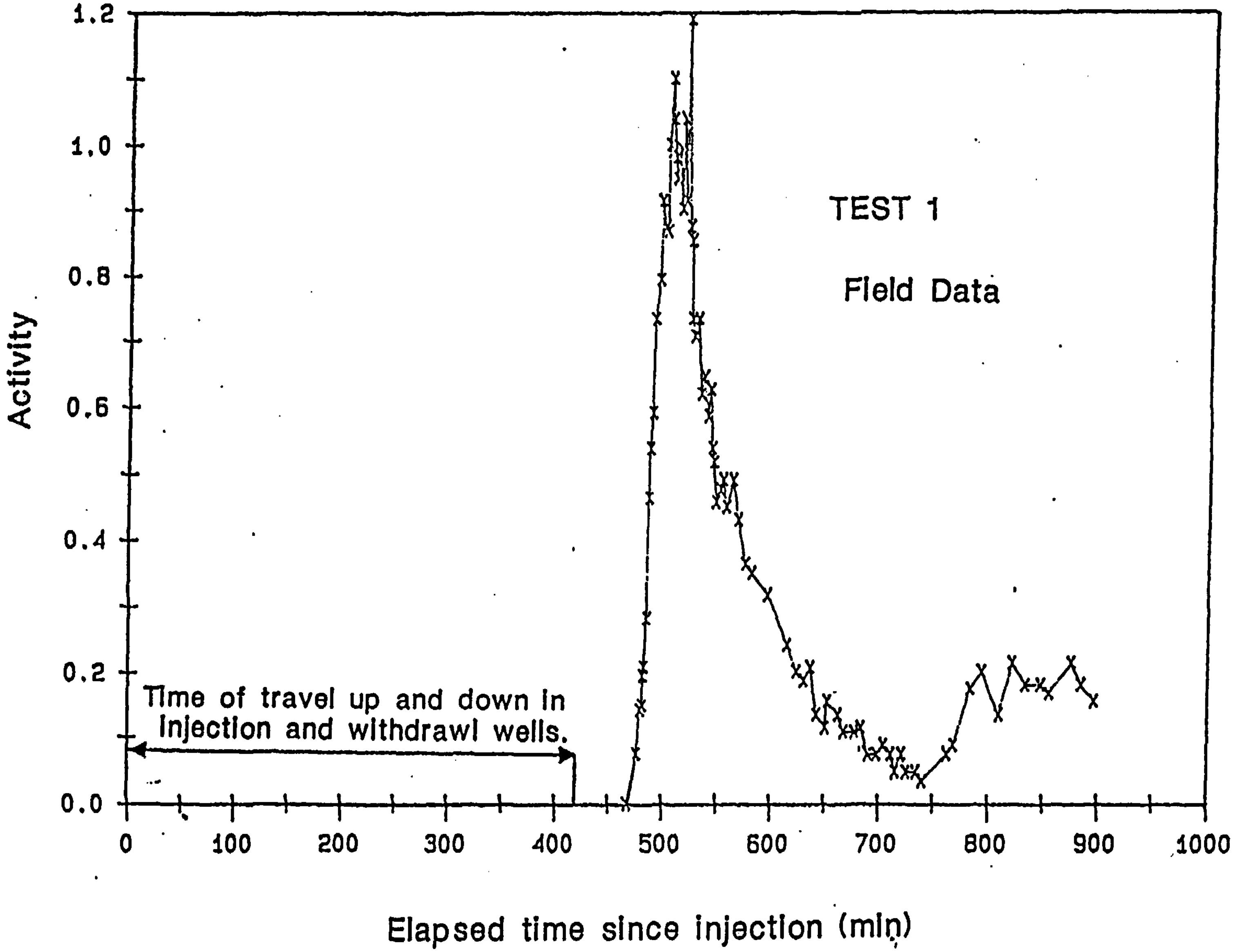
- SIMULATES WATER FLOW AND SOLUTE TRANSPORT IN FRACTURED AND POROUS MEDIA
- USES STREAMLINED CURVILINEAR FINITE ELEMENT SCHEME TO MINIMIZE NUMERICAL DISPERSION
- HANDLES FLUCTUATIONS OF PUMPING RATES
- HANDLES UNEQUAL FLOW RATES FOR TWO WELL TRACER TESTS
- HANDLES PULSE INJECTION OF CONSERVATIVE OR NONCONSERVATIVE TRACERS
- ACCOUNTS FOR RECIRCULATION OF WITHDRAWN TRACER INTO THE RECHARGING WELL
- ACCOUNTS FOR COMBINED EFFECT OF HYDRODYNAMIC DISPERSION, ADVECTION, AND MOLECULAR DIFFUSION INTO THE ROCK MATRIX

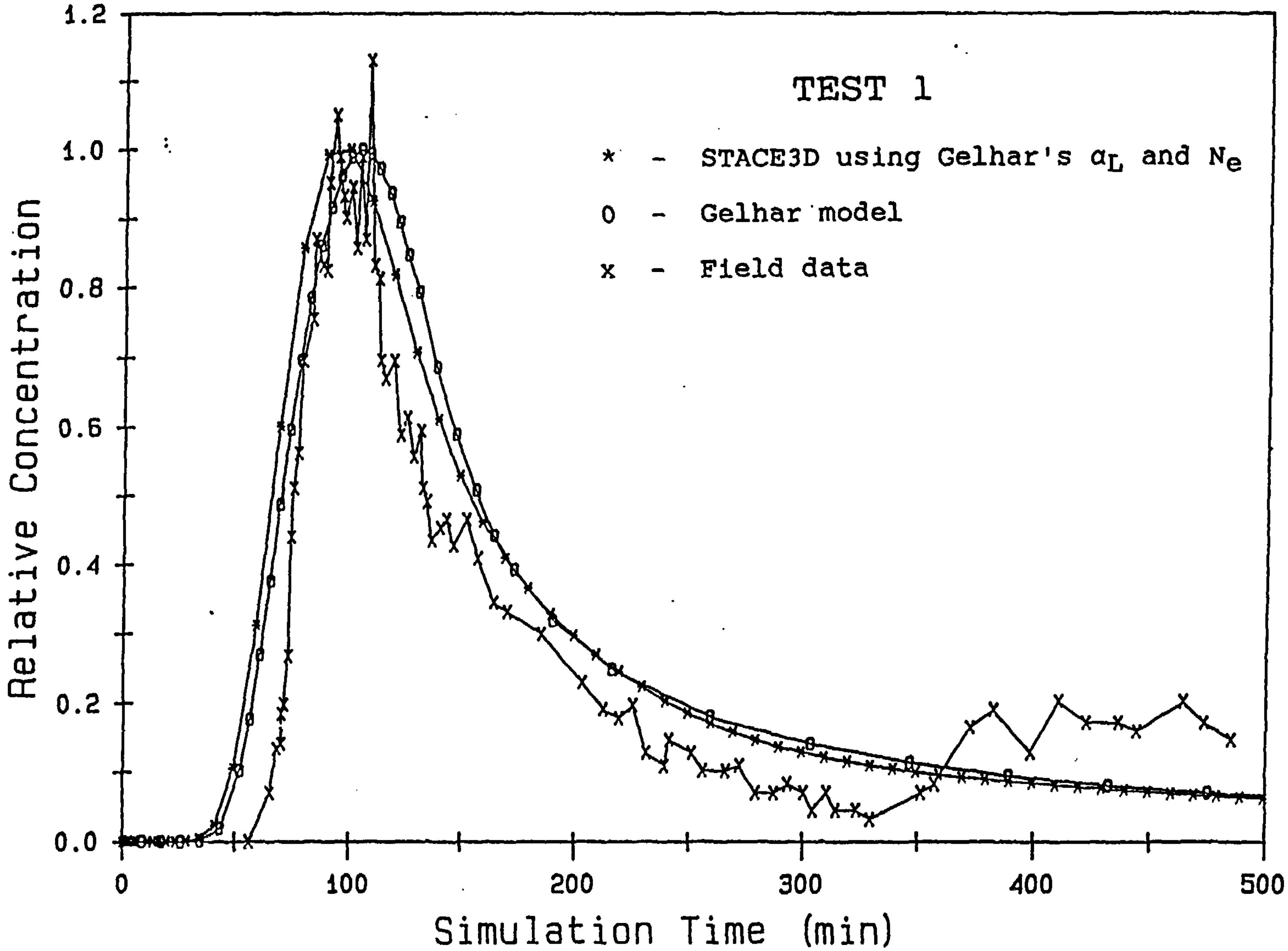


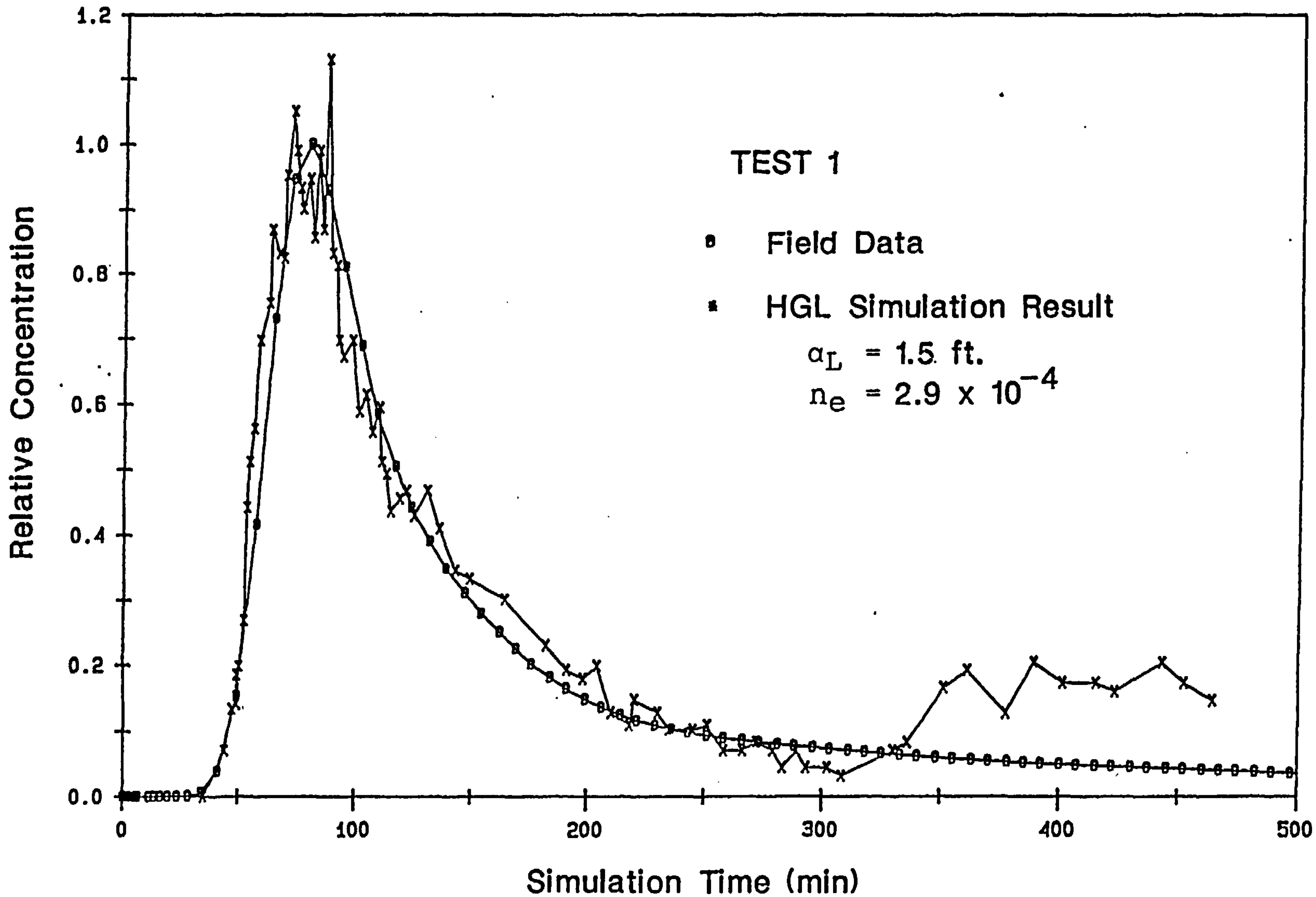
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Concentration
0
100
200
300
400
500
Time (min)
HGL Numerical
GELHAR Analytical
HAH Analytical



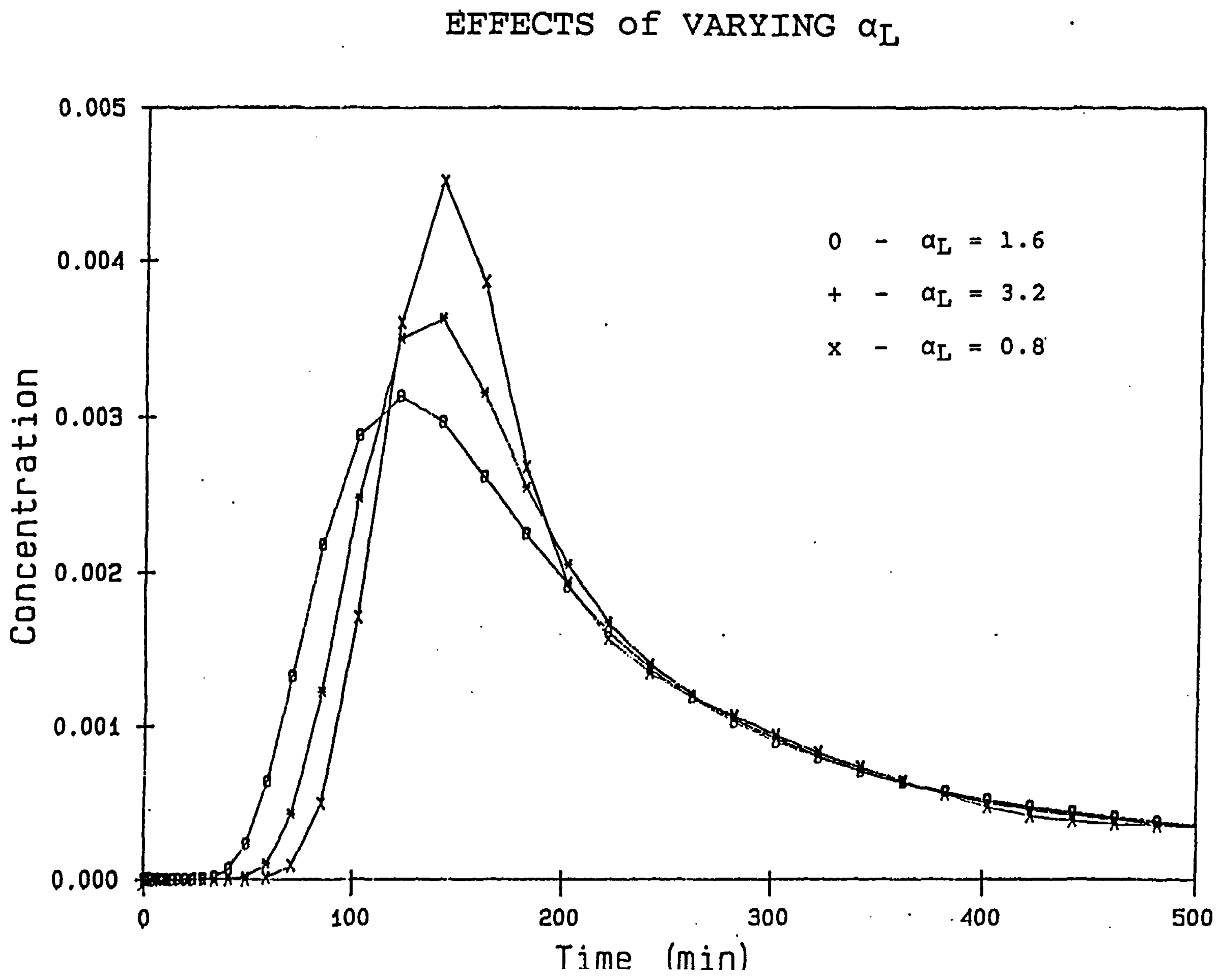
UNEQUAL FLOW
EQUAL FLOW
ε = 0.02,0.05
0.02
0.05
1
0.5
0.1
0.05
0.01
0.1
0.5
1
5
10
$\hat{c} = \frac{nHL^2 c_W}{M}$
$T = \frac{\bar{Q}t}{nHL^2}$


1.2
1.0
0.8
0.6
0.4
0.2
0.0
Activity
TEST 1
Field Data
Time of travel up and down in
injection and withdrawl wells.
0
100
200
300
400
500
600
700
800
900
1000
Elapsed time since injection (min)

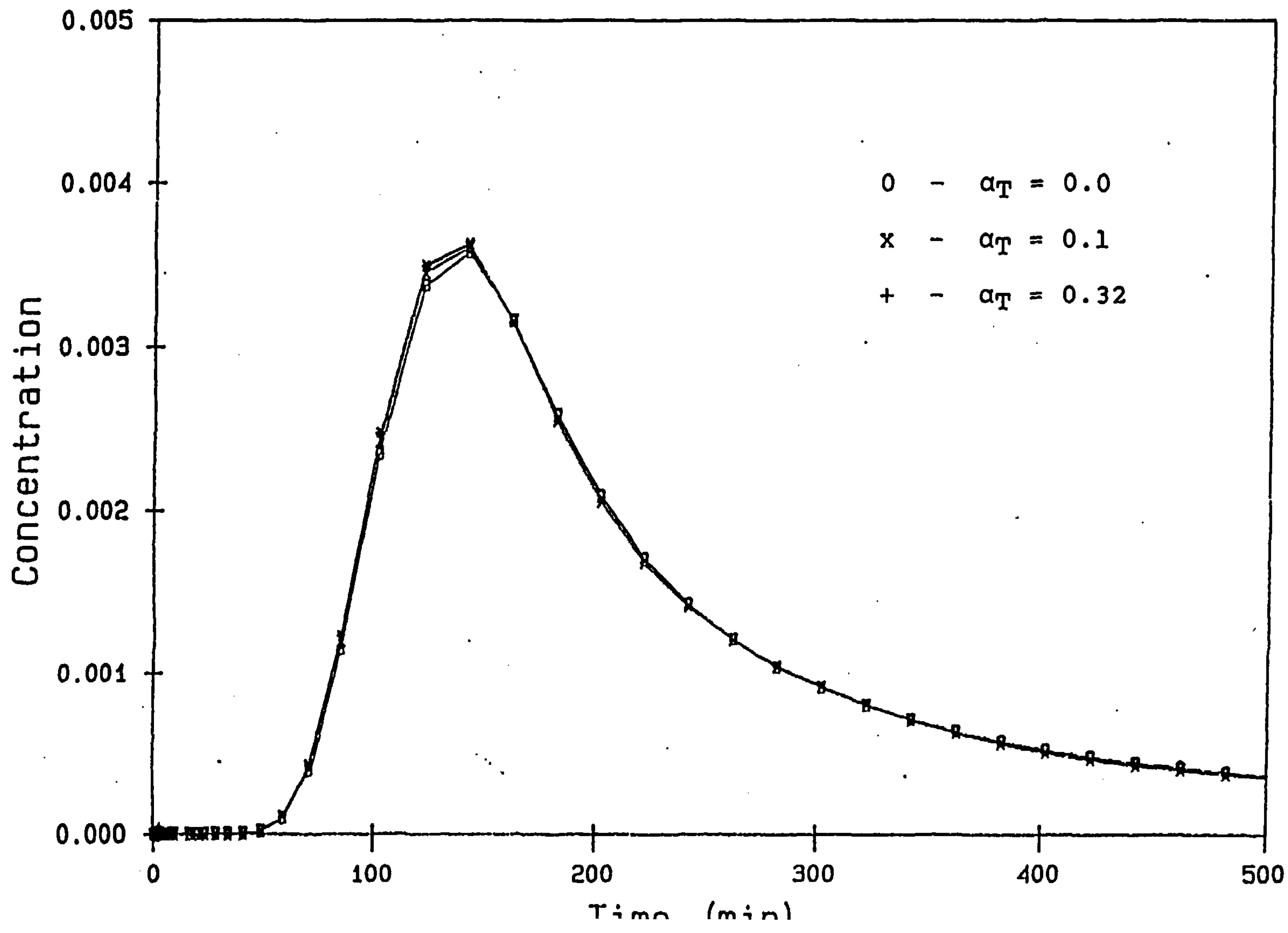

TEST 1
* - STACE3D using Gelhar's α_L and N_e
o - Gelhar model
x - Field data
Relative Concentration
Simulation Time (min)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
100
200
300
400
500

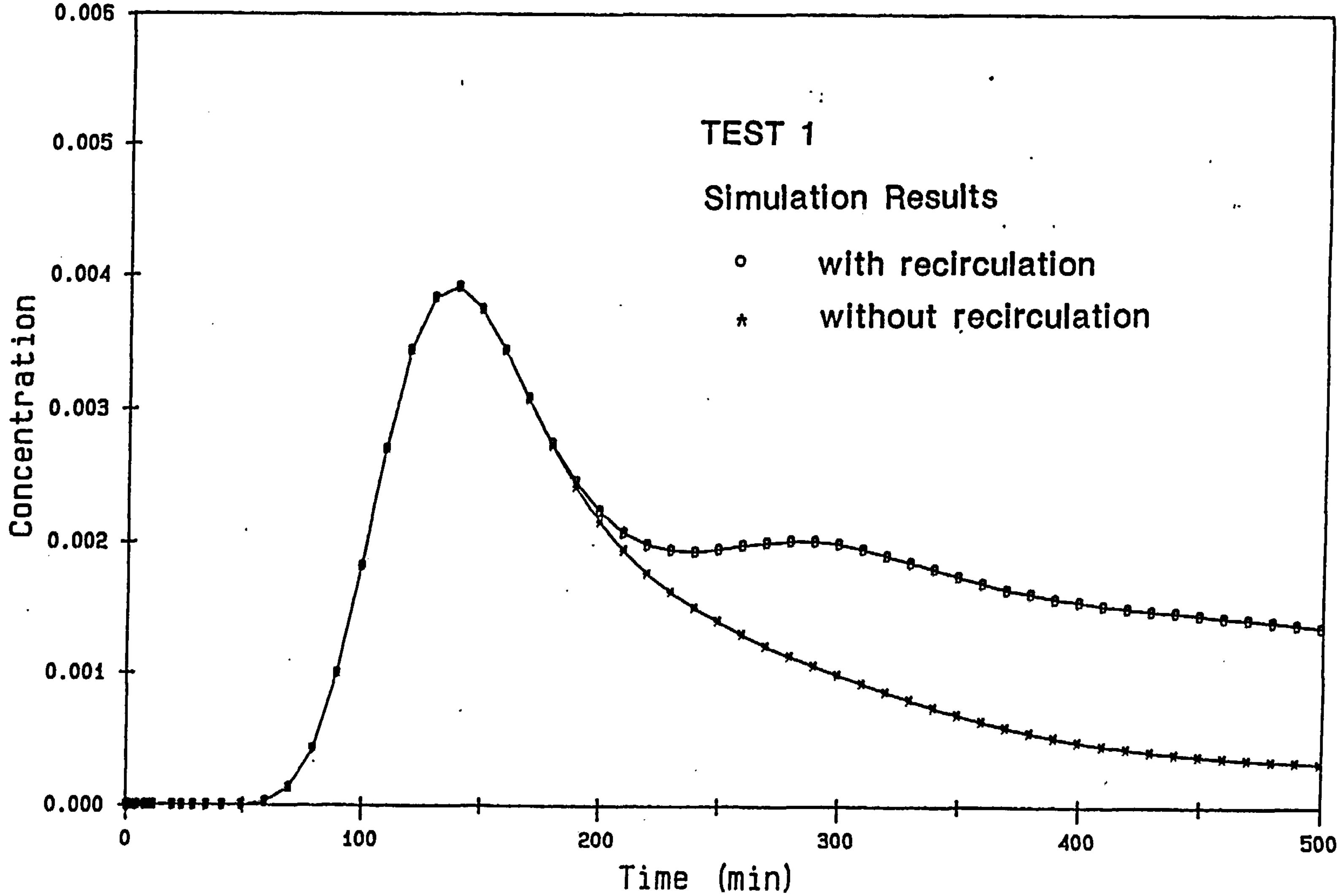


TEST 1
Field Data
HGL Simulation Result
α_L = 1.5 ft.
n_e = 2.9 x 10^{-4}
Relative Concentration
Simulation Time (min)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
100
200
300
400
500

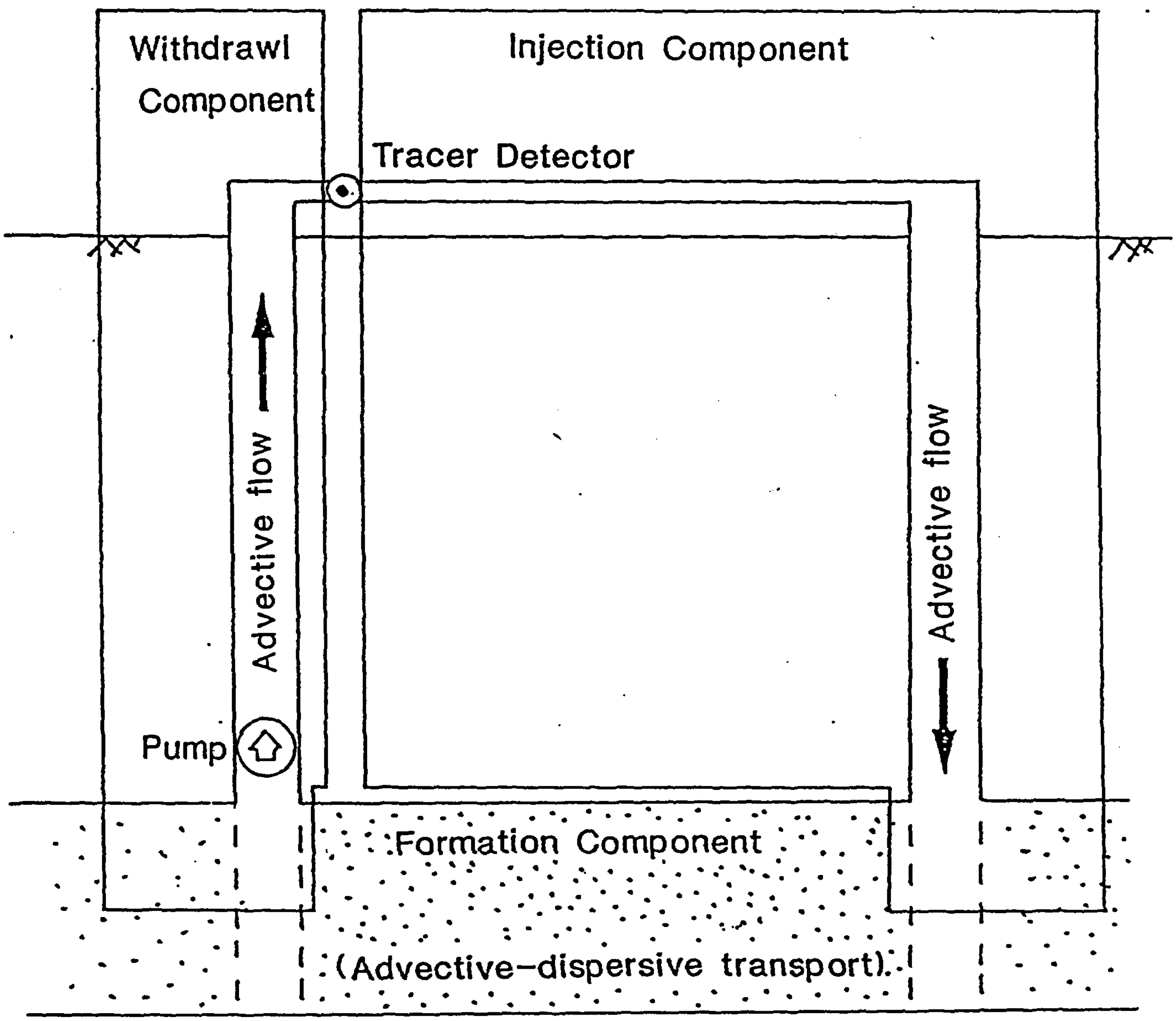

EFFECTS of VARYING α_L
0 - α_L = 1.6
+ - α_L = 3.2
x - α_L = 0.8
Concentration
0.000
0.001
0.002
0.003
0.004
0.005
0
100
200
300
400
500
Time (min)

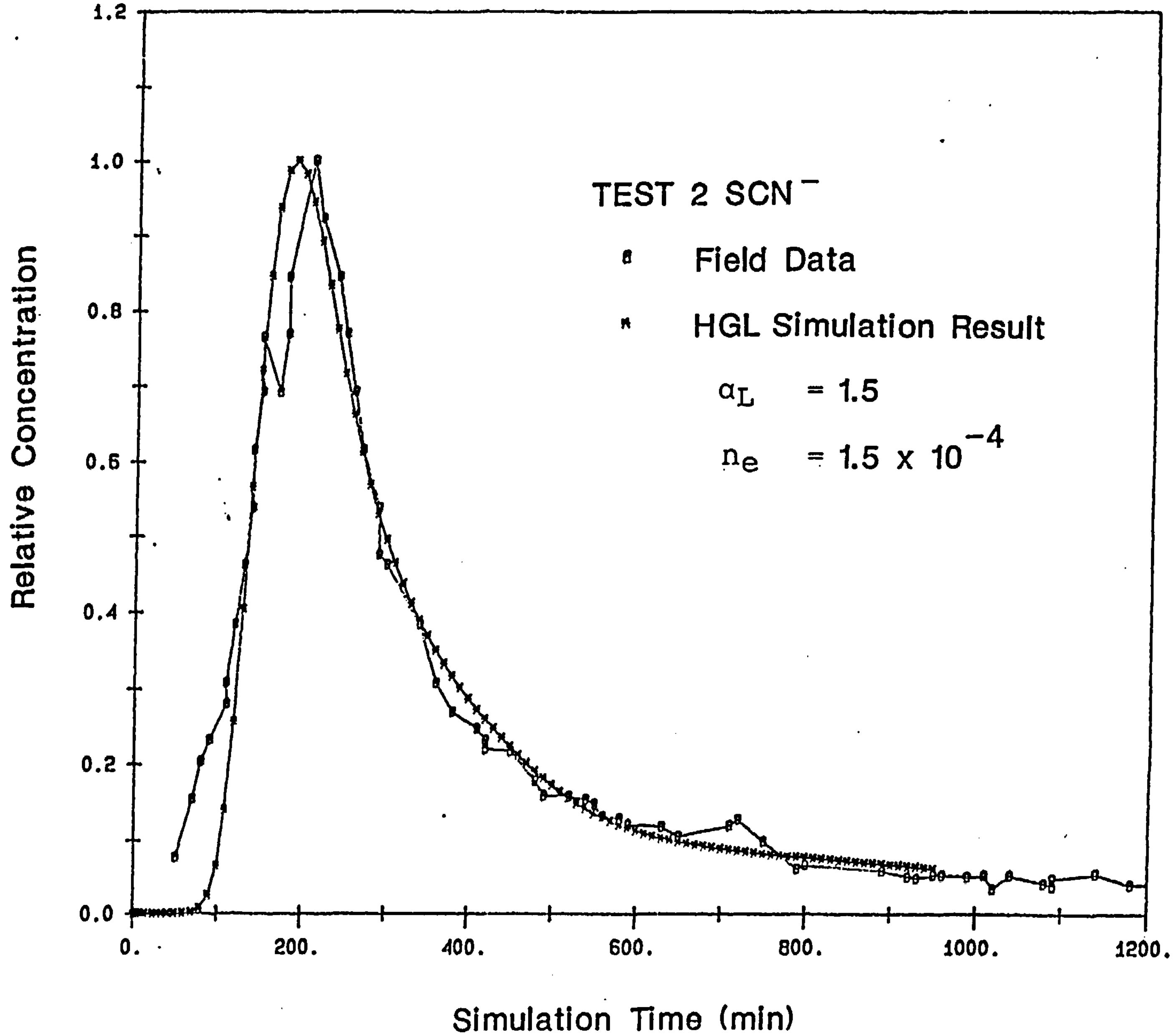
EFFECTS OF VARYING α_T

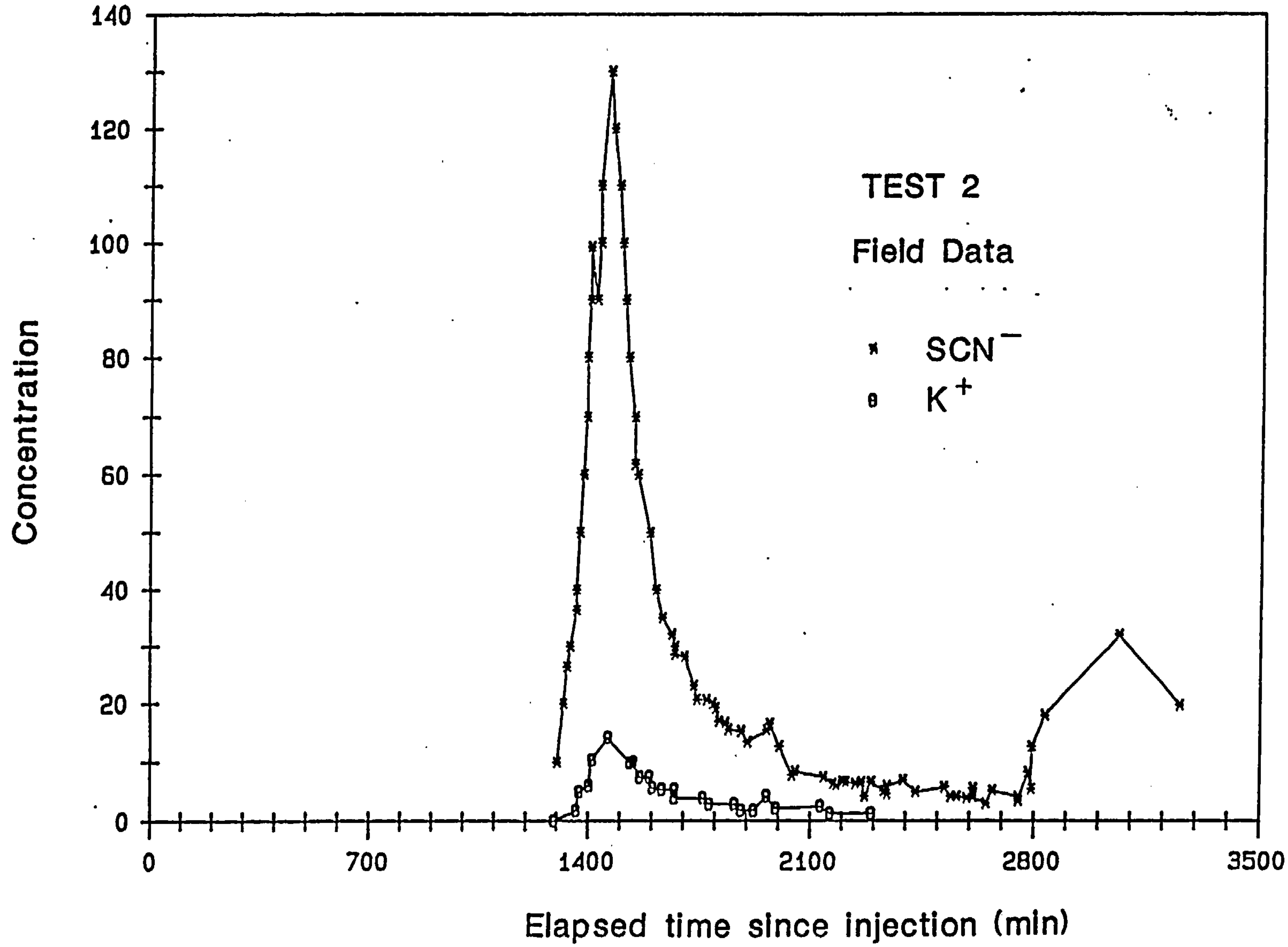



TEST 1
Simulation Results
o with recirculation
* without recirculation
Concentration
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
100
200
300
400
500
Time (min)

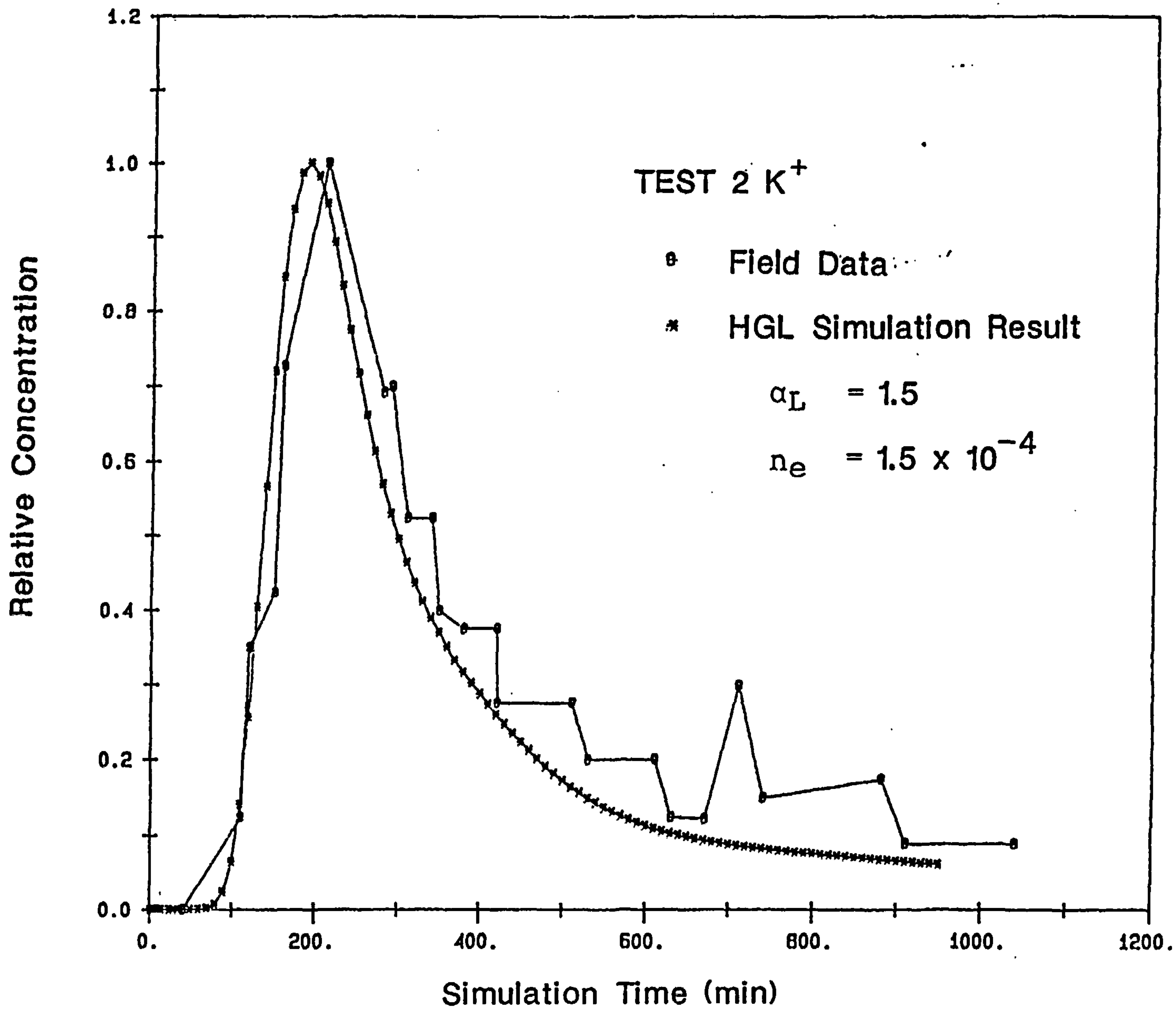
COMPONENTS OF COMPOSITE MODEL




TEST 2 SCN⁻
Field Data
HGL Simulation Result
α_L = 1.5
n_e = 1.5 x 10^{-4}
Relative Concentration
Simulation Time (min)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.
200.
400.
600.
800.
1000.
1200.



TEST 2
Field Data
SCN⁻
K⁺
Concentration
0
20
40
60
80
100
120
140
0
700
1400
2100
2800
3500
Elapsed time since injection (min)



TEST 2 K^+
Field Data
HGL Simulation Result
α_L = 1.5
n_e = 1.5 x 10^{-4}
Relative Concentration
Simulation Time (min)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.
200.
400.
600.
800.
1000.
1200.

DRAFT

YAKIMA INDIAN NATION/EWA, Inc.

LIST OF TOPICS FOR THE HANFORD HYDROLOGY REVIEW MEETING

Minneapolis, September 3-4, 1987
Ritz Hotel, 315 Nicollet Mall, 612/332-4000

I. Overview of Site Characterization Problems in Hydrology
(Mr. J. Wittman/YIN)

II. Stochastic Methods of Hanford Groundwater Travel Time Analysis
(Dr. G. Dagan/Dr. V. Nguyen)

III. Geostatistic Problems Associated with Head Fields and Hydraulic Conductivity Mapping in the Grande Ronde Basalt
(Dr. V. Nguyen/Dr. A. Djerrari/Dr. P. Kitanidis)

IV. Optimization of Monitoring Network for the Reduction of Site Characterization Uncertainty at RRL-2
(Dr. P. Kitanidis/Dr. G. Abi-Ghanem)

V. Three-Dimensional Analysis of Well and Tracer Tests in Layered and Fractured Basalts
(Dr. A. Calash/Dr. P. Huyakorn/Dr. E. Frind)

VI. Evaluation of Hydraulic Impact of Proposed Shaft Sinking on LHST
(Dr. V. Nguyen/Mr. J. Robertson)

Each subject will take 1-2hrs for presentation and discussion.

OBJECTIVES

- ASSESS POTENTIAL IMPACTS OF SINKING EXPLORATORY SHAFT THROUGH UNCONSOLIDATED SEDIMENTS TO TOP OF BASALT

  - DETERMINE LIKELY RANGES OF EFFECTIVE K_v AND K_h FOR MAJOR GROUPS OF STRATA

  - ASSESS POTENTIAL IMPACTS OF THROUGH-CUTTING PERMEABLE FEATURE

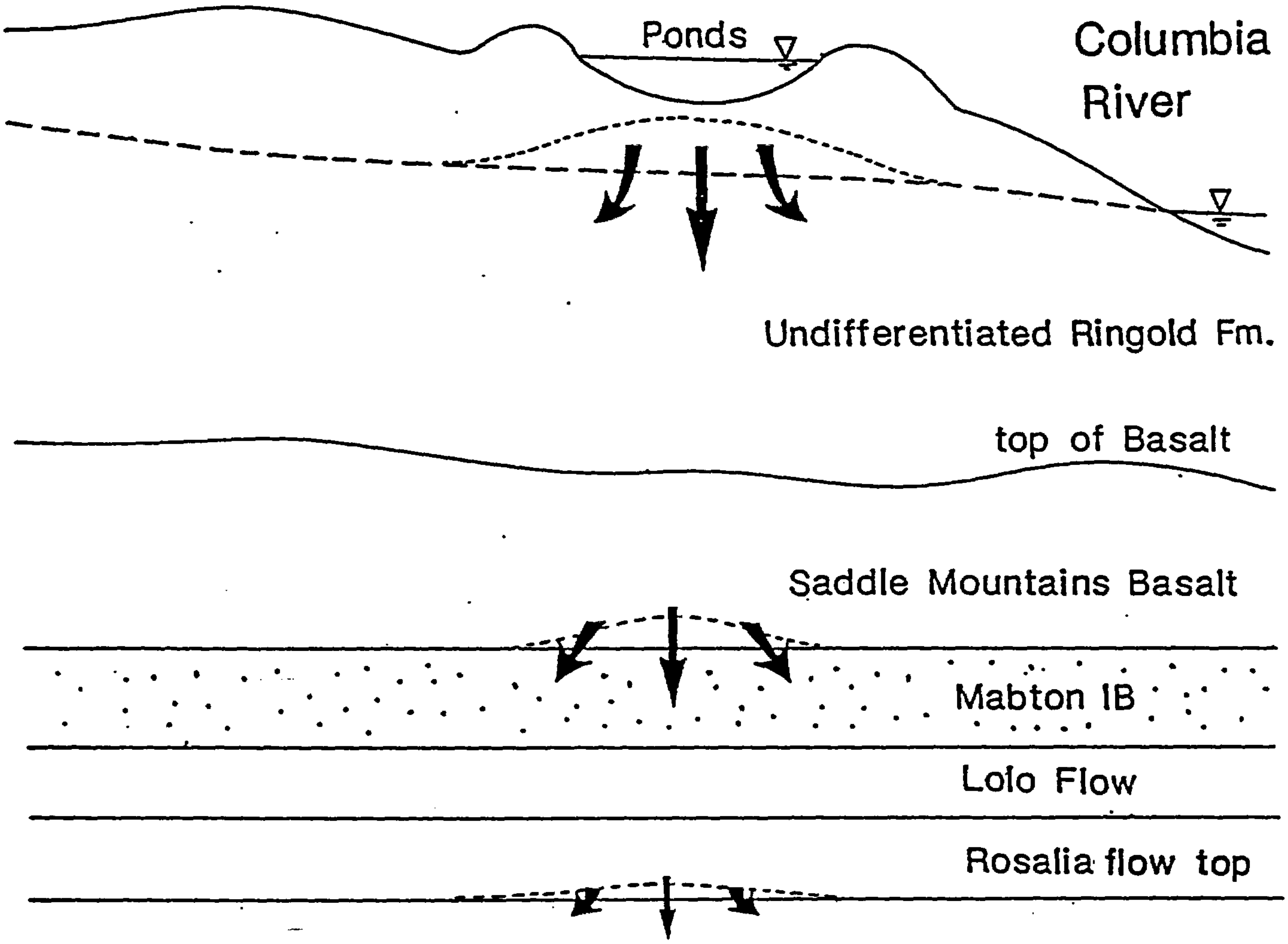
APPROACH

- 3-D MODEL, VAM3D

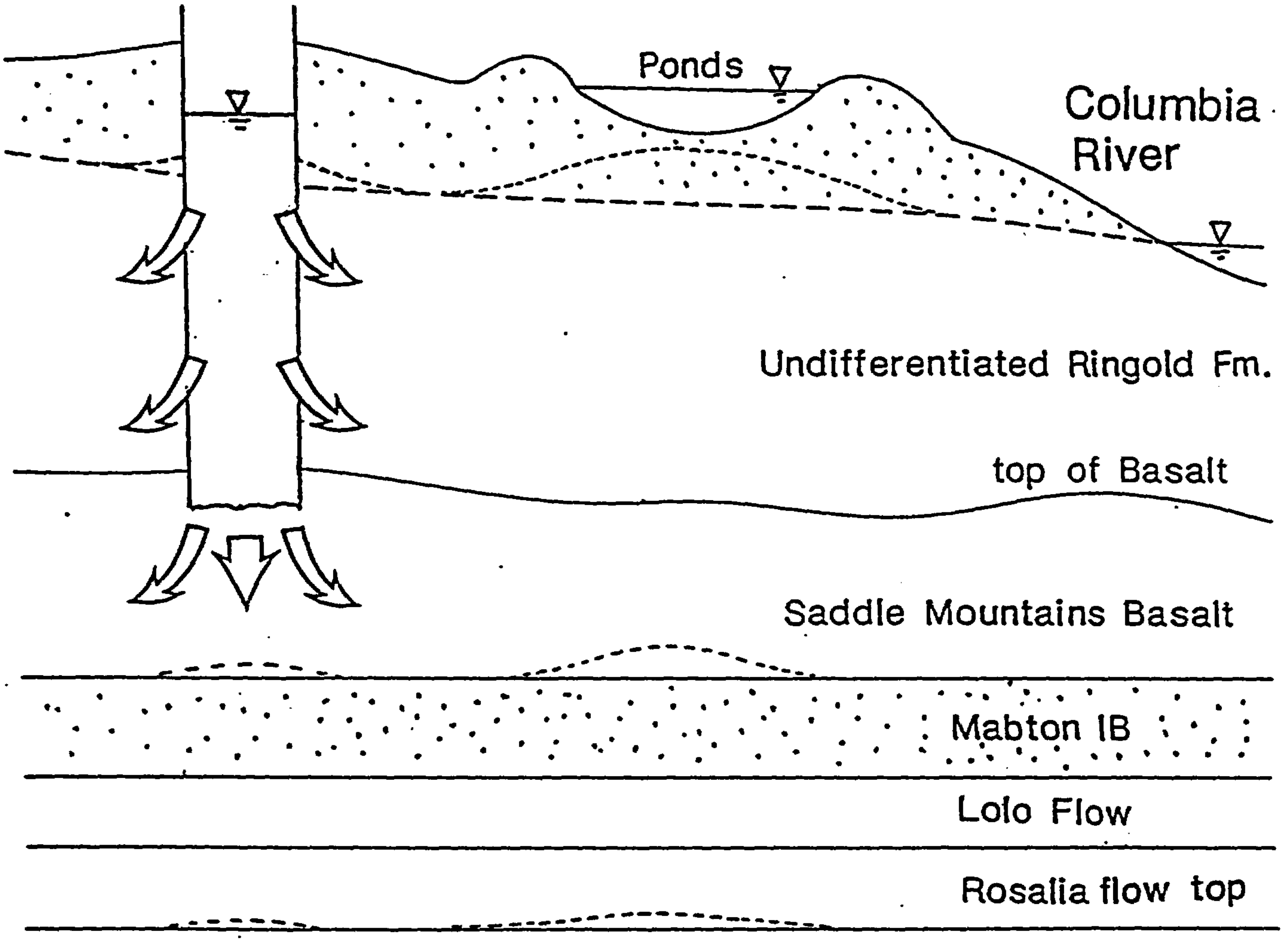
  (VARIABLY-SATURATED FLOW ANALYSIS MODEL IN 3-DIMENSIONS)

- CALIBRATION AGAINST OBSERVED SUBSURFACE EFFECTS FROM SURFACE DISCHARGES AT 200-WEST AREA

- USE CALIBRATED MODEL TO EXAMINE RANGE OF SHAFT IMPACT SCENARIOS



Schematic Cross-Section Through 200-West Area Showing Mounding of Water Levels in the Ringold, Mabton, and Rosalia formations



Potential Effects of Fluid Loss During ES Drilling on Water Levels

VAM3D

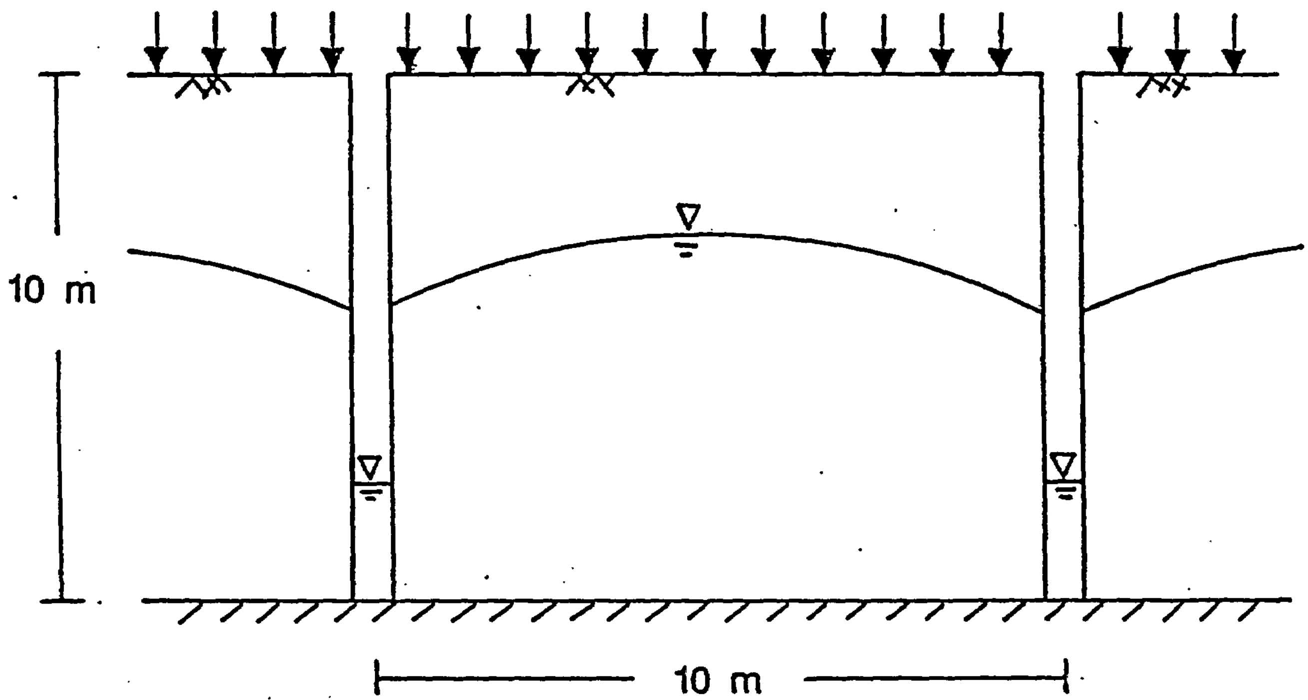
Variably Saturated Analysis Model in 3-Dimensions

- SINGLE-PHASE WATER FLOW AND SOLUTE TRANSPORT IN VARIABLY SATURATED POROUS MEDIA
- MODIFIED PICARD ITERATIVE TECHNIQUE TO HANDLE HIGHLY NON-LINEAR FLOW PROBLEMS
- INFLUENCE COEFFICIENT TECHNIQUE FOR ELEMENT MATRIX GENERATION
- SLICE SUCCESSIVE OVER-RELAXATION (SSOR) MATRIX SOLUTION TECHNIQUE DESIGNED TO ACCOMODATE SEVERAL THOUSAND NODAL UNKNOWNS
- COORDINATE STRETCHING TECHNIQUE FOR HANDLING HIGHLY NON-LINEAR VARIABLY SATURATED FLOW AND TRANSPORT PROBLEMS
- LOGARITHMIC INTERPOLATION AND EXTRAPOLATION OF SOIL MOISTURE RELATIONSHIPS
- AUTOMATIC REDUCTION IN COMPUTATIONAL TIME-STEPS WHEN DESIRED TIME-STEP IS TOO LARGE TO ACHIEVE CONVERGENCE

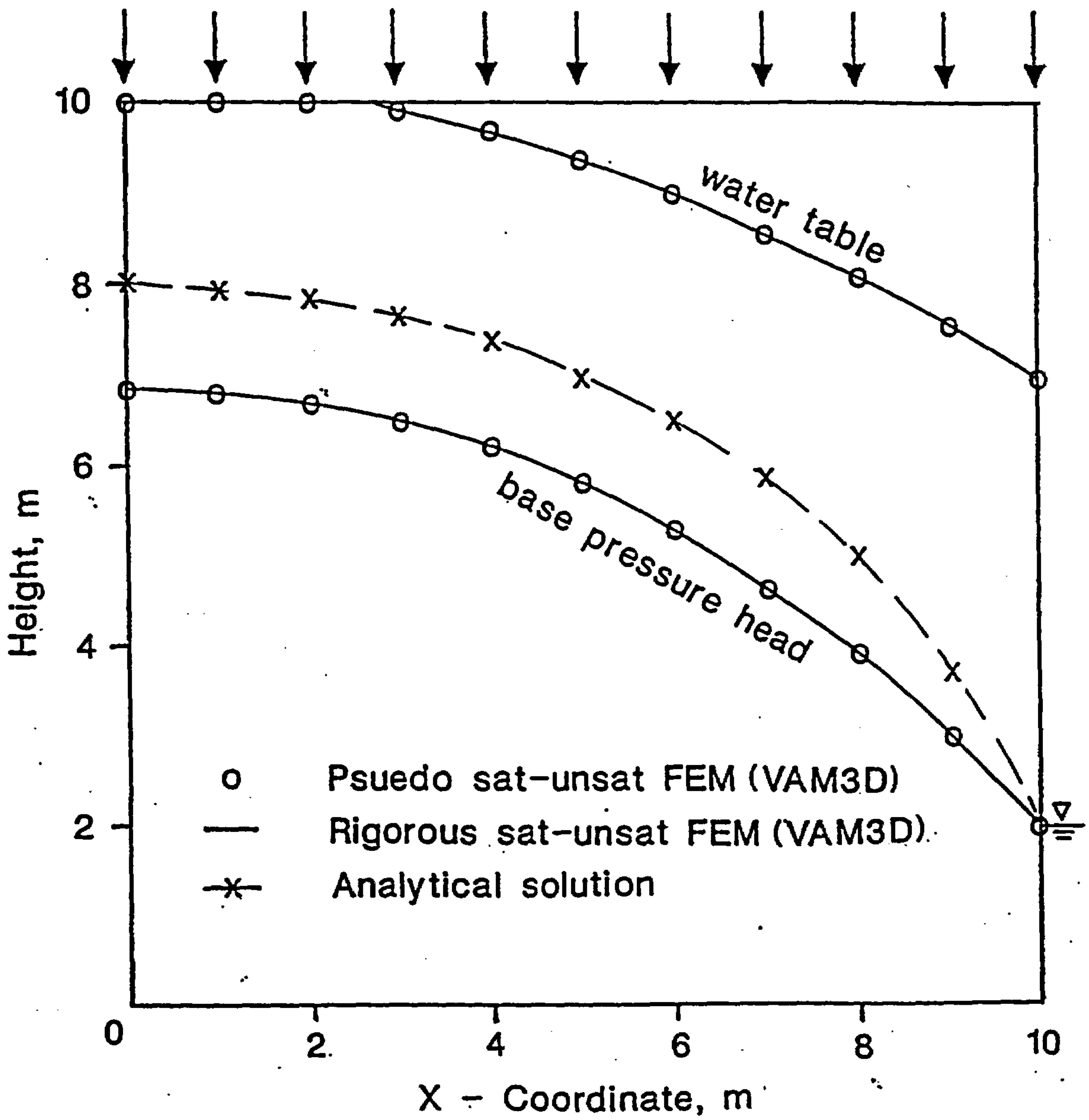
ADDITIONAL FEATURES OF VAM3D CODE

- FINITE ELEMENT APPROACH
- RIGOROUS TREATMENT OF CHANGING WATER TABLE
- RIGOROUS TREATMENT OF UNSATURATED ZONE
- CAPACITY FOR HETEROGENEOUS AND ANISOTROPIC HYDRAULIC PARAMETERS
- CAPACITY FOR VARIETY OF BOUNDARY CONDITIONS
- CAPACITY FOR DISCRETE PERMEABILITY FEATURES

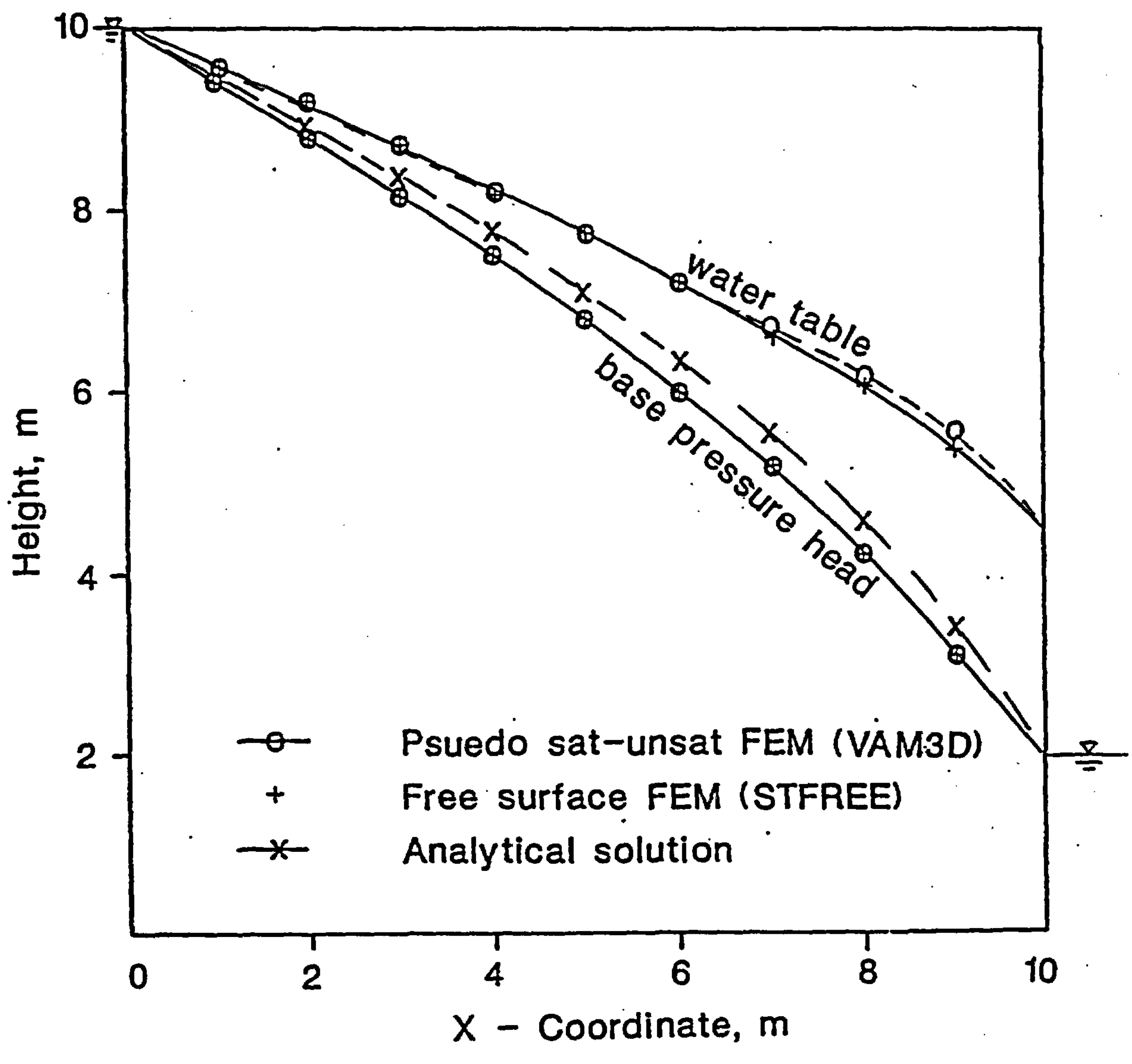
STEADY FLOW TO PARALLEL DRAINS



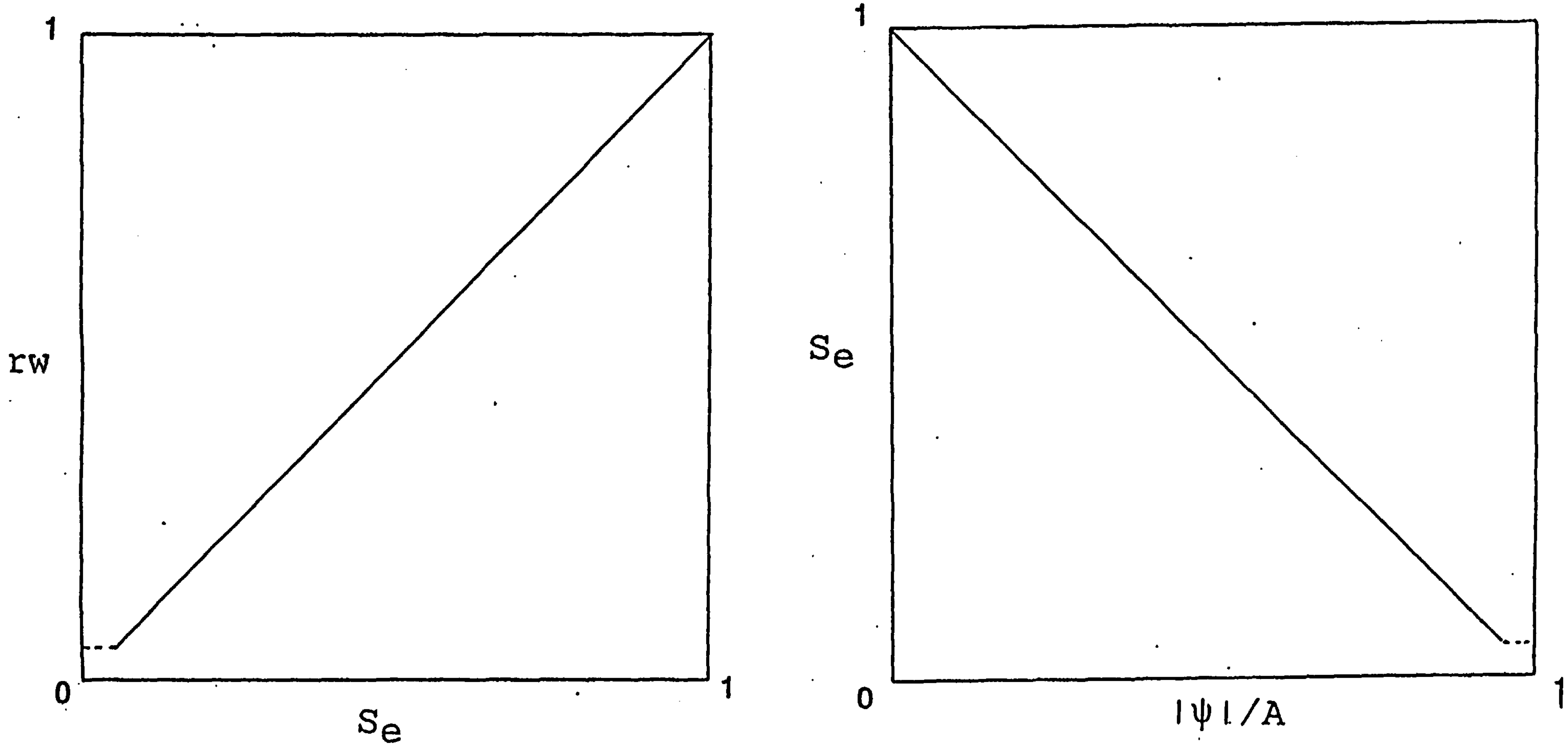
SQUARE BLOCK WITH INFILTRATION



STEADY FLOW THROUGH SQUARE EMBANKMENT



PSUEDO SAT-UNSAT SOIL MOISTURE CHARACTERISTIC CURVES

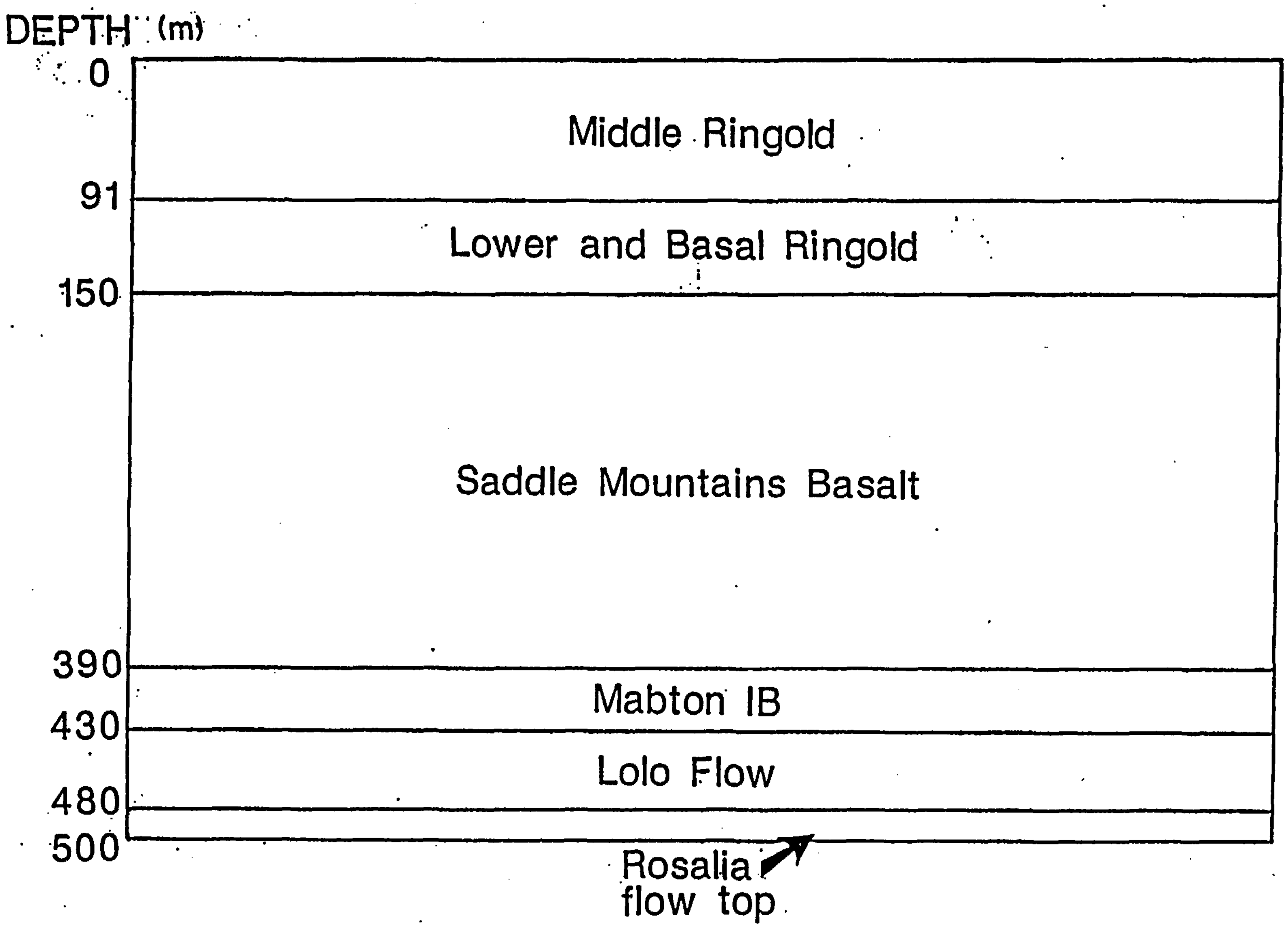


S_e = effective saturation

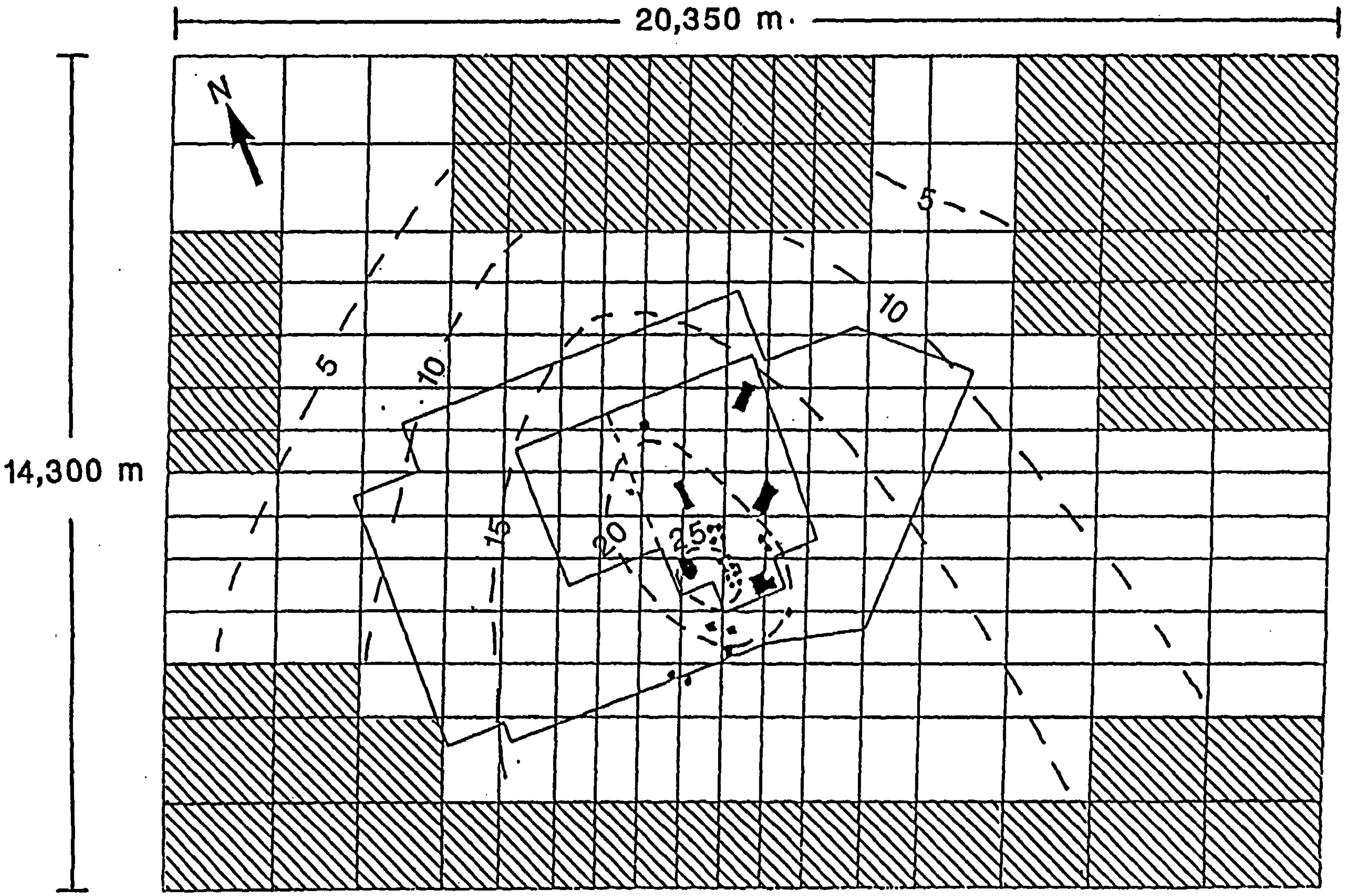
A = soil layer thickness

$$S_e = \frac{S_w - S_{wr}}{1 - S_{wr}}$$

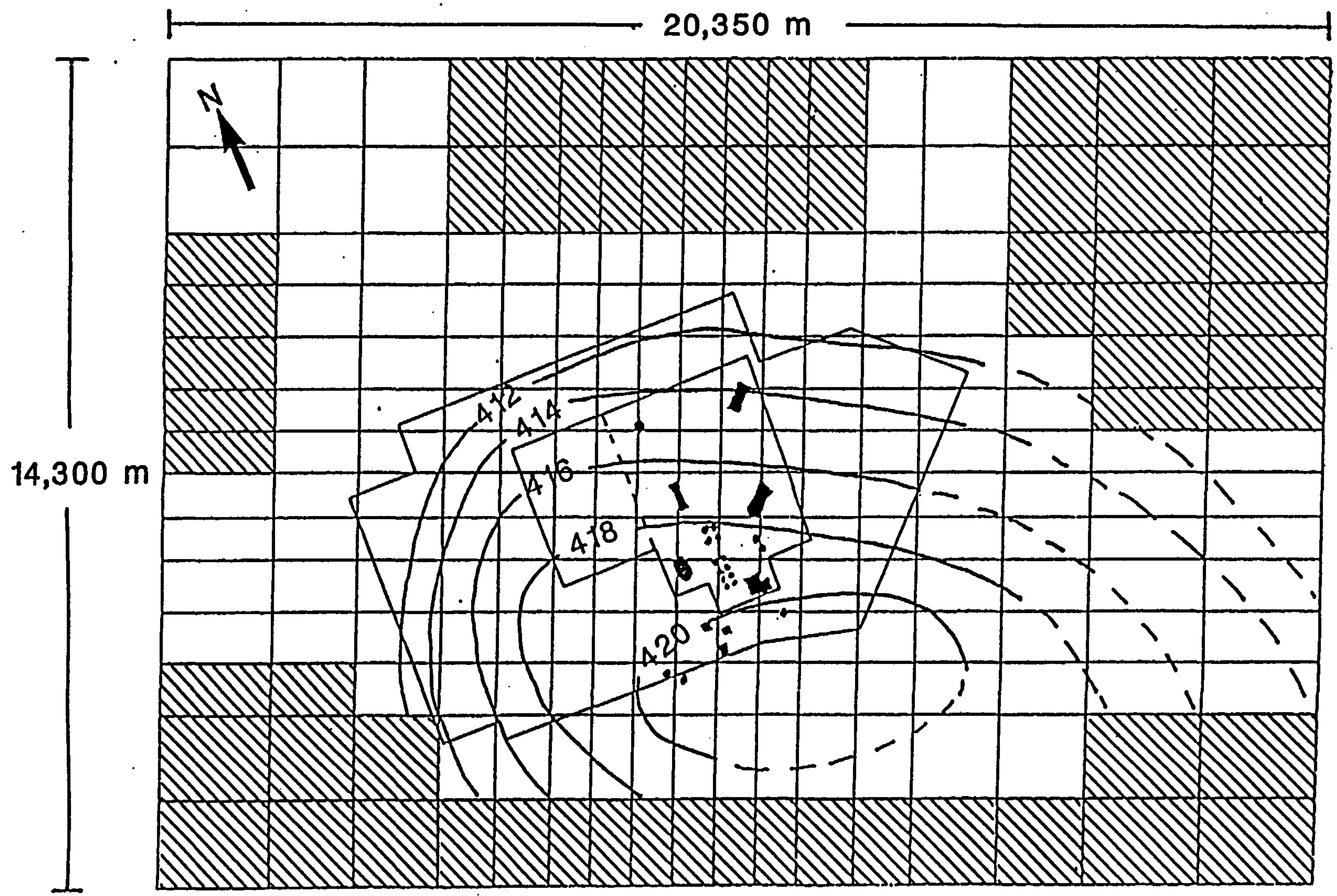
Simplified Cross-Section of 200-West Area Showing Layers used in Three-Dimensional Model



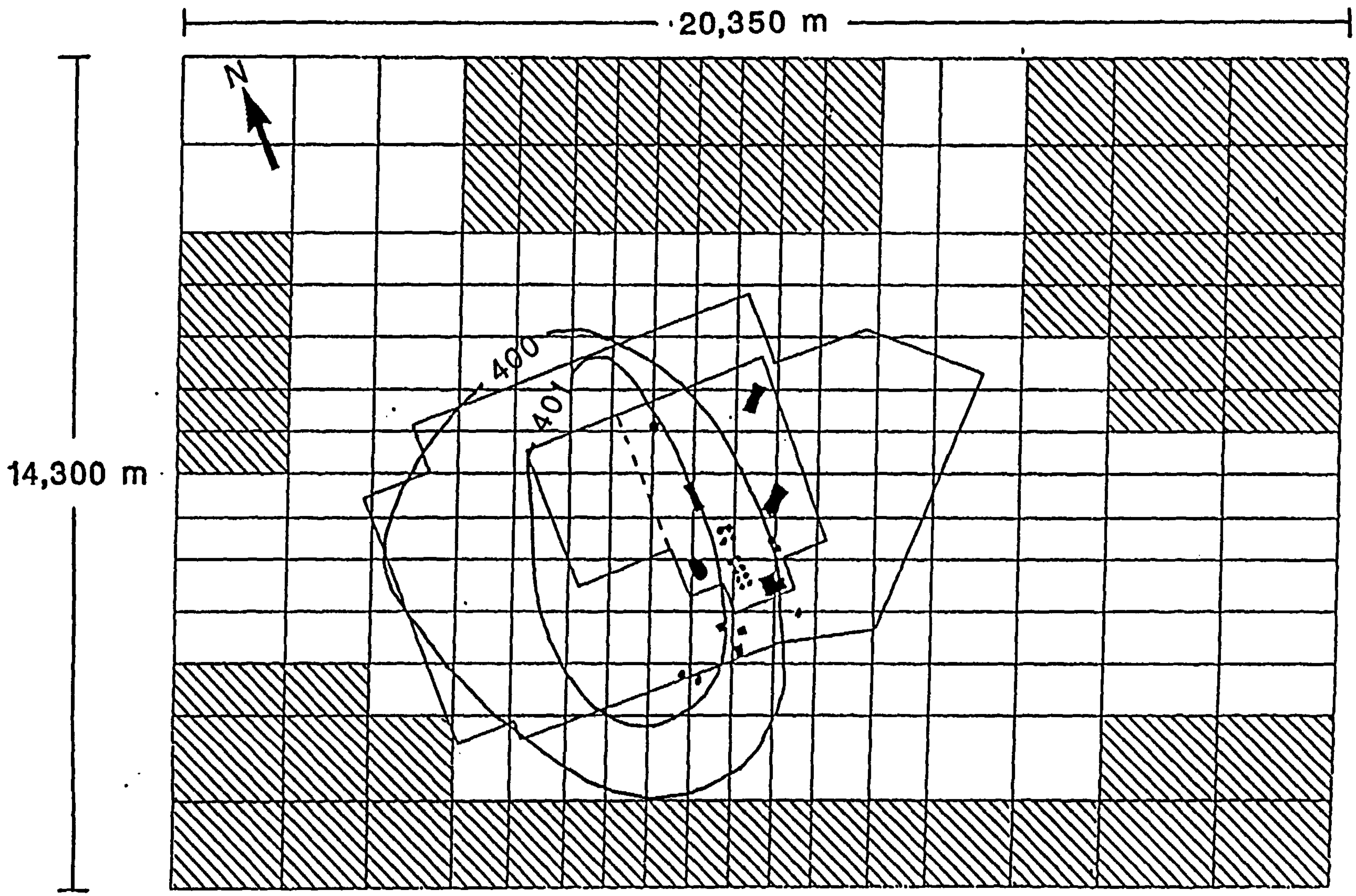
Water Table Rise (Ringold formation) 1944 to 1980



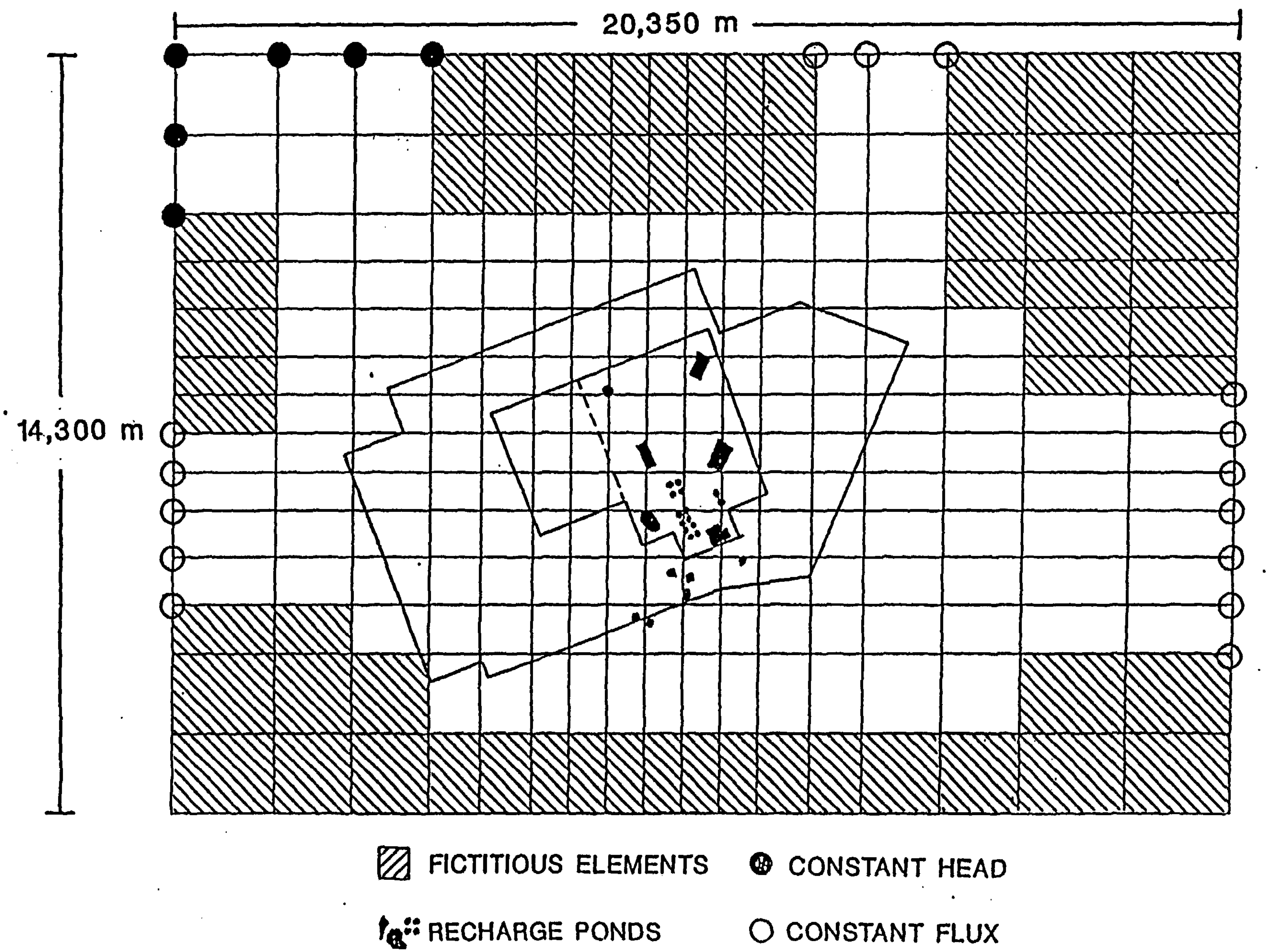
Potentiometric Levels in the Mabton Interbed (circa 1980)



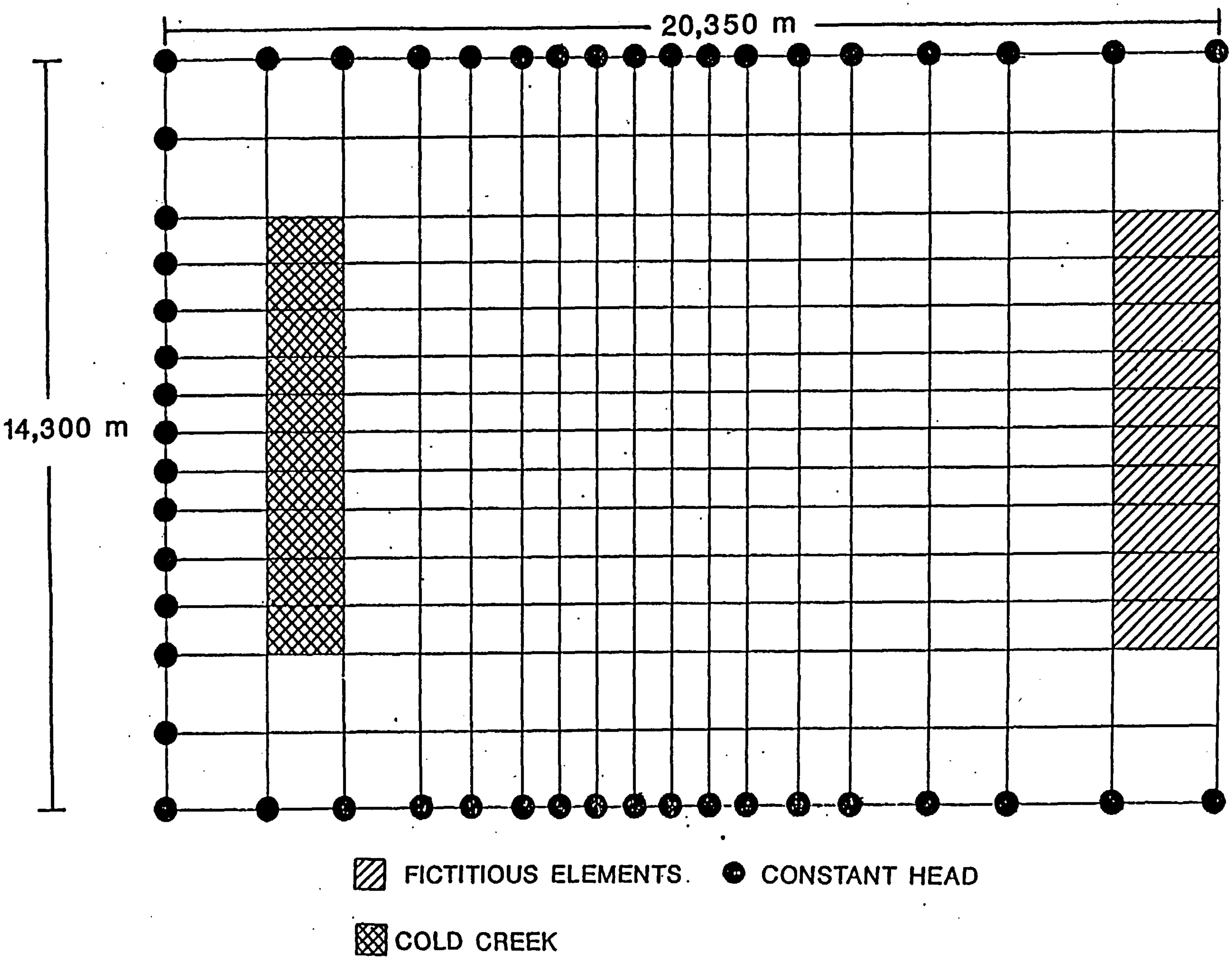
Potentiometric Levels in the Rosalia Flow Top (circa 1980)



Boundary Conditions and Locations of Recharge Ponds for the Top Model Layer



Boundary Conditions for Underlying Model Layers



RANGES OF REPORTED HYDRAULIC PROPERTY VALUES

FORMATION	K_h	K_v	S	AUTHOR
Middle Ringold	3 - 70 m/d		0.06 - 0.016	Graham, Hall, Straight, Brown, 1981
	2 - 600 m/d			Gephart et al., 1979
	6.096 - 182.88 m/d		0.05	Strait & Mercer
Lower Ringold	20 - 600 ft/d 0.11 - 10 ft/d		0.01 - 0.1	Gephart et al., 1979
Elephant Mountain	622 m/d 10^2 - 10^{-2} m/d			Graham, Last, & Fecht
Rattlesnake Ridge Interbed	10 - 10^{-2} m/d			Graham, 1984
	0.03 - 7.7 m/d			Graham, Last, & Fecht
Pomona Flow	10^{-6} - 10^{-8} m/d			Graham, 1984
Rosalia	10^{-3} - 10^{-2} m/~~s~~day (?)		10^{-4} - 10^{-3}	Linesay, 1986

ESTIMATES OF EFFECTIVE K_v, FLOW INTERIORS

1.5×10^{-5} m/s (Luzier and Skrivan, 1975)

6.0×10^{-11} m/s (Tanaka, 1974)

$10^{-11} - 10^{-12}$ m/s (Arnett et al., 1981)

2.1×10^{-9} m/s (Nevulis et al., 1987)

$K_v / K_h = 10^{-2}$ to 10^{-3} (Dove et al., 1982)

$= 10^{-3}$ to 10^{-4} (Arnett et al., 1981)

SUMMARY AND CONCLUSIONS

- HEAD INCREASES HAVE BEEN DOCUMENTED AT THE WATER TABLE, MABTON, AND ROSALIA UNITS DUE TO SURFACE WASTE LEAKAGE

- MODEL ANALYSIS REQUIRES CAPABILITY TO ACCOMMODATE SIGNIFICANT CHANGES IN WATER TABLE ELEVATION AND THREE-DIMENSIONAL FLOW WITH HIGH DEGREE OF HETEROGENEITY AND ANISOTROPY

- CALIBRATED MODEL WILL BE USED TO ASSESS IMPACTS OF VARIOUS SHAFT-SINKING SCENARIOS

- NEXT STEPS

  - TEST MODEL RUNS

  - CALIBRATION

  - SHAFT IMPACT SIMULATIONS

See pocket 2 for enclosure

PDe-1
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