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NUCLEAR WASTE CONSULTANTS INC.
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April 15, 1987

009/2.3/NWC.005
RS-NMS-85-009
Communication No. 147

Encl. in Pocket

U.S. Nuclear Regulatory Commission
Division of Waste Management
Geotechnical Branch
MS 623-SS
Washington, DC 20555

Attention: **Mr. Jeff Pohle, Project Officer**
Technical Assistance in Hydrogeology - Project B (RS-NMS-85-009)

Re: **Trip Report - NRC/DOE BWIP Hydrology Workshop, Richland, WA, April 5-8, 1987**

Dear Mr. Pohle:

This letter transmits Nuclear Waste Consultants' (NWC) trip report for the NRC/DOE BWIP Hydrology Workshop, Richland, WA, April 5-8, 1987. Nuclear Waste Consultants was represented at the meeting by Mr Adrian Brown, per the direction of the NRC Project Officer. Preparation for and attendance at this meeting is accountable under Subtask 2.3 of the current contract.

The purpose of the meeting was to review the DOE proposals for hydrologic testing at the BWIP site prior to construction of the Exploratory shaft. The attached memorandum from Mr. Brown to Mr. Mark Logsdon (NWC Project Manager) summarizes the activities that were part of the meeting. Attached to the memorandum is a set of view-graph masters of the material prepared by NWC/TTI in preparation for the meeting and a set of notes prepared by Mr. Brown during the meeting at the direction of Dr. Tilak Verma, NRC's Senior Hydrologist and technical lead for the meeting.

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WM Project 10, 11, 16
Docket No.
PDR ✓
x LPDR ✓ (B,N,S)

Distribution:
x Pohle

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If you have any questions about this trip report, please contact me immediately.

Respectfully submitted,
NUCLEAR WASTE CONSULTANTS, INC.

Mark J. Logsdon

Mark J. Logsdon, Project Manager

Att: Trip Report - NRC/DOE Bwip Workshop, Richland, WA, April 5-8, 1987

cc: US NRC - Director, NMSS (ATTN PSB)
DWM (ATTN Division Director)
Mary Little, Contract Administrator
WMGT (ATTN Branch Chief)

M. Galloway, TTI

MEMORANDUM

TO: Mark Logsdon, Project Manager

FROM: Adrian Brown, BWIP Technical Director

RE: **Trip Report - DOE-NRC Technical Meeting on the Geohydrology Testing Program for the Hanford Site Before Construction of the Exploratory Test Shaft**, Richland, Washington, April 7-9, 1987.

DATE: March 14, 1987

This memorandum indicates NWC/TTI activities undertaken as part of the above noted meeting at Richland.

Saturday, April 4 — The NWC/TTI team comprising Adrian Brown left Denver at 7 p.m. and arrived at the Rivershore Inn in Richland at 10 p.m. Arrival and departure times for the meeting had been agreed upon with the NRC Contract Officer. NWC/TTI group size had been reduced from 3 to 1 by directive from the Contract Officer at 5 p.m. on Thursday, April 2.

Sunday, April 5 — The NRC team, comprising T. Verma, J. Linehan, N. Coleman, and D. Chery (NRC), R. Williams, G. Winter (W&A), A. Brown (NWC), and T. Steele (InSitu) met to discuss the proposed program, make presentations to the group about the various evaluations of the proposed DOE test plan (articulated in an undated letter from James Knight to John Linehan believed to have been sent around March 16, 1987). The meeting was conducted by Dr. Verma, with comment where requested by the other participants. As requested by Dr. Verma, attached are copies of viewgraphs that were prepared by NWC/TTI for this pre-meeting and which form the technical basis for the contributions made by NWC/TTI. In general these materials were not presented at the meeting.

Monday, April 5 — The same NRC team, plus R. Browning of the NRC, met to discuss the responses to the letter from J. Linehan to O. Olson dated April 10, 1986, containing NRC concerns to the previously presented test plan. This meeting was open, and was attended by representatives of the States of Washington and Oregon, and of the Nez Perce and Umatilla Tribes, as well as the Council of Energy Resource Tribes.

Tuesday, April 6	The meeting between the DOE and the NRC was begun on this day, attended by representatives of affected states, Indian Tribes, and the public. The agenda was generally followed closely. The NRC team caucused as planned: this caucus was open, and was attended in part by representatives of the press, and some of the affected Indian Tribes.
Wednesday, April 7	The meeting continued between the DOE and the NRC, with similar participation by affected parties and the public. The agenda was generally followed. The NRC team caucused in the afternoon, to prepare positions on the proposed test plan, and on the responses to the April 10, 1986 letter. During this caucus Mr. Brown was also requested to prepare notes on the various testing matters that had been reviewed during the four days of the trip. A copy of these notes was handed to Dr. Verma, and a further copy is attached to this trip report for reference. The positions and responses to the April 10, 1986 letter were presented to the meeting in the evening. Mr. Brown left the meeting as had been previously arranged at 6.00 p.m., and traveled to Spokane.

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STABILIZATION OF WATER LEVELS

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LEAKY AQUIFER EVALUATIONS

TRACER TRAVEL DISTANCE

DRILLING RESPONSE

SIGNIFICANT HEAD ERRORS

ATTACHMENT 2

NOTES ON LHS TESTING PLAN

Encl to Ltr dat'd
4-15-87, rec'd
4-22-87
To: Pohle
From: Logsdon

VOLUME I

NWC/TTI

PRE-MEETING PRESENTATION VIEWGRAPHS

D-1021

DOE-NRC MEETING ON THE GEOHYDROLOGY TESTING PROGRAM FOR THE HANFORD SITE BEFORE CONSTRUCTION OF THE EXPLORATORY SHAFT

Richland, Washington
April 7-9, 1987

REVIEW OF "GEOHYDROLOGIC TESTING PROGRAM FOR THE HANFORD SITE BEFORE CONSTRUCTION OF THE FIRST EXPLORATORY SHAFT"

by

Nuclear Waste Consultants Inc
Terra Therma Inc

April 7-9, 1987

SCOPE OF EVALUATION

1. Objectives. Review objectives for gaps, and adequacy.

2. Feasibility of Proposal. Review feasibility of proposal with respect to technology, equipment, and instrumentation.

3. Sequence. Review sequence of tests with respect to whether it is reasonable with respect to the objectives of the program.

4. Vertical Permeability. Review the proposed testing program with respect to the extent to which the vertical permeability of the units in the Grande Ronde will be evaluated. Discuss any percieved problems with the proposed testing in obtaining supportable values, and examine the rationale behind the tests.

5. Porosity. Review the testing program with respect to the extent to which the porosity of the units in the Grande Ronde will be evaluated.

STRUCTURE OF EVALUATION

1. Review objectives of program

2. Review proposed program:

   Hydraulic baseline
   LHS tests
   Hydrochemical sampling
   Tracer testing

   Review of each item uses the following categories:

   Description of proposed action
   Evaluation with test objectives
   Data needs assessment
   Feasibility assessment
   Conclusions on utility of test

3. Overview

1.0 EVALUATION OF OBJECTIVES

1.1 OBJECTIVES

1. To collect data on geohydrologic conditions that will be significantly changed or rendered unobtainable after shaft construction (the "perishable data" objective).

2. To provide an early indication of whether disqualifying conditions are present before proceeding with construction of the ES (the "disqualification" objective).

3. To provide data on geohydrologic conditions that may affect the design of the ESF or the repository (the "engineering design" objective)."

4. To collect data on geohydrologic conditions in order to identify the effects of the ESF on the geohydrologic system and on subsequent geohydrologic tests (the "ESF impact" objective).

1.0 EVALUATION OF OBJECTIVES

1.2 EVALUATION

1. Objectives appear complete with respect to pre-ESF testing objectives.

2. Objectives appear reasonable.

3. Objectives have differing relative importance with respect to licensing.

2.0 REVIEW OF PROPOSED PROGRAM

2.1 HYDRAULIC BASELINE

2.1.1 Description

1. Install two new nests of piezometers (DC-24 and DC-25), to bring total to 36 locations.

2. Allow head measurements to stabilize and measure pre-waste-emplacement head conditions, presumably using up-hole techniques.

3. Calculate flow directions and gradients from results.

2.0 REVIEW OF PROPOSED PROGRAM

2.1 HYDRAULIC BASELINE

2.1.2 Evaluation with respect to objectives

1. Perishable?
   - Yes.
   - ESF program will perturb both flows and heads in the site area.
   - Appropriate prior to ESF program.

2. Needed to evaluate disqualification?
   - Probably minor.
   - Gradient uncertainties reflect in GWTT uncertainties, but remaining uncertainties are minor.
   - Head impact on uncertainties about inflow to ESF are negligable.

3. Need for design?
   - No.

4. Need for evaluation of ES impact?
   - Possibly: the head impact of the ES construction may be able to be measured against this head.

2.0 REVIEW OF PROPOSED PROGRAM

2.1 HYDRAULIC BASELINE

2.1.3 Data Needs Assessment

1. Does the data already exist?
   - Gradient is quite well known already.
   - Pre-test gradients have been established.
   - GWTT gradients essentially established.
   - May be other constituencies that need better gradient data.
   - Improvement in spatial data density minor.

2. Can the proposed data be obtained?
   - Yes, provided accuracy is not required to be better than about 1-2 meters.

3. Is the data necessary for licensing evaluations?
   - Yes: GWTT, and possibly for flux evaluations.

2.0 REVIEW OF PROPOSED PROGRAM

2.1 HYDRAULIC BASELINE

2.1.4 Feasibility

1. Uphole head measurements of water pressure continue to be a problem due to density differences in the column of water.

2. Less than 1-2 meter absolute accuracy unrealistic by any method.

3. Downhole pressure measurements should be taken for the most supportable evaluation of real "heads".

4. Strongly recommend drawing formation water into all piezometers ASAP.

2.0 REVIEW OF PROPOSED PROGRAM

2.1 HYDRAULIC BASELINE

2.1.5 Conclusions

1. Generally the additional head information that is proposed does not appear to provide significant additional understanding for licensing purposes.

2. Current accuracy of readings is sufficient to observe the key vertical and horizontal gradients that will be required for licensing.

2.0 REVIEW OF PROPOSED PROGRAM

2.2 LARGE SCALE HYDRAULIC STRESS TESTS

2.2.1 Description

1. Perform four tests: Rocky Coulee Flow Top, Cohassett Flow Top, Cohassett Vesicular Zone, and Birkett Flow Top.

2. Pump each horizon in RRL-2B.

3. Pump for up to 100 days.

4. Observe in all piezometers; these are essentially in flow tops, not dense interiors, which is appropriate.

2.0 REVIEW OF PROPOSED PROGRAM

2.2 LARGE SCALE HYDRAULIC STRESS TESTS

2.2.2 Evaluation with respect to objectives

1. Perishable?
   - Perhaps.
   - Shaft may cause some leakage.
   - Installation of ESF may cause significant perturbations to heads, rendering evaluation of tests harder.

2. Needed to evaluate disqualification?
   - Yes.
   - Very high vertical hydraulic conductivity would likely lead to engineering disqualification due to inflow.
   - High horizontal hydraulic conductivity would probably not lead to disqualification.

3. Need for design?
   - Yes.
   - Flow to ESF important for design.

4. Need for evaluation of ES impact?
   - Possibly.
   - Might be possible to identify change in vertical permeability due to shaft installation using retest of Birkett.

2.0 REVIEW OF PROPOSED PROGRAM

2.2 LARGE SCALE HYDRAULIC STRESS TESTS

2.2.3 Data Needs Assessment

1. Does the data already exist?
   - Vertical hydraulic conductivity not known.
   - Large scale values of horizontal hydraulic conductivity are poorly known at present.
   - Boundary locations are poorly known.

2. Can the proposed data be obtained?
   - Vertical hydraulic conductivity: yes, within bounds.
   - Horizontal hydraulic conductivity: yes.
   - Boundaries: probably not.

3. Is the data necessary for licensing evaluations?
   - Vertical hydraulic conductivity: yes.
   - Horizontal hydraulic conductivity: yes.
   - Boundaries: probably not.

2.0 REVIEW OF PROPOSED PROGRAM

2.2 LARGE SCALE HYDRAULIC STRESS TESTS

2.2.4 Feasibility

1. The test does not have very good discrimination for vertical permeabilities less than about 1E-10 meters/second. Discrimination would be improved with a piezometer at about 500 meters.

2. Horizontal hydraulic conductivity will be excellent.

3. Boundaries will likely not be identified unless the transmissivities are in the order of 100 square meters per day (the highest spot value recorded in the Grande Ronde).

4. Use of sucker pumps is not considered to be a significant problem in the test, providing appropriate flows and drawdowns can be obtained.

2.0 REVIEW OF PROPOSED PROGRAM

2.2 LARGE SCALE HYDRAULIC STRESS TESTS

2.2.5 Conclusions

1. Plans appear appropriate for evaluating general vertical hydraulic conductivities.

2. Horizontal hyraulic conductivities will be very well identified in the area of the RRL.

3. Boundaries will in general not be identified.

4. Sequence of testing is considered to be appropriate, if somewhat overdone for the matters to be evaluated.

2.0 REVIEW OF PROPOSED PROGRAM

2.3 HYDROCHEMICAL SAMPLING

2.3.1 Description

1. Measure water quality in output from LHS tests.

2.3.2 Evaluation with respect to objectives

1. Perishable?
   - Probably not.

2. Needed to evaluate disqualification?
   - No.

3. Need for design?
   - Possibly, for cannister design.

4. Need for evaluation of ES impact?
   - Probably not.

2.0 REVIEW OF PROPOSED PROGRAM

2.3 HYDROCHEMICAL SAMPLING

2.3.3 Data Needs Assessment

1. Does the data already exist?
   - Yes.

2. Can the proposed data be obtained?
   - Yes, although the degassing and temperature changes make the value of the data questionable.

3. Is the data necessary for licensing evaluations?
   - Not directly.

2.3.4 Feasibility

1. Yes, however the samples are not significantly better than currently available.

2.3.5 Conclusions

1. Data is not needed, but is readily and cheaply available, so may as well be collected.

2.0 REVIEW OF PROPOSED PROGRAM

2.4 TRACER TESTS

2.4.1 Description

1. Perform four tests: Rocky Coulee Flow Top, Cohassett Flow Top, Cohassett Vesicular Zone, and Birkett Flow Top.

2. Radial convergent tests from two locations between 50 and 150 meters distant from the pumped well.

3. Pump for up to 100 days.

4. Inject from RRL-2A and RRL-2C with different tracers.

2.0 REVIEW OF PROPOSED PROGRAM

2.4 TRACER TESTS

2.4.2 Evaluation with respect to objectives

1. Perishable?
   - Possibly.
   - If done at a larger scale, then would be perishable.

2. Needed to evaluate disqualification?
   - Yes.
   - Porosity a key uncertainty in GWTT evaluations.
   - Dispersivity important for licensing, but not necessarily for disqualification.

3. Need for design?
   - No.

4. Need for evaluation of ES impact?
   - No.

2.0 REVIEW OF PROPOSED PROGRAM

2.4 TRACER TESTS

2.4.3 Data Needs Assessment

1. Does the data already exist?
   - No. Two tests remote from the site.

2. Can the proposed data be obtained?
   - Probably not in right place.
   - Probably too small scale.
   - Probably unconservative value of Kv.

3. Is the data necessary for licensing evaluations?
   - Yes.
   - GWTT and flux measurements require porosity.

2.0 REVIEW OF PROPOSED PROGRAM

2.4 TRACER TESTS

2.4.4 Feasibility

1. Porosity likely to be overestimated, which is unconservative with respect to GWTT and flux.

2. Test may very well fail.

3. Short distance not necessarily representative, and not between boundary of repository and accessibly environment.

4. Alternatives exist and are feasibly. However note that they may not be perishable.

2.0 REVIEW OF PROPOSED PROGRAM

2.4 TRACER TESTS

2.4.5 Conclusions

1. Poor tracer test selection for needs of project.

2. Disqualification due to GWTT will not be seriously addressed in entire program.

3. This is seen as the major weakness in the program.

3.0 OVERVIEW

TEST	NEEDED?	METHOD OK?	TIMELY?	PROGRAM OK?
Hydraulic baseline	No	Yes	--	Yes
Large-scale hydraulic stress	Yes	Yes	Yes	Yes
Water quality	No	Yes	--	Yes
Tracer	Yes	No	Yes	No

DATA OBTAINED	PERISH-ABLE	DISQUAL-IFIER?	DESIGN NEED?	ESF IMPACT?
Vertical hydraulic conductivity	?	Yes	Yes	?
Horizontal hydraulic conductivity	?	No	?	?
Effective porosity	Yes	Yes	No	?
Boundaries	?	No	No	No

EFFECTIVE POROSITY AS A DATA NEED FOR 10 CFR 60

1. 10 CFR 60.113(a)(2) - Pre-emplacment Groundwater Travel Time

$$GWTT = L / \bar{V}$$

$$\bar{V} = K\, i / n_e$$

Therefore, $GWTT = n_e\, L / K\, i$

2. 10 CFR 60.112 - EPA Limits

Consider 1-D Flow and Transport:

$$\partial C / \partial t = D_x\, (\partial^2 C / \partial x^2) - \bar{v}_x\, (\partial C / \partial x)$$

$$\bar{v}_x = (K\, i / n_e)_x$$

Therefore,

$$\partial C / \partial t = D_x\, (\partial^2 C / \partial x^2) - (K\, i / n_e)_x (\partial C / \partial x)$$

VOLUME I

STABILIZATION OF WATER LEVELS

STABILIZATION OF WATER LEVELS AND GRADIENTS

OBJECTIVE

Determine the extent to which BWIP water levels have stabilized and baseline conditions have been achieved.

ANALYSIS

Construct hydrographs using all available data (at the time, was January, 1985 to April, 1986) for piezometers DC-19C, 20C, and 22C.

Using a straightline extrapolation, determine predicted water level channges per year and total expected change to some date (January 1, 1992).

Compare these values to projections made by DOE.

Calculate water levels and gradients for November 1, 1986 and compare to recently obtained water level data.

COMPARISON OF WATER LEVELS AND GRADIENTS BETWEEN PREDICTED (FROM TTI MR #9) AND ACTUAL VALUES FOR NOVEMBER 1, 1986

WATER LEVELS AND VERTICAL GRADIENTS

WELL/ MONITORED ZONE	WATER LEVEL ELEV. (FT MSL)			VERTICAL GRADIENTS			
DC-19C	PREDICTED NOV. 86	ACTUAL NOV. 86	DIFFER-ENCE	PREDICTED NOV. 86	ACTUAL NOV. 86	DIFFER-ENCE	INTERVAL
ROCKY COULEE	402.06	402.00	-.06	.0034	.0028	-.0006	(RC-COH)
COHASSET	401.29	401.38	.09	.0017	.0018	.0001	(COH-UM)
UMTANUM	402.26	402.38	.12				
DC-20C							
ROCKY COULEE	405.62	405.43	-.19	.0008	.0007	-.0001	(RC-COH)
COHASSET	405.47	405.30	-.17	.0020	.0018	-.0002	(COH-UM)
UMTANUM	406.73	406.45	-.28				

HORIZONTAL GRADIENTS (DETERMINED FROM DC-19C, DC-20C, AND DC-22C)

MONITORED ZONE	PREDICTED NOV. 86	ACTUAL NOV. 86	DIFFER-ENCE
ROCKY COULEE	.0001	.0007	.0006
COHASSET	.0008	.0001	-.0007
UMTANUM	.0001	.0003	.0002

CONCLUSIONS

Water levels have stabilized sufficiently to calculate vertical and horizontal gradients in the Grande Ronde Basalts.

Errors in predicted vertical gradients, compared to actual gradients, are consistently an order of magnitude lower than the gradient values.

VOLUME I

TRACER TEST

TRACER TEST EVALUATION

OBJECTIVE

Determine the feasibility of performing tracer tests at distances approaching 5 kilometers.

ANALYSIS

Determination of likely horizontal flow-path, based on effects of thermal build-up.

Determine feasibility and define tracer test configuration, using hydraulic parameters related to flow-path determined in step 1.

Calculate likely tracer travel time.

Assess significance of vertical leakage to results of step 3.

CALCULATED TRACER TRAVEL TIME (days)

SPACING OF WELL FIELDS (Kilometers)	EFFECTIVE POROSITY		
	10^{-3}	10^{-4}	10^{-5}
2	69	6.9	.69
5	431	43.1	4.31

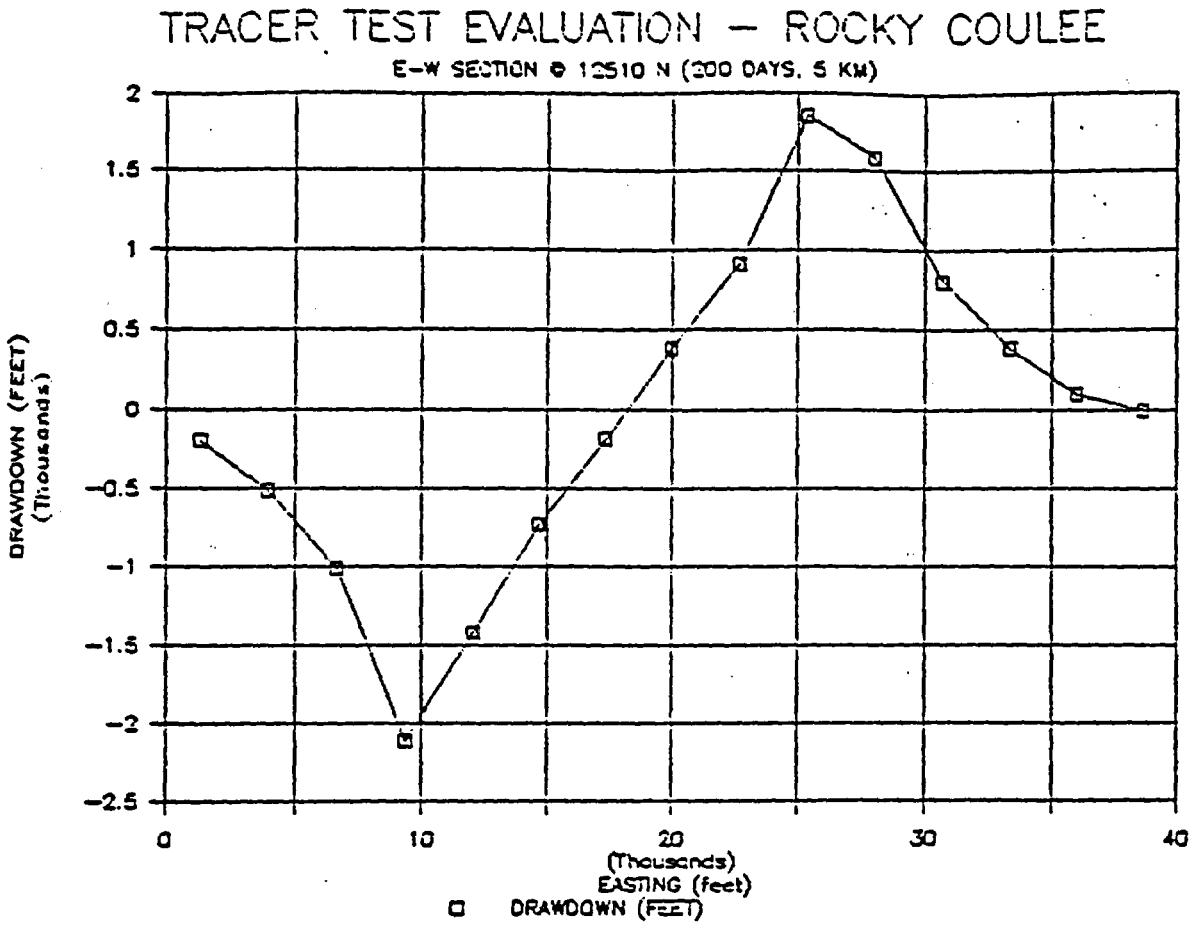
CONCLUSIONS

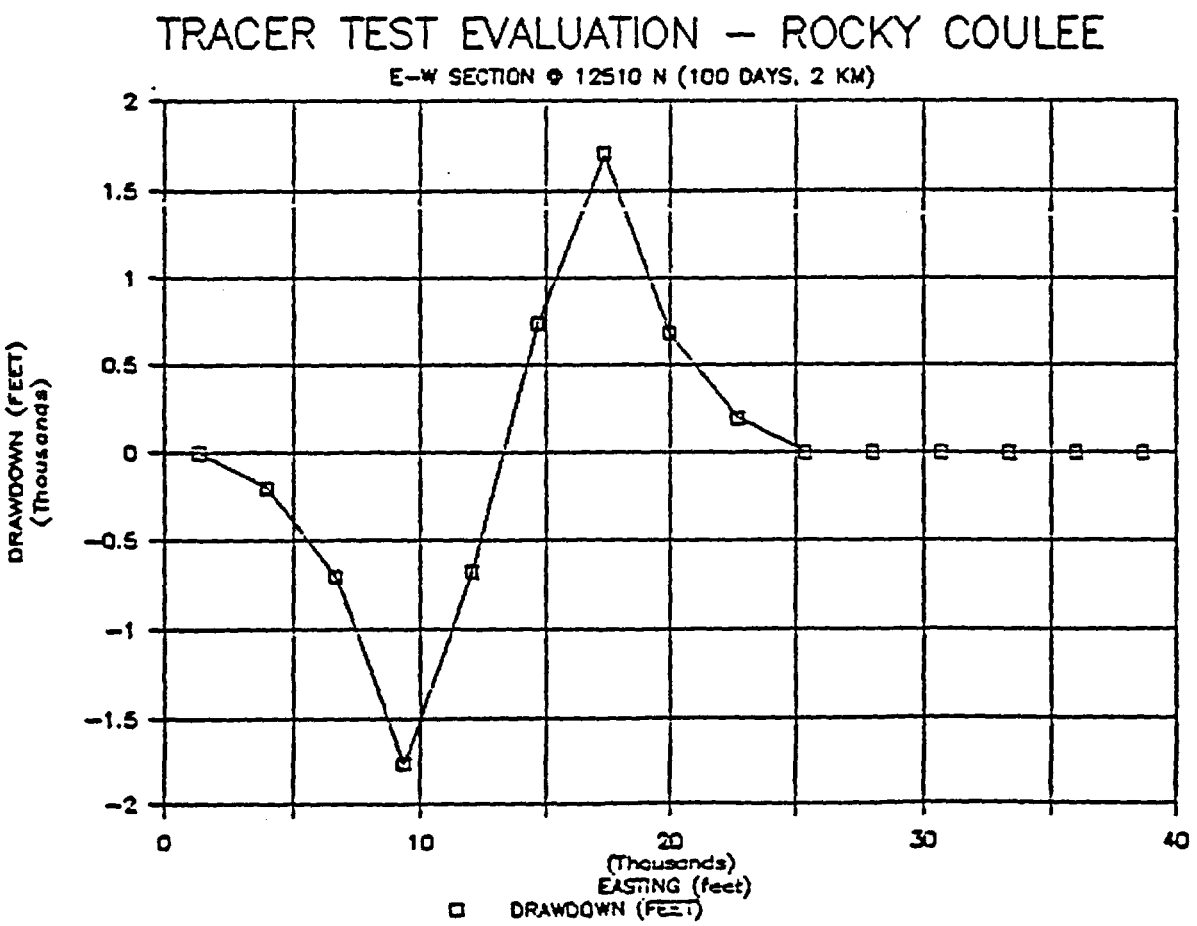
Thermally induced vertical gradients could introduce radionuclides to the Rocky Coulee flow top. The probability of radionuclides reaching interflows above the Rocky Coulee is considerably less.

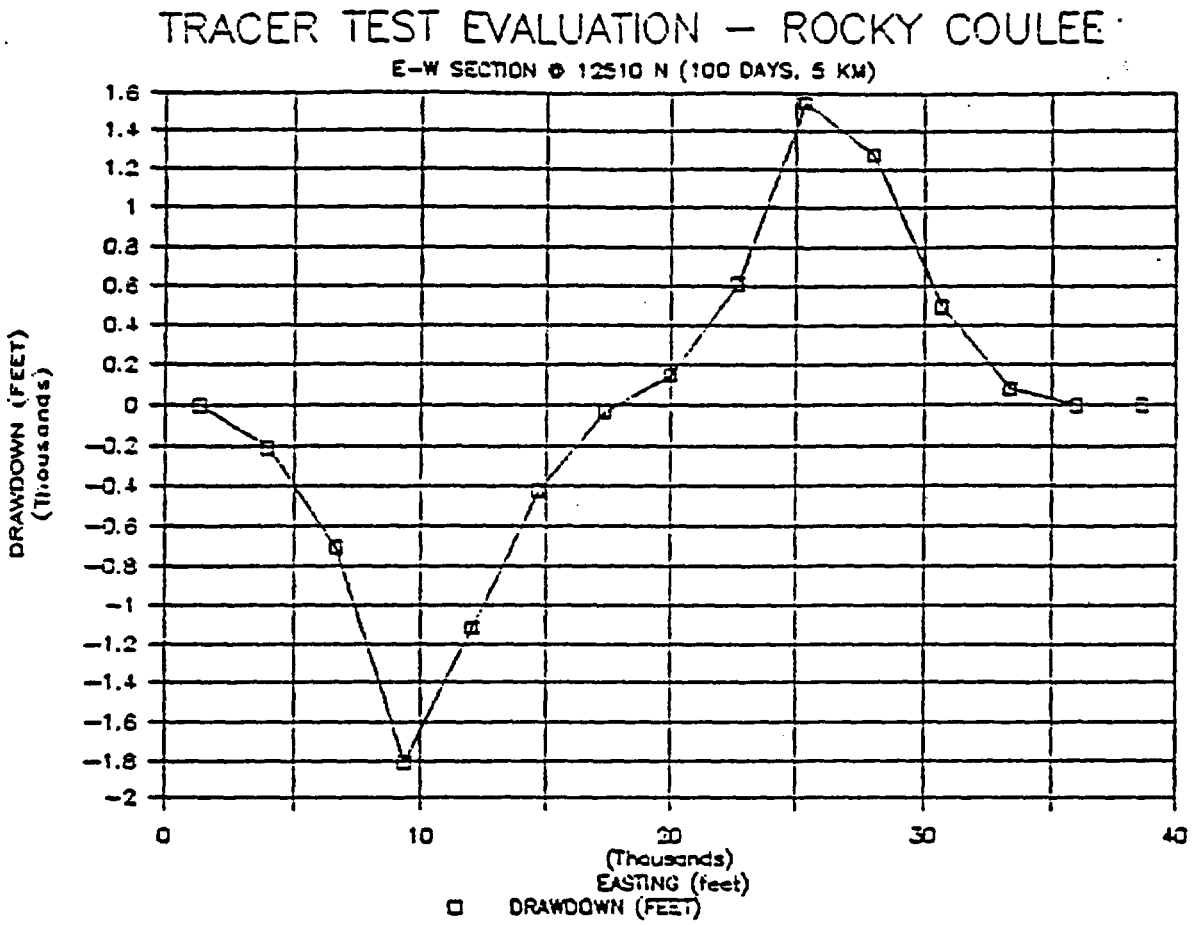
A push-pull tracer test with 3 pumping and 3 injection wells could produce gradients sufficient to transport a tracer in the Rocky Coulee over distances of 2 to 5 km.

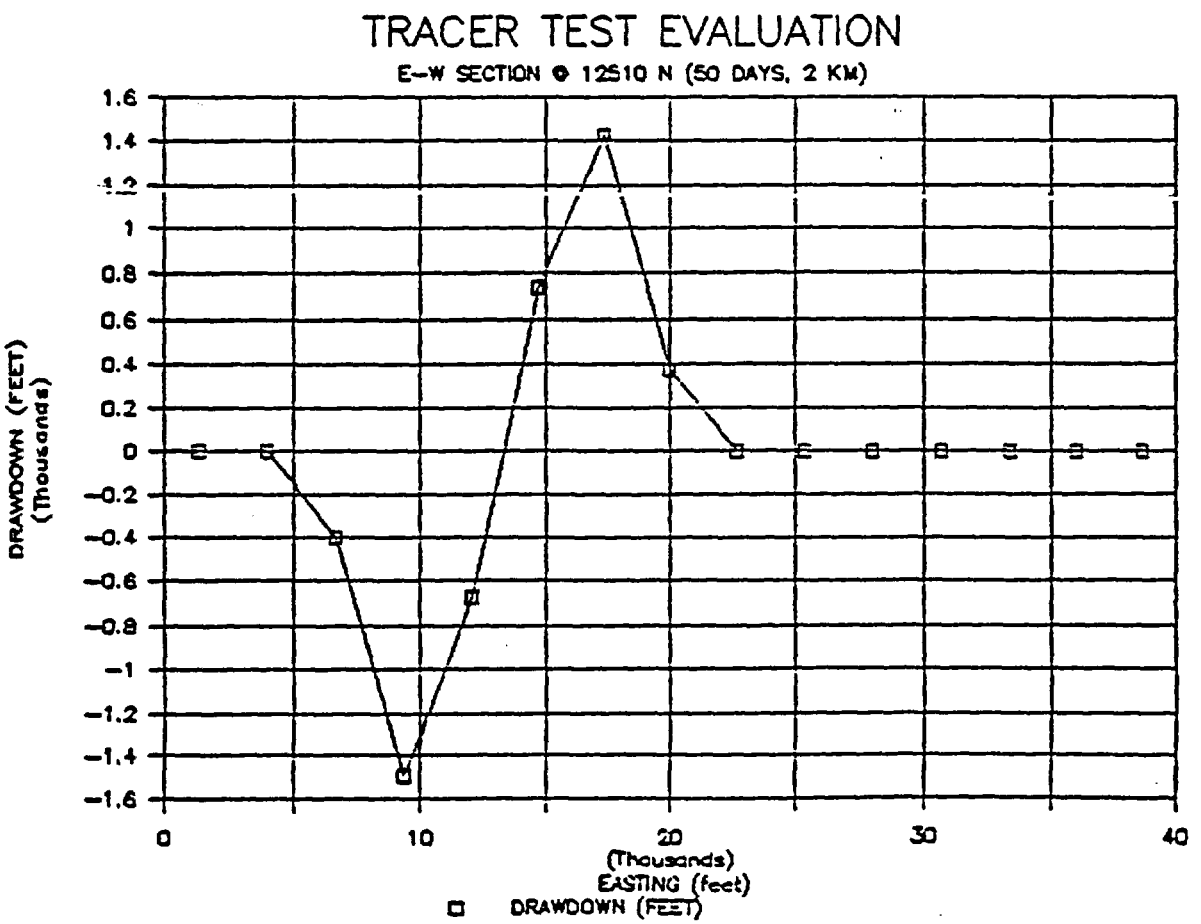
Minimum tracer travel times calculated for 2 and 5 km tests indicate tracer tests performed at this scale are feasible, based on the level of this analysis.

Vertical leakage would not have a significant impact on tracer travel times for aquitard hydraulic conductivities less than 10^{-12} m/s for the 5 km test and 10^{-11} m/s for the 2 km test.


TRACER TEST EVALUATION – ROCKY COULEE
E-W SECTION @ 12510 N (200 DAYS, 5 KM)
DRAWDOWN (FEET)
(Thousands)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
10
20
30
40
(Thousands)
EASTING (feet)
DRAWDOWN (FEET)


TRACER TEST EVALUATION – ROCKY COULEE
E-W SECTION @ 12510 N (100 DAYS, 2 KM)
DRAWDOWN (FEET)
(Thousands)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
20
30
40
(Thousands)
EASTING (feet)
DRAWDOWN (FEET)


TRACER TEST EVALUATION – ROCKY COULEE
E-W SECTION @ 12510 N (100 DAYS, 5 KM)
DRAWDOWN (FEET)
(Thousands)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
0
10
20
30
40
(Thousands)
EASTING (feet)
DRAWDOWN (FEET)


TRACER TEST EVALUATION
E-W SECTION @ 12510 N (50 DAYS, 2 KM)
DRAWDOWN (FEET)
(Thousands)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
0
10
20
30
40
(Thousands)
EASTING (feet)
DRAWDOWN (FEET)

VOLUME I

LEAKY AQUIFER EVALUATIONS

LEAKY AQUIFER ANALYSES

OBJECTIVES

PRE-ANALYSIS OF LHS TESTS CONDUCTED IN SELECTED BASALT INTERFLOWS

FEASIBILITY OF MEASURING VERTICAL HYDRAULIC CONDUCTIVITY OF FLOW INTERIORS

FEASIBILITY OF CONDUCTING A MULTIFLE BOREHOLE TEST IN THE COHASSETT FLOW TOP

LEAKY AQUIFER ANALYSES

ANALYSIS

MODIFIED HANTUSH (1960) LEAKY AQUIFER SOLUTION

NUMERICAL INVERSION OF LaPlace TRANSFORM SOLUTION USING SELFEST ALGORITHM (MOENCH AND OGATA, 1984)

IMAGE WELLS TO SIMULATE HYDROLOGIC BOUNDARIES

LEAKY AQUIFER ANALYSES

ASSUMPTIONS

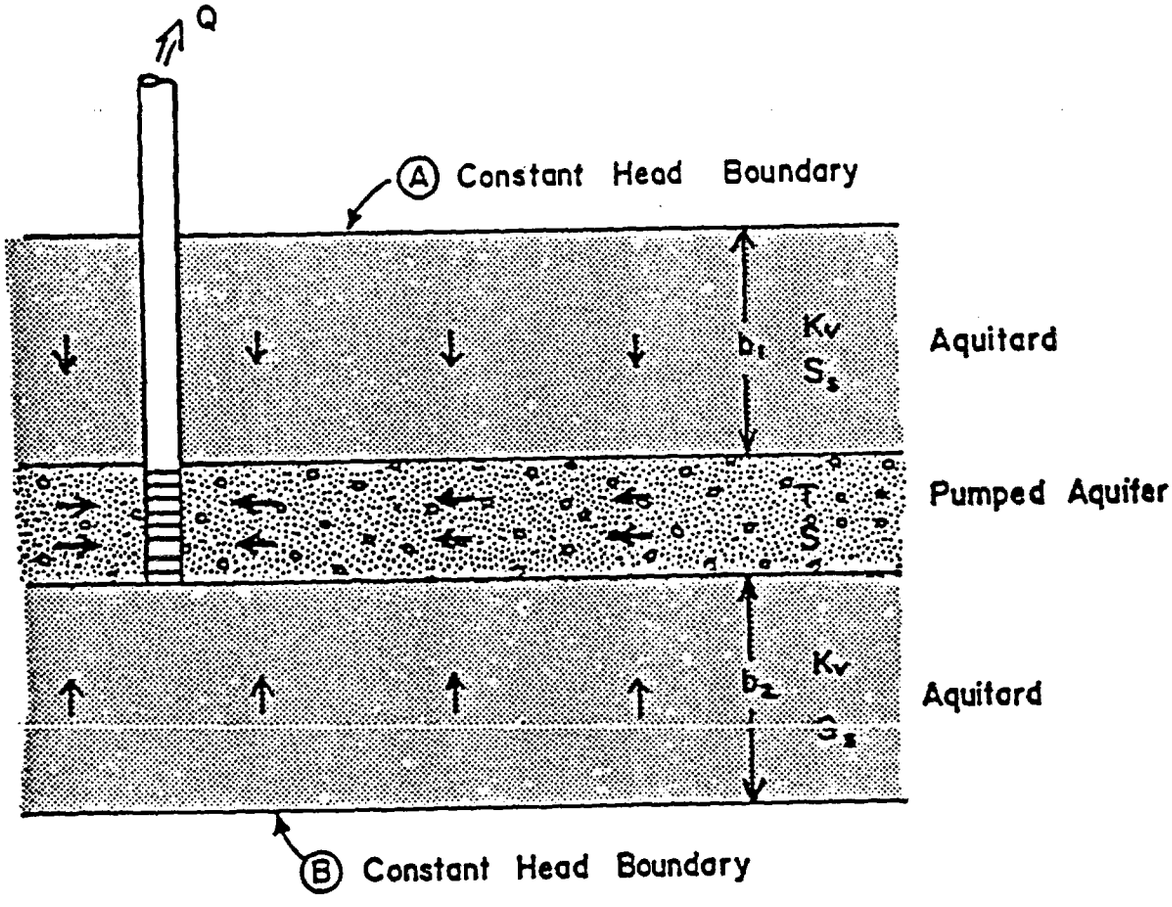
BASIC ASSUMPTIONS GENERALLY ASSOCIATED WITH WELL HYDRAULICS PROBLEMS

AQUITARDS ABOVE AND BELOW THE PUMPED AQUIFER ARE A SOURCE OF WATER TO THE PUMPING WELL

AQUITARDS ARE CAPABLE OF GROUNDWATER STORAGE

TOP OF UPPER AQUITARD AND BOTTOM OF LOWER AQUITARD ARE MAINTAINED AT CONSTANT HEAD (ZERO DRAWDOWN)

LEAKY AQUIFER ANALYTICAL MODEL



ROCKY COULEE LHS TEST ANALYSIS

OBJECTIVES

ASSESS ABILITY OF LHS TEST IN ROCKY COULEE FLOW TOP TO MEASURE OR PROVIDE UPPER BOUND VALUE OF FLOW INTERIOR VERTICAL HYDRAULIC CONDUCTIVITY

EVALUATE USEFULNESS OF 500 METER OBSERVATION WELL

ASSESS ABILITY OF LHS TEST IN ROCKY COULEE FLOW TOP TO IDENTIFY HYDROLOGIC BOUNDARIES

ROCKY COULEE LHS TEST ANALYSIS

ASSUMPTIONS

UPPER AQUITARD EXTENDS FROM ROCKY COULEE FLOW TOP TO LOWER-MOST FRENCHMAN SPRINGS FLOW TOP

LOWER AQUITARD EXTENDS FROM ROCKY COULEE FLOW TOP TO BIRKETT FLOW TOP

ROCKY COULEE LHS TEST ANALYSIS

INPUT PARAMETERS

AQUIFER TRANSMISSIVITY (T):	0.24 m^2/d (2.6 ft^2/d)
AQUIFER STORATIVITY (S):	10^{-5}
DISCHARGE RATE (Q):	43.6 m^3/d (8 gpm)
AQUITARD VERTICAL HYDRAULIC CONDUCTIVITY (K_v):	10^{-12} 10^{-11} 10^{-10} 10^{-9} m/s
AQUITARD SPECIFIC STORAGE (S_s):	10^{-7} m^{-1}
UPPER AQUITARD THICKNESS (b_1):	61 m
LOWER AQUITARD THICKNESS (b_2):	126 m
OBSERVATION WELL RADIAL DISTANCE (r):	100 500 1000 2500 m

ROCKY COULEE LHS TEST ANALYSIS

CONCLUSIONS

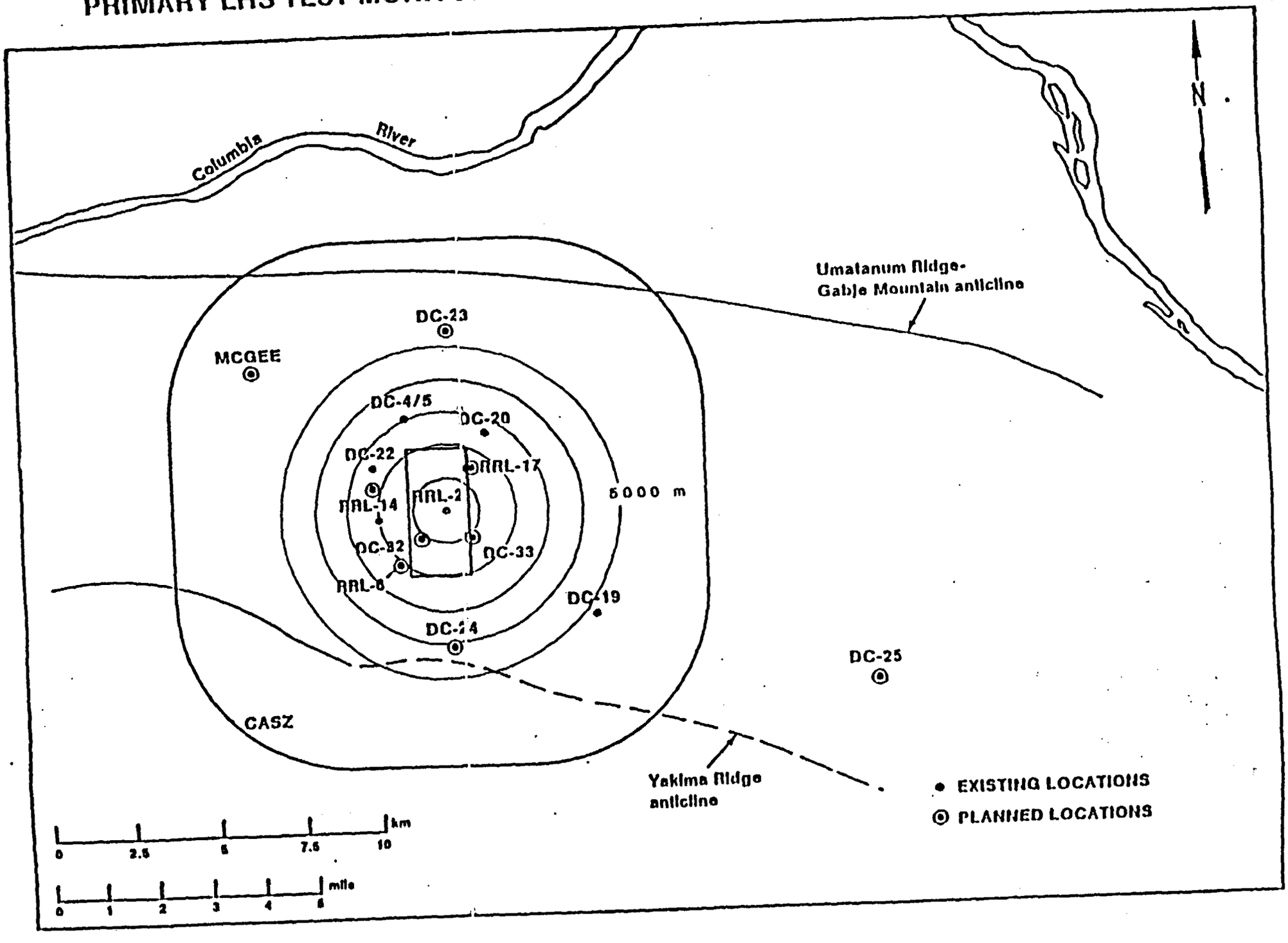
100 METER OBSERVATION WELLS PROVIDE RELIABLE VALUES OF AQUIFER TRANSMISSIVITY AND STORATIVITY, BUT HAVE LIMITED CAPABILITY TO MEASURE AQUITARD CONDUCTIVITIES BELOW 10^{-10} M/S

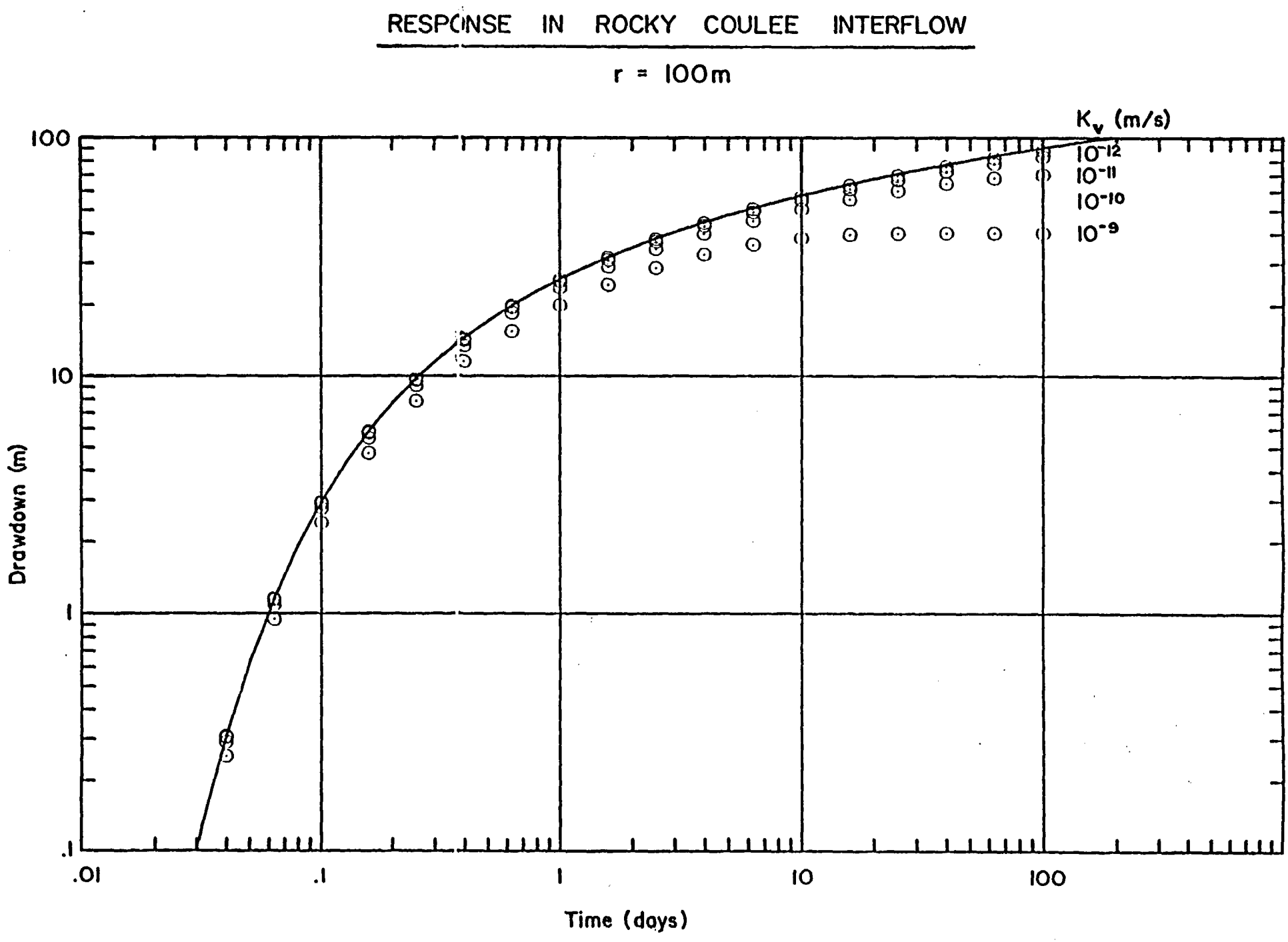
500 AND 1000 METER OBSERVATION WELLS PROVIDE FOR BEST RESOLUTION OF AQUITARD CONDUCTIVITY, BUT HAVE LIMITED CAPABILITY TO MEASURE AQUITARD CONDUCTIVITIES BELOW 10^{-11} M/S

2500 FOOT OBSERVATION WELLS ARE OF LIMITED VALUE FOR MEASURING AQUIFER/AQUITARD PROPERTIES, BUT MAY HAVE THE ABILITY TO CONFIRM THE PRESENCE OF HIGH AQUITARD CONDUCTIVITY

LHS TEST IN ROCKY COULEE FLOW TOP WILL NOT BE CAPABLE OF IDENTIFYING HYDROLOGIC BOUNDARIES

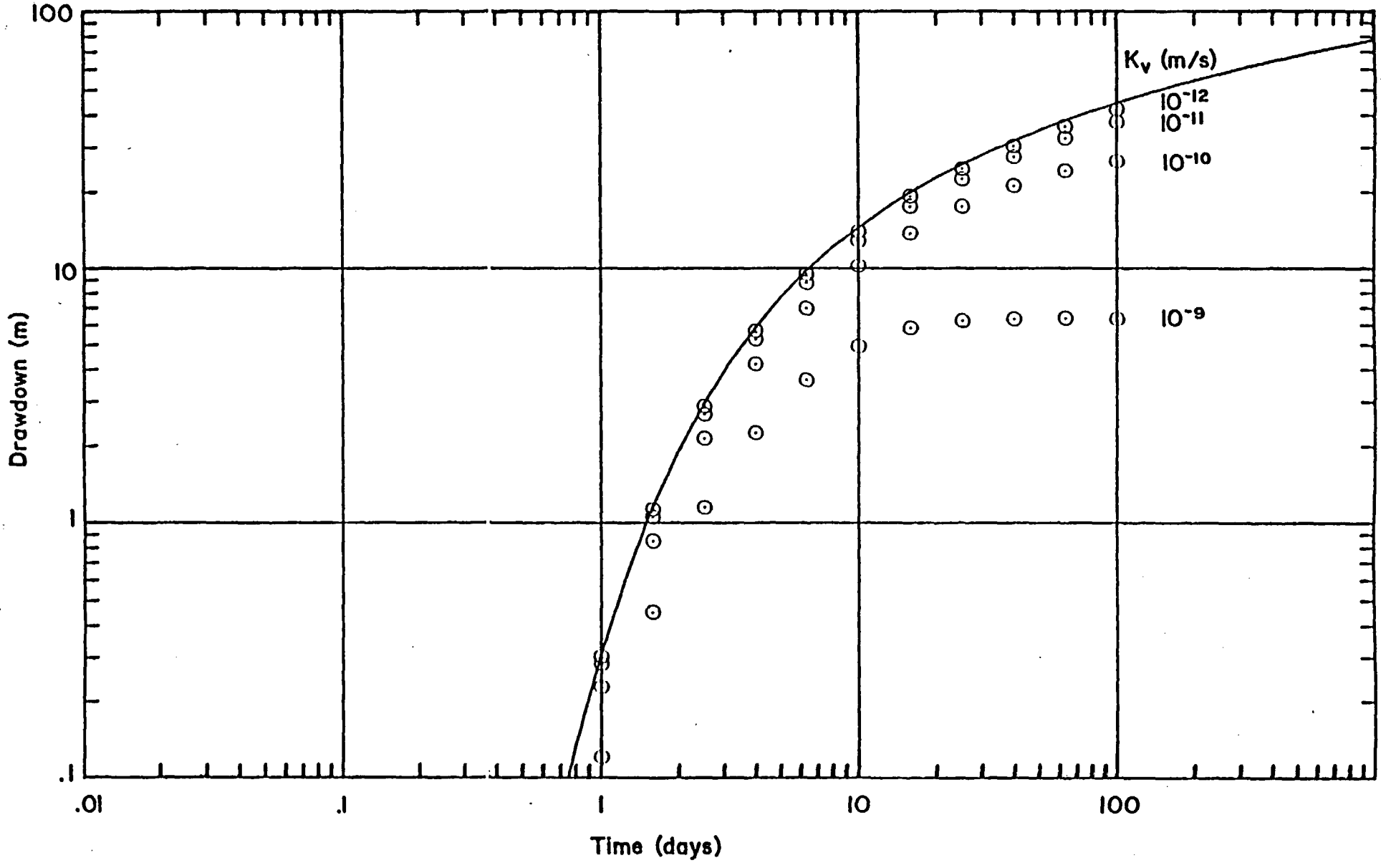
PRIMARY LHS TEST MONITORING FACILITIES IN THE ROCKY COULEE FLOW TOP




RESPONSE IN ROCKY COULEE INTERFLOW
r = 100m
K_v (m/s)
10^{-12}
10^{-11}
10^{-10}
10^{-9}
100
10
1
.1
Drawdown (m)
.01
.1
1
10
100
Time (days)

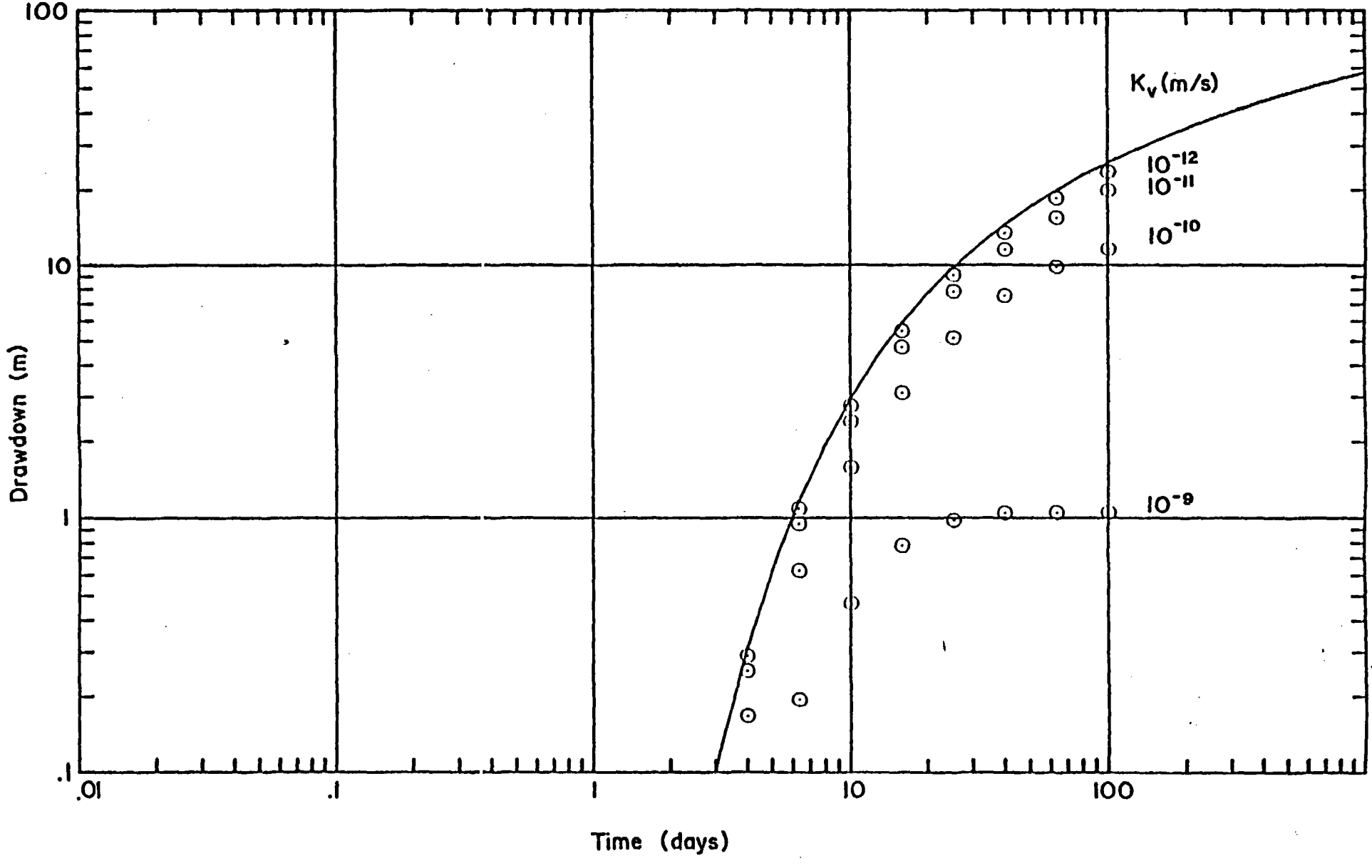
RESPONSE IN ROCKY COULEE INTERFLOW

r = 500m



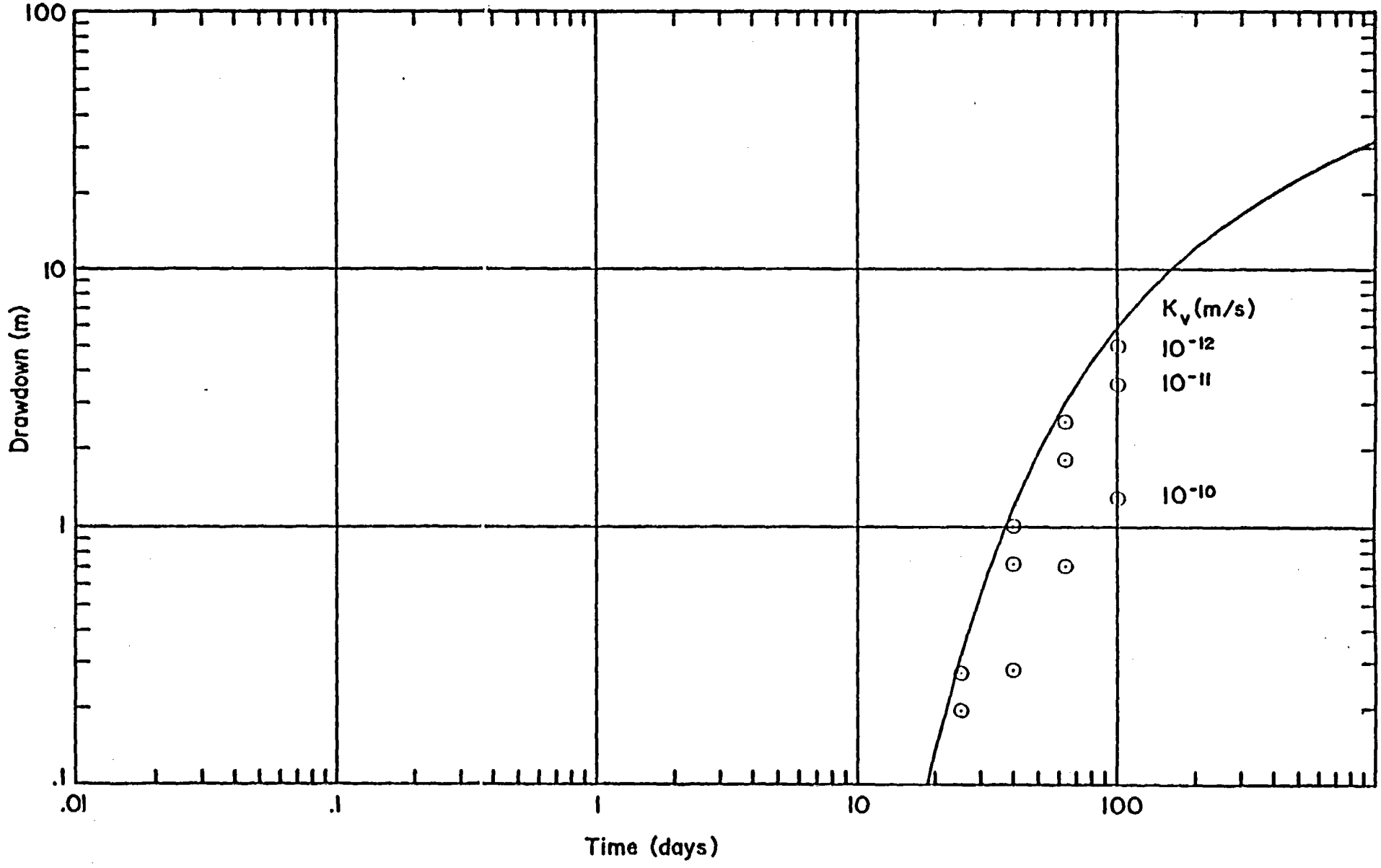
RESPONSE IN ROCKY COULEE INTERFLOW

r = 1000m



RESPONSE IN ROCKY COULEE INTERFLOW

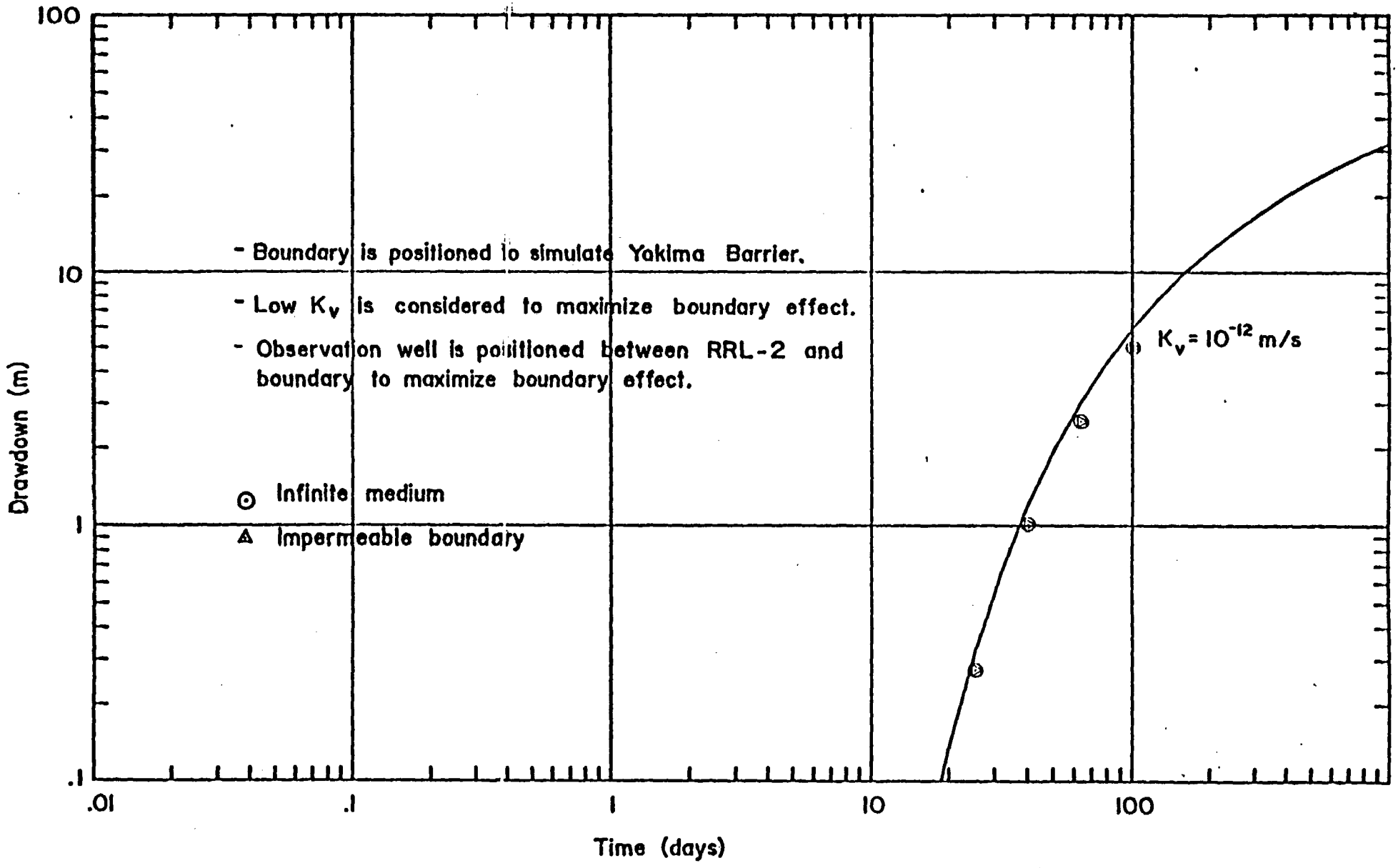
r = 2500m



RESPONSE IN ROCKY COULEE INTERFLOW WITH IMPERMEABLE BOUNDARY

$r = 2500m$

$r_i = 6000m$



COHASSETT MULTIPLE BOREHOLE TEST ANALYSIS

OBJECTIVES

ASSESS ABILITY OF MULTIPLE BOREHOLE TEST IN COHASSETT FLOW TOP TO MEASURE OR PROVIDE UPPER BOUND VALUE OF FLOW INTERIOR VERTICAL HYDRAULIC CONDUCTIVITY

EVALUATE USEFULNESS OF OBSERVATION WELLS AT 500 M OR GREATER DISTANCES

COHASSETT MULTIPLE BOREHOLE TEST ANALYSIS

ASSUMPTIONS

UPPER AQUITARD EXTENDS FROM COHASSETT FLOW TOP TO ROCKY COULEE FLOW TOP

LOWER AQUITARD EXTENDS FROM COHASSETT FLOW TOP TO BIRKETT FLOW TOP

COHASSETT MULTIPLE BOREHOLE TEST ANALYSIS

INPUT PARAMETERS

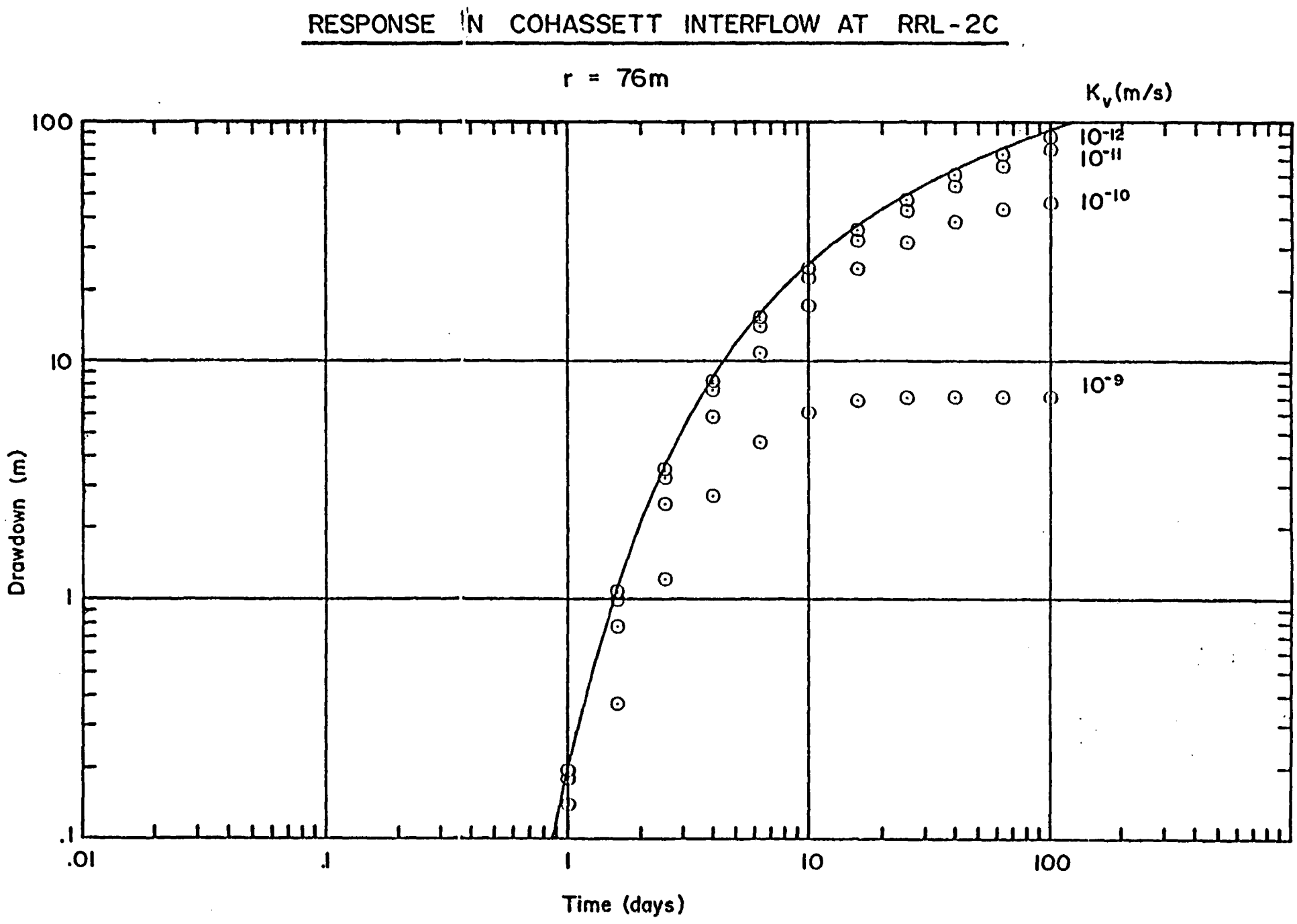
AQUIFER TRANSMISSIVITY (T):	0.004 m^2/d
	(0.04 ft^2/d)
AQUIFER STORATIVITY (S):	10^{-5}
DISCHARGE RATE (Q):	1.68 m^3/d (0.31 gpm)
AQUITARD VERTICAL HYDRAULIC CONDUCTIVITY (K_v):	10^{-12}
	10^{-11}
	10^{-10}
	10^{-9} m/s
AQUITARD SPECIFIC STORAGE (S_s):	10-7 m^{-1}
UPPER AQUITARD THICKNESS (b_1):	47 m
LOWER AQUITARD THICKNESS (b_2):	78 m
OBSERVATION WELL RADIAL DISTANCE (r):	76
	152
	500 m

COHASSETT MULTIPLE BOREHOLE TEST ANALYSIS

CONCLUSIONS

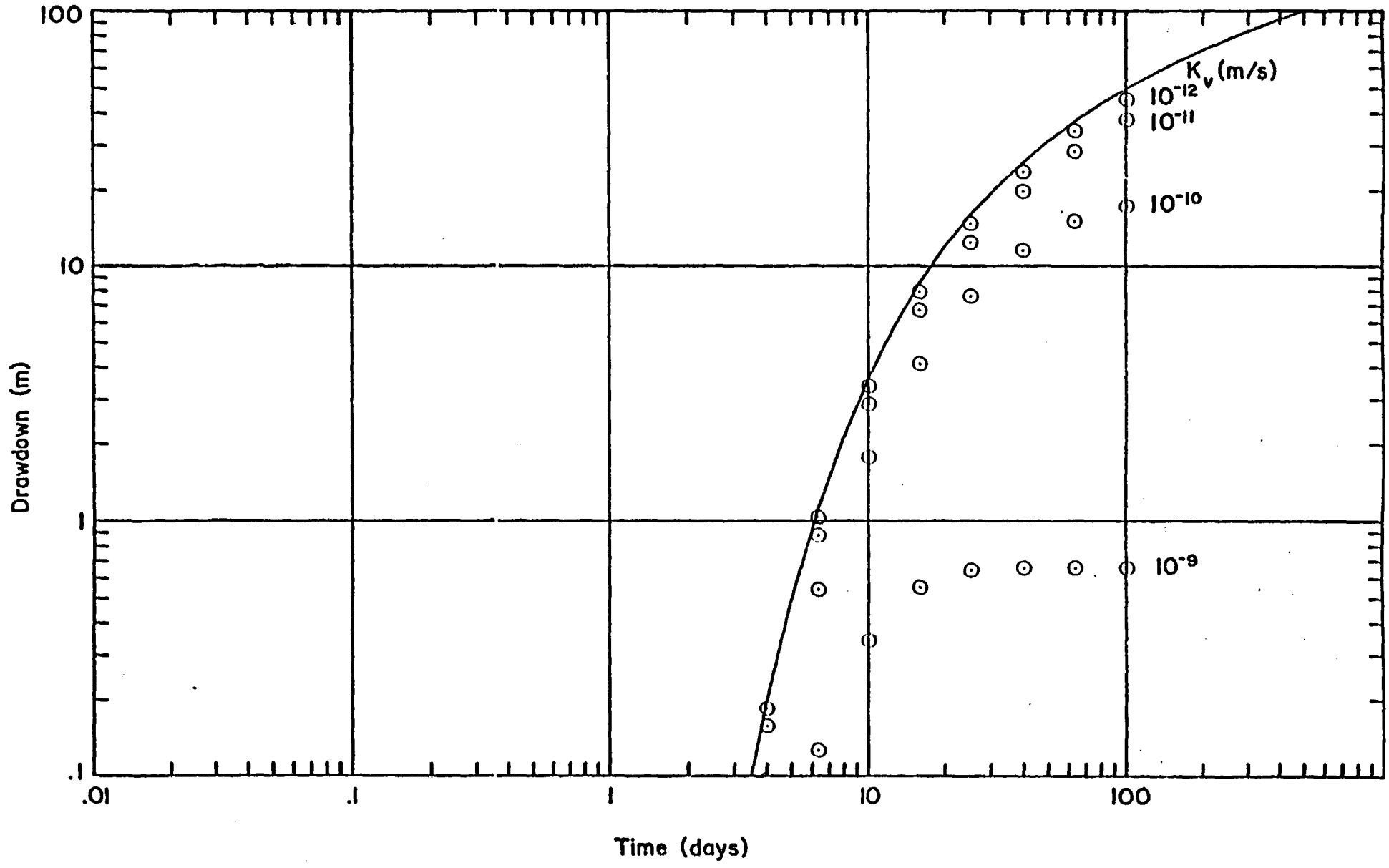
OBSERVATION WELLS AT RRL-2A AND RRL-2C PROVIDE GOOD RESOLUTION OF AQUITARD HYDRAULIC CONDUCTIVITY, BUT HAVE LIMITED ABILITY TO MEASURE CONDUCTIVITIES BELOW 10^{-11} M/S

500 METER OBSERVATION WELLS ARE OF LIMITED VALUE FOR MEASURING AQUIFER/AQUITARD PROPERTIES, BUT MAY HAVE ABILITY TO CONFIRM PRESENCE OF HIGH AQUITARD CONDUCTIVITY

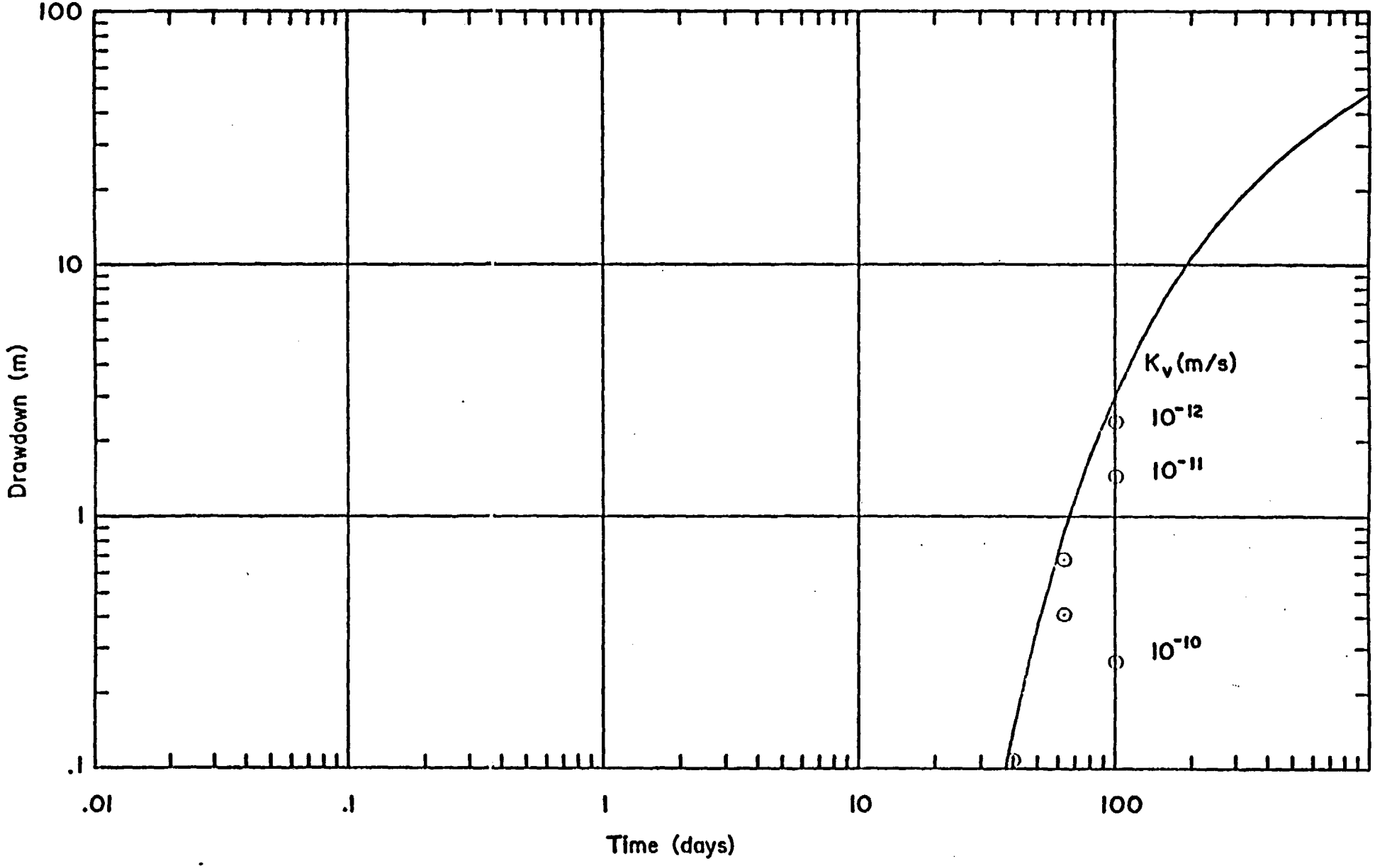

RESPONSE IN COHASSETT INTERFLOW AT RRL-2C
r = 76m
K_v(m/s)
10^{-12}
10^{-11}
10^{-10}
10^{-9}
100
10
1
.1
.01
.1
1
10
100
Drawdown (m)
Time (days)

RESPONSE IN COHASSETT INTERFLOW AT RRL-2A

r = 152 m



RESPONSE IN COHASSET INTERFLOW AT r = 500m



VOLUME I

TRACER TRAVEL DISTANCE

TRACER TRAVEL DISTANCE ANALYSIS

OBJECTIVES

DETERMINE DISTANCE IN ROCKY COULEE INTERFLOW THAT A CONSERVATIVE TRACER CAN TRAVEL FROM POINT OF INJECTION TO PRODUCTION WELL WITHIN TIME FRAME OF CONVERGENT TRACER TEST

EVALUATE TRACER TRAVEL DISTANCE FOR DIFFERENT VALUES OF EFFECTIVE POROSITY

EVALUATE FEASIBILITY OF 500 METER CONVERGENT TRACER TEST

TRACER TRAVEL DISTANCE ANALYSIS

ASSUMPTIONS

BASALT INTERFLOW TREATED AS AN EQUIVALENT POROUS MEDIUM

BASALT INTERFLOW IS HOMOGENEOUS AND ISOTROPIC WITH REGARD TO HYDRAULIC AND TRANSPORT PROPERTIES

BASALT INTERFLOW HAS CONSTANT THICKNESS

NEGLIGIBLE VERTICAL LEAKAGE FROM AQUITARDS

CONSERVATIVE TRACER

UNIFORM PUMPING RATE AT PRODUCTION WELL

TRACER TRAVEL DISTANCE ANALYSIS

INPUT PARAMETERS

ROCKY COULEE INTERFLOW THICKNESS (b):	5.1 m
PUMPING RATE (Q):	8
	25 gpm
EFFECTIVE POROSITY (ne):	10^{-4}
	10^{-3}
	10^{-2}
	10^{-1}

TRACER TRAVEL DISTANCE ANALYSIS

CONCLUSIONS

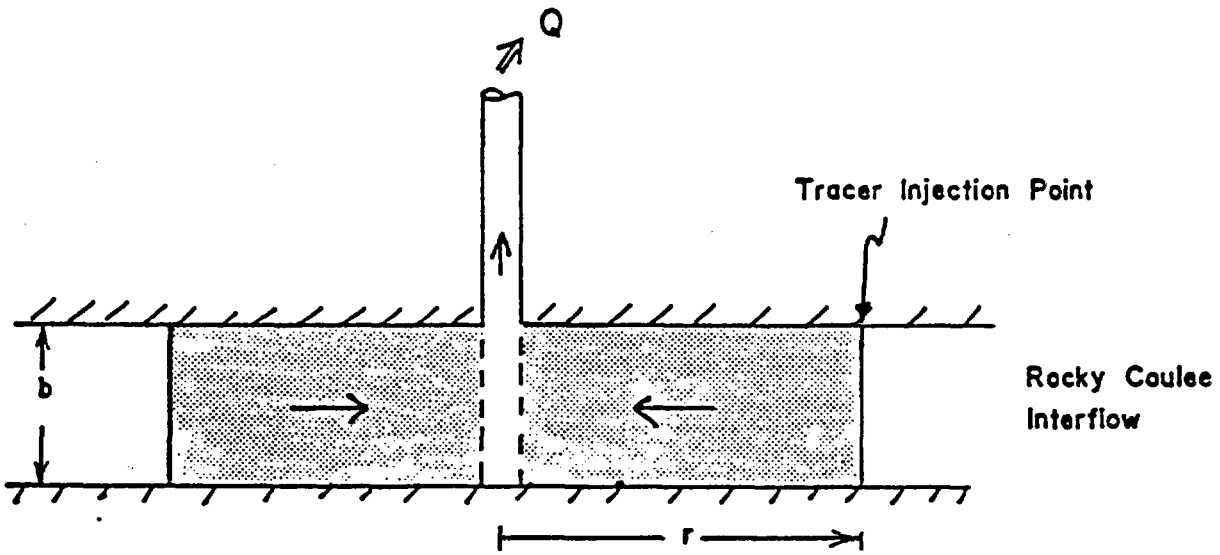
FOR A 500 METER INJECTION POINT AND PUMPING RATE OF 8 GPM, EFFECTIVE POROSITY MUST BE LESS THAN ABOUT 10^{-3} FOR CENTER OF MASS OF TRACER TO REACH PUMPING WELL IN 100 DAYS

FOR A 500 METER INJECTION POINT AND PUMPING RATE OF 25 GPM, EFFECTIVE POROSITY MUST BE LESS THAN ABOUT 2×10^{-3} FOR CENTER OF MASS OF TRACER TO REACH PUMPING WELL IN 100 DAYS

500 METER CONVERGENT TRACER TEST IN ROCKY COULEE INTERFLOW IS FEASIBLE FOR MEASURING EFFECTIVE POROSITY LESS THAN ABOUT 10^{-3}

TRACER TRAVEL DISTANCE

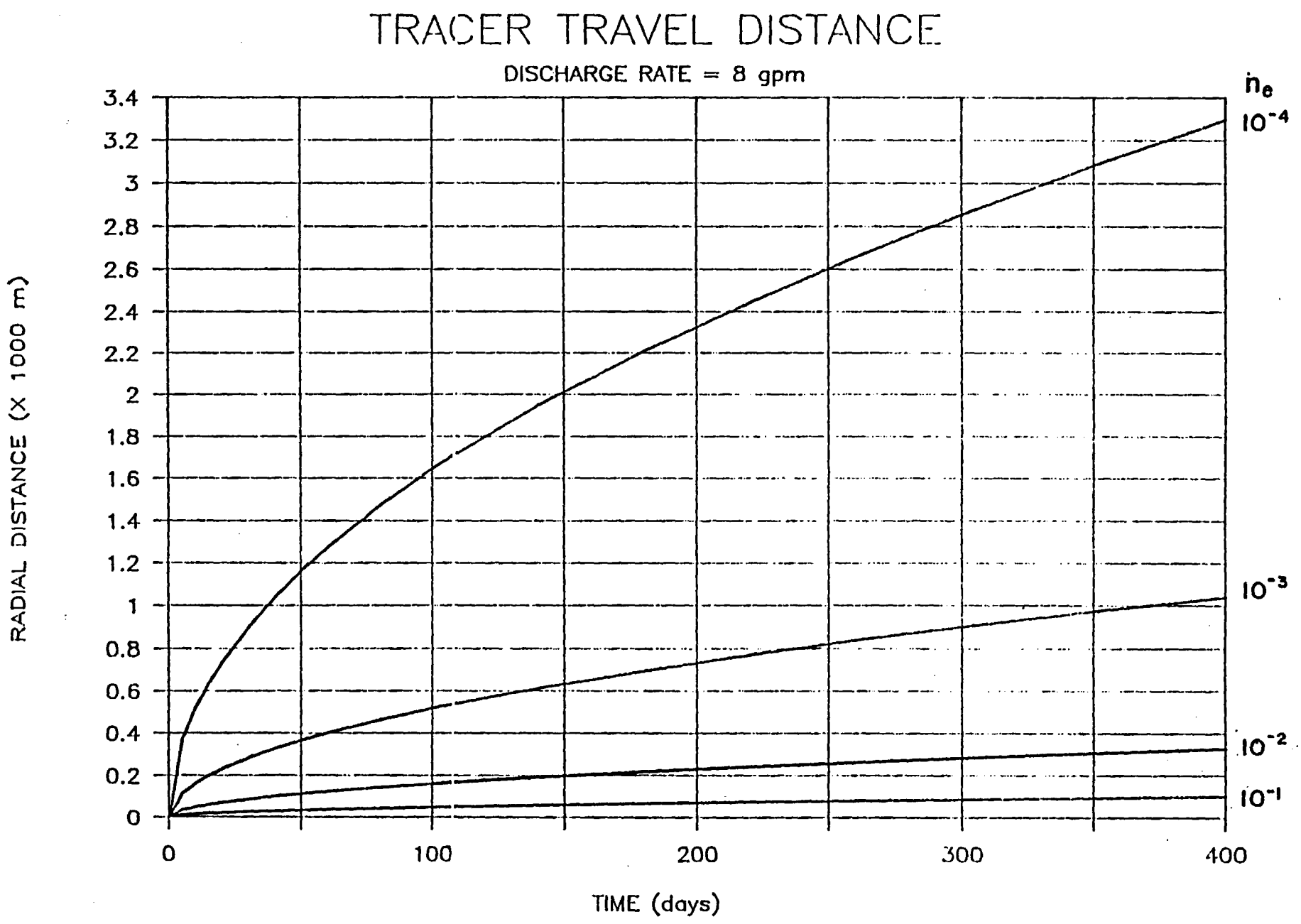
ANALYTICAL MODEL

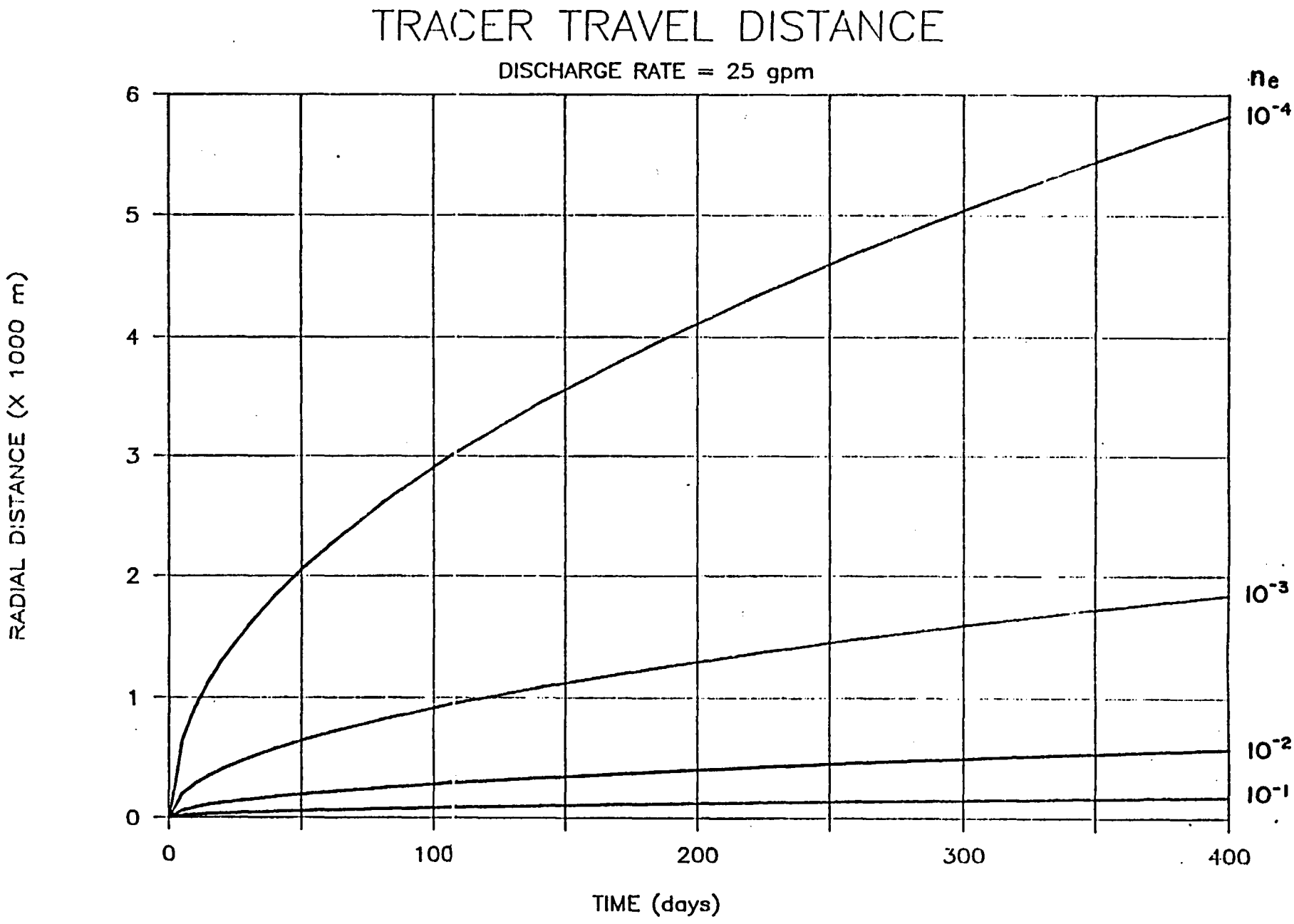


Volume of water removed from formation before arrival of tracer center of mass at well (V)

$$V = Qt = \pi r^2 b n_e$$

$$r = \sqrt{\frac{Qt}{\pi b n_e}}$$


TRACER TRAVEL DISTANCE
DISCHARGE RATE = 8 gpm
RADIAL DISTANCE (X 1000 m)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
TIME (days)
n_e
10^{-4}
10^{-3}
10^{-2}
10^{-1}


TRACER TRAVEL DISTANCE
DISCHARGE RATE = 25 gpm
RADIAL DISTANCE (X 1000 m)
TIME (days)
0
1
2
3
4
5
6
0
100
200
300
400
n_e
10^{-4}
10^{-3}
10^{-2}
10^{-1}

VOLUME I

DRILLING RESPONSE

DRILLING RESPONSE OBSERVATIONS

~~PURPOSE~~ OBJECTIVES

EVALUATE LATERAL HYDRAULIC CONTINUITY OF BASALT INTERFLOWS

IDENTIFY EVIDENCE OF VERTICAL LEAKAGE

ASSESS RELATIVE DIFFERENCES IN TRANSMISSIVITY OF BASALT INTERFLOWS

DRILLING RESPONSE OBSERVATIONS

APPROACH

CORRELATE DRILLING/COMPLETION ACTIVITIES WITH HYDRAULIC RESPONSES MEASURED IN OBSERVATION WELLS/PIEZOMETERS

NOTE MAGNITUDE, DIRECTION, AND DISTANCE OF HYDRAULIC RESPONSE

NOTE ABSENCE OF RESPONSES WHERE EXPECTED

DRILLING RESPONSE OBSERVATIONS

ASSUMPTIONS

RAPID AND/OR LARGE MAGNITUDE RESPONSES GENERALLY ASSOCIATED WITH HIGH TRANSMISSIVITY

SIMILAR RESPONSES IN DIFFERENT FLOW TOPS INDICATE VERTICAL COMMUNICATION (FORMATION LEAKAGE OR POOR INTEGRITY OF BOREHOLE SEALS)

RESPONSES OBSERVED AT LARGE DISTANCES FROM POINT OF STRESS INDICATE LATERAL HYDRAULIC CONTINUITY

DRILLING RESPONSE OBSERVATIONS

WANAPUM BASALTS

SPACIAL AND CHRONOLOGICAL LIMITATIONS OF DATA ARE RECOGNIZED

DRILLING OF DC-19C, DC-20C, DC-22C, AND DC-23W INVOLVED LARGE WITHDRAWAL/INJECTION OF FLUID

DRILLING RESPONSES FROM ABOVE WELLS OBSERVED AT LARGE RADIAL DISTANCES FROM POINT OF STRESS. SUGGESTS RELATIVELY HIGH TRANSMISSIVITY IN PRIEST RAPIDS

NO EVIDENCE TO SUGGEST LACK OF HYDRAULIC CONTINUITY IN PRIEST RAPIDS

DRILLING RESPONSE OBSERVATIONS

GRANDE RONDE BASALTS

SPACIAL AND CHRONOLOGICAL LIMITATIONS OF DATA ARE RECOGNIZED

SOME RESPONSES OBSERVED OVER LARGE DISTANCES

DURING BRIDGE PLUG REMOVAL IN RRL-14, NO RESPONSE OBSERVED IN ROCKY COULEE AT DC-22C.

DURING BRIDGE PLUG REMOVAL IN RRL-14, SIGNIFICANT RESPONSES IN COHASSETT AND UMTANUM AT DC-22C

DURING BRIDGE PLUG REMOVAL IN RRL-14, LARGER RESPONSE OBSERVED IN COHASSETT AT DC-22C

WHILE DRILLING RRL-17, RESPONSE NOT OBSERVED IN ROCKY COULEE AT DC-20C UNTIL COHASSETT PENETRATED

WHILE DRILLING RRL-17, FLUID LOSSES IN COHASSETT LARGER THAN THOSE IN ROCKY COULEE

WHILE DRILLING RRL-17, ROCKY COULEE AND COHASSETT INTERFLOWS RESPOND IN UNISON AT DC-20C

NO DRILLING RESPONSES OBSERVED IN

DC-19C

DRILLING RESPONSE OBSERVATIONS

PRELIMINARY CONCLUSIONS

PRIEST RAPIDS APPEARS TO EXHIBIT LATERAL HYDRAULIC CONTINUITY THE ACROSS RRL AND VICINITY

IN GRANDE RONDE, SOME RESPONSES OBSERVED OVER LARGE DISTANCES, BUT INSUFFICIENT DATA TO ASSESS OVERALL LATERAL HYDRAULIC CONTINUITY THROUGHOUT RRL AND VICINITY

COHASSETT INTERFLOW MAY HAVE RELATIVELY HIGH TRANSMISSIVITY IN VICINITY OF RRL-14 AND RRL-17

VERTICAL HYDRAULIC COMMUNICATION IN GRANDE RONDE INDICATED AT DC-20C (FORMATION LEAKAGE OR POOR BOREHOLE SEAL)

ADDITIONAL MONITORING INSTALLATION MAY BE REQUIRED IN NE AREA OF RRL TO PROVIDE DATA ON VERTICAL COMMUNICATION IN GRANDE RONDE

DRILLING RESPONSE OBSERVATIONS

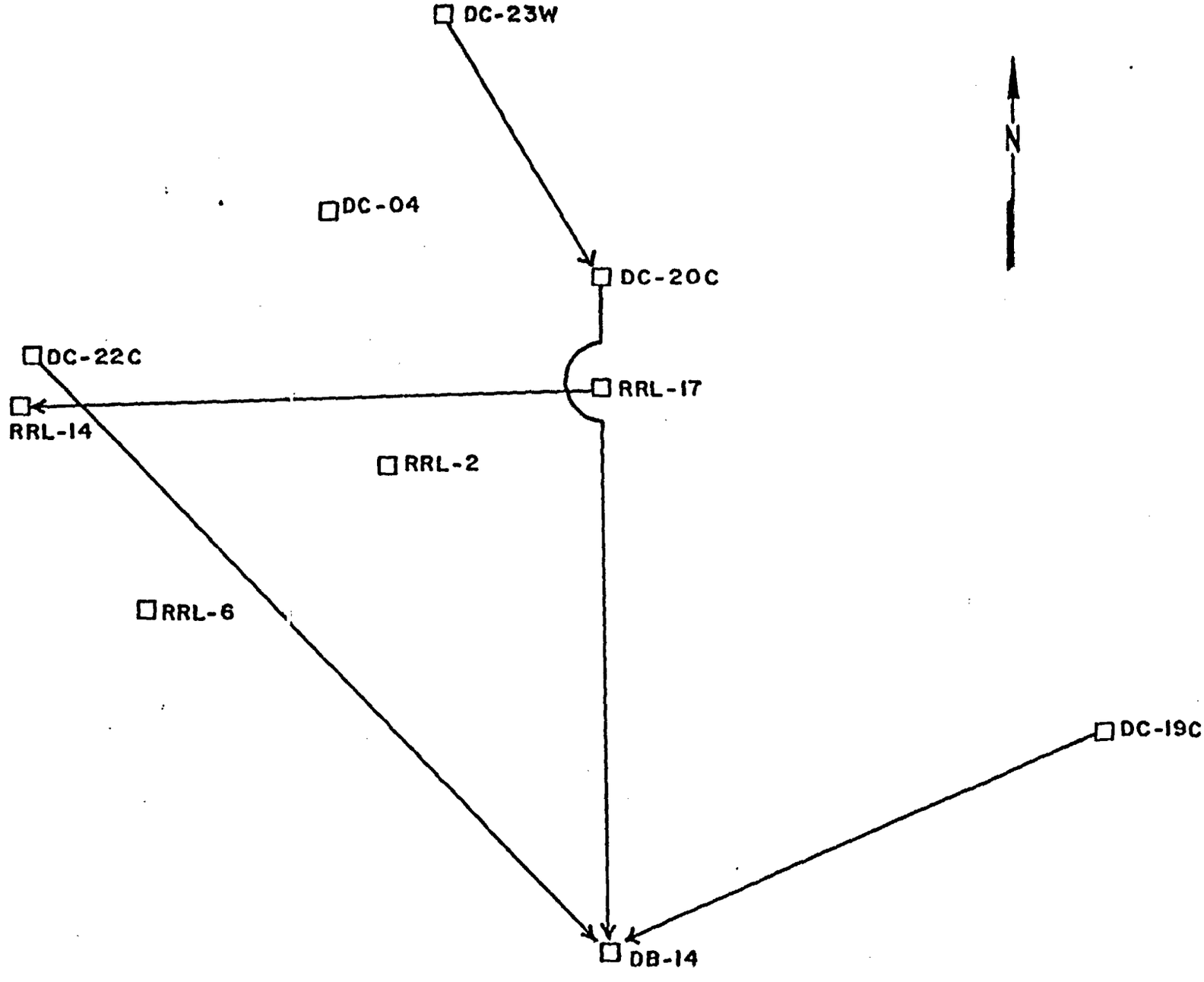
EXPLANATION

☐ WELL LOCATION

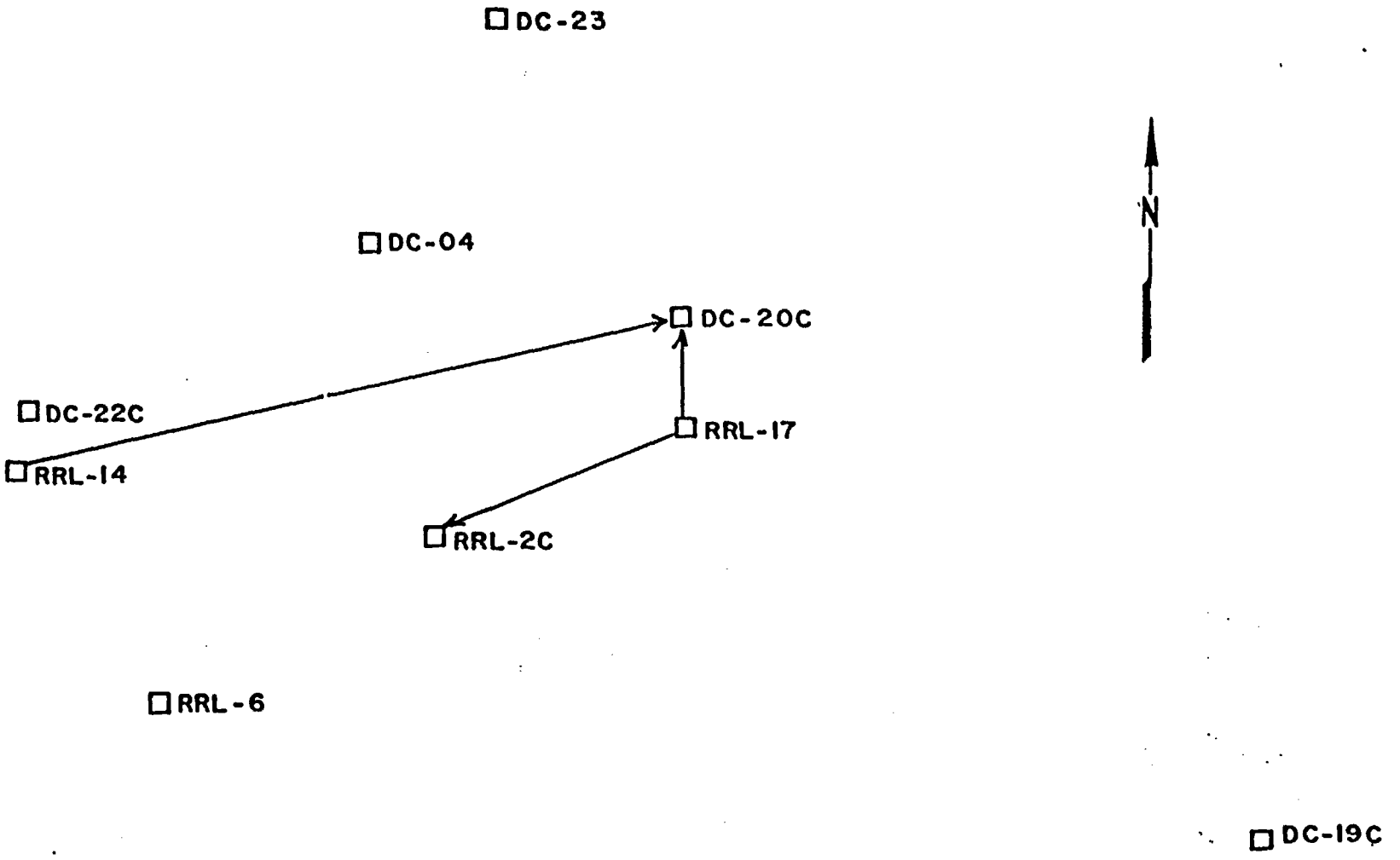
OBSERVED HYDRAULIC RESPONSE
Tail indicates location of hydraulic stress.
Arrow indicates location of observed head change.

POSSIBLE HYDRAULIC RESPONSE

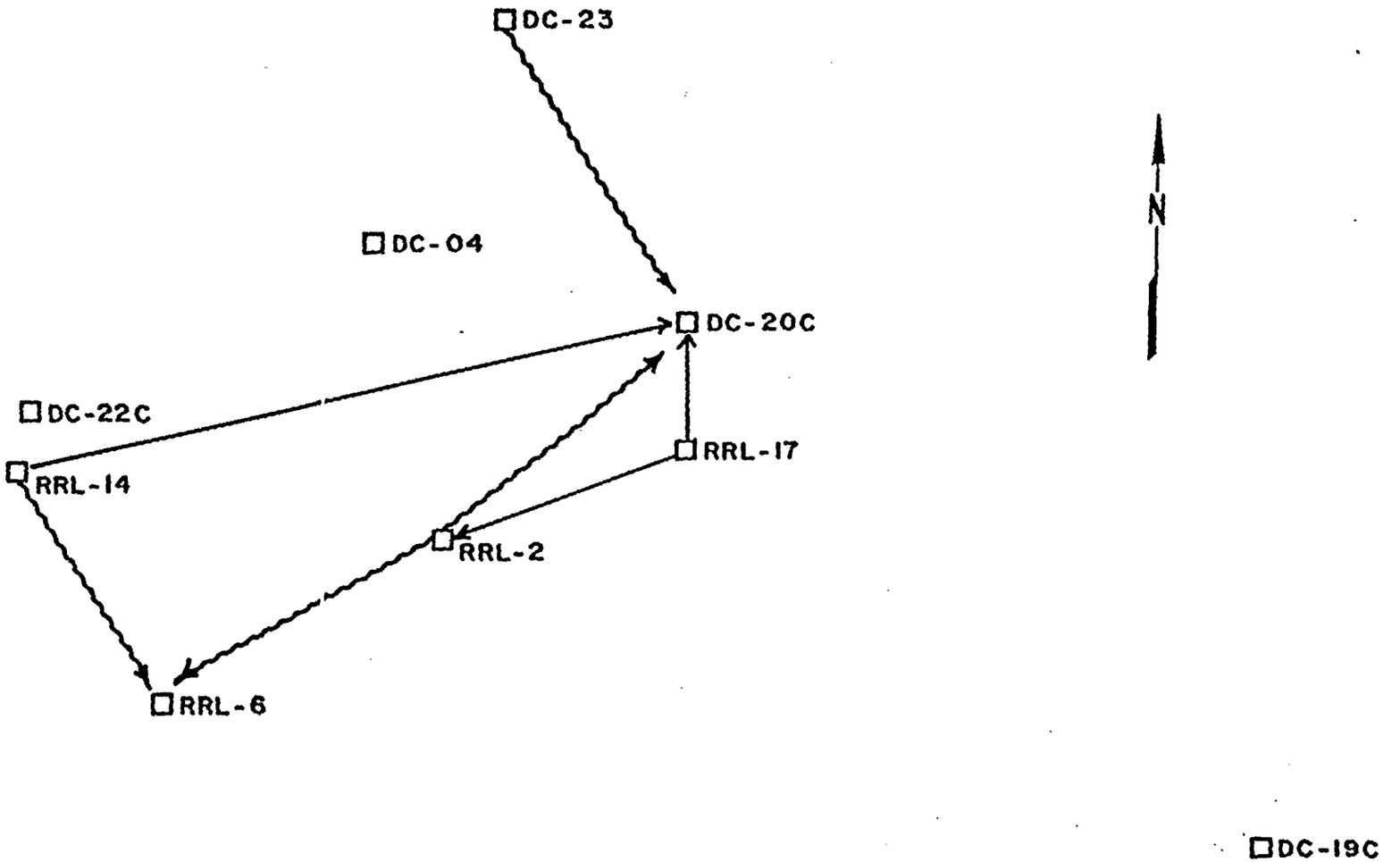
PRIEST RAPIDS INTERFLOWS



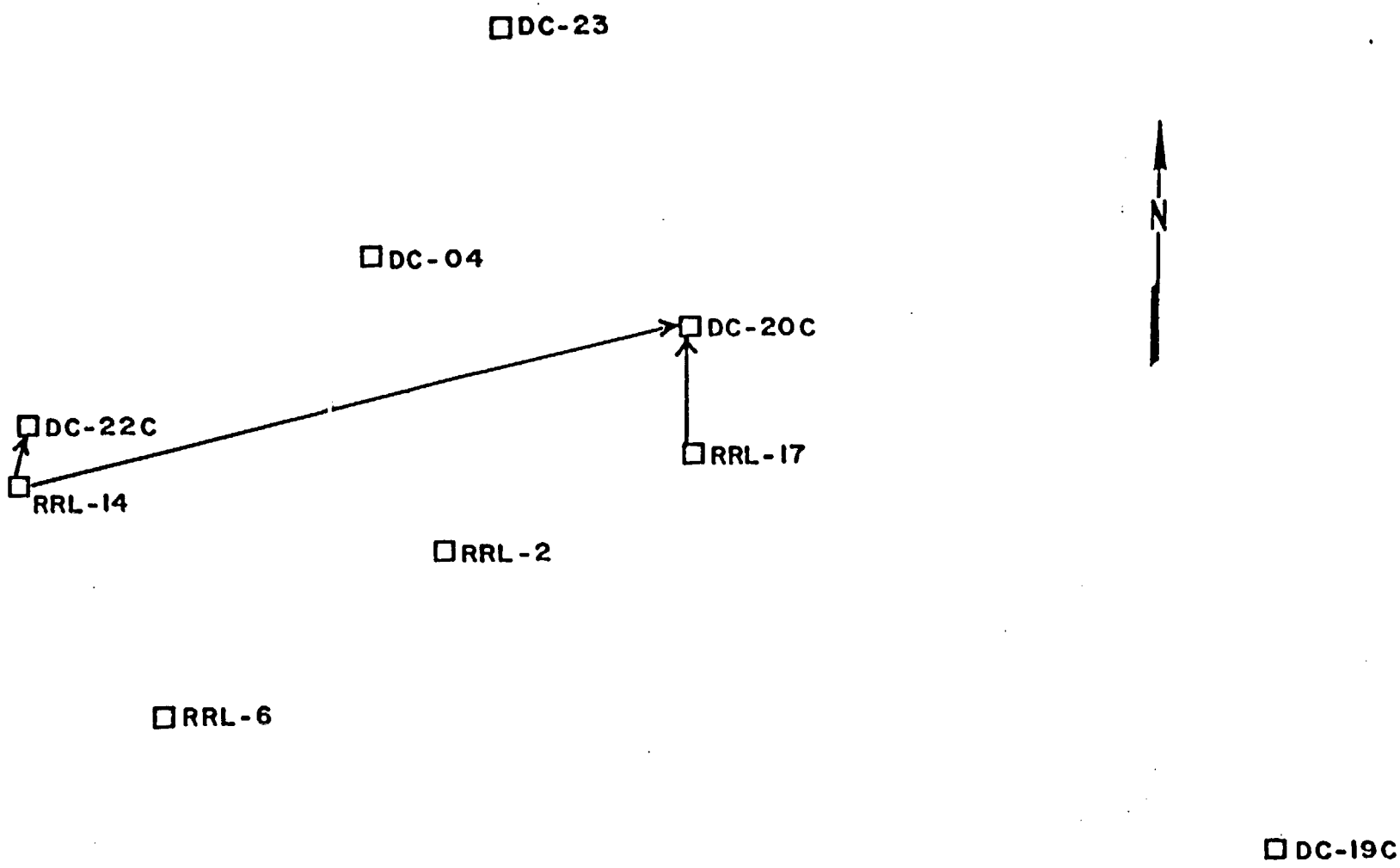
ROCKY COULEE INTERFLOW



ROCKY COULEE INTERFLOW



COHASSETT INTERFLOW



UMTANUM INTERFLOW

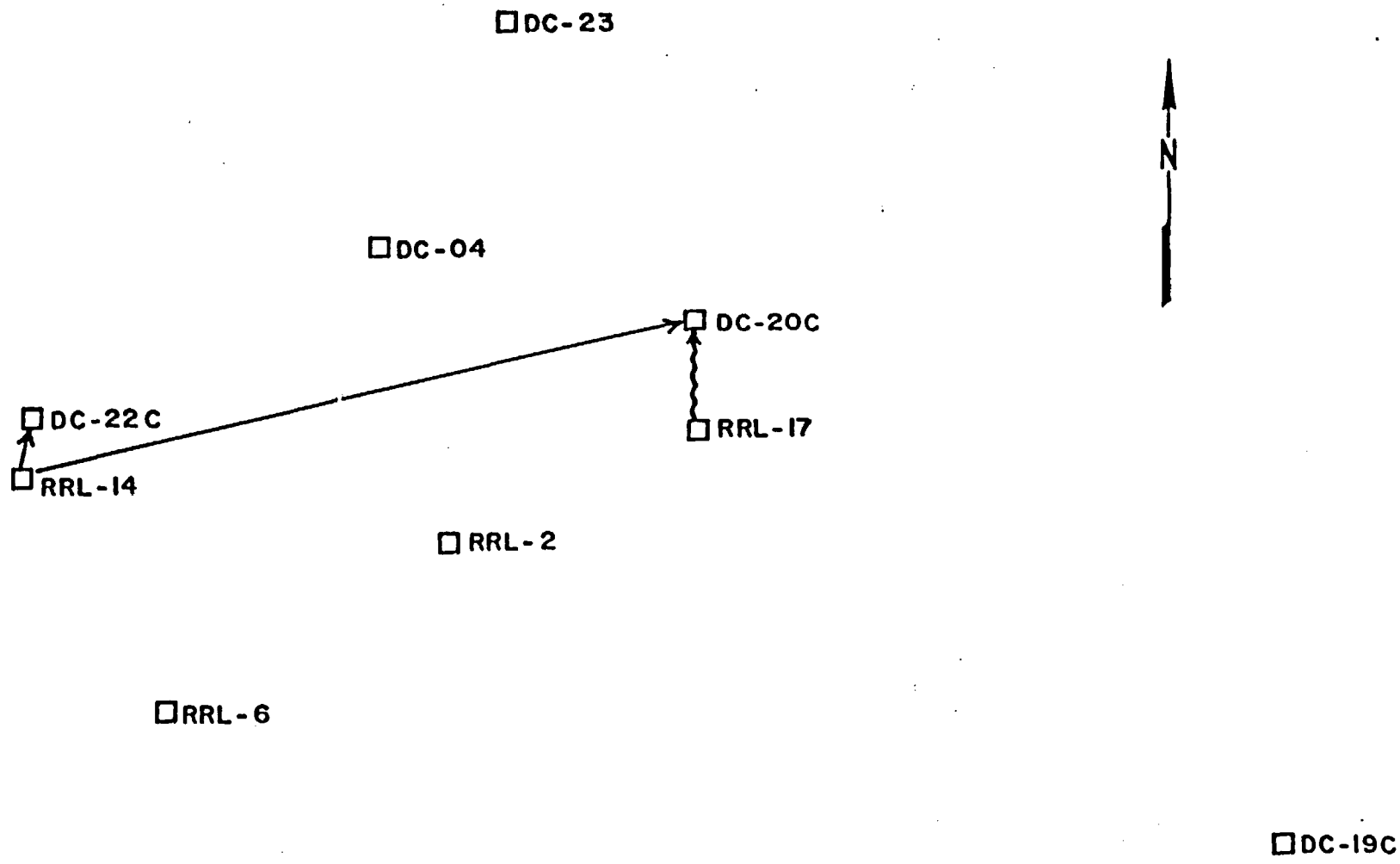


FIGURE 1. FLUID LOSS DATA AND HYDROGRAPH AT DC-20C
DURING RRL-17 DRILLING

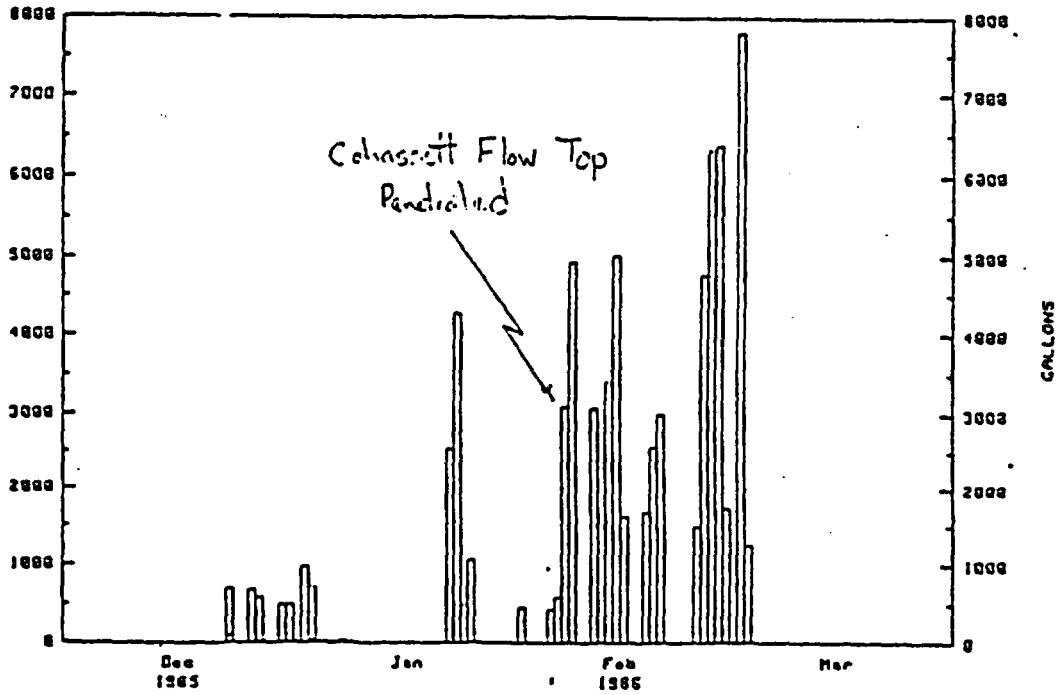


FIGURE 1A

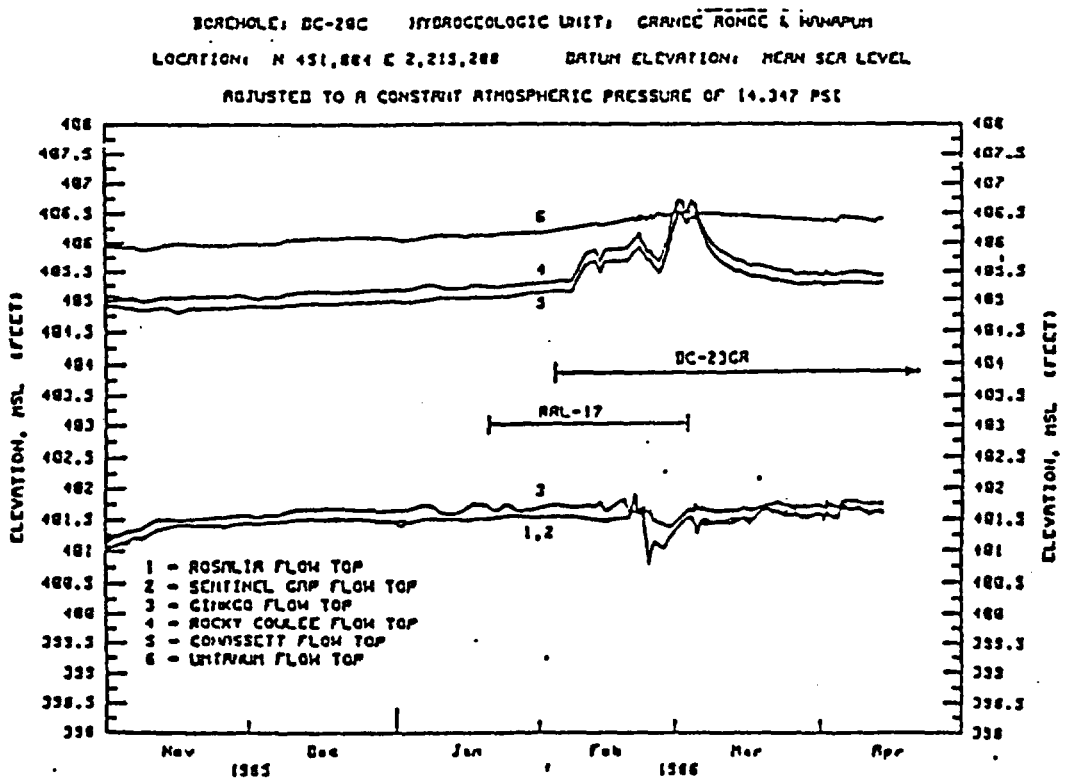
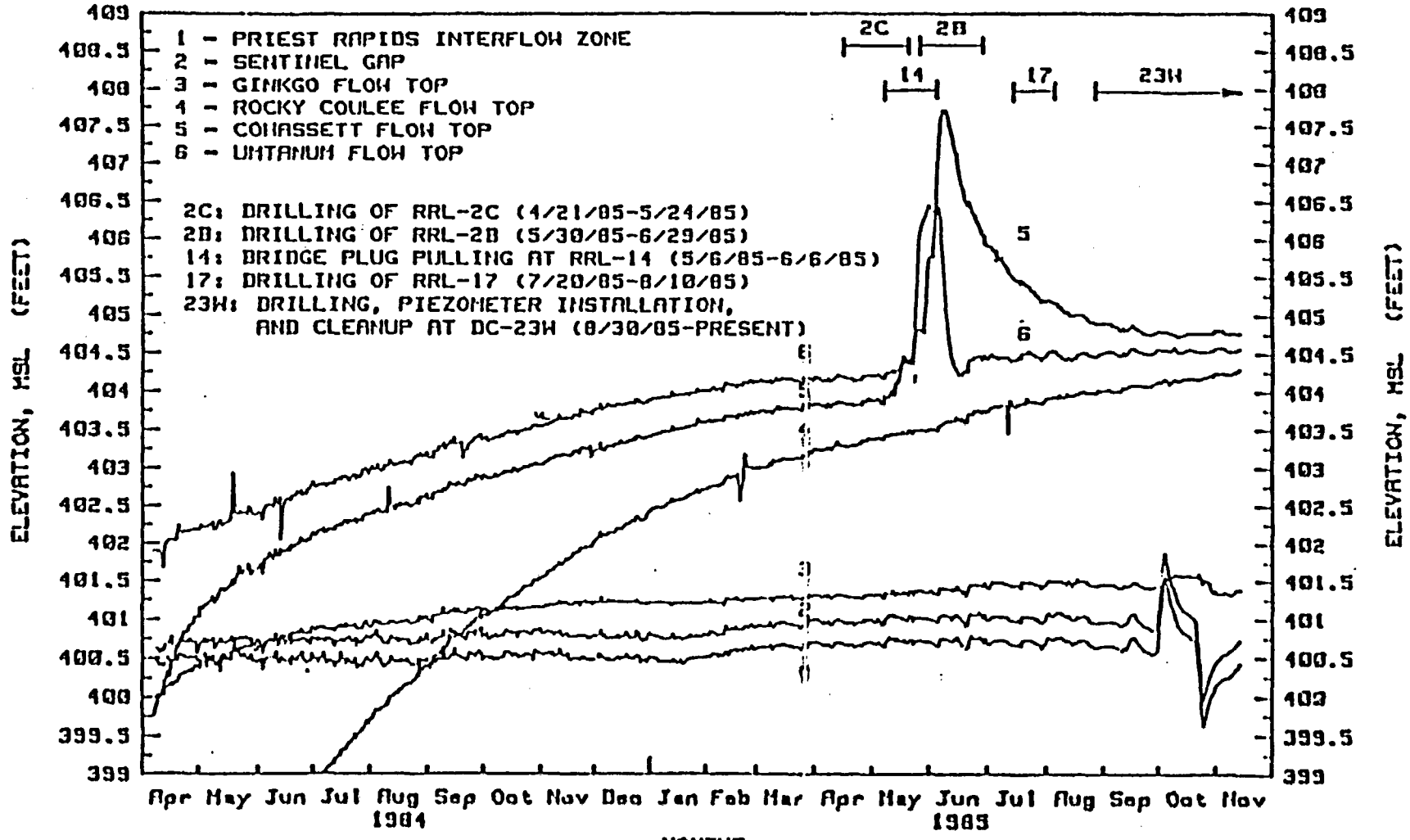


FIGURE 1B
Terra Therma, Inc

BOREHOLE: DC-22C HYDROGEOLOGIC UNIT: GRANDE RONDE & WANAPUM

LOCATION: N 440,600 E 2,204,100 DATUM ELEVATION: MEAN SEA LEVEL

ADJUSTED TO A CONSTANT ATMOSPHERIC PRESSURE OF 14.347 PSI



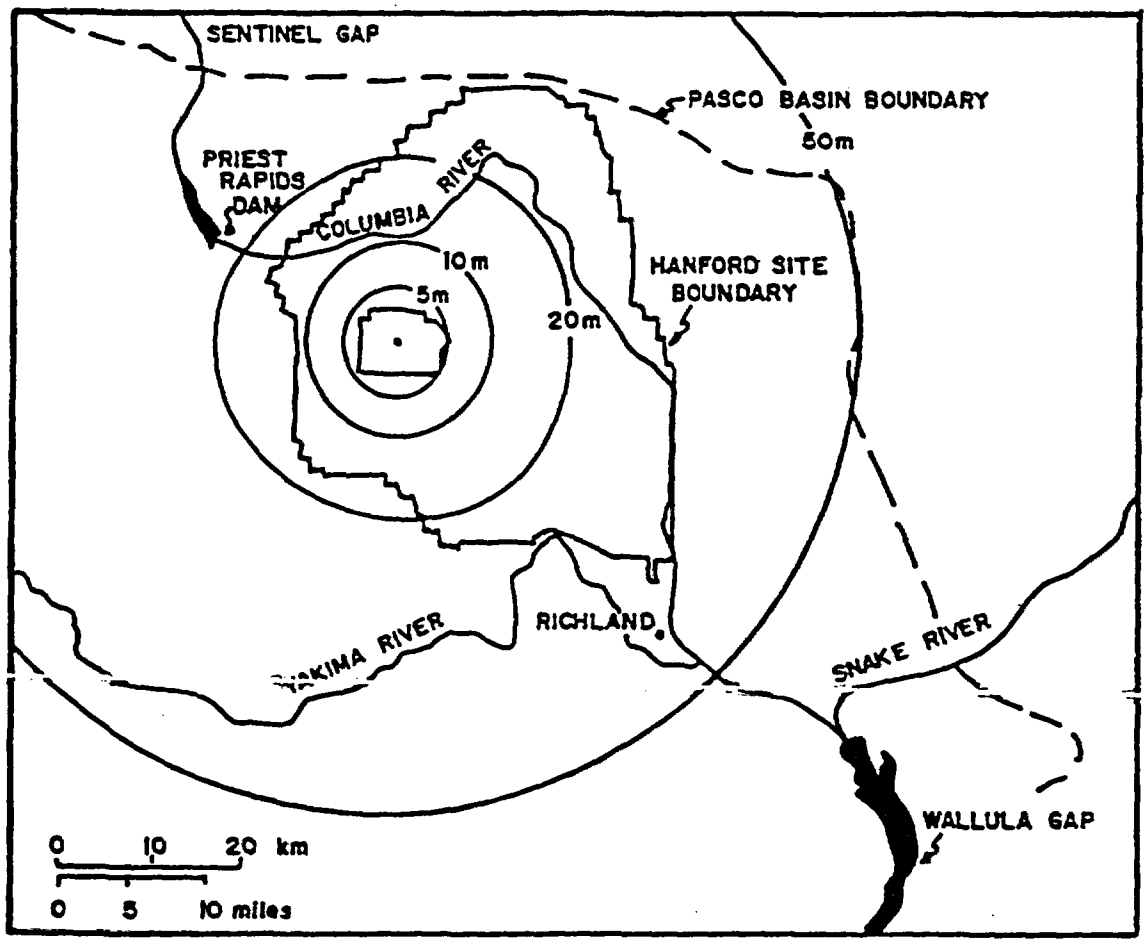
HYDROGRAPH PRODUCED BY

Program HYDAT Rev 4.7 FILE: N22HPR85

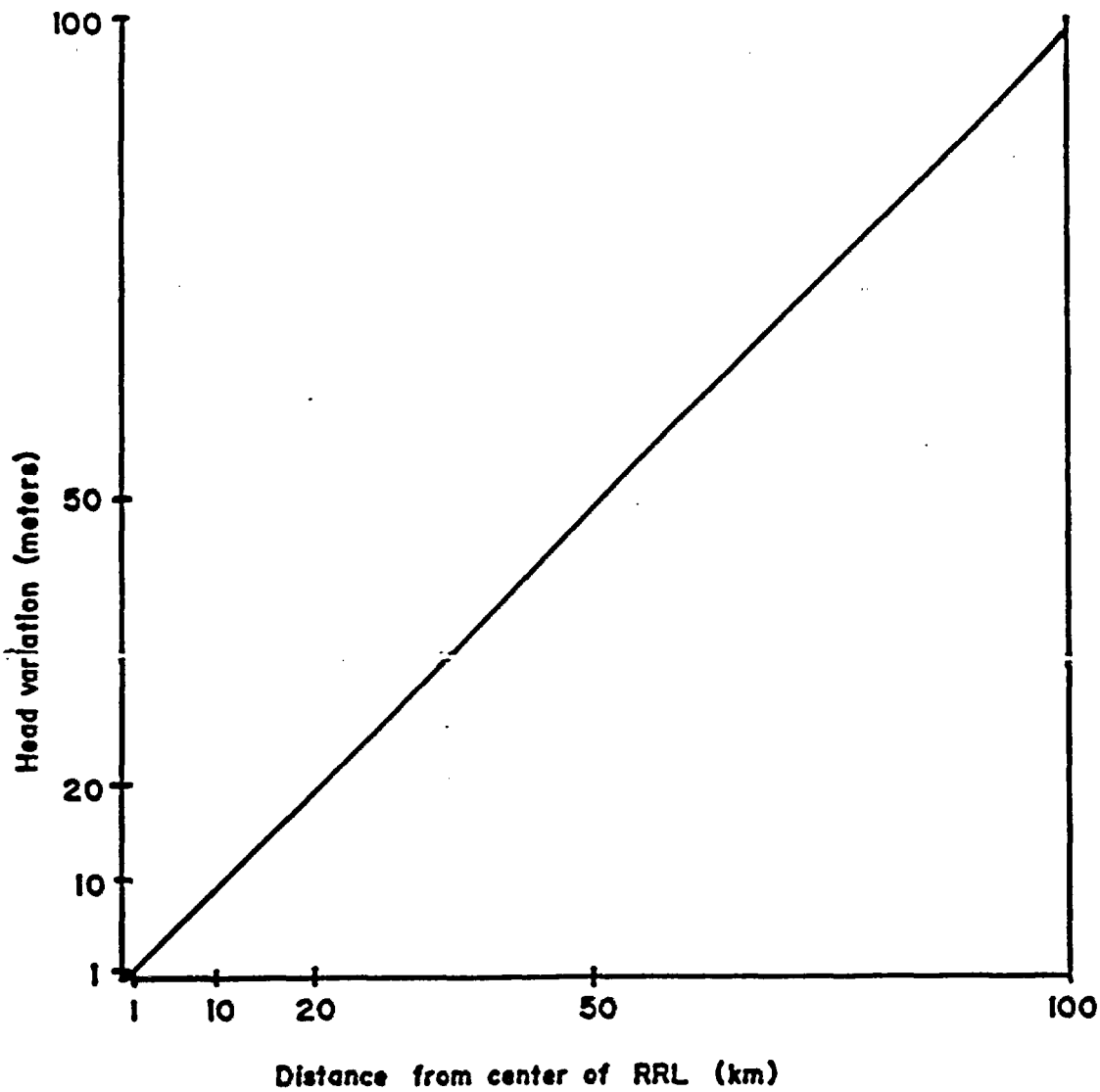
VOLUME I

SIGNIFICANT HEAD ERRORS

CONTOURS OF SIGNIFICANT HEAD VARIATION RELATIVE TO GRADIENT THROUGH THE RRL



HEAD VARIATION REQUIRED TO PRODUCE SIGNIFICANT EFFECTS ON GRADIENT AT THE RRL; AS A FUNCTION OF DISTANCE FROM THE RRL



ATTACHEMENT 2

NOTES ON LHS TESTING PLAN
Adrian Brown, April 8, 1987

SUMMARY:

These notes contain information in support of specific technical problems/questions that have been identified by the NWC/TTI team with respect to the proposed LHS program.

1. HEAD MEASUREMENTS/BASELINE

1.1 DOE Proposal

The DOE proposal is that the network of 36 piezometers will be measured to create the baseline, and the resulting set of heads will form the "pre-emplacement" network for the evaluation of GWTT.

1.2 Issues

There are three principal technical issues that arise in respect of the head baseline:

1. Is the distribution of the locations of the observation points adequate for the definition of the GWTT gradients?

2. Is the head information adequately equilibrated so as to provide a "true" pre-emplacement head database?

3. Are the heads being measured truly representative of the pressures at the completion locations of the piezometers?

4. Are the holes completed in such a way that the pressures that actually occur at the piezometer tip are actually representative of the pressures in the formation in which they are completed?

1.3 Comments

The following technical comments are made, based on the evaluations performed by the team:

1. Distribution. Review by the team indicates that the distribution of the total monitoring network appears to be appropriate for providing head information needed for the evaluation of the pre-emplacement groundwater travel time.

2. Equilibration. Review of the vertical and horizontal gradients measured in DC-19, 20, and 22 indicates that the equilibration process is sufficiently well advanced in these locations that there will not be a significant modification of the gradients with further equilibration. Therefore equilibration is considered to have been reached for the purposes of licensing.

3. Accuracy of Pressures. Detailed evaluation of the measurements and the approach to evaluating them performed as part of the TTI mini-report series indicates that the most accurate method of estimating head gradients is to measure the level of water in a properly completed well where the wellbore is filled with formation water, and to compute the gradients based on these measurements and the distances between them. Accordingly, the technology being used is considered to be appropriate. There remains some question as to the nature of the fluid in some of the wells. It is considered that all the piezometers should be pumped prior to the performance of the LHS test, to ensure that there is a consistent fluid in all wells.

4. Completion. The completion of some of the piezometers has been called into question as a result of some responses to external perturbations that are difficult to explain by other means. In particular, the seals between the piezometers in some of DC-19, 20, and 22 have been questioned. Evaluation by the NWC/TTI team indicates that for the impact of a poor seal to be felt, the effective hydraulic conductivity of the defective seal would need to be in the order of 1E-4 m/s or higher, approximately the permeability of coarse sand. However, it is considered that this is a sufficiently important matter for licensing that further testing of the integrity of multi-piezometer installations should be undertaken (it is planned by BWIP).

2. VERTICAL PERMEABILITY MEASUREMENTS

2.1 DOE proposal

The proposed approach to the investigation of vertical permeability in the Hanford situation is the use of large scale, high stress tests, and to measure the impact of those tests in the pumped and adjacent horizons.

2.2 Issues

The concept that is being used is consistent with that set out in STP 1.1, and is therefore acceptable to the NRC. However there are some remaining concerns that the NRC would raise, in

preparation to the review of the detailed test plan later this year:

1. Heterogeneities in vertical permeability. It is considered possible that the vertical permeability in the material under test will be the result of flow in a few heterogeneities. NWC/TTI has evaluated the extent to which the measurement of a "gross" vertical leakance (the actual result of this kind of test) will provide information needed for licensing. The conclusion of this preliminary work is that the location of the vertical leakage is important for the purposes of GWTT evaluation, under the strictest interpretation of the Rule, but that in general the gross evaluation will be appropriate for licensing purposes. Further, evaluation suggests that the vertical leakage measurement will include the effects of these possible heterogeneities, and thus that the testing will be appropriate. It is suggested that the DOE perform independent checks to assure themselves that this matter is not a problem.

2. Discrimination of testing. Evaluations performed by NWC/TTI indicate that the discrimination of the Hantush style test that is contemplated by BWIP is limited to about 1E-10 m/s for the typical Grande Ronde flow top. For a lower permeability flow top (such as the Cohassett flow top is believed to be) it appears that the discrimination of the test improves to about 1E-11 m/s, which is about the value that is expected by BWIP. Accordingly, it is considered that the test in the Cohassett flow top is particularly important, and should be conducted at the largest scale possible.

3. HORIZONTAL PERMEABILITY EVALUATION

3.1 DOE proposal

The DOE proposal is that the horizontal hydraulic conductivity will be evaluated by the large scale tests using as many of the piezometers in the tested horizon that respond. It is proposed that the test be analyzed using the standard Hantush-style approach; it is further suggested that the analysis may use a response matching procedure, using models of the groundwater system being tested.

3.2 Issues

The possible issues that arise in this case are:

1. Is the test approach appropriate?

2. Can the test be analyzed by methods that have general acceptance?

3.3 Comments

The proposed testing is a standard procedure, and is not contentious. It is considered that both approaches to analysis are potentially appropriate; the modeling approach also has the advantage of being a method of calibrating the models of the hydraulics of the site, which is a principal objective of the LHS testing.

4. BOUNDARY CONDITIONS

4.1 DOE Proposal

The DOE has no pre-ES plans to directly interrogate remote lateral boundaries. If the tests happen to stress far enough from the test well to discover boundaries, this will be considered a further benefit.

4.2 Issues

The issues with respect to lateral boundaries (boundaries within the RRL are discussed under vertical permeability) include the following:

1. Are lateral boundaries "perishable"?

2. Are lateral boundaries likely to lead to disqualifying conditions?

4.3 Comments

NWC/TTI have evaluated the impact of lateral boundaries on the GWTT criterion. Provided that the evaluations are made using properly observed heads, the impact of boundaries is only expected to increase travel times, and hence not being aware of boundaries is considered by the NRC to be conservative for the purposes of the pre-ES test program.

With respect to the evaluation of the constructability issues, lateral boundaries were found to have little or no adverse effects. Accordingly, it was considered that they were not important for pre-ES evaluation.

5. EFFECTIVE POROSITY MEASUREMENTS

5.1 DOE position

The DOE position is that essentially preliminary evaluations of porosity will be conducted using a radially convergent tracer test technology, as an adjunct to the LHS tests.

5.2 Issues

The issues that appear to be important with respect to the porosity in a pre-ES time-frame are:

1. Will the test as proposed produce reasonable estimates of effective porosity in the location where the test will be conducted?

2. Will data collected in the center of the RRL be adequate to provide at least an indication of compliance or non-compliance of the site with the GWTT criterion?

5.3 Comments

The comments which have been developed in preparation for the meeting by the NWC/TTI team are as follows:

1. Quality of Effective Porosity Estimates. The quality of the effective porosity estimates that can be derived from a radially convergent tracer test appears to be questionable, particularly in a situation where (as might occur) the flow in the basalts is dominated by a few "master" joints. In this case, the gradient of the flow field is large around the withdrawal well, and it is expected to be efficient as a collector. However the gradient around the injection well is small, so the time that it may take for tracer to get from the well to the first major joint may be a very significant portion of the transit time. Such an occurrence would have the effect of providing a considerable overestimate of the porosity that would be computed from the test, which would in turn lead to an overestimate of the GWTT. Evaluations indicate that a considerably better technology is a two-hole or "push-pull" tracer test.

2. Adequacy of data. Presuming that accurate effective porosity data is collected from whatever test is conducted at RRL-2, it is still debatable that this data would provide support for either disqualifying or not disqualifying the site. The data will be essentially small scale (over lengths of between 50 and 150 meters), and will be taken in an area which currently is considered to be of relatively

high permeability (and possibly therefore of high porosity). If this data is to be used in the evaluation of GWTT, it would have to be transported from the RRL-2 area to the pathway of interest, which may not be reasonable. At the end of the currently proposed pre-ES testing, the project would have the current two small scale effective porosity values plus about four more, all of them not in the area between the RRL and the accessible environment. It is questioned whether this is an adequate basis for a continue/abandon decision.