PROJECT RIO BLANCO
EVALUATION OF POSSIBLE
RADIOACTIVITY TRANSPORT
IN
GROUNDWATER

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By
Carroll F. Knutson
Chief Geologist

CER Geonuclear Corporation
Las Vegas, Nevada

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TABLE OF CONTENTS

		<u>Page No.</u>
I.	SUMMARY	1
II.	DISCUSSION	2
	A. INTRODUCTION	2
	B. SOURCE FUNCTION MODEL	2
	1. Effects of Seepage	2
	2. Models for Communication Between Chimney and Aquifers	3
	3. Radionuclide Concentrations	3
	C. CHARACTERISTICS OF "B" AQUIFER	4
	D. CALCULATIONS OF WATER VELOCITY IN "B" AQUIFER	5
	E. CALCULATION OF RADIOACTIVITY TRANSPORT IN "B" AQUIFER	7
	REFERENCES	10
	APPENDIX A - CONTINGENCY OF SEEPAGE INTO GROUNDWATER	A-1
	A. AQUIFERS	A-1
	B. MODELS FOR COMMUNICATION BETWEEN CHIMNEY AND AQUIFERS	A-1
	C. NUCLIDES	A-4
	D. CONCENTRATIONS	A-4
	E. PRELIMINARY ESTIMATE OF MOVEMENT OF RADIOACTIVITY (DIRECTION AND VELOCITY)	A-13

TABLE OF CONTENTS

	<u>Page No.</u>
1. Introduction	A-13
2. Direction and Velocity	A-13
3. Retardation	A-13
4. Residence Time	A-16
5. Use Points	A-16
 REFERENCES	 A-21
 APPENDIX B - DETAILED LOG CALCULATIONS FOR PARACHUTE CREEK MEMBER POROSITY AND OIL CONTENT	 B-1
A. INTRODUCTION	B-1
B. DISCUSSION	B-1
REFERENCES	B-6
 APPENDIX C - EVALUATION PREPARED BY CLYDE Q. SHEELY	 C-1
A. MATHEMATICAL DESCRIPTION	C-1
B. METHOD OF NUMERICAL SOLUTION	C-2
C. SOLUTION OF RADIOACTIVE CONTAMINATION	C-4
REFERENCES	C-10

TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
I.	Aquifers and porous zones in the Rio Blanco site area.	2
II.	Calculated radiochemical concentration in chimney gas.	4

APPENDIX A

A-I.	Gaseous radioactive nuclide inventory at T + 2 days and their decay factors.	A-5
A-II.	Assumed relative chemical composition of chimney gas.	A-6
A-III.	Assumed radioactivity concentrations in chimney gas.	A-6
A-IV.	Maximum concentrations of radioactivity in groundwater.	A-12
A-V.	Inventory of water wells, Rio Blanco Project area, Rio Blanco County, Colorado.	A-18

APPENDIX B

B-I.	Calculated oil shale yield and fracture porosity.	B-7
------	---	-----

APPENDIX C

C-I.	Flow rate parameters.	C-4
C-II.	Partition of gas.	C-6
C-III.	Radioactivity content of water in 100-foot cylinder.	C-7
C-IV.	Nuclide concentrations.	C-6
C-V.	Zone concentrations.	C-9

ILLUSTRATIONS

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
1.	Stratigraphy through Fawn Creek Number 1, RB-D-01, and RB-D-02/RB-D-03 locations.	6

APPENDIX A

A-1.	Rio Blanco RB-E-01 schematic.	A-3
A-2.	Rio Blanco experiment postdetonation pressure condition seepage model.	A-8
A-3.	Migration of gas in flowing water.	A-15

APPENDIX B

B-1.	Well RB-D-01 water rate and conductivity air lifted while the well was being drilled.	B-3
------	---	-----

APPENDIX C

C-1.	Grid system for aquifer.	C-11
C-2.	Subsystem B tritium - 35.0 MCFD rate - time = 5,000 days	C-12
C-3.	Subsystem B tritium - 35.0 MCFD rate - time = 15,000 days	C-13
C-4.	Subsystem B tritium - 35.0 MCFD rate - time = 25,000 days	C-14
C-5.	Subsystem B tritium - 35.0 MCFD rate - time = 35,000 days	C-15
C-6.	Subsystem B tritium - 35.0 MCFD rate - time = 50,000 days	C-16
C-7.	Subsystem B krypton 85 - time = 5,000 days	C-17
C-8.	Subsystem B krypton 85 - time = 15,000 days	C-18
C-9.	Subsystem B krypton 85 - time = 25,000 days	C-19

ILLUSTRATIONS

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
C-10.	Subsystem B krypton 85 - time = 35,000 days	C-20
C-11.	Subsystem B krypton 85 - time = 50,000 days	C-21
C-12.	Subsystem B carbon 14 - time = 5,000 days	C-22
C-13.	Subsystem B carbon 14 - time = 15,000 days	C-23
C-14.	Subsystem B carbon 14 - time = 25,000 days	C-24
C-15.	Subsystem B carbon 14 - time = 35,000 days	C-25
C-16.	Subsystem B carbon 14 - time = 50,000 days	C-26
C-17.	Subsystem B argon 37 - time = 5,000 days	C-27
C-18.	Undissolved gas - Zone B - 5,000 days	C-28
C-19.	Undissolved gas - Zone B - 15,000 days	C-29
C-20.	Undissolved gas - Zone B - 25,000 days	C-30
C-21.	Undissolved gas - Zone B - 35,000 days	C-31
C-22.	Undissolved gas - Zone B - 50,000 days	C-32

NOTE: Plate A1 has been inserted in back cover envelope.

I. SUMMARY

The possibility of radioactivity transport in the groundwater system as the result of a hypothetical maximum credible gas leak following the Rio Blanco detonation was evaluated.

This evaluation used the specific aquifer characteristics developed from tests in the emplacement well area, instead of the general basinal characteristics used in the initial calculations presented in the Environmental Impact Evaluation. (1)

The present study confirms the low radiation levels in the groundwater predicted in the initial calculations.

II. DISCUSSION

A. INTRODUCTION

The evaluation of the contingency of seepage of radioactive material into the groundwater system requires a "modeling" of three "components": 1) the leak or source function, 2) the groundwater system, and 3) the mechanism governing the behavior of the radioactive material after it enters the groundwater system. These three "components" and the resulting picture of the nuclide distribution as a function of time are summarized in the following sections of this report. A more detailed treatment of various parts of the evaluation will be found in the appendices or in the references.

B. SOURCE FUNCTION MODEL

1. Effects of Seepage

No contamination of groundwater around the Rio Blanco site due to seepage is anticipated. However, seepage calculations are presented to define the upper limits of aquifer contamination if the unexpected were to occur.

The aquifer subsystems have been identified at the Rio Blanco site although a number of other porous zones are known to exist. Table 1 summarizes these features.

Table I. Aquifers and porous zones in the Rio Blanco site area.

<u>Strata</u>	<u>Depth below surface (feet)</u>	
	<u>Top</u>	<u>Bottom</u>
Aquifer		
Alluvium	Surface	100
"A"	245	845
"B"	880	1,650
Porous Zone		
Douglas Creek Sand No. 1	2,400	2,450
Wasatch "G" Sand	4,180	4,210
Wasatch "J" Sand	4,500	4,540
Wasatch "K" Sand	4,570	4,700
Basal Wasatch Sand	5,190	5,220

2. Models for Communication Between Chimney and Aquifers

The bottom of the lowest aquifer (the "B" aquifer) is more than 3,500 feet above the calculated top of the detonation-induced rock fractures.⁽¹⁾ Therefore, this aquifer cannot communicate directly with the chimney. However, the remote possibility of seepage outside the well casing has been postulated as the maximum credible incident.⁽¹⁾ If a permeable path developed in the casing to formation cement prior to detonation time, this path would be filled with water flowing toward the bottom of the well or with water at hydrostatic conditions. Since the hydrostatic pressure of the water would be greater than the postdetonation chimney pressure, the water would continue to flow to the chimney. It would only be after an appreciable amount of time, and fortuitous conditions, that a continuous gas phase would be formed and an upward flow of gas could take place.

The most critical set of circumstances would be for the cement to be fractured by the explosion and for water to start moving downward and gas to start to move upward at the same time. It is this counterflow system that will be evaluated in this report.

3. Radionuclide Concentrations

If seepage to an aquifer were to occur, the radioactive contaminants of concern would be tritium, carbon-14 and noble gases. Since the countercurrent flow would result in a relatively slow movement of the activity up the seepage path, the inventory of radionuclides 180 days after detonation is used to calculate the radioactivity concentrations in the groundwater. These concentrations, presented in Table II, represent maxima, since the minimum chimney and gas volumes and the maximum calculated amounts of radioactive substances were used to determine the "expected values."⁽¹⁾

The volume of gas which could reach and enter the "A" and "B" aquifers (see Appendix A) is estimated from a simplified flow model⁽²⁾ and an approximate pressure profile for gas in the seepage path. Under the quasi-steady-state conditions assumed, somewhat less than 35 MSCF of gas per day could reach the base of the "B" aquifer.

Table II. Calculated radiochemical concentration in chimney gas. (1)

<u>Nuclide</u>	Concentration (pCi/cc)
	<u>T + 180 D</u>
Tritium	< 123
Krypton-85	205
Argon-37	< 267*
Argon-39	< 2
Carbon-14	< 2.3

*Argon-37, with a one-month half life, will not be a factor in radiation in groundwater.

About 3,535/3,536 or 99.97 percent of the gas would enter the "B" aquifer, and only 1/3,536 or 0.03 percent would continue up the leak path (see Appendix A). Thus, the "B" aquifer is the critical zone in the analysis of gas seepage.

C. CHARACTERISTICS OF "B" AQUIFER

The "A" and "B" aquifers in the Rio Blanco experiment area are predominately fractured oil shale intervals. The oil shale is a layered rock. The individual rock layers tend to be fractured depending on their brittleness and thickness. (3) There is a hierarchy of fractures: 1) the most numerous fractures are minor closely spaced systems that are confined vertically to thin brittle layers and have a vertical extent of a few feet, 2) the major fractures are less numerous and cut across several layers and have a vertical extent of a few tens of feet, while 3) the master fractures are relatively rare zones that cut across a number of layers and may have a vertical extent of a hundred or more feet.

The fracture aquifer systems thus consist of a number of horizontal layers with closely spaced minor fractures and a relatively high permeability. The nearby horizontal permeable layers are tenuously connected vertically by the major fracture systems, and these permeable layers are even more tenuously connected vertically by the "master" fracture sets.

At greater depths of burial, the more plastic layers tend to close or "heal" the cross cutting major and master fracture sets, and a series of horizontal permeable layers are found without viable vertical interconnection. Below approximately 1,400-foot subsurface in the Rio Blanco experiment area, viable vertical connection of layers ceases, and isolated horizontal permeable zones are encountered with variable salinity, gas saturation, and pressure. (4,5,6)

The Mahogany Zone has a number of layers with a sufficiently high oil shale content to be plastic enough, even at a depth of burial of less than 1,000 feet, to tend to close on the major and master fracture sets.

Thus, the Mahogany Zone is the "top" on the "B" aquifer. However, it is a leaky roof since there are enough uncemented holes punched through the Mahogany Zone, as well as natural leaks, to have pretty well equalized pressure and water quality between the "A" and "B" aquifers in the area of interest. Figure 1 is a stratigraphic section of the area which shows the general relationships of the previously described zones.

The transmissivity of the "B" zone, approximately 30 to 60 ft²/day, has been calculated from production testing.^(5,6) The evaluation of the porosity is not as straight forward.

An effective porosity of 0.025 was calculated for the "B" aquifer in a location approximately 4 miles to the west from data obtained in an in situ shale recovery project.⁽⁷⁾

Conservative porosities of from about 0.0125 to 0.02 have been calculated utilizing the logs. The details of these calculations are presented in Appendix B.

Estimates of the net feet of permeable rock and conservative estimates of the average porosities for the "A" and "B" zones are summarized below:

<u>Item</u>	<u>"A" Zone Value</u>	<u>"B" Zone Value</u>
Net feet	260	185
Average porosity	0.0125	0.0198
Average permeability (darcy)	2.0	0.05

D. CALCULATIONS OF WATER VELOCITY IN "B" AQUIFER

The water velocity in the "B" aquifer in the area of the Rio Blanco experiment can be calculated utilizing the transmissivity and porosity data previously discussed and the approximately 100-foot/mile piezometric surface gradient data from the site.⁽⁷⁾

Figure 1. Stratigraphy through Fawn Creek Number 1, RB-D-01, and RB-D-02/RB-D-03 locations.

$$\bar{v} = 6.33 \frac{Ak}{\mu} \frac{dp}{dL} \frac{1}{\phi_e}$$

where:

$$\bar{v} = \text{Average velocity, ft/day}$$

$$k = \text{Permeability, darcy}$$

$$A = \text{Cross sectional area, ft}^2$$

$$\mu = \text{Viscosity, cp}$$

$$dp/dL = \text{Pressure gradient, psi/ft}$$

$$\phi_e = \text{Effective porosity,}$$

$$\bar{v}_B = \frac{6.33 \times 0.05 \times 43.3 \times 1}{0.51 \times 5,280 \times 0.0198} = 0.256 \text{ ft/day}$$

The "A" zone velocity can be calculated in a similar manner:

$$\bar{v}_A = \frac{6.33 \times 2.0 \times 43.3 \times 1}{0.71 \times 5,280 \times 0.0125} = 11.7 \text{ ft/day}$$

E. CALCULATION OF RADIOACTIVITY TRANSPORT IN "B" AQUIFER

A computer simulation of the possible radioactivity transport in the "A" and "B" aquifer has been made. The details are presented in Appendix C.

The transport equation used to calculate the shape and location of the radioactive material in the "B" zone leak case previously described (see Appendix A for detailed description) treats dispersion in a two dimensional flow regime:

$$\phi \frac{\partial c}{\partial t} = K_x \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} - v_x \frac{\partial C}{\partial x} - v_y \frac{\partial C}{\partial y}$$

where:

ϕ	=	Porosity
C	=	Concentration
t	=	Time
K_x	=	Dispersion coefficient in x direction
K_y	=	Dispersion coefficient in y direction
V_x	=	Velocity component in x direction
V_y	=	Velocity component in y direction

This equation was solved by the method of characteristics⁽⁸⁾ using the following boundary conditions:

1. The gas moving out into the aquifer percolated through a cylinder with a 100-foot diameter.
2. Part of the gas went into solution and part formed a gas bubble against the Mahogany Zone.
3. Gas from the gas bubble did not subsequently go into solution.
4. A point source was used at the emplacement well.
5. Water vapor is 100 percent water soluble.
6. The other gases have a solubility of 5 SCF/BBL at aquifer conditions.
7. The water vapor has an activity of 0.05 μ Ci/gm.
8. The flow in the leak path is reversed at 120 days postdetonation when the chimney pressure is drawn down in the production test program.

The graphic presentations in Appendix C show that even in the worse case considered:

1. a leak rate of 35 MCF/D or 7 times that used in the Addendum presented to the Environmental Statement,⁽⁹⁾ or equal to the maximum calculated in Appendix A, and

2. all of the tritium present in the water vapor of all the escaped gas is condensed in the "B" aquifer

the slug of water containing the radioactivity has moved less than 3.3 miles in 50,000 days (137 years) and the maximum concentration of tritium in the slug yields less than 1.0 pCi/ml activity. The guidelines for this nuclide in drinking water is 3,000 pCi/ml. Thus, even under this extremely conservative analysis, no problems are developed.

The "A" aquifer cases are also presented in detail in Appendix C. They represent no problems since the maximum initial tritium concentration is only about 0.1 pCi/ml at a 35 MCFD leak rate and this decreases rapidly because of diffusion in the aquifer.

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8. Garder, A. O. Jr., D. W. Peaceman, A. L. Pozzi "Numerical Calculation of Multi-Dimensional Miscible Displacement by the Method of Characteristics, " Society Petroleum Engineers Journal (March 1964).
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APPENDIX A

APPENDIX A

CONTINGENCY OF SEEPAGE INTO GROUNDWATER

A. AQUIFERS

No contamination of the groundwater around the EW is anticipated. However, as in the case of the radiological safety analysis presented in Reference A-1, pages 239 to 252, the "maximum credible" seepage calculations are presented to define the aquifer contamination limits if the unexpected were to occur. Depths from ground level to aquifers in the EW area are:

<u>Aquifer</u>	<u>Depth (ft)</u>	
	<u>From</u>	<u>To</u>
Alluvium	Surface	100
"A" Subsystem	250	750
"B" Subsystem (gas shows expected from from 1,400 feet to 1,650 feet)	940	1,650

In addition, significant porous zones were found from log analysis at the following levels between the aquifers and the gas reservoirs:

<u>Porous Zone</u>	<u>Depth (ft)</u>		<u>Fluid Content</u>
	<u>From</u>	<u>To</u>	
Douglas Creek Sand No. 1	2,400	2,450	Gas & Water
Wasatch "G" Sand	4,180	4,210	Gas & Water
Wasatch "J" Sand	4,500	4,540	Gas & Water
Wasatch "K" Sand	4,570	4,700	Gas & Water
Basal Wasatch Sand	5,190	5,220	Gas & Water

B. MODELS FOR COMMUNICATION BETWEEN CHIMNEY AND AQUIFERS

A careful consideration of NTS and off-site experience, coupled with a study of gas reservoirs, leads to the conclusion that "...the only remaining credible pathway for communication between the nuclearly created chimney and the surface (or aquifers occurring between the chimney and the surface*) would

*Added for clarity in report.

be through the man-made emplacement facility. "(A-2) The seepage paths proposed for this model were discussed previously in this report.⁽¹⁾ Their implications with respect to the transport of radioactivity in groundwater are:

1. Cracks were assumed to occur in cement near or at contact with the outside of 10-3/4-inch OD casing and to provide communication between the chimney and spall zone.^(A-2) RB-E-01 is schematically presented in Figure A-1. Thus, the first model would predict gas from the chimney traveling up the cement sheath and out a break in the 16-inch casing in the spall region, 0 to a maximum of 600 feet subsurface. This could cause a loss of water from the sealed annular space between the 10-3/4-inch and 16-inch pipes (plugged at the bottom by cement and at the top of the wellhead). When the gas from the chimney arrived, it could cause a pressure rise that would be detected by the pressure gauge installed postdetonation at the wellhead. Any sensible seepage rate would be detected, and the annular space and formation beyond the break in the 16-inch pipe could be filled with cement by perforating and squeeze cementing below the break. Thus, a seep by this model would be detected and stopped before any appreciable quantity of radioactive material had escaped. Hence, for the seep to release a significant amount of radiation, a second model must be considered.
2. The cement in the annular region between the 10-3/4-inch OD casing and the drilled hole becomes permeable. The seep paths are tortuous cracks through the cement, around the cement, or a combination of these. This seep path is assumed to communicate with the formations forming the outside boundary of the annular space, and this path occurs:
 - a. before the explosion as a result of shrinkage cracks, chemical action, gas entrainment, or
 - b. postdetonation as a result of the explosion.^(A-2)

If the seep path has appreciable permeability (a necessary assumption; otherwise, no sensible seepage would occur), then under conditions of model a, the path would be completely filled with water originating in the Green River "A" and "B" subsystems under a hydrostatic gradient at detonation. Thus, initially, the driving pressure would be toward the cavity instead of away and water would be flowing down into the cavity. A two-phase counter

SEE FIGURE IV-A-2 OF PROJECT RIO BLANCO DEFINITION PLAN VOL. II
FOR WELLHEAD DETAILS

— NOT TO SCALE —

Figure A-1. Rio Blanco RB-E-01 schematic.

flow region could start postdetonation as the gas-filled detonation-induced fractures mesh with the seep path fracture system. Initially, the gas would move upward under a gravity differential drive, and an appreciable transient period would occur before the gas reached the "B" subsystem level. In addition, the volume of fluids flowing would be reduced by at least an order of magnitude because of phase interference. (A-3)

Under conditions of model b the gas would start to flow from the bottom, up the seep path, and water would start to flow from the top, down the seep path. Quasi-equilibrium would occur sooner under these conditions, and reduction in gas permeability would not be as great as for model a.

C. NUCLIDES

The flow of the chimney gas up the seep path would result in the movement of the mixture of radioactive and host gases that are in "equilibrium" in the chimney at the time the incremental volume starts its journey in the seep path. Some decay activity would occur because of the travel time in the path. Also, some reduction in volume would occur because of the condensation of the water vapor and from solution of the gas in the water moving down the seep path. Therefore, the nuclides of interest are those present approximately two days or more postdetonation. These nuclides are noble gases, tritiated water vapor, hydrogen and hydrocarbons, carbon dioxide, and possibly but not probably, iodine and/or volatile iodides. These nuclides will be mixed with the host gas. Table A-I presents the amounts of these nuclides per unit yield expected at T + 2 days and their decay factors. (A-1) It is apparent from the values in this table that the only nuclides existing in any significant quantities at T + 180 days would be T, ^{85}Kr , ^{39}Ar , ^{37}Ar , and ^{14}C . Since it will be shown that years would be required for any seeped gases to move in the aquifers to any use points, only these nuclides are considered.

D. CONCENTRATIONS

The noble gases will probably be rather uniformly distributed in the chimney gas, while the tritium will probably be partitioned in the chimney material, in the water, and in the chimney gas in a ratio of 4:5:1. (A-4) Using this partition and the seepage model pressure versus time curve (A-2) result in the following calculated radioactivity in the seeping gas at T + 180 days (see Tables A-II and A-III).

Table A-I. Gaseous radioactive nuclide inventory
at T + 2 days and their decay factors
(from PU-239 fission product tables). (A-1)

<u>Nuclide</u>	<u>Amount (Ci/kt)</u>	<u>Decay Constant (1/min)</u>
^{14}C	2.5×10^{-1}	-
^3H	3.3×10	-
<u>"Noble" Gases</u>		
^{37}Ar	1.04×10^3	1.40×10^{-5}
^{39}Ar	-*	4.91×10^{-9}
^{85}Kr	2.07×10	1.24×10^{-7}
$^{85\text{m}}\text{Kr}$	1.0×10^2	2.63×10^{-3}
^{87}Kr	-*	8.88×10^{-3}
^{88}Kr	-*	4.12×10^{-3}
(^{88}Rb)	-*	3.89×10^{-2}
$^{131\text{m}}\text{Xe}$	-**	4.01×10^{-5}
^{133}Xe	2.4×10^5	9.13×10^{-5}
$^{133\text{m}}\text{Xe}$	1.1×10^4	2.09×10^{-4}
$^{135\text{m}}\text{Xe}$	1.1×10^4	4.53×10^{-2}
^{135}Xe	3.0×10^5	1.26×10^{-3}
^{138}Xe	-*	4.08×10^{-2}
(^{138}Cs)	-*	2.15×10^{-2}
<u>Iodine Family</u> (Assumes 1% of direct fission products available for seepage)		
^{130}I	-*	9.25×10^{-4}
^{131}I	1.7×10	6.08×10^{-5}
^{132}I	-*	4.95×10^{-3}
^{133}I	5.5×10^2	5.52×10^{-4}
^{134}I	-*	1.34×10^{-3}
^{135}I	2.0×10^2	1.72×10^{-4}

* Indicates less than 1 Ci/kt

** Indicates peak of 4×10^2 Ci/kt at approximately 20 days.

Table A-II. Assumed relative chemical composition of chimney gas.⁽¹⁾

<u>Component</u>	<u>Volume Percent T + 180D</u>
Hydrocarbons	26
Carbon Dioxide	34
Hydrogen	18
Water Vapor	22

Table A-III. Assumed radioactivity concentrations in chimney gas.⁽¹⁾

<u>Nuclide</u>	<u>Concentration pCi/cc</u>
Tritium	< 123
Krypton 85	205
Argon 37	< 267
Argon 39	< 2
Carbon 14	< 2.3

The maximum volumes of gas that could seep to the various sinks (i.e., the "B" subsystem, the "A" subsystem, and the atmosphere) can be approximated using a pressure diagram (Figure A-2). An inspection of this figure indicates no seep of gas from the fractured cement sheath would occur until the gas reaches the "B" subsystem. The maximum volume of gas that could reach the base of the "B" subsystem, under quasi-steady-state conditions, is 35 MCFD. This is based upon the following boundary conditions:

1. The pressure in the seep path has to be slightly higher than the pressure in the "B" subsystem for gas to flow up instead of water flowing down; i.e., $p_c \geq 575$ psia.
2. Other parameters of the linear flow equation area are presented in the seepage model. (A-2)

$$q_c = 6.33 A k_{gc} \frac{p_o^2 - p_c^2}{\mu p_a L}$$

where:

- A = cross sectional area of cement, ~ 0.597 feet³
- k_{gc} = relative permeability to gas in partially wet seep path, $\sim 3d$ (relative permeability is less than the specific permeability derived in seepage model)
- μ = gas viscosity, ~ 0.02 cp
- p_a = reference pressure, ~ 15 psia
- p_o = chimney pressure, $\sim 2,015$ psia
- p_c = pressure in seep path at base of "B" zone, ~ 575 psia
- L = seep path length, $\sim 4,000$ feet

Figure A-2. Rio Blanco experiment postdetonation pressure condition seepage model.

$$\begin{aligned}
q_c &= \frac{633 \times 0.597 \times 3}{0.02 \times 15 \times 4,000} (2,015^2 - 575^2) \\
&= \frac{6.33 \times 5.97 \times 3 \times 10^{-1}}{2.0 \times 1.5 \times 4.0 \times 10^2} \left[(2.015)^2 - (0.575)^2 \right] \times 10^6 \\
&= (9.45 \times 10^{-3}) (3.73 \times 10^6) \\
&= \text{approximately } 35 \text{ MCFD}
\end{aligned}$$

When the gas reaches the "B" subsystem, it can proceed up the seep path or go into the "B" zone. The ratio of gas going to the "B" zone to gas going up the seep path can be evaluated by dividing q_b by q_{ca} and noting that $(p_c^2 - p_b^2)/(p_c^2 - p_{ca}^2)$ is approximately 1, since the larger squared term in both expressions is the same, and p_{ca} is not too different from p_b .

$$\begin{aligned}
q_b &= \frac{39.6 h_b k_{gb} (p_c^2 - p_b^2)}{\mu p_a \ln \left(\frac{r_e}{r_w} \right)} \\
q_{ca} &= \frac{6.33 A k_{gc} (p_c^2 - p_{ca}^2)}{\mu p_a L}
\end{aligned}$$

where:

- h_b = net "B" thickness, ~ 185 ft
- k_{gb} = relative permeability of "B" zone to gas, ~ 0.05 darcies
- μ = gas viscosity, ~ 0.02 cp
- p_a = reference pressure, ~ 15 psia
- $\left(\frac{r_e}{r_w} \right)$ = ratio of effective to well radius, ~ 600
- A = cross sectional area, ~ 0.597 ft²
- k_c = relative permeability of seep path to gas, ~ 3 darcies
- L = seep path length, ~ 700 ft

$$\frac{q_b}{q_{ca}} = \frac{\frac{39.6 \times 185 \times 0.05}{0.02 \times 15 \times \ln 600}}{\frac{6.33 \times 0.597 \times 3}{0.02 \times 15 \times 700}}$$

$$= 3,536/1$$

Thus, much more than 99 percent of the gas reaching the "B" subsystem goes into the aquifer, and much less than 1 percent continues up the seep path.

The same general analysis can be made of the "A" subsystem. Again, the driving pressure would be the same; hence:

$$\frac{q_a}{q_l} = \frac{\frac{p_{ca}^2 - p_a^2}{p_{ca}^2 - p_l^2} \text{ would approach 1.}}{\frac{39.6 h_a k_{ga} (p_{ca}^2 - p_a^2)}{\mu p_a \ln \left(\frac{r_e}{r_w} \right)}}$$

$$= \frac{6.33 A_1 k_{gc} (p_a^2 - p_l^2)}{\mu p_a L}$$

where:

- h_a = net thickness of "A" zone, ~ 260 ft
- k_{ga} = relative permeability to gas "A" zone, ~ 2.0 darcies
- $\left(\frac{r_e}{r_w} \right)$ = ratio of effective to well radii, ~ 500
- p_a = reference pressure, ~ 15 psia
- μ = gas viscosity, ~ 0.02 cp
- A_1 = area of seep path, ~ 0.785 ft²

k_{g1} = relative permeability to gas of seep path, ~ 3 darcies

L = length of seep path, ~ 500 ft

$$\frac{q_a}{q_1} = \frac{\frac{39.6 \times 260 \times 2}{0.02 \times 15 \times 6.21}}{\frac{6.33 \times 0.785 \times 3}{0.02 \times 15 \times 500}}$$
$$= 111,220/1$$

Hence, much more than 99 percent of the very small amount of gas penetrating the Mahogany Zone would be dissipated in the "A" subsystem, and only a trivial amount would remain in the seep path.

The concentration of radioactivity in the Green River "A" and "B" groundwater subsystems would be:

"A" Subsystem: The amount of gas that dissolves in the water and moves with the water in the aquifer (excess gas beyond that soluble in the water would be part of the gas that seeps to the atmosphere).

"B" Subsystem: The amount of gas that dissolves in the water and moves with the water, plus the amount of gas that remains as a gas phase and forms a gas bubble against the base of the Mahogany Zone.

The critical gas saturation in a fracture system is less than 10 percent; hence, each cubic foot of gas would contact at least 9 cubic feet of water prior to forming a bubble. Thus, the maximum concentration of radioactivity in the water would be that predicted by the solubility of the gases in the water. This value would decrease as the water moved along the aquifer and mixing occurred. These maximum concentrations in the water are presented in Table A-IV.

The concentration of radioactive components in the gas phase would be that predicted by the initial concentrations and decay rates (Table A-I).

Table A-IV. Maximum concentrations of radioactivity in groundwater.*

<u>Species</u>	<u>Concentration (pCi/ml @ 180 days)</u>
T Total	< 43**
^{13}C	< 0.8
^{85}Kr	< 72
^{37}Ar Total	< 94
^{39}Ar	< 0.8

*Assumes a solubility equivalent to natural gas in fresh water at 100°F and 275 psia.

**The maximum possible tritium concentration 1.5 percent of the radioactivity concentration guide for uncontrolled area. Note that this analysis does not consider the dilution that must occur as the water moves through the aquifer.

E. PRELIMINARY ESTIMATE OF MOVEMENT OF RADIOACTIVITY
(DIRECTION AND VELOCITY)

1. Introduction

A consideration of the radioactivity transport in the "B" subsystem would evaluate the bulk of the radioactivity released under the proposed maximum seepage model. The "A" subsystem velocities are higher, but the volume reaching the "A" subsystem is much less than 1 percent of that reaching the "B" subsystem. Thus, dilution would result in no detectable "A" zone activity even a short distance from the EW.

2. Direction and Velocity

The direction and velocity of transport of any dissolved gas released from the EW system into the "B" subsystem water would be to the NNE at a maximum of about 0.256 feet per day.

The direction and velocity of a gas bubble is a more complicated function. The moving water pushes on the bubble in the direction of flow with a force proportional to the water velocity. The bubble is acted upon by gravity forces, and the resultant movement and velocity is the vector sum of the forces.

3. Retardation

Tritium and the noble gases will be assumed to have a retardation factor of one for this conservative evaluation;* hence, they are assumed to experience no retardation, only a decrease in concentration due to mixing.

The ^{14}C is present in such a low concentration that its retardation will have no appreciable effect upon the total radioactive concentration. Thus, to simplify calculations, no retardation will be assumed to apply to this component.

*

$$v_1 = \frac{v}{K_f}, \quad v_1 = \text{velocity of radiation transport, } v = \text{velocity of water}$$

$$K_f = \left[\frac{(1 - \phi)}{\phi} \right] \rho K_d ; \text{ if } K_d = 0, K_f = 1,$$

where:

ϕ = fractional porosity
 ρ = grain density, gm/cc
 K_f = retardation factor
 K_d = distribution coefficient

In the EW area, the gravity and flow forces are in opposition (see Figure A-3), and the resultant is 2.4 feet per day at an azimuth of 206 degrees:

$$\frac{dz}{dx} = \frac{\rho_w}{\rho_w - \rho_g} \frac{dh}{dx}$$

where:

$$\frac{dz}{dx} = \text{tilt of gas water interface}$$

$$\rho_w = \text{density of water, } \sim 1.0 \text{ gm/cc}$$

$$\rho_g = \text{density of gas, } \sim 0.025 \text{ gm/cc}$$

$$\frac{dh}{dx} = \text{gradient of piezometric surface, } \sim 70/5280 \text{ (feet/feet)}$$

$$\frac{dz}{dx} = \frac{1}{1 - 0.024} \times \frac{70}{5280}$$

$$= 1.39 \times 10^{-2}$$

$$\tan \phi = \frac{dz}{dx} = 1.39 \times 10^{-2}$$

$$\phi = 0^\circ 48'$$

The velocity in the up-dip direction would be the ratio of the x components:

$$\frac{1.39}{1.2} = \frac{3.14}{x}$$

$$x = 2.7 \text{ feet per day}$$

Since the dip and piezometric gradient are in opposite directions, the azimuth will be the converse of the dip, or 206 degrees.

Figure A-3. Migration of gas in flowing water. If angle ϕ ($dz/dx = \tan \phi$) is less than θ (dip of strata) then gas will migrate up-dip. If ϕ is greater than θ gas will be carried down-dip.

4. Residence Time

The down-gradient distance to the nearest potential "mixing point" is 4.8 to 8.6 miles. These are the Black Sulphur Creek and Piceance Creek fault zones. These are not the principal areas of discharge for the "B" subsystem (this is further to the north toward the White River), but they represent areas where "B" subzone water could enter the biosphere, although at a very reduced concentration. The distance to the up-dip recharge zone is about 8 miles. Thus, the minimum residence time would be in the order of 270 years, although the most probable residence time would be in the order of a thousand years.

Applying a similar analysis to the "A" zone, the nearest discharge point is about 4.8 miles to the north. This would result in a residence time of about 8 years before radiation entrained in the "A" subsystem could become available to the biosphere; however, only an insignificant amount of radioactivity would be introduced into this subsystem. The resulting dilution would result in a very benign situation.

5. Use Points

The wells tapping the "A" and "B" aquifer system within an area of about 10 miles from the EW are plotted on Plate A1, and the available information is summarized in Table A-V. The water source, whether alluvium (AL), "A" or "B" system or unknown (?), is shown on Plate A1.

The nearest current use point for the "A-B" system water is the Equity Oil Company facilities about 3.6 miles from the EW area in a direction almost perpendicular to the groundwater flow, and, consequently, the assumed flow of radiation contained in the water.

The nearest down gradient use point is about 6.5 miles northeast in the Piceance Creek Valley. If some of the water containing dissolved radioactive gas from the seepage model were to move in the direction of these use points, it would have a velocity less than the calculated maximum velocity in the normal flow direction. Hence, it would take more than 203 years to reach the use point, and the activity would have undergone a 10^5 fold decay. Since the maximum concentration in the water is initially less than 2 percent of the guideline for drinking water, this situation would not constitute a problem.

Any "gas bubble" in the "B" subsystem under gravity drive would be in an up-dip or southern direction. There are no use points within 10 miles of the EW area in this direction; hence, the gas phase seepage would not constitute a problem under the current usage pattern. If the bubble moved in a non up-dip direction, it would have to be carried by the water and would have a valocity equal to or less than the water velocity. Thus, a non up-dip gas bubble movement would result in residence times the same as or greater than the radiation in the water.

Table A-V. Inventory of water wells, Rio Blanco Project area, Rio Blanco County, Colorado.

Location number: See text for numbering system.

Date of inventory: August and October, 1972.

Depths: All depths are in feet.

Yield: As reported in gallons per minute.

Permit number: Permit on file at State Engineer's Office, Denver, Colorado, under this number.

Altitude: Altitude of land surface estimated from 7-1/2 minute quadrangle topographic maps or as reported from well files in feet above mean sea level

Lift method: S - submersible pump E - electric, further as indicated

Location Number	Name or Location	Owner	Year Completed	Depth of Well	Depth to Water	Yield (gpm)	Altitude Of Land-surface	Casing Data	Lift Method	Use of Water	Permit Number	Remarks
1-98-29	84 Ranch	GFP	1912	26'	10'	5	6,338'	6"	S. E.	Domestic	GFP-58112	BLM installed pump
1-97-32	W of cabin	GFP	1913	100'	-	-0-					GFP-50623	Well plugged w/rocks
2-99-12	Stake Springs Creek	Occidental	1972				6,600'	8"	Shut-in			Leaked gas 3/72 no leak 8/72
2-99-14	In campsite	GFP	1966	30'		2			Handpump	Domestic	GFP-58110	
2-99-15	Windmill near house	Kay Hughes			24'	2	6,716'		Windmill	Irrigation		Ref. 1
2-99-21		Kay Hughes			55'		6,890'					Ref. 1
2-99-22		Kay Hughes			207'	2	6,796'					Ref. 1
2-99-25	Galloway Gulch	Reigle							Windmill	Stock		
2-98-1	Shell 22X-1	Shell	1968	2,642'	229'	500 @ 1,700'	6,414'	8-5/8" @ 267'	S. E.	Wildlife & irrigation		BLM pump
2-98-2	Shell 23X-2	Shell	1968	2,700'	331'	270 @ 2,700'	6,520'	8-5/8" @ 747'	Shut-in			GS recorder
2-98-9dc	Near Ryan School	BLM	1965	37'	17'	2	6,393'	6"	Windmill	Wildlife stock		
2-98-9dd	Near Ryan School	GFP	1965	37'		1	6,420'	6"	Handpump	Domestic	GFP-56282	
2-98-10	Near Ryan School	GFP	1965	15'	Artesian	1			Flow	Irrigation	GFP-58109	
2-98-12	Ryan Gulch	GFP	1960	95'	50'	10		6"	Windmill	Stock	GFP-4830	
2-98-30	Eq-15	Equity	1963	1,691'	430'		6,682'	9-5/8" @ 62" 5-1/2" @ 1,520'	S. E.	Wildlife		BLM pump in-operative Salt water
2-97-4ba	Mar. #1	Marathon		2,134'			6,122'	8"		Unused		Padlocked
2-97-4bb					G. L.		6,090'	8"		Unused		Open casing west of road
2-97-9bc	Love Ranch Wells	Humble	(6 wells, at least 3 under pressure, no data)						Shut-in	Industrial	P5762	
2-97-9cc	Love Ranch	Love		63'	6'	80	6,120		Shut-in			
2-97-8	Robert Miller Well #2	American Petroleum Co.					6,160	5"	Welded shut			
2-97-21ba	Near Rock School	Equity		Bridge @ 250'	@G. L.		6,160'	10-3/4"		Unused		Open
2-97-21bd	Equity Johnson #2	Johnson	1962	5,000'		Dry	6,200	13-3/8'				Plugged and abandoned
2-97-21	Mobil #2	Mobil Oil	1968	1,504'	329'	350	6,440'	8-5/8"	Shut-in	Industrial	13450	Overlooks Rock School

Table A-V. Inventory of water wells, Rio Blanco Project area, Rio Blanco County, Colorado (Cont.)

Location Number	Name or Location	Owner	Year Completed	Depth of Well	Depth to Water	Yield (gpm)	Altitude Of Land-surface	Casing Data	Lift Method	Use of Water	Permit Number	Remarks
2-97-22ca	On Johnson Ranch	Johnson		50'			6,160'	Hand dug	E.	Domestic		Near house wall
2-97-22ac	On Johnson Ranch	Johnson		350'	Artesian	2	6,180'	6"		Stock		Near road side
2-97-26aa	Along Piceance Road	Johnson		750'				7"		Unused		Water cascading downhole. Open to 60'
2-97-27	Johnson #1	Johnson		2,563'	8'		6,286'	7" to 1,022'				Open bridge @ 220'
2-97-28	Mobil Oil #3	Mobil Oil	1968	1,648'	376'	540		8-5/8"	Shut-in	Industrial	13449	2" valve locked
2-97-33bb	Mobil Oil #1	Mobil Oil	1967	1,300'	205'	450		8-5/8"	Shut-in	Industrial	12722	
2-97-33ac	Mobil Oil #4	Mobil Oil	1969	1,750'	183'	450		15" 10-3/4" 8-5/8"	Shut-in	Commercial	14232	Valve & pressure gauge
2-97-34	Mobil Oil #5	Mobil Oil	1969	1,752'	201'	450		15" & 10-3/4" & 8-5/8"	Shut-in	Industrial	14233	Valve & pressure gauge
2-96-19		Mobil Oil	1967	571'	200'	10		8-1/4" & 7"	Subm. pump	Commercial	11425	
3-99-36	Arco #36-1	Atlantic Richfield	1969	452'	72'	10	7,478'	5-1/2" @ 55'				GS recorder
3-98-14	RB-D-01	CER	1971	1,651'	50'	675 @ 1,651'	6,631'	7-5/8" @ 245'		Hydro. control well	71676	Open
3-98-14	RB-W-01	CER	1973	98'	39'		6,631'	4-1/2" to 97'		Industrial		
3-98-6	BX-1	Equity		1,708'			6,629'			Disposal well		4 DST all water from 941' to 1,365'
(This is one of 11 wells drilled on the Equity oil shale experiment site. Four of these have water at ground level. TD's vary from 1,200' to 1,700')												
3-98-31	Arco #31-1	Atlantic Richfield	1970	2,420'	639'	283 @ 2,420"	7,814'	8-5/8" to 53'				GS sample data available
3-98-34		Brennan		250'					Windmill	Stock		Water cascades downhole
3-98-36	Hunter Gulch Well	Humble			90'		7,000'	8-5/8"				Padlocked. Bridge @ 443'; top of plug @ 425'
3-97-4	Greeno 1-4	Shell		2,700'			6,417'					
(This is one of four wells, steel plates welded on casing tops, no plugs in wells)												
3-97-6		Brennan		250'		2			Windmill	Stock		
3-97-13	Tosco 71-1	Tosco							Shut-in	Industrial		A&B zone samples
3-97-21		Johnson		250'		1 to 2			Windmill	Stock		
3-97-24		Johnson				1 to 2			Windmill	Stock		
3-97-25		Johnson		73'		1 to 2			Windmill	Stock		
3-97-26		BLM							Windmill	Wildlife		
3-97-29		Johnson		355'	310'	15		6"	E & S	Stock	25816	Pump out of order in October

Table A-V. Inventory of water wells, Rio Blanco Project area, Rio Blanco County, Colorado (Cont.)

Location Number	Name or Location	Owner	Year Completed	Depth of Well	Depth to Water	Yield (gpm)	Altitude Of Land-surface	Casing Data	Lift Method	Use of Water	Permit Number	Remarks
3-96-7		Oldland	1959	800'	Artesian	180				Stock	R15500	
3-96-17	Tosco 71-2	Tosco										Well locked
3-96-29	Tosco 71-3	Tosco										Well locked
3-96-30	Red's Cow Camp	Oldland (Tosco)		80'		1 to 2			Handpump			
4-98-2		Johnson		250'	80'	2		150' pipe(1")	Windmill	Stock		
4-98-10		Brennan		250'		2			Windmill	Stock		
4-98-15	Jumps Cabin	Humble		1,176'	38'		7,550'					8-5/8" bridge at 345' Padlocked
4-98-16		Johnson	1972	130'		2			Windmill	Stock		
4-98-21	Tosco CH-25	Tosco	1972	500'			7,739'					Padlocked
4-98-25	Whiskey Gulch	Johnson	1965	83'	60'	20				Stock	25815	
4-97-12		Oldland	1952	350'	30'	10				Stock	N0076	
4-97-23		Oldland	1952	350'	30'	10				Stock	N0075	
4-97-28		Humble			11'		7,450'					
4-97-29				65'	30'		7,720'		Shut-in			Ref. 1

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APPENDIX B

APPENDIX B

DETAILED LOG CALCULATIONS FOR PARACHUTE CREEK MEMBER POROSITY AND OIL CONTENT

A. INTRODUCTION

Oil yields from oil shale have been estimated with some success in the past using geophysical logs. (B-1, B-2, B-3, B-4) The problem of evaluating the water-filled oil shale porosity is more complex. The processes used to calculate these parameters for the Rio Blanco Project area are described in the following portions of this appendix.

B. DISCUSSION

One technique that may be used to estimate fracture porosity is to calculate the oil yield from the sonic log, and the oil yield and fracture porosity from the density log. The fracture porosity is obtained as the difference between the sonic oil yield, which essentially overlooks the fractures; and the density oil yield, which is high because of the effect of the water bearing fractures upon the logging response.

The logs from the RB-E-01 and RB-D-01 wells were digitized. A simple computer program was written that used the correlations developed by Bardsley and Algermission^(B-1) and Smith^(B-2) to calculate the oil yield using the sonic and density logs. The logs from the RB-E-01 were anomalously effected, apparently by the hole size, and were not used for further calculations. The output from this calculation is presented as Table B-I. An evaluation of this table shows a number of places where negative porosities would be calculated because sonic oil yield is higher than density oil yield.

A refinement of the original calculation was effected by selecting the intervals where the resistivity log was pegged (i.e., read no conductivity) and developing a correlation equation for oil yield on sonic and density logs by assuming that fracture porosity would be essentially zero in these intervals; hence, oil yields calculated from the two logs should be identical. A second program was written which calculated fracture porosity by utilizing the difference between the density log response and the correlative sonic log response. These values are also presented in Table B-I.

The intervals of calculated fracture porosities were compared with the zones of water entry found while drilling the well (see Figure B-1). Between a quarter and a half of the intervals which indicated water entry during drilling also indicated fracture porosity in the log calculations. This information is tabulated below:

<u>Zone</u>	<u>Net Feet of Water Entry</u>	<u>Net Feet Showing Both Water Entry And Fracture Porosity</u>	<u>Average Fracture Porosity (%)</u>
"A" Subsystem	260	70	3
"B" Fresh Subsystem	185	75	4
"B" Saline Subsystem	50	27	4

A maximum fracture porosity can be calculated for the intervals with pegged or "saturated" resistivity logs. The "Archie" porosity equation^(B-6) is:

$$\frac{R_o}{R_w} = f = \frac{a}{\phi^m}$$

where:

R_o = Resistivity of rock saturated with water, ohm-m.

R_w = Resistivity of water, ohm-m.

f = Formation factor

ϕ = Porosity

a - Constant depending on rock type and pore geometry, ranges from 0.5 to 1.

m = Constant depending on rock type and pore geometry, ranges from 1 to > 3.0.

The values usually used in the Archie equation are 0.62 for a , and 2.15 for m ; i.e.,

$$f = 0.62 / \phi^{2.15}$$

B-3

Figure B-1. Well RB-D-01 water rate and conductivity air lifted while the well was being drilled. (after Knutson⁽⁵⁾)

This can be considered as an end point for common porous media; i.e., most rocks. Another end point can be defined by considering the case of a non-conducting medium with a hole or channel of moderately large size and simple geometry; i.e., a round elliptical, or rectangular hole drilled through an insulator and filled with a nonreactive electrolyte. This equation would be:

$$R_o/R_w = 1/\phi, ("a" = "m" = 1).$$

The fractured oil shale aquifer material would be closer to the perforated resistor than the porous media end point. The porosity calculated from the two end points for several rock resistivities is tabulated below.

R_o/R_w	$\phi = \sqrt[2.15]{0.62 R_w/R_o}$	$\phi^* = R_w/R_o$
100/10	0.275	0.1
500/10	0.13	0.02
1,000/10	0.094	0.01
1,500/10	0.078	0.0068
2,000/10	0.068	0.005

A conservative approach for calculating maximum fracture porosity from the resistivity logs would be to use the "a = m = 1" end point equation, because this would give a minimum porosity and, hence, a maximum velocity. The porosities derived in this manner from the three different resistivity logs are tabulated below:

Log	R_w/R_o	Porosity
Deep Induction	10/1,200	8.35×10^{-3}
Intermediate Induction	10/1,600	6.25×10^{-3}
Laterolog "8"	10/1,800	5.55×10^{-3}
Average		6.7×10^{-3}

If the minimum fracture porosity of approximately 6.0×10^{-3} is used for the water producing intervals with a saturated resistivity log response, then the average porosities from the combined techniques are attainable. The composite porosities are tabulated below.

*Case where a = m = 1.

<u>Zone</u>	<u>Thickness of Water Producing Interval (ft)</u>	<u>Calculation</u>	<u>Average Porosity</u>
"A"	260	$70 \times 0.03 = 2.10$ $190 \times 0.006 = \underline{1.14}$ $3.24/260$	1.25×10^{-2}
"B" Fresh	185	$75 \times 0.04 = 3.00$ $110 \times 0.006 = \underline{0.66}$ $3.66/185$	1.98×10^{-2}
"B" Brackish	50	$27 \times 0.04 = 1.08$ $23 \times 0.006 = \underline{0.14}$ $1.22/50$	2.44×10^{-2}

The values calculated above were used in the radioactive transport evaluation.

APPENDIX B

REFERENCES

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- B-5. Knutson, C. F. "Rio Blanco Hydrologic Testing Through January 30, 1973" CER Geonuclear Corporation, Las Vegas, Nevada (Jan. 1973).
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Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
400.00	.00000	.11000	.00000	20.41050	20.74204
401.00	.00000	.00000	.00000	15.81018	20.07422
402.00	.00000	.00000	.00000	9.06790	20.07422
403.00	.0000	.00000	.00000	9.02424	20.74904
404.00	.00000	.00000	.00000	11.47179	22.56002
405.00	.00000	.00000	.00000	21.22308	23.54474
406.00	.00000	.00000	.00000	22.00320	20.07422
407.00	.00000	.05085	.15088	12.70220	14.52202
408.00	.00000	.03793	.10971	2.09418	14.40470
409.00	.00000	.05752	.14522	11.00000	20.07422
410.00	.00000	.03742	.10961	11.85209	14.42520
411.00	.00000	.03740	.10957	8.26100	15.00000
412.00	.00000	.03686	.10751	2.73954	16.40400
413.00	.00000	.05506	.14190	2.02758	22.15601
414.00	.17331	.06320	.15477	17.32710	21.07272
415.00	.00000	.03783	.10942	29.58240	22.56002
416.00	.00000	.03781	.10930	31.74000	24.22004
417.00	.00000	.03779	.10934	21.45474	17.90201
418.00	.00000	.03623	.10627	8.83600	11.78132
419.00	.00000	.03723	.10924	.00540	11.05202
420.00	.00000	.03879	.11128	-1.17222	10.25000
421.00	.00000	.08406	.18614	.52874	11.74502
422.00	.00000	.00000	.00000	2.23070	12.40005
423.00	.00000	.00000	.00000	20.17004	12.40005
424.00	.00000	.03713	.10904	-1.22500	13.82802
425.00	.00000	.03711	.10890	2.60700	20.07422
426.00	.00000	.03709	.10706	9.94700	22.05002
427.00	.00000	.03759	.10900	14.87150	21.46140
428.00	.00000	.03809	.10902	11.22400	14.52202
429.00	.00000	.04885	.13904	4.67700	15.90000
430.00	.00000	.04555	.12405	6.37000	16.40400
431.00	.00000	.04248	.11934	6.00274	14.24000
432.00	.00000	.03748	.10974	14.62750	24.22004
433.00	.05373	.04071	.11490	27.05240	20.62300
434.00	.0000	.03744	.10855	27.60518	22.70700
435.00	.00000	.03794	.10964	14.41028	13.92002
436.00	.00000	.03684	.10755	4.13179	12.40005
437.00	.00000	.03738	.10854	2.03758	14.52202
438.00	.00000	.03805	.11150	3.54630	15.21505

*High utilizes the equation:
in fraction form.

$$\frac{R_w}{R_o} = f = \frac{0.62}{\phi 2.15} \quad \text{and presents the porosity}$$

Low utilizes the equation:
fractional form.

$$\frac{R_w}{R_o} = f = \frac{1}{\phi} \quad \text{and presents the porosity in}$$

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
439.00	.00000	.08111	.18319	5.24840	14.52203
440.00	.00000	.03784	.10944	4.11679	15.21605
441.00	.00000	.03730	.10838	2.60799	14.52203
442.00	.00000	.03728	.10834	5.43239	15.90999
443.00	.00000	.03778	.10932	6.37999	17.29803
444.00	.00000	.03724	.10826	6.75719	17.99205
445.00	.00000	.03774	.10924	8.83640	17.29803
446.00	.00000	.04099	.11551	11.66080	20.07402
447.00	.00000	.03667	.10713	15.81918	20.76804
448.00	.00000	.03716	.10810	13.93320	20.07402
449.00	.00000	.05948	.14855	8.08200	16.60400
450.00	.00000	.03764	.10904	4.30080	15.90999
451.00	.00000	.03710	.10798	5.05519	16.60400
452.00	.00000	.03708	.10794	6.57320	17.29803
453.00	.00000	.03758	.10892	5.43239	14.52203
454.00	.00000	.03653	.10686	2.41479	14.52203
455.00	.00000	.03651	.10682	1.28320	13.82802
456.00	.00000	.03649	.10678	1.66039	13.13400
457.00	.00000	.03698	.10775	4.11679	14.52203
458.00	.00000	.03696	.10771	7.32759	15.90999
459.00	.00000	.03643	.10667	4.49399	14.52203
460.00	.00000	.03591	.10564	1.85359	13.13400
461.00	.00000	.03639	.10659	3.36240	13.82802
462.00	.00000	.03637	.10655	2.23079	15.21605
463.00	.00000	.03636	.10651	2.03758	16.60400
464.00	.00000	.03634	.10648	3.36240	17.29803
465.00	.00000	.03682	.10744	5.62558	17.29803
466.00	.00000	.03630	.10640	7.70479	15.21605
467.00	.00000	.03678	.10736	8.64320	15.90999
468.00	.00000	.03676	.10732	7.32759	15.21605
469.00	.00000	.03624	.10629	9.02039	16.60400
470.00	.00000	.03622	.10625	11.09959	17.29803
471.00	.00000	.03671	.10721	12.41519	18.68599
472.00	.00000	.03772	.10920	12.23119	17.29803
473.00	.00000	.00000	.00000	10.52919	16.60400
474.00	.00000	.05254	.13667	10.72240	17.99205
475.00	.00000	.03663	.10706	10.52919	18.68599
476.00	.00000	.06284	.15417	11.09959	17.29803
477.00	.00000	.03710	.10799	9.02039	15.21605
478.00	.00000	.03607	.10594	7.32759	15.90999
479.00	.00000	.03655	.10690	6.95039	15.21605
480.00	.00000	.03653	.10686	4.87119	15.21605
481.00	.00000	.03601	.10583	7.70479	17.99205
482.00	.00000	.03599	.10579	12.79239	17.29803
483.00	.00000	.03647	.10675	13.54678	19.38000
484.00	.00000	.03595	.10572	12.60840	21.46199
485.00	.00000	.00000	.00000	14.49440	22.85002

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
485.00	.00000	.00000	.00000	20.15279	24.23005
487.00	.00000	.00000	.00000	21.28398	25.62602
488.00	.00000	.00000	.00000	27.76999	28.40221
489.00	.00000	.00000	.00000	36.61114	27.70739
490.00	.00000	.00000	.00000	37.51274	27.70739
491.00	.00000	.00000	.00000	33.36459	27.01405
492.00	.00000	.00000	.00000	26.34479	26.32004
493.00	.00000	.00000	.00000	22.00159	24.62602
494.00	.00000	.00000	.00000	24.34760	25.62602
495.00	.00000	.00000	.00000	23.08719	26.32004
496.00	.00000	.00000	.00000	24.08719	28.40221
497.00	.00000	.00000	.00000	28.13799	30.48399
498.00	.00000	.00000	.00000	31.01759	24.79225
499.00	.00000	.00000	.00000	31.56038	29.79225
500.00	.00000	.00000	.00000	33.36459	24.23005
501.00	.00000	.00000	.00000	36.79420	27.01405
502.00	.00000	.00000	.00000	32.82994	22.85002
503.00	.00000	.00000	.00000	20.34458	22.15001
504.00	.00000	.00000	.00000	16.19440	27.01405
505.00	.45372	.04891	.13015	24.70434	31.87202
506.00	.00000	.03554	.10490	30.48399	32.56004
507.00	.83075	.03807	.10989	31.91919	29.09604
508.00	.00000	.00000	.00000	30.48399	24.79225
509.00	.00000	.00000	.00000	26.50460	25.62602
510.00	.30512	.03547	.10674	22.71919	26.32004
511.00	.55830	.05225	.13610	27.59518	28.40221
512.00	.00000	.03543	.10469	28.68080	27.70739
513.00	.00000	.03591	.10563	30.11600	26.32004
514.00	.00000	.03589	.10560	29.21440	24.23005
515.00	.00000	.03587	.10556	24.43159	21.46199
516.00	.00000	.03536	.10454	18.64359	20.76904
517.00	.00000	.03584	.10549	18.83679	14.39200
518.00	.00000	.03582	.10545	17.13480	17.09205
519.00	.00000	.03580	.10541	11.85399	16.60400
520.00	.00000	.04853	.12947	9.96794	17.29203
521.00	.00000	.03576	.10534	8.26599	10.39200
522.00	.00000	.03575	.10530	10.34518	22.85002
523.00	.06111	.05566	.14203	16.00320	24.23005
524.00	.00000	.00000	.00000	18.64359	23.54404
525.00	.16470	.06475	.15732	21.45879	17.09205
526.00	.01540	.03876	.11123	17.51199	15.00200
527.00	.00000	.03615	.10511	10.34518	16.60400
528.00	.00000	.04267	.11868	9.34758	17.29203
529.00	.00000	.03765	.10906	9.39758	17.29203
530.00	.00000	.07951	.18073	8.08200	17.29203
531.00	.00000	.03608	.10597	7.13440	20.76904

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
532.00	.00000	.03507	.10396	11.47679	29.09604
533.00	.00000	.03506	.10393	25.60799	31.17801
534.00	.00000	.03504	.10389	26.50960	24.23905
535.00	.00000	.03502	.10386	16.19640	17.24803
536.00	.00000	.04949	.13120	7.51158	13.82802
537.00	.00000	.05085	.13363	6.37999	13.82802
538.00	.00000	.03497	.10375	6.37999	13.82802
539.00	.00000	.03593	.10568	2.79199	13.82802
540.00	.00000	.03493	.10368	-.40061	13.82802
541.00	.00000	.03492	.10365	2.79199	15.00999
542.00	.00000	.03490	.10361	6.18678	15.00999
543.00	.00000	.03488	.10357	6.95039	12.44005
544.00	.00000	.03736	.10850	5.43239	11.74603
545.00	.00000	.06235	.15335	1.66039	13.13400
546.00	.00000	.04469	.12246	1.28320	13.82802
547.00	.00000	.03530	.10441	5.05619	14.52203
548.00	.00000	.03528	.10437	6.75714	13.82802
549.00	.00000	.03526	.10434	6.00279	15.00999
550.00	.00000	.03476	.10333	2.60799	23.54404
551.00	.00000	.03474	.10329	13.36279	31.87202
552.00	.00000	.03425	.10230	29.21440	32.56604
553.00	.00000	.03423	.10226	31.20158	22.85002
554.00	.00000	.03469	.10319	14.96840	15.00999
555.00	.00000	.03515	.10412	4.30080	15.21605
556.00	.00000	.03465	.10312	2.03758	17.29803
557.00	.00000	.04569	.12431	6.95039	17.00205
558.00	.00000	.03710	.10799	9.96799	15.90999
559.00	.00000	.03460	.10302	5.80060	18.69599
560.00	.00000	.03655	.10691	2.03758	24.73005
561.00	.20746	.03554	.10489	18.08240	32.56604
562.00	.00000	.03407	.10195	27.23639	29.00604
563.00	.00000	.03453	.10288	21.09099	16.60400
564.00	.00000	.03452	.10284	5.05619	17.29803
565.00	.00000	.03547	.10475	5.24840	16.60400
566.00	.00000	.03448	.10277	1.09918	15.21605
567.00	.00000	.03543	.10468	-1.73442	13.82802
568.00	.00000	.03542	.10465	1.47639	15.90999
569.00	.00000	.03589	.10559	1.47639	14.52203
570.00	.00000	.03489	.10360	-.03241	24.93201
571.00	.00000	.03488	.10357	16.00320	28.40201
572.00	.00000	.03438	.10257	28.31279	26.32004
573.00	.00000	.03484	.10350	23.26199	19.38000
574.00	.00000	.04469	.12245	11.09959	17.29803

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
575.00	.00000	.07457	.17307	5.24840	19.38000
576.00	.00000	.00000	.00000	10.15199	22.15601
577.00	.00000	.03477	.10336	14.68759	22.85702
578.00	.00000	.03476	.10333	13.73949	27.01405
579.00	.24138	.03522	.10426	18.45959	34.64803
580.00	.00000	.03472	.10326	29.03960	33.95401
581.00	.00000	.03470	.10322	22.90320	30.48399
582.00	.20036	.05791	.14589	15.06679	40.20001
583.00	.79148	.07636	.17587	24.21440	40.20001
584.00	.00000	.00000	.00000	35.35080	27.70709
585.00	.00000	.03464	.10309	32.82909	20.07402
586.00	.00000	.04696	.12562	9.39758	27.77799
587.00	.13634	.07014	.16605	14.49440	35.34204
588.00	.00000	.00000	.00000	25.60709	40.20001
589.00	.00000	.00000	.00000	31.74440	36.73001
590.00	.00000	.00000	.00000	28.49678	31.17801
591.00	.09917	.06266	.15386	17.13480	24.93201
592.00	.00000	.00000	.00000	19.96840	26.32004
593.00	.09695	.05841	.14673	19.02080	19.38000
594.00	.00000	.03447	.10375	4.67798	15.90999
595.00	.00000	.03353	.10084	-.03241	18.68599
596.00	.00000	.03398	.10176	8.45918	22.15601
597.00	.00000	.03396	.10172	13.73949	22.15601
598.00	.00000	.03394	.10159	10.72240	18.68599
599.00	.00000	.03343	.10166	7.88879	19.38000
600.00	.00000	.03438	.10258	99.17499	20.07402
601.00	.00000	.00000	.00000	12.41519	22.15601
602.00	.00000	.00000	.00000	17.88919	23.54404
603.00	.00000	.03783	.10942	14.68759	20.07402
604.00	.00000	.03385	.10149	9.02039	27.70799
605.00	.00000	.03383	.10146	18.45959	36.73001
606.00	.00000	.03381	.10142	33.00479	40.89404
607.00	.00000	.03380	.10139	37.51279	36.73001
608.00	.00000	.03378	.10136	33.54759	30.48399
609.00	.00000	.03424	.10228	21.28398	20.07402
610.00	.00000	.03375	.10129	11.47579	18.68599
611.00	.00000	.03373	.10126	14.31038	17.29804
612.00	.00000	.03372	.10123	11.47579	15.90999
613.00	.00000	.06030	.14993	7.13440	15.90999
614.00	.00000	.00000	.00000	15.24879	20.07402
615.00	.12654	.04320	.11968	19.02080	22.15601
616.00	.00000	.03412	.10205	11.85399	15.90999
617.00	.00000	.03410	.10201	5.43239	15.90999
618.00	.00000	.03808	.10991	5.43239	17.29803
619.00	.00000	.04751	.12762	6.95039	20.76804
620.00	.00000	.03453	.10287	10.90639	23.54404

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
621.00	.00000	.03357	.10093	17.32799	25.62502
622.00	.00000	.03355	.10090	15.81418	24.23005
623.00	.02281	.03545	.10471	15.62599	21.46199
624.00	.00000	.03446	.10274	11.28360	19.38000
625.00	.00000	.04360	.12042	9.21359	17.99205
626.00	.00000	.05591	.14247	8.83640	17.29803
627.00	.00000	.05826	.14648	6.37999	15.21505
628.00	.00000	.03346	.10070	3.73959	15.90999
629.00	.00000	.03391	.10162	3.36240	17.99205
630.00	.00000	.03389	.10159	16.38039	24.93201
631.00	.49824	.03681	.10742	25.96678	30.48390
632.00	.00000	.03386	.10152	26.86839	28.40201
633.00	.11914	.04343	.12011	19.02080	21.46199
634.00	.00000	.03336	.10051	14.11719	17.99205
635.00	.00000	.03476	.10334	11.45399	16.60000
636.00	.00000	.03724	.10826	6.95039	15.21505
637.00	.00000	.03332	.10041	3.36240	13.82902
638.00	.00000	.03330	.10038	4.49399	13.82802
639.00	.00000	.04271	.11876	4.87119	13.13470
640.00	.00000	.03656	.10711	5.62558	15.90999
641.00	.00000	.03325	.10029	6.75719	17.29803
642.00	.00000	.03324	.10025	3.54639	15.90999
643.00	.00000	.03322	.10022	3.54639	17.29803
644.00	.00000	.03367	.10113	6.00279	14.52203
645.00	.00000	.03365	.10110	7.32759	15.90999
646.00	.00000	.03272	.09919	4.49399	17.29803
647.00	.00000	.03457	.10294	5.80960	17.29803
648.00	.00000	.03754	.10886	7.32759	18.68599
649.00	.00000	.03600	.10581	7.32759	20.07802
650.00	.00000	.03357	.10094	8.83640	30.48390
651.00	.00000	.03356	.10091	18.08240	39.50600
652.00	.00000	.00000	.00000	27.95499	47.83400
653.00	.39763	.04675	.12524	23.08719	33.25999
654.00	.00000	.03260	.09894	3.36240	17.29803
655.00	.00000	.03350	.10078	9.02039	18.68599
656.00	.00000	.03348	.10075	16.75758	24.23005
657.00	.00000	.03346	.10072	18.26639	24.93201
658.00	.00000	.03253	.09892	18.08240	27.70799
659.00	.64410	.03583	.10547	29.39839	27.01805
660.00	.00000	.00000	.00000	28.85559	28.40201
661.00	.00000	.05424	.13958	11.85399	17.29803
662.00	.00000	.03339	.10056	23.98878	12.44005
663.00	.00000	.03431	.10243	6.75719	10.35900
664.00	.00000	.04163	.11673	10.34518	13.82902
665.00	.00000	.00000	.00000	-6.0281	24.93201
666.00	.00000	.00000	.00000	4.87119	30.48399
667.00	.00000	.07038	.16643	11.28360	28.40201

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
668.00	.00000	.00000	.00000	18.84359	33.95401
669.00	.00000	.00000	.00000	25.96678	49.22203
670.00	1.27845	.03665	.10710	32.82099	59.63200
671.00	1.53190	.06376	.15558	36.96099	51.99803
672.00	.11542	.03817	.11008	16.19540	24.09604
673.00	.04478	.03868	.11108	11.28360	33.25994
674.00	.00000	.03509	.10400	5.80450	22.15671
675.00	.00000	.03319	.10015	6.95034	15.90999
676.00	.00000	.03226	.09826	6.00279	13.82802
677.00	.00000	.03316	.10009	-.08001	15.90939
678.00	.00000	.03503	.10387	12.60840	22.85002
679.00	.00000	.03312	.10002	23.98878	28.40201
680.00	.00000	.00000	.00000	26.69359	29.09604
681.00	.00000	.00000	.00000	23.26199	22.85002
682.00	.03516	.05757	.14531	16.38039	20.76904
683.00	.00000	.03306	.09490	10.15199	17.29803
684.00	.00000	.03259	.09894	6.18678	17.29803
685.00	.00000	.03258	.09891	4.49394	15.90999
686.00	.00000	.03302	.09981	4.49394	20.76904
687.00	.00000	.03300	.09977	16.38039	26.32004
688.00	.00000	.03209	.09789	23.26199	29.09604
689.00	.00000	.03252	.09878	17.51199	24.93201
690.00	.00000	.03296	.09468	11.09059	22.15601
691.00	.00000	.03249	.09872	11.09459	22.15601
692.00	.00000	.03247	.09859	14.31038	25.62602
693.00	.00000	.03246	.09856	22.00159	29.09604
694.00	.00000	.03200	.09771	23.26199	36.73001
695.00	.00000	.03288	.09953	28.85559	44.22203
696.00	.00000	.03242	.09857	32.28720	63.79674
697.00	.00000	.03240	.09854	36.61119	65.87801
698.00	.00000	.03284	.09944	35.70959	46.44603
699.00	.00000	.03282	.09941	22.54440	25.62602
700.00	.00000	.03147	.09662	13.73999	20.76904
701.00	.00000	.03279	.09834	28.13799	20.76904
702.00	.90881	.06286	.15419	34.09039	22.85002
703.00	.90881	.03660	.10700	34.09039	22.85002
704.00	.67434	.05779	.14568	30.65878	23.58404
705.00	.31996	.03607	.10594	25.06519	18.68599
706.00	.00000	.03182	.09735	16.95079	17.29803
707.00	.00000	.03225	.09824	25.06519	13.13400
708.00	.00000	.03180	.09729	2.98518	11.74603
709.00	.00000	.03267	.09910	2.41479	15.21605
710.00	.00000	.03221	.09815	7.13440	21.46199
711.00	.00000	.03220	.09812	10.90639	23.54404
712.00	.00000	.03130	.09627	14.11714	28.40201
713.00	.46034	.03594	.10558	24.16359	34.64803

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
714.00	.81665	.04183	.11711	31.20158	31.87202
715.00	.26954	.03691	.10761	21.81760	26.32004
716.00	.00000	.03257	.09889	8.26594	13.82802
717.00	.00000	.05287	.13718	5.62558	12.44205
718.00	.00000	.03165	.09700	5.24840	12.44205
719.00	.00000	.03438	.10257	5.05514	15.21605
720.00	.00000	.04471	.12250	4.77480	18.60509
721.00	.00000	.03205	.09782	18.83679	24.23005
722.00	.00000	.03204	.09779	19.96840	24.23005
723.00	.00000	.03247	.09868	22.00159	22.15601
724.00	.00000	.03157	.09682	22.36038	20.76804
725.00	.00000	.03199	.09770	17.13480	17.99205
726.00	.00000	.03242	.09859	9.21359	15.00994
727.00	.00000	.03241	.09856	6.37994	15.00994
728.00	.00000	.03240	.09853	8.08200	14.38000
729.00	.00000	.03283	.09943	11.66080	22.15601
730.00	.00000	.03192	.09755	21.81760	31.17801
731.00	.00000	.03235	.09844	29.44119	35.34204
732.00	.00000	.03234	.09841	32.28720	34.64003
733.00	.00000	.03232	.09838	25.06519	27.70799
734.00	.00000	.03231	.09835	16.57354	22.15601
735.00	.00000	.03229	.09832	14.49440	20.07402
736.00	.00000	.03140	.09647	12.60840	18.68594
737.00	.00000	.03227	.09826	9.59070	18.68594
738.00	.00000	.03225	.09823	11.09954	19.38000
739.00	.00000	.03224	.09821	11.47679	18.68594
740.00	.00000	.03222	.09818	9.77480	18.68594
741.00	.00000	.03221	.09815	12.23119	17.20803
742.00	.00000	.03088	.09540	11.09954	15.90999
743.00	.00000	.03174	.09717	11.66080	17.20802
744.00	.00000	.03172	.09714	16.57359	24.23005
745.00	.00000	.03171	.09712	24.16350	29.00604
746.00	.00000	.03214	.09800	24.53150	28.40201
747.00	.00000	.03212	.09797	28.13799	26.32004
748.00	.00000	.03123	.09612	24.89038	25.62602
749.00	.00000	.03209	.09791	17.89919	22.85002
750.00	.22570	.03344	.10067	19.77514	29.09604
751.00	.00000	.00000	.00000	31.20158	35.34204
752.00	2.31002	.07060	.16678	44.36679	47.83400
753.00	.00000	.03204	.09779	47.25558	47.14005
754.00	.00000	.00000	.00000	43.10638	36.03600
755.00	.00000	.00000	.00000	32.28720	23.54404
756.00	.00000	.06855	.16350	10.90639	17.99205
757.00	.00000	.00000	.00000	15.81918	18.68594
758.00	.00000	.00000	.00000	18.26639	19.38000
759.00	.00000	.00000	.00000	16.95079	18.68594
760.00	.00000	.00000	.00000	24.53159	22.15601
761.00	.00000	.00000	.00000	24.89038	18.68594

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
762.00	.00000	.00000	.00000	14.44320	14.52203
763.00	.00000	.00000	.00000	12.60910	17.22203
764.00	.00000	.00000	.00000	16.00320	17.86205
765.00	.00000	.00000	.00000	17.51124	21.07402
766.00	.00000	.00000	.00000	18.64359	21.07402
767.00	.00000	.00000	.00000	15.24070	21.76209
768.00	.00000	.00000	.00000	19.64359	23.54409
769.00	.00000	.00000	.00000	31.44559	22.56138
770.00	.00000	.00000	.00000	29.95720	41.20001
771.00	1.74672	.04371	.12764	40.21754	43.67903
772.00	.00000	.00000	.00000	44.55080	45.75203
773.00	.00000	.00000	.00000	39.41040	42.97001
774.00	.00000	.03131	.09620	21.50060	25.62602
775.00	.52957	.03217	.09007	27.95724	24.22805
776.00	.32704	.05253	.15356	24.16359	22.25002
777.00	.00000	.00000	.00000	23.00074	27.01405
778.00	.73614	.05744	.14518	30.42310	29.07408
779.00	1.18965	.04003	.13217	25.00200	23.25334
780.00	.00000	.03166	.09702	22.28720	22.56604
781.00	.00000	.03171	.09609	27.05240	27.70700
782.00	.00000	.03120	.09605	36.96094	36.72001
783.00	2.75053	.03251	.09476	47.43059	47.83400
784.00	.00000	.03074	.09511	50.96200	49.22203
785.00	.00000	.03116	.09597	44.00730	47.03400
786.00	.00000	.03158	.09695	53.56674	47.02400
787.00	4.75000	.04291	.11406	57.10230	49.57002
788.00	3.02413	.03429	.10738	50.14430	35.02000
789.00	2.00500	.05122	.13427	43.43319	21.87202
790.00	.00000	.03056	.09494	34.99000	26.33004
791.00	.00000	.03102	.09581	31.20150	24.22201
792.00	.59400	.03771	.10014	27.06409	22.15001
793.00	.54693	.03282	.09040	29.12734	24.02001
794.00	.58130	.03191	.09753	29.03000	23.58404
795.00	.00000	.03146	.09650	29.72274	14.20000
796.00	.00000	.03059	.09478	14.00240	14.30000
797.00	.15000	.03560	.10402	20.40170	14.20000
798.00	.00000	.00000	.00000	24.26199	14.20000
799.00	.51110	.05390	.13809	24.60000	14.30000
800.00	.42015	.06189	.15250	20.23870	22.15501
801.00	.34343	.04256	.11848	23.08710	28.40201
802.00	1.36504	.04138	.11520	36.06094	29.50000
803.00	2.56537	.05848	.14595	47.25558	43.67003
804.00	.00000	.03091	.09545	41.11014	34.64002
805.00	.00000	.03089	.09542	35.16674	27.70700
806.00	.00000	.03045	.09459	30.40304	27.01000
807.00	.00000	.03087	.09536	25.74194	27.01400
808.00	.00000	.03043	.09445	24.94119	34.64002
809.00	.00000	.03084	.09531	34.80704	38.01100

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
810.00	.00000	.03126	.09618	40.04279	44.36404
811.00	.00000	.03081	.09525	53.93480	52.69275
812.00	.00000	.03123	.09612	70.22798	58.03805
813.00	.00000	.03122	.09609	88.44398	66.57202
814.00	21.95232	.04794	.12841	83.47600	58.65401
815.00	.00000	.00000	.00000	64.93799	58.24403
816.00	.00000	.03118	.09601	42.20479	44.36404
817.00	.00000	.03031	.09420	44.65080	43.67003
818.00	.00000	.03072	.09506	42.74759	38.81198
819.00	.00000	.03071	.09503	33.36359	32.56604
820.00	.00000	.02986	.09325	28.85559	33.25099
821.00	.00000	.03026	.09410	29.03060	36.73001
822.00	.00000	.03067	.09495	36.25240	44.36404
823.00	.00000	.03056	.09493	43.46519	48.52802
824.00	.00000	.03064	.09490	44.73479	45.75201
825.00	.00000	.03106	.09576	33.00479	33.95401
826.00	.00000	.03105	.09574	24.16359	28.40201
827.00	.00000	.03103	.09571	22.00159	27.70799
828.00	.00000	.03059	.09479	21.64279	25.62602
829.00	.00000	.03058	.09476	19.77519	26.32004
830.00	.00000	.03049	.09563	19.39798	30.48399
831.00	.00000	.03098	.09560	31.20158	36.73001
832.00	.00000	.03012	.09380	44.19200	48.52802
833.00	.00000	.03095	.09555	47.43059	46.44603
834.00	.00000	.03094	.09552	45.09350	40.20001
835.00	.00000	.03093	.09549	38.59839	46.44603
836.00	.00000	.03091	.09546	35.16679	58.24403
837.00	.00000	.03090	.09544	48.34119	65.18399
838.00	.00000	.03046	.09452	51.58879	70.73599
839.00	2.51766	.03264	.09902	45.26840	53.38599
840.00	.64813	.03129	.09625	26.69359	40.70001
841.00	.45355	.03128	.09623	24.53159	22.56604
842.00	.91453	.06164	.15218	31.38559	38.81198
843.00	1.53064	.06884	.16397	38.59839	40.20001
844.00	1.72814	.04009	.11379	40.40158	40.89404
845.00	.00000	.03080	.09522	32.46199	29.79005
846.00	.29807	.03209	.09791	22.54440	26.32004
847.00	.66207	.04291	.11914	28.13799	34.64002
848.00	1.71819	.03119	.09604	40.04279	42.97601
849.00	.00000	.03075	.09511	44.00798	43.67003
850.00	.00000	.02989	.09332	41.84599	42.97501
851.00	2.02745	.03432	.10245	42.56360	44.36404
852.00	2.14987	.05889	.14755	44.00798	40.20001
853.00	.00000	.03070	.09501	36.61119	35.34204
854.00	.00000	.03068	.09498	32.46199	37.42403
855.00	.00000	.03067	.09495	37.69679	38.81198
856.00	.00000	.03024	.09404	39.31599	40.89404

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
857.00	.00000	.03065	.00400	40.40154	41.50000
858.00	.00000	.03065	.00400	40.20070	41.50000
859.00	.00000	.03065	.00400	39.60000	39.70000
860.00	1.12000	.04000	.11000	34.50000	35.20000
861.00	1.30000	.05000	.15000	31.20000	30.90000
862.00	1.17000	.03800	.11000	34.00000	30.90000
863.00	.50000	.03000	.10000	30.80000	30.20000
864.00	.00000	.03000	.00400	30.40000	30.00000
865.00	.55000	.05000	.14000	28.60000	28.60000
866.00	.15000	.05000	.13000	10.70000	22.40000
867.00	.50000	.03000	.10000	24.20000	24.00000
868.00	.70000	.03000	.10000	20.40000	24.00000
869.00	.50000	.05000	.14000	22.60000	24.50000
870.00	.00000	.03000	.00400	24.40000	24.00000
871.00	.50000	.04000	.12000	24.10000	24.00000
872.00	.22000	.05000	.15000	22.00000	21.40000
873.00	.00000	.04000	.12000	14.60000	14.00000
874.00	.00000	.00000	.00000	20.00000	25.50000
875.00	.00000	.00000	.00000	24.40000	22.80000
876.00	.00000	.03000	.00400	10.00000	20.70000
877.00	.00000	.00000	.00000	15.00000	22.80000
878.00	.00000	.00000	.00000	15.00000	24.00000
879.00	.50000	.03000	.11000	21.20000	21.40000
880.00	.80000	.04000	.12000	22.10000	21.40000
881.00	.00000	.02000	.00000	22.00000	22.80000
882.00	.00000	.04000	.12000	17.70000	21.40000
883.00	.00000	.00000	.00000	22.00000	24.00000
884.00	.50000	.05000	.15000	21.60000	34.60000
885.00	.00000	.03000	.09000	25.00000	27.40000
886.00	.00000	.03000	.00400	33.00000	36.70000
887.00	.00000	.03000	.00400	10.50000	24.00000
888.00	.57000	.04000	.13000	20.10000	25.20000
889.00	1.22000	.00000	.12000	36.20000	23.00000
890.00	.40000	.05000	.15000	27.00000	25.60000
891.00	.00000	.00000	.00000	10.00000	22.80000
892.00	.00000	.00000	.00000	24.00000	25.00000
893.00	.42000	.05000	.14000	24.20000	20.40000
894.00	.70000	.03000	.10000	20.70000	22.00000
895.00	1.15000	.04000	.13000	25.00000	22.00000
896.00	.80000	.05000	.14000	31.20000	22.00000
897.00	.70000	.04000	.11000	30.80000	21.00000
898.00	.00000	.02000	.09000	31.50000	23.00000
899.00	.00000	.03000	.09000	41.00000	28.10000
900.00	4.00000	.03000	.10000	58.20000	41.00000
901.00	3.00000	.03000	.11000	50.00000	27.00000
902.00	.91000	.03000	.00400	31.00000	27.70000

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
903.00	.401507	.05012	.14952	26.15080	21.66130
904.00	.10000	.00000	.00000	39.23960	21.70730
905.00	.00000	.00000	.00000	40.21750	21.70730
906.00	.99950	.04427	.12158	34.26518	24.02271
907.00	.28022	.03263	.01909	23.08710	23.46474
908.00	.32794	.06083	.15082	24.16250	22.65702
909.00	.09110	.00000	.00000	26.50960	22.15601
910.00	.00000	.00000	.00000	21.91760	20.76904
911.00	.05072	.04868	.12974	16.75758	22.15601
912.00	.25784	.06414	.15641	22.13568	22.11601
913.00	.91738	.04177	.11698	22.78350	21.11406
914.00	1.25084	.04352	.12028	36.70520	21.11601
915.00	.77893	.05355	.13837	31.01750	20.70905
916.00	.00000	.02992	.00000	20.74710	21.70730
917.00	.00000	.00000	.00000	20.74550	22.15601
918.00	.00000	.00000	.00000	11.85000	14.52202
919.00	.00000	.00000	.00000	16.52350	10.25800
920.00	.00000	.00000	.00000	15.24870	14.52202
921.00	.00000	.00000	.00000	12.60000	17.22903
922.00	.00000	.00000	.00000	23.26190	13.29701
923.00	.00000	.00000	.00000	23.44000	14.26000
924.00	.00000	.00000	.00000	23.26170	22.15601
925.00	.00000	.00000	.00000	21.50510	18.68500
926.00	.00000	.00000	.00000	22.15670	17.00200
927.00	.00000	.00000	.00000	26.72520	14.29700
928.00	.00000	.00000	.00000	20.12000	18.68500
929.00	.00000	.00000	.00000	27.41100	12.07800
930.00	.00000	.00000	.00000	28.64000	12.07800
931.00	.00000	.00000	.00000	24.70620	12.22202
932.00	.00000	.00000	.00000	22.71010	14.52202
933.00	.00000	.00000	.00000	30.24000	18.62500
934.00	.00000	.00000	.00000	41.40720	24.22000
935.00	.00000	.00000	.00000	38.05270	26.72201
936.00	.00000	.02458	.09287	20.21000	40.00000
937.00	1.55178	.03008	.00071	36.70620	34.11000
938.00	1.55155	.03049	.00057	36.46000	34.64000
939.00	.00000	.00000	.00000	20.50000	34.64000
940.00	.00000	.02022	.09190	21.15000	36.02000
941.00	2.72070	.04188	.11710	47.25550	41.82400
942.00	2.88550	.13354	.10087	48.70000	40.22000
943.00	2.84195	.13694	.10767	47.08000	47.10000
944.00	.00000	.02418	.09181	42.02000	24.50000
945.00	.00000	.02457	.09254	27.76000	26.22000
946.00	.00000	.02415	.09176	10.02000	20.07000
947.00	.05203	.02405	.00000	17.12000	21.66100

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
040.00	.00000	.02013	.00171	24.24760	24.50400
040.00	.00000	.02012	.00160	27.50510	24.62600
040.00	.21545	.02003	.00339	22.00159	20.76000
041.00	.00000	.00057	.11471	12.23110	16.10000
042.00	.13203	.03580	.10502	20.34558	18.12500
043.00	.00000	.00000	.00000	20.24558	24.27000
044.00	.00000	.00000	.00000	20.15224	24.50000
045.00	.00000	.00000	.00000	24.60000	24.07000
046.00	.53601	.05000	.14074	26.06800	20.70000
047.00	.00000	.02503	.00149	24.44000	24.62000
048.00	.05673	.05102	.13551	16.28000	22.00000
049.00	.00000	.03286	.00000	13.03300	20.07000
049.00	.00000	.03899	.00141	17.70510	22.15000
049.00	.46621	.02980	.00312	24.06670	27.70000
049.00	1.07761	.03202	.00000	24.00000	20.48000
049.00	.05007	.13104	.00572	22.64000	24.20000
049.00	.00000	.02935	.00210	24.44000	20.48000
049.00	.24180	.05473	.14042	21.20000	24.62000
049.00	.00000	.00000	.00000	24.00000	24.27000
049.00	.65674	.05102	.13303	20.05000	20.48000
049.00	.00000	.02800	.00122	29.04110	20.48000
049.00	.73623	.02054	.00468	20.65078	27.70000
049.00	.47303	.03655	.10600	24.70000	20.00000
049.00	.00000	.02527	.00201	20.40078	24.70000
049.00	.78002	.03014	.11106	20.40000	24.20000
049.00	.85035	.04079	.11512	21.20000	24.20000
049.00	.00000	.02024	.00103	22.10000	24.05000
049.00	.00000	.02023	.00101	20.03000	24.20000
049.00	.00000	.02021	.00100	20.48000	24.03000
049.00	.00000	.02020	.00101	40.60000	24.11000
049.00	2.41015	.03129	.00624	51.76000	01.00000
049.00	.00000	.00000	.00000	27.41279	40.00000
049.00	.00000	.00000	.00000	24.00000	27.01000
049.00	.00000	.00000	.00000	24.15000	20.48000
049.00	.00000	.00000	.00000	24.00000	24.64000
049.00	.00000	.02873	.00035	40.00000	24.50000
049.00	.00000	.02872	.00004	42.03000	40.00000
049.00	.00000	.02871	.00001	40.01000	40.00000
049.00	1.46002	.02951	.00251	27.51279	24.03000
049.00	.00000	.02859	.00077	20.40000	24.25000
049.00	.00000	.02868	.00074	24.06670	24.40000
049.00	.00000	.02867	.00072	24.16000	27.70000
049.00	.00000	.02946	.00241	12.00000	20.07000
049.00	.00000	.00000	.00000	4.75710	12.00000
049.00	.00000	.00000	.00000	10.00000	22.15000
049.00	.28204	.05122	.13427	22.00000	24.40000
049.00	1.02534	.00444	.12030	34.40000	24.70000

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
995.00	.00000	.02860	.09058	65.29678	35.34204
996.00	1.42698	.03568	.10518	38.59839	32.56674
997.00	1.83695	.06383	.15580	42.38879	32.56674
998.00	.00000	.00000	.00000	45.81119	31.87202
999.00	.00000	.00000	.00000	42.93159	37.42473
1000.00	.00000	.00000	.00000	34.80798	34.64803
1001.00	.22782	.03232	.09839	19.39798	30.49399
1002.00	.00000	.00000	.00000	25.43320	31.17971
1003.00	.00000	.00000	.00000	30.65878	36.73771
1004.00	.00000	.00000	.00000	28.49678	40.99474
1005.00	1.45124	.04378	.12076	37.88080	39.50600
1006.00	.00000	.02809	.08948	33.00479	34.64803
1007.00	.00000	.02887	.09115	23.62999	22.85002
1008.00	.00000	.02886	.09112	18.26639	22.15671
1009.00	.00000	.00000	.00000	22.90320	24.93201
1010.00	.58416	.06177	.15240	27.76999	29.79005
1011.00	.66607	.03132	.09631	28.49678	33.25999
1012.00	.00000	.02803	.08934	33.90639	33.95471
1013.00	.00000	.02841	.09016	36.25240	36.03600
1014.00	.00000	.02839	.09013	41.66200	36.73771
1015.00	1.92244	.04872	.12981	42.93154	33.95471
1016.00	.00000	.00000	.00000	30.11600	24.23905
1017.00	.00000	.00000	.00000	17.32799	20.07402
1018.00	.00000	.00000	.00000	18.26639	22.15671
1019.00	.00000	.00000	.00000	12.60840	22.85002
1020.00	.00000	.00000	.00000	19.02080	29.09604
1021.00	.00000	.00000	.00000	31.74440	36.73771
1022.00	.00000	.02870	.09074	39.85880	41.58806
1023.00	.00000	.02830	.08993	42.03000	40.20701
1024.00	.00000	.00000	.00000	36.43639	29.79005
1025.00	.57442	.06403	.15613	24.34760	26.32074
1026.00	.81883	.06400	.15609	31.74440	29.09604
1027.00	1.03765	.04341	.12008	34.26518	31.87202
1028.00	.00000	.00000	.00000	30.29999	36.03600
1029.00	1.52877	.03673	.10726	38.95720	37.42473
1030.00	.00000	.02745	.08810	40.04279	34.64803
1031.00	.00000	.02861	.09059	34.99200	27.70799
1032.00	.74976	.05116	.13818	30.29999	31.17971
1033.00	.00000	.00000	.00000	42.38879	42.97601
1034.00	.00000	.00000	.00000	45.81119	45.75201
1035.00	2.90633	.03516	.10413	48.15720	49.91605
1036.00	.00000	.02816	.08963	52.49039	51.99803
1037.00	.00000	.02815	.08960	50.31918	46.44603
1038.00	.00000	.02814	.08958	44.19200	41.58806
1039.00	.00000	.02813	.08956	39.14119	30.48399
1040.00	1.06795	.06107	.15123	35.53479	26.32074
1041.00	.94880	.03319	.10015	34.26518	24.93201
1042.00	.00000	.00000	.00000	29.39839	22.15671

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1043.00	.00000	.00000	.00000	22.71919	17.99205
1044.00	.00000	.00000	.00000	16.19640	15.21605
1045.00	.00000	.00000	.00000	13.16960	14.52203
1046.00	.00000	.00000	.00000	17.70518	16.60400
1047.00	.00000	.00000	.00000	18.64359	18.68599
1048.00	.00000	.00000	.00000	22.00159	19.38000
1049.00	.19185	.03596	.10572	22.18558	17.99205
1050.00	.00000	.00000	.00000	21.81760	19.38000
1051.00	.00000	.00000	.00000	27.41119	24.93201
1052.00	.00000	.00000	.00000	34.63319	27.70799
1053.00	.00000	.00000	.00000	38.50839	32.56504
1054.00	.00000	.00000	.00000	36.43639	31.87202
1055.00	.00000	.00000	.00000	31.74440	29.70005
1056.00	.00000	.00000	.00000	29.39839	25.62602
1057.00	.00000	.00000	.00000	21.64279	22.95002
1058.00	.00000	.00000	.00000	15.81918	26.32004
1059.00	.00000	.00000	.00000	18.83679	31.17001
1060.00	.39880	.03785	.10445	22.18558	36.73001
1061.00	.32982	.02990	.09333	22.18558	30.48399
1062.00	.13272	.06228	.15323	19.21399	22.15601
1063.00	.00000	.00000	.00000	13.93320	22.15601
1064.00	.00000	.00000	.00000	17.13480	24.93201
1065.00	.00000	.00000	.00000	27.23639	29.70005
1066.00	.00000	.00000	.00000	35.89360	34.64803
1067.00	2.06964	.03426	.10233	43.46514	39.50600
1068.00	.00000	.02744	.08808	49.24278	41.59906
1069.00	.00000	.02820	.08972	50.50320	37.42403
1070.00	.00000	.02819	.08970	42.56360	30.48399
1071.00	1.23065	.03718	.10813	36.70520	30.48399
1072.00	.00000	.00000	.00000	35.35080	32.56504
1073.00	1.06838	.05787	.14582	34.09039	35.34204
1074.00	.00000	.00000	.00000	41.66200	40.80404
1075.00	3.10630	.03870	.11110	49.78558	45.05800
1076.00	.00000	.02813	.08956	46.17000	42.97601
1077.00	1.53790	.05392	.13902	39.14114	36.73001
1078.00	1.38593	.04086	.11526	37.98080	34.64803
1079.00	.00000	.00000	.00000	31.20158	22.85002
1080.00	.00000	.00000	.00000	33.36359	24.23805
1081.00	.00000	.00000	.00000	37.51274	26.32004
1082.00	.00000	.00000	.00000	32.64600	24.23805
1083.00	.00000	.00000	.00000	29.58240	22.85002
1084.00	.00000	.00000	.00000	30.11600	21.46190
1085.00	.00000	.00000	.00000	21.09999	20.07402
1086.00	.00000	.00000	.00000	27.76999	26.32004
1087.00	.00000	.00000	.00000	33.90639	27.70799
1088.00	.00000	.00000	.00000	31.74440	27.01405

Table B-1. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1080.00	.83937	.02878	.09096	31.91919	29.79705
1090.00	1.54596	.03351	.10080	39.68399	23.25999
1091.00	2.11275	.02836	.09007	44.73479	31.17801
1092.00	.00000	.00000	.00000	37.69679	27.70799
1093.00	.00000	.00000	.00000	32.82994	24.03201
1094.00	.56085	.04475	.12257	28.68080	23.54404
1095.00	.00000	.00000	.00000	26.64354	24.23905
1096.00	.00000	.00000	.00000	31.01759	24.93201
1097.00	.00000	.00000	.00000	32.82999	24.23805
1098.00	.00000	.00000	.00000	37.11600	21.46199
1099.00	.00000	.00000	.00000	27.23639	20.76804
1100.00	.00000	.00000	.00000	27.23639	14.38000
1101.00	.00000	.00000	.00000	22.71919	10.33000
1102.00	.00000	.00000	.00000	22.71919	20.07402
1103.00	.00000	.00000	.00000	26.64354	20.76904
1104.00	.00000	.00000	.00000	29.94119	22.85002
1105.00	.00000	.00000	.00000	29.39839	22.15501
1106.00	.00000	.00000	.00000	25.24919	20.76904
1107.00	.00000	.00000	.00000	25.24919	20.07402
1108.00	.00000	.00000	.00000	24.89038	21.46199
1109.00	.00000	.00000	.00000	21.64274	21.46199
1110.00	.00000	.00000	.00000	19.06440	20.76904
1111.00	.00000	.00000	.00000	23.44600	21.46199
1112.00	.00000	.00000	.00000	26.33479	18.68599
1113.00	.00000	.00000	.00000	23.80474	18.68599
1114.00	.00000	.00000	.00000	21.45879	18.68599
1115.00	.00000	.00000	.00000	20.72279	20.07402
1116.00	.00000	.00000	.00000	23.08719	21.46199
1117.00	.00000	.00000	.00000	23.62999	20.76804
1118.00	.00000	.00000	.00000	24.53154	20.07402
1119.00	.00000	.00000	.00000	26.64354	20.07402
1120.00	.00000	.00000	.00000	26.33474	20.07402
1121.00	.00000	.00000	.00000	22.90320	22.15501
1122.00	.00000	.00000	.00000	25.24919	22.85002
1123.00	.00000	.00000	.00000	25.43320	22.85002
1124.00	.00000	.00000	.00000	23.26199	22.15501
1125.00	.40466	.05678	.14396	26.50960	20.07402
1126.00	.00000	.00000	.00000	19.39798	16.60400
1127.00	.00000	.00000	.00000	14.11719	17.09205
1128.00	.00000	.00000	.00000	21.29398	20.76804
1129.00	.00000	.00000	.00000	25.79199	21.46199
1130.00	.00000	.00000	.00000	24.53154	19.38000
1131.00	.00000	.00000	.00000	22.90320	18.68599
1132.00	.00000	.00000	.00000	23.80479	20.07402
1133.00	.00000	.00000	.00000	28.68080	22.15501
1134.00	.00000	.00000	.00000	33.18880	22.15501
1135.00	.00000	.00000	.00000	23.62999	20.76904
1136.00	.00000	.00000	.00000	17.88019	17.29803

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1137.00	.00000	.00000	.00000	26.86839	20.07472
1138.00	.00000	.00000	.00000	29.58740	20.07472
1139.00	.00000	.00000	.00000	25.60709	18.68599
1140.00	.00000	.00000	.00000	20.34558	15.90909
1141.00	.00000	.00000	.00000	23.80479	15.21675
1142.00	.00000	.00000	.00000	24.89038	17.29803
1143.00	.00000	.00000	.00000	28.68080	20.07472
1144.00	.00000	.00000	.00000	34.09039	27.01405
1145.00	.00000	.00000	.00000	34.99200	25.62607
1146.00	.00000	.00000	.00000	25.60799	17.99205
1147.00	.00000	.00000	.00000	18.09240	14.52273
1148.00	.00000	.00000	.00000	13.43320	12.44005
1149.00	.00000	.00000	.00000	11.28460	13.13400
1150.00	.00000	.00000	.00000	12.98558	13.82907
1151.00	.00000	.00000	.00000	19.39798	17.29803
1152.00	.00000	.00000	.00000	27.76999	24.23805
1153.00	.00000	.00000	.00000	35.16678	31.87272
1154.00	.00000	.00000	.00000	45.90519	40.20001
1155.00	.00000	.00000	.00000	49.60159	38.81108
1156.00	1.59323	.02848	.09033	40.58559	29.79005
1157.00	.00000	.00000	.00000	29.58740	20.07472
1158.00	.00000	.00000	.00000	21.09999	18.68599
1159.00	.00000	.00000	.00000	23.09719	20.07472
1160.00	.00000	.00000	.00000	20.15239	17.99205
1161.00	.00000	.00000	.00000	19.77519	17.99205
1162.00	.00000	.00000	.00000	22.54440	20.76874
1163.00	.00000	.00000	.00000	26.15080	23.54474
1164.00	.00000	.00000	.00000	28.85550	27.70799
1165.00	.00000	.00000	.00000	27.23639	35.34274
1166.00	.00000	.00000	.00000	37.33798	44.36404
1167.00	.00000	.00000	.00000	47.79840	47.14005
1168.00	.00000	.02683	.08676	53.20799	45.75271
1169.00	2.48641	.02758	.08838	46.35399	40.89474
1170.00	.00000	.02682	.08672	35.53479	31.87272
1171.00	.00000	.00000	.00000	26.69359	29.79005
1172.00	.00000	.00000	.00000	29.21440	23.95401
1173.00	.00000	.00000	.00000	34.26518	38.11804
1174.00	.00000	.00000	.00000	35.70959	38.81198
1175.00	1.64066	.03945	.11256	40.21759	36.03600
1176.00	1.06278	.05131	.13444	34.80798	30.48399
1177.00	.00000	.00000	.00000	24.16359	21.46199
1178.00	.00000	.00000	.00000	25.60799	23.54404
1179.00	.00000	.00000	.00000	26.50960	26.32004
1180.00	.00000	.00000	.00000	22.54440	24.93271
1181.00	.41769	.05490	.14072	25.79199	24.23805
1182.00	.51869	.02942	.09232	27.76999	24.23805

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1183.00	.45302	.05262	.13675	26.50960	24.23895
1184.00	.00000	.00000	.00000	24.16359	22.15601
1185.00	.00000	.00000	.00000	25.43320	27.01405
1186.00	.00000	.00000	.00000	37.33798	38.81198
1187.00	2.01277	.04152	.11653	42.93159	40.20001
1188.00	.00000	.02665	.08635	45.99519	40.20001
1189.00	2.58492	.03471	.10121	47.08080	40.20001
1190.00	1.46004	.04699	.12668	42.74759	38.11804
1191.00	.00000	.02699	.08710	35.53479	37.42403
1192.00	.00000	.02651	.08626	41.66200	37.42403
1193.00	1.71908	.02812	.08953	40.76034	37.42403
1194.00	.00000	.02622	.08542	39.41440	37.42403
1195.00	.00000	.02622	.08540	39.05559	38.11804
1196.00	.00000	.02657	.08518	40.76039	37.42403
1197.00	1.53651	.05384	.13888	39.49998	33.95401
1198.00	.00000	.00000	.00000	36.61119	28.40001
1199.00	.00000	.00000	.00000	32.10320	24.93201
1200.00	.68524	.03911	.11190	29.94119	27.70799
1201.00	.81023	.03803	.10980	31.74440	28.40001
1202.00	.00000	.00000	.00000	29.58240	29.79005
1203.00	.00000	.00000	.00000	36.06834	37.42403
1204.00	.00000	.00000	.00000	51.94759	42.97601
1205.00	.00000	.00000	.00000	58.61758	42.97601
1206.00	.00000	.00000	.00000	52.84918	39.50600
1207.00	.00000	.00000	.00000	44.00798	33.95401
1208.00	.00000	.00000	.00000	30.84279	28.40001
1209.00	.00000	.02645	.08592	23.08719	29.00604
1210.00	.23751	.02834	.09002	19.02080	32.56604
1211.00	1.08660	.02833	.08999	32.82999	44.36404
1212.00	3.23567	.05067	.13330	50.31918	47.14005
1213.00	.00000	.02678	.08655	57.54120	47.83400
1214.00	2.82343	.02791	.08909	48.51599	40.89404
1215.00	3.11168	.04469	.12245	50.31918	39.50600
1216.00	2.56354	.05275	.13697	47.08080	38.81198
1217.00	.00000	.02675	.08657	45.99519	42.29200
1218.00	.00000	.02601	.08494	53.39200	47.14005
1219.00	4.11349	.03383	.10145	54.46840	49.22203
1220.00	.00000	.02263	.07731	47.61440	44.36404
1221.00	2.75404	.02708	.08730	48.15720	40.20001
1222.00	.00000	.02633	.08566	39.31599	32.56604
1223.00	.00000	.02669	.08645	34.63319	36.03600
1224.00	.90482	.02900	.09142	31.74440	36.03600
1225.00	.76143	.03022	.09400	30.48399	31.17801
1226.00	.00000	.02630	.08558	30.48399	30.48399
1227.00	.00000	.02629	.08556	31.91019	32.56604

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1228.00	.00000	.02592	.08474	33.36459	38.81199
1229.00	.00000	.02591	.08472	35.70959	47.14005
1230.00	.00000	.02590	.08470	34.49200	53.38599
1231.00	.00000	.02662	.08628	31.56038	38.11804
1232.00	.00000	.02624	.08546	24.34760	24.23005
1233.00	.00000	.03461	.10303	13.93320	20.76804
1234.00	.00000	.00000	.00000	15.24879	21.46199
1235.00	.00000	.00000	.00000	19.21399	22.15601
1236.00	.00000	.00000	.00000	15.24879	22.15601
1237.00	.00000	.00000	.00000	24.34760	25.62602
1238.00	.00000	.00000	.00000	27.95399	31.87202
1239.00	.00000	.00000	.00000	31.56038	35.34204
1240.00	.00000	.02617	.08530	34.80798	40.20001
1241.00	.00000	.02653	.08609	33.36359	42.97601
1242.00	.23148	.04247	.11832	18.83679	32.56004
1243.00	.00000	.02651	.08605	19.96840	35.34204
1244.00	.00000	.00000	.00000	43.46419	47.14005
1245.00	.00000	.02613	.08520	51.40480	50.60999
1246.00	4.17954	.02878	.09095	54.65239	50.60999
1247.00	3.46295	.03956	.11278	51.58879	46.44603
1248.00	.00000	.02646	.08595	45.45239	37.42403
1249.00	.00000	.02646	.08593	37.51279	27.01405
1250.00	.00000	.00000	.00000	34.09039	22.85002
1251.00	.00000	.00000	.00000	26.15080	23.54404
1252.00	.00000	.00000	.00000	20.90678	19.38000
1253.00	.00000	.00000	.00000	19.21399	26.32004
1254.00	.00000	.00000	.00000	31.91919	30.48399
1255.00	.00000	.00000	.00000	32.46199	29.79005
1256.00	.40694	.04722	.12710	24.89038	27.01405
1257.00	.00000	.00000	.00000	30.11600	27.01405
1258.00	.00000	.02637	.08575	25.43320	24.93201
1259.00	.00000	.03430	.10242	14.11719	15.21605
1260.00	.00000	.00000	.00000	20.72279	20.76804
1261.00	.00000	.00000	.00000	26.50960	24.23005
1262.00	.00000	.00000	.00000	22.90320	24.23905
1263.00	.00000	.00000	.00000	22.90320	22.15601
1264.00	.00000	.00000	.00000	27.76999	27.01405
1265.00	.00000	.00000	.00000	35.70459	34.64803
1266.00	.00000	.02594	.08480	37.69679	37.42403
1267.00	.00000	.02629	.08557	30.29999	36.03600
1268.00	.00000	.02629	.08555	21.64279	36.03600
1269.00	.00000	.02628	.08553	23.26199	34.50600
1270.00	1.43490	.02738	.08795	37.51279	40.89404
1271.00	.00000	.00000	.00000	39.31599	31.17001
1272.00	.00000	.00000	.00000	30.48399	24.93201
1273.00	.00000	.02588	.08456	15.81918	24.23905
1274.00	.21189	.03658	.10696	17.51199	34.64803

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1275.00	1.51194	.02772	.08868	35.53479	45.05000
1276.00	.00000	.02515	.08303	37.51279	45.05000
1277.00	.00000	.02585	.08458	23.44600	25.62602
1278.00	.00000	.02620	.08536	26.15080	33.25999
1279.00	.00000	.02583	.08455	20.68080	38.11904
1280.00	.00000	.02546	.08374	27.76999	39.50670
1281.00	.00000	.02617	.08530	32.46199	48.52802
1282.00	.00000	.02580	.08440	30.65878	52.69205
1283.00	.94143	.02652	.08607	29.21440	52.64205
1284.00	.00000	.02614	.08524	24.34760	32.56604
1285.00	.11195	.02650	.08603	17.32709	25.62602
1286.00	.29244	.05755	.14527	21.81760	28.40201
1287.00	1.59073	.04421	.12157	37.33798	38.81198
1288.00	.00000	.02540	.08350	46.71278	45.67003
1289.00	.00000	.02610	.08515	45.09360	41.58806
1290.00	.00000	.02609	.08513	38.70230	40.20001
1291.00	.00000	.02608	.08511	42.56360	43.67003
1292.00	2.53926	.02794	.08917	46.35399	44.36004
1293.00	2.35109	.02994	.09342	45.63638	38.81198
1294.00	.00000	.02535	.08347	39.79239	33.25999
1295.00	.94518	.02641	.08583	33.36354	33.95401
1296.00	.00000	.02604	.08501	35.53479	33.95401
1297.00	.00000	.02567	.08420	35.16678	31.17001
1298.00	.00000	.02566	.08418	28.31279	24.23905
1299.00	.00000	.02566	.08415	18.83679	16.80400
1300.00	.00000	.02565	.08415	12.60840	18.68599
1301.00	.00000	.02600	.08492	16.38030	22.15601
1302.00	.00000	.02599	.08490	24.34760	24.93201
1303.00	.00000	.02552	.08409	29.31279	27.70799
1304.00	.21716	.03242	.09857	21.64274	22.15601
1305.00	.00000	.00000	.00000	36.06839	29.09604
1306.00	.00000	.00000	.00000	40.94440	27.01405
1307.00	.00000	.00000	.00000	28.68080	22.95002
1308.00	.00000	.00000	.00000	28.85559	23.54404
1309.00	.00000	.00000	.00000	23.90479	22.85002
1310.00	.00000	.00000	.00000	29.21440	26.32004
1311.00	.00000	.00000	.00000	29.58240	25.62602
1312.00	.00000	.00000	.00000	26.15080	20.76904
1313.00	.00000	.00000	.00000	27.76999	27.01405
1314.00	.00000	.00000	.00000	28.31279	40.20001
1315.00	.00000	.00000	.00000	38.05559	46.44603
1316.00	3.07520	.02971	.09294	49.41759	47.14005
1317.00	.00000	.00000	.00000	44.00798	41.58806
1318.00	.00000	.02550	.08381	31.91919	29.09604
1319.00	.00000	.02549	.08379	33.73158	29.79005
1320.00	.13124	.03969	.11302	19.39798	21.46199

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1321.00	.00000	.00000	.00000	25.06519	27.70700
1322.00	.00000	.00000	.00000	28.68090	27.01405
1323.00	.00000	.00000	.00000	35.16678	33.25999
1324.00	.00000	.00000	.00000	38.59839	35.34204
1325.00	2.03935	.05085	.13352	43.46519	37.42404
1326.00	.00000	.00000	.00000	42.74759	36.03600
1327.00	.14716	.05081	.13356	22.71019	16.60400
1328.00	.00000	.05754	.14526	7.70874	13.13400
1329.00	.00000	.00000	.00000	12.41519	15.90999
1330.00	.00000	.00000	.00000	12.98558	16.60400
1331.00	.00000	.00000	.00000	8.45918	17.20003
1332.00	.00000	.00000	.00000	17.13480	23.54404
1333.00	.00000	.00000	.00000	31.01419	29.70005
1334.00	.00000	.00000	.00000	44.36679	43.67007
1335.00	.00000	.00000	.00000	53.75074	47.83400
1336.00	5.47452	.02606	.08505	59.88719	46.44607
1337.00	6.62334	.04471	.12250	63.49359	44.36404
1338.00	5.48668	.02677	.08662	60.06200	44.36404
1339.00	4.20712	.02408	.09160	55.19519	45.05000
1340.00	3.33624	.03835	.11044	51.08599	45.05000
1341.00	.00000	.00000	.00000	51.94759	46.44603
1342.00	.00000	.02495	.08259	57.18239	47.83400
1343.00	6.55680	.04401	.12119	63.30060	44.36404
1344.00	.00000	.00000	.00000	50.68719	27.70704
1345.00	.00000	.00000	.00000	31.01759	25.62602
1346.00	.00000	.00000	.00000	22.90320	22.15601
1347.00	.00000	.00000	.00000	20.34558	23.54404
1348.00	.00000	.00000	.00000	26.15080	24.43201
1349.00	.51744	.04098	.11550	28.49678	20.76004
1350.00	.00000	.02523	.08322	23.80479	17.29903
1351.00	.00000	.02557	.08398	10.15199	21.46129
1352.00	.18386	.02702	.08717	18.26639	29.70005
1353.00	.00000	.00000	.00000	29.94119	30.48799
1354.00	.00000	.00000	.00000	34.44019	24.00604
1355.00	.00000	.00000	.00000	35.89360	30.48799
1356.00	.00000	.00000	.00000	30.11600	26.32004
1357.00	.00000	.00000	.00000	24.89038	17.49205
1358.00	.00000	.00000	.00000	12.23119	13.82802
1359.00	.00000	.03508	.10397	9.96749	13.82802
1360.00	.00000	.00000	.00000	10.72240	13.82802
1361.00	.00000	.02621	.08538	12.03798	13.13400
1362.00	.00000	.03456	.10294	9.96749	13.13400
1363.00	.00000	.02612	.08534	9.54079	14.52203
1364.00	.00000	.03859	.11089	11.85399	14.52203
1365.00	.00000	.02581	.08451	10.34518	15.90999
1366.00	.00000	.02545	.08371	15.24879	17.29903
1367.00	.00000	.02580	.08447	11.09959	12.44005

Table B-I. Calculated oil shale yield and fracture porosity.

Depth (ft)	Porosity			Oil Shale Yield	
	By Difference (%)	High* (-)	Low* (-)	Sonic (gal/ton)	Density (gal/ton)
1369.00	.00000	.02579	.08446	2.74194	12.44775
1369.00	.00000	.02614	.08523	2.46240	14.52203
1370.00	.07050	.02577	.08442	18.64354	17.99275
1371.00	.00000	.02541	.08361	24.16354	20.07472
1372.00	.00000	.02540	.08360	20.97674	17.79903
1373.00	.00000	.02798	.08424	12.98558	13.82802
1374.00	.00000	.00000	.00000	5.43234	13.82802
1375.00	.00000	.00000	.00000	15.24879	14.38070
1376.00	.00000	.00000	.00000	25.24919	25.62602
1377.00	.00000	.00000	.00000	31.91919	28.40201
1378.00	.00000	.00000	.00000	30.29999	27.70709
1379.00	.00000	.00000	.00000	29.04114	22.85002
1380.00	.00000	.00000	.00000	24.89038	22.85002
1381.00	.00000	.00000	.00000	27.76999	27.01405
1382.00	.00000	.00000	.00000	31.91919	27.70794
1383.00	.00000	.00000	.00000	34.26518	31.17801
1384.00	2.21496	.05273	.13694	44.19200	42.97601
1385.00	5.06525	.03886	.11142	57.89999	54.77402
1386.00	.00000	.00000	.00000	56.63960	54.63200
1387.00	.00000	.00000	.00000	56.99840	58.24403
1388.00	.00000	.00000	.00000	50.86200	57.55002
1389.00	.00000	.00000	.00000	42.20479	45.05800
1390.00	.00000	.00000	.00000	36.43139	33.95401
1391.00	.00000	.00000	.00000	35.89360	36.73001
1392.00	.00000	.00000	.00000	39.14119	34.50600
1393.00	.00000	.00000	.00000	42.03000	37.42403
1394.00	.00000	.00000	.00000	45.26840	47.14005
1395.00	.00000	.00000	.00000	54.46840	54.77402
1396.00	.00000	.00000	.00000	56.63960	61.71405
1397.00	.00000	.00000	.00000	54.65234	61.71405
1398.00	.00000	.00000	.00000	48.51599	51.30400
1399.00	2.19228	.05624	.14303	44.83319	45.05800

SLOP P

APPENDIX C

APPENDIX C

By Clyde Q. Sheely, Reservoir Engineering Section
Continental Oil Company, Production Research Department*

A. MATHEMATICAL DESCRIPTION

The dispersion transport equation for dissolved material in two-dimensional flow is:

$$\phi \frac{\partial C}{\partial t} = K_x \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} - V_x \frac{\partial C}{\partial x} - V_y \frac{\partial C}{\partial y}, \quad (1)$$

where C is concentration of dissolved gas in the liquid, t is time, ϕ is porosity, V_x is velocity component in the x direction, V_y is velocity component in the y direction, K_x is the dispersion coefficient in the x direction and K_y is the dispersion coefficient in the y direction. Garder et al^(C-1) derived the characteristic curves of Equation (1) which results in the following set of "ordinary" differential equations.

$$\frac{dx}{dt} = \frac{V_x}{\phi} \quad (2)$$

$$\frac{dy}{dt} = \frac{V_y}{\phi} \quad (3)$$

$$\frac{dC}{dt} = \frac{K_x}{\phi} \frac{\partial^2 C}{\partial x^2} + \frac{K_y}{\phi} \frac{\partial^2 C}{\partial y^2} \quad (4)$$

The velocity component V_x and V_y are calculated from the following:

$$V_x = - \frac{k}{u} \left(\frac{\partial P}{\partial x} + \rho g \frac{\partial h}{\partial x} \right) \quad (5)$$

*This computerized evaluation was prepared for CER Geonuclear Corporation by Continental Oil Company's Production Research Department under Contract Job Number 752-13.

$$V_y = - \frac{k}{\mu} \left(\frac{\partial P}{\partial y} + \rho g \frac{\partial h}{\partial x} \right) \quad (6)$$

The pressure solution is obtained from a numerical solution of:

$$\nabla \frac{k}{\mu} (\nabla P + \rho g \nabla h) = 0 \quad (7)$$

where ∇ represents a gradient $\vec{i} \frac{\partial}{\partial x} + \vec{j} \frac{\partial}{\partial y}$, where $\vec{i}$ and $\vec{j}$ are unit vectors in this x and y direction, respectively, k is permeability, μ the viscosity, ρ the fluid density, g the acceleration due to gravity, h the height above the datum, p the pressure.

Radioactive decay is expressed by:

$$\frac{C}{C_o} = \exp(-\lambda t) \quad (8)$$

where λ is a decay constant.

B. METHOD OF NUMERICAL SOLUTION

The numerical procedure when using the method of characteristics involves both a conventional stationary grid system and a set of moving points. The stationary grid is used for handling the finite difference approximations of Equations (5), (6), and (7). Also a stationary grid system, not necessarily the same one, is used to approximate the second order concentration gradients in Equation (4).

Moving points are used to numerically solve the "ordinary" differential Equations (2), (3), and (4). Since each point corresponds to one characteristic curve, values of x, y, and C can be obtained as functions of time for each point. If we let ℓ be the index identifying the moving point and n the time-step index, then $X_{\ell, n}$, $Y_{\ell, n}$ and $C_{\ell, n}$ can be calculated at each point ℓ at each time t_n .

The finite difference approximation of Equation (7), deleting the density term term, is:

$$P_{i, j} = \frac{A_1 P_{i+1, j} + A_2 P_{i-1, j} + A_3 P_{i, j+1} + A_4 P_{i, j-1} \pm \frac{Q}{\Delta x \Delta y \Delta z}}{A_1 + A_2 + A_3 + A_4} \quad (9)$$

where A_1 , A_2 , A_3 , and A_4 are coefficients ($A_1 = \frac{(\bar{k})_{i, i+1}}{(\bar{\mu})_{i, i+1} \Delta x^2}$)

The term $\pm Q/(\Delta x \Delta y \Delta z)$ represents the source-sink contribution. The computer model uses the point successive over-relaxation (PSOR) method to solve the pressure distribution.

Velocity components obtained from the difference analogues of Equations (5) and (6) are:

$$V_{x_{i+\frac{1}{2}, j, n}} = - \left[\frac{k}{\mu} \right]_{i+\frac{1}{2}, j, n} \left[\frac{P_{i+1, j, n} - P_{i, j, n}}{\Delta x} \right] \quad (10)$$

$$V_{y_{i, j+\frac{1}{2}, n}} = - \left[\frac{k}{\mu} \right]_{i, j+\frac{1}{2}, n} \left[\frac{P_{i, j+1, n} - P_{i, j, n}}{\Delta y} \right] \quad (11)$$

These velocity components apply at the mid-points between the centers of the grid blocks.

The velocities at a particular x and y position (i.e. a moving point) are determined by bilinear interpolation of the velocities obtained from Equations (10) and (11).

Difference equations of Equations (2) and (3) are used to calculate new positions of the moving points. These equations are:

$$x_{l, n+1} = x_{l, n} + \frac{t}{\phi} V_x(x_{l, n}, y_{l, n}) \quad (12)$$

$$y_{l, n+1} = y_{l, n} + \frac{t}{\phi} V_y(x_{l, n}, y_{l, n}) \quad (13)$$

After the moving points have been moved, each point is checked to see which of the concentration grid blocks it is contained in. The concentration of the grid block is calculated by averaging the concentrations of the moving points in the grid block. This concentration is defined by $C^*_{i, j, n}$. The concentration change due to dispersion for each grid block is calculated by the difference analogue of Equation (4).

$$\Delta C_{i,j,n+\frac{1}{2}} = \frac{\Delta t}{\phi} (K_x \Delta x^2 C_{i,j,n}^* + K_y \Delta y^2 C_{i,j,n}^*) \quad (14)$$

where:

$$\Delta x^2 C_{i,j,n}^* = (C_{i-1,j,n}^* - 2C_{i,j,n}^* + C_{i+1,j,n}^*) / \Delta x^2 \quad (15)$$

$$\Delta y^2 C_{i,j,n}^* = (C_{i,j-1,n}^* - 2C_{i,j,n}^* + C_{i,j+1,n}^*) / \Delta y^2 \quad (16)$$

A new concentration including dispersion is obtained for each moving point by:

$$C_{l,n+1} = C_{l,n} + \Delta C_{i,j,n+\frac{1}{2}} \quad (17)$$

The concentration of the grid blocks are computed for a new time step by:

$$C_{i,j,n+1}^* = C_{i,j,n}^* + \Delta C_{i,j,n+\frac{1}{2}} \quad (18)$$

Since this completes the calculations for the time step t_n to t_{n+1} , the procedure is now repeated for the next time step until the desired total time has been reached.

C. SOLUTION OF RADIOACTIVE CONTAMINATION

A computer model was used with some modifications to approximate a solution to the possible radioactive contamination of the "A" and "B" subsystems. The major modification of the model was to convert it from a rectangular system to the irregular shape shown in Figure C-1. The flow rates at the boundaries were selected to give a water velocity of 0.256 feet/day and 8.5 feet/day for zones "B" and "A", respectively, in the EW area. These rates are based on the parameters in Table C-I.

Table C-I. Flow rate parameters.

	<u>Zone "A"</u>	<u>Zone "B"</u>
Net feet (h)	260 ft	185 ft
Porosity	1.25 %	1.98 %
Permeability	2,000 md	50 md
Velocity at EW	8.5 ft/day	0.256 ft/day

The initial solution for concentrations as a function of time and position was for the 11-mile x 11-mile irregular shaped system (Figure C-1) which simulated the entire area of interest. Due to the large size of the concentration grid block (0.5 x 0.5 mile), the calculated dispersion was too small to give a meaningful answer that could be contoured.

The results of the first attempt suggested that a rectangular grid system 48 units in the direction of flow by 14 units normal to flow would be adequate to describe the area of interest. The size of a grid unit is 0.1 miles by 0.1 miles.

Some assumptions were necessary to calculate the dissolved gas concentration in the "B" zone. These assumptions are:

1. Gas dissolved in water in a cylinder 100 feet in diameter.
2. Undissolved gas does not get in solution at a later time.
3. A point source at the emplacement well is used.
4. Carbon dioxide, hydrogen, hydrocarbons, krypton, and argon are soluble at rate of natural gas in water (approximately 5 ft³/bbl).
5. The water vapor is 100 percent soluble.
6. The water vapor contains a maximum of 0.05 μ Ci/gm of tritium.
7. The leak stops at approximately 150 days, when the pressure in the chimney is drawn down for testing.

Three additional possibilities were considered, as a result of assumption 5. One possibility is that most, if not all, of the water vapor will condense as the gas moves up the leak path and is cooled. The condensed water would then move back toward the chimney with the other counterflow water. This would result in only the CO₂, H₂, CH₄, Kr, and Ar being present when the gas reaches the "B" aquifer. Another possibility is that the gas velocity will be high enough to transport the condensed water to the "B" zone. In this case, all the radiation present in the gas that leaks from the chimney reaches the "B" aquifer. An intermediate situation is the condensation of enough of the water vapor so that the gas reaching the "B" aquifer is saturated at "B" aquifer maximum temperature and pressure. All three possibilities were considered.

Based upon the foregoing assumptions, the partition of gas in solution in the water or into the gas bubble in the "B" zone at the two leak rates used (calculated maximum leak rate, 35 MCF/D;* and approximate 2/3 calculated leak rate, 3.5 MCF/D) is as shown in Table C-II.

*The 35 MCF/D rate is 7 times the maximum credible rate used in the Addendum to the Environmental Statement. (C-3)

Table C-II. Partition of Gas.

<u>Leak Rate (MCF/D)</u>	<u>Gas into Solution in "B" Zone Water (CF/D)</u>	<u>Gas into Bubble (MCF/D)</u>
3.5	84	3.416
35	84	34.916

The maximum radiation levels in the 100-foot cylinder of water are given in Table C-III.

Table C-IV. Nuclide concentrations.

<u>Nuclide (2)</u>	<u>Concentration (pCi/ml)</u>	
	<u>in Gas</u>	<u>in Water*</u>
Tritium	<120	<108
Krypton-85	263	234
Argon-37	<267	238
Argon-39	2	< 2
Carbon-14	2.3	< 2
	Total	624 pCi/ml

The concentration of the various nuclides in the water-vaporfree or dry gas which dissolves in the "B" aquifer is given in Table C-IV.

The calculated locations and general shapes and isotope concentrations of the slug of radioactivity bearing water in the "B" aquifer under the assumed conditions of (1) a maximum leak rate of 35 MCF/D and (2) a maximum isotopic composition in the gas consistent with no water dropout in the leak path, are presented as Figures C-2 through C-17. The maximum tritium concentration, for the first time step of 5,000 days under the assumed condition is 1,006 pCi/ml, and the point of this maximum concentration has moved less than 1,400 feet from the emplacement well. The initial maximum concentration in the emplacement well area, Table C-3, and the concentration at this time step are both below the

*Assuming a solubility of 5 SCF/B water free for the gases in the "B" aquifer water, and a time of 180 days postdetonation.

Table C-III. Radioactivity content of water in 100-foot cylinder.

Leak Rate (MCF/D)	No. 1			No. 2			No. 3		
	Cond. H ₂ O (pCi/ml)	Dissolved Gas (pCi/ml)	Total	Cond. H ₂ O (pCi/ml)	Dissolved Gas (pCi/ml)	Total	Cond. H ₂ O (pCi/ml)	Dissolved Gas (pCi/ml)	Total
3.5	137	783	920	0.55	783	784	0	783	783
35	1,370	783	2,153	5.5	783	789	0	783	783

C-7

- No. 1 Case involving no water dropout in leak path.
- No. 2 Case involving water dropout in leak path so that gas is saturated with water vapor at "B" zone maximum temperature (80°F) and pressure (575 psi).
- No. 3 Case involving complete solution of water vapor in counterflowing water in leak path.

guideline concentrations for drinking water of 3,000 pCi/ml. The maximum tritium concentration decreases with time and distance and at the final time step of 50,000 days the maximum tritium concentration is 1.0 pCi/ml and has moved approximately 14,250 feet or approximately 2.7 miles.

The krypton concentrations location and geometries are displayed in Figures C-7 through C-11. The final time step of 50,000 days resulted in a maximum concentration of 0.0061 pCi/ml and a location of approximately 2.7 miles northeast of the emplacement well.

The 50,000-day time step for Carbon-14 results in a maximum concentration of approximately 1 pCi/ml and a distance from the emplacement well of approximately 2.7 miles.

The maximum Argon-37 concentration at the end of 5,000 days has declined to approximately 1×10^{-42} pCi/ml as a result of its short half-life; hence, no further calculations were carried out.

The concentrations of nuclide in the "B" zone water is thus seen to be extremely low and confirms the previous less sophisticated calculations presented in the Environmental Evaluation. (C-2)

The calculation of the migration of the undissolved gas in the updip direction is a difficult problem. A conservative method approach was taken which based the updip gas velocity on the calculation on page 282 of the Project Rio Blanco Environmental Impact Evaluation. (C-2) Using the new "B" aquifer permeability value, an updip velocity of 0.576 feet per day was calculated. The point containing the decayed radioactivity was moved in the updip direction. The location of the bubble front and the calculated radioactivities are presented for time steps of 5,000; 15,000; 25,000; 35,000; and 50,000 days in Figures C-18 through C-22.

The initial concentrations in zone "A" are calculated based on the same set of assumptions as were used in zone "B". In this case, however, all of the leaking gas was soluble in the water.

The calculated initial concentrations for zone "A" are given in Table C-V.

Table C-V. Zone concentrations.

Nuclide	Leak Rate		
	3.5 MCF/D	35 MCF/D	350 MCF/D
Tritium (pCi/ml)	0.01	0.1	1.0
Carbon-14 (pCi/ml)	0.000208	0.00208	0.0208
Krypton-85 (pCi/ml)	0.0187	0.187	1.87
Argon-37 (pCi/ml)	0.0244	0.244	2.44

A dispersion coefficient of $0.0047 \text{ ft}^2/\text{day}$ was used in the calculations. This value was chosen as being a typical value for a water system. The amount of dispersion calculated depends on the value of the dispersion coefficient.

Additional calculations at rates of from 3.5 to 350 MCF/D have been run and are available upon request.

REFERENCES

- C-1 Garder, A.O., Jr., Peaceman, D. W., and Pozzi, A.L., Jr.:
"Numerical Calculation of Multi-Dimensional Miscible Displacement by the Method of Characteristics," Society of Petroleum Engineering Journal (March, 1974).
- C-2 CER Geonuclear Corporation "Project Rio Blanco Environmental Impact Evaluation" Las Vegas, Nevada (October 12, 1971)
- C-3 Addendum to Environmental Statement (March 1973).

Figure C-1. Grid system for aquifer.

Z-B OSK DAYS 4-3 35.0 MCFO

05/19/72

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
TRITIUM - 35.0 MCFO RATE
TIME = 5000 DAYS

EW 0

MAXIMUM CONCENTRATION OF TRITIUM
RADIOACTIVITY = 1006.0 PCI/ML

SCALE IN FEET
750 0 750 1500

Figure C-2.

Z-B 15K DAYS 4-3 35.0 MCFD

05/22/72

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
TRITIUM - 35.0 MCFD RATE
TIME = 15000 DAYS

EW 0

MAXIMUM CONCENTRATION OF TRITIUM
RADIOACTIVITY = 225.0 PCI/ML

SCALE IN FEET
750. 0. 750. 1500.

Figure C-3.

Figure C-4.

Z-B 35K DAYS H-3 35.0 MCFO

05/24/72

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PC1/ML

SUBSYSTEM B
TRITIUM - 35.0 MCFO RATE
TIME = 35000 DAYS

EW 0

MAXIMUM CONCENTRATION OF TRITIUM
RADIOACTIVITY = 10.2 PC1/ML

SCALE IN FEET
750 0 750 1500

C-15

Figure C-5.

Z-B 50K DAYS H-3 35.0 MCFD

05/24/72

Figure C-6.

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B:
KRYPTON - 85
TIME = 5000 DAYS

MAXIMUM CONCENTRATION OF KRYPTON 85
RADIOACTIVITY = 29.5 PCI/ML

SCALE IN FEET
750 0 750 1500

Figure C-7.

Figure C-8.

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
KRYPTON - 85
TIME = 25000 DAYS

EW 0

MAXIMUM CONCENTRATION OF KRYPTON 85
RADIOACTIVITY = 0.815 PCI/ML

SCALE IN FEET
750 0. 750. 1500

Figure C-9.

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
KRYPTON - 85
TIME = 35000 DAYS

EW0

MAXIMUM CONCENTRATION OF KRYPTON 85
RADIOACTIVITY = 0.135 PCI/ML

SCALE IN FEET
/50. 0. 750 1500.

Figure C-10.

Figure C-11.

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
CARBON - 14
TIME = 5000 DAYS

MAXIMUM CONCENTRATION OF CARBON 14
RADIOACTIVITY = 0.797 PCI/ML

SCALE IN FEET
750. 0. 750. 1500.

Figure C-12.

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
CARBON - 14
TIME = 15000 DAYS

EW 0

MAXIMUM CONCENTRATION OF CARBON 14
RADIOACTIVITY = 0.795 PCI/ML

SCALE IN FEET
750. 0. 750. 1500

Figure C-13.

Z-B 25K DAYS C-14

05/23 '72

CONTOURS ARE LOGS OF CONCENTRATIONS
OF RADIOACTIVITY IN PCI/ML

SUBSYSTEM B
CARBON - 14
TIME = 25000 DAYS

EW 0

MAXIMUM CONCENTRATION OF CARBON 14
RADIOACTIVITY = 0.794 PCI/ML

SCALE IN FEET
750. 0. 750. 1500

C-24

Figure C-14.

Z-B 35K DAYS C-14

05/24/72

Figure C-15.

Figure C-16.

Z-B 5K DAYS AR-37

Figure C-17.

UNDISSOLVED GAS - ZONE B

5000. DAYS

△

EW

RADIOACTIVE CONTENT OF GAS

TRITIUM 56.80BAPCI/ML
CARBON 14 2.3796PCI/ML
KRYPTON 85 83.7645PCI/ML
RADON 37 0.0000PCI/ML

SCALE IN FEET
750 0 750 1500

Figure C-18.

UNDISSOLVED GAS - ZONE B

15000. DAYS

△

RADIOACTIVE CONTENT OF GAS

TRITIUM 12.1175PC1/ML
CARBON 14 2.3788PC1/ML
KRYPTON 85 13.9853PC1/ML
ARGON 37 0.0000PC1/ML

EW

SCALE IN FEET
750. 0. 750. 1500

Figure C-19.

UNDISSOLVED GAS ZONE B

25000. DAYS

△

RADIOACTIVE CONTENT OF GAS

TRITIUM 2 5849PCI/ML
CARBON 14 2 3780PCI/ML
KRYPTON 85 2 3350PCI/ML
RADON 37 0 0000PCI/ML

EW

750 SCALE IN FEET 750 1500
0

Figure C-20.

UNDISSOLVED GAS - ZONE B

35000. DAYS

RADIOACTIVE CONTENT OF GAS

TRITIUM 0.5514PC1/ML
CARBON 14 2.3773PC1/ML
KRYPTON 85 0.3659PC1/ML
ARGON 37 0.0000PC1/ML

EW

SCALE IN FEET
750. 0. 750 1500.

Figure C-21.

Figure C-22.

LEGEND

- WATER WELL
- ◉ WATER WELL (SAMPLED)
- WINDMILL
- ARTESIAN WELL
- △ SPRING
- ▲ SPRING (FLUMED & SAMPLED)

SELECTED SPRINGS AND WELLS
IN THE RIO BLANCO PROJECT AREA
RIO BLANCO COUNTY, COLORADO

SCALE IN MILES