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Assessment of Effectiveness of
Geologic Isolation Systems

Comparison of INTERA and WISAP Consequence Model Application

C. R. Cole
F. W. Bond

January 1980

Prepared for the
Office of Nuclear Waste Isolation
under its Contract with the
U.S. Department of Energy

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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COMPARISON OF INTERA AND WISAP CONSEQUENCE MODEL APPLICATION

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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

The Waste Isolation Safety Assessment Program (WISAP) is being conducted to develop, for the Office of Nuclear Waste Isolation (ONWI), the methodology necessary to perform long-term safety assessments of deep geologic repositories. The Waste Isolation Pilot Plant (WIPP) program is developing a nuclear waste storage facility and is performing assessments of that site. WISAP and WIPP have similar, though independent, methodologies for assessing the consequences of a repository breach subsequent to closure. Intera Environmental Consultants are under contract to Sandia Laboratories to conduct the hydrologic and transport modeling for the WIPP Site Release Consequence Analysis (WIPP EIS/ER 1978). To provide a mutual benchmark check of the radionuclide and ground-water transport models of these two programs, ONWI has requested WISAP to perform a release consequence analysis based on the WIPP site, utilizing the same data and conceptual model which the WIPP program used for its environmental assessments. Therefore, only a portion of the WISAP methodology was used; specifically, only WISAP geotransport models were exercised. The other important parts of WISAP assessment methodology were not used, so that WISAP did not develop the scenario nor did WISAP interpret the field data to develop the conceptual model of the geohydrology of the WIPP site.

This report presents the results of the comparative assessment. Although the different models required slightly different input parameters, the results of the hydrologic simulations show a very close correspondence between the WISAP and WIPP predictions. This was as expected, since the various hydrologic codes available essentially utilize and solve the same basic flow equations. In addition, this report presents the results of the WISAP radionuclide transport model simulations. These results will provide the basis for comparison with WIPP results when these become available.

ACKNOWLEDGMENTS

This research was supported by the Waste Isolation Safety Assessment Program (WISAP) conducted by Pacific Northwest Laboratory. This program was sponsored by the Office of Nuclear Waste Isolation managed by Battelle Memorial Institute for the Department of Energy under Contract EY-76-C-06-1830. On 1 October 1979 WISAP was divided into two programs with separate areas of concern: the Assessment of Effectiveness of Geologic Isolation Systems (AEGIS) Program and the Waste/Rock Interaction Technology (WRIT) Program. This report was issued by AEGIS.

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INTRODUCTION

Intera Environmental Consultants are under contract to Sandia Laboratories to conduct the hydrologic and transport modeling for the WIPP site release consequence analysis (WIPP EIS/ER 1978). To provide a mutual benchmark check of the ground-water and radionuclide transport models of the WIPP and WISAP methodologies, ONWI requested WISAP to perform a release consequence modeling of the WIPP site, using the data and conceptual model provided by the WIPP program. Therefore, only a portion of the WISAP methodology was used. This report presents the WISAP results of the hydrologic modeling and the transport modeling for the WIPP release scenario No. 1 (WIPP EIS/ER 1978).

HYDROLOGIC MODELING

PNL performed the hydrologic modeling by using, as nearly as possible, the same input parameters and the same geohydrologic interpretation made by Intera as reported in WIPP EIS/ER (1978). This geohydrologic interpretation was based only on geohydrologic data collected prior to January 1, 1978.

INTERPRETATION OF THE DATA

A cross-section plot of the geologic layers above and below the proposed repository is shown in Figure 1. Intera modeled the flow in four different geologic units:

1. Rustler (upper aquifer--Figure 2)
2. Shallow dissolution zone (Figure 3)
3. Delaware Mountain Group (below the salt layers Figure 4)
4. Capitan (Figure 5).

Intera concluded that the "travel time for the waste from the repository to either the shallow dissolution zone or the Capitan aquifer would be very long and of little concern" (WIPP EIS/ER 1978); therefore, they only studied flow in the Delaware Mountain Group and the Rustler aquifer.

WISAP deviated slightly from Intera in the modeling of the Delaware Mountain and Capitan. Based on the cross-section plot (Powers et al. 1978) shown in Figure 6 and the hydraulic conductivity distributions for the Delaware Mountain and Capitan shown in Figures 4 and 5, WISAP modeled these as one horizontal layer with the hydraulic conductivity distribution shown in Figure 7 instead of two separate layers in vertical communication.

The measured hydraulic potential distributions[a] for the Rustler Formation and the Delaware Mountain Group-Capitan aquifer are shown in Figures 8 and 9, respectively. All model-predicted potential distribution results were

(a) It should be noted that the data on potentials are measured at discrete point (wells) and these potential distributions are interpreted from these discrete data by a geohydrologist.

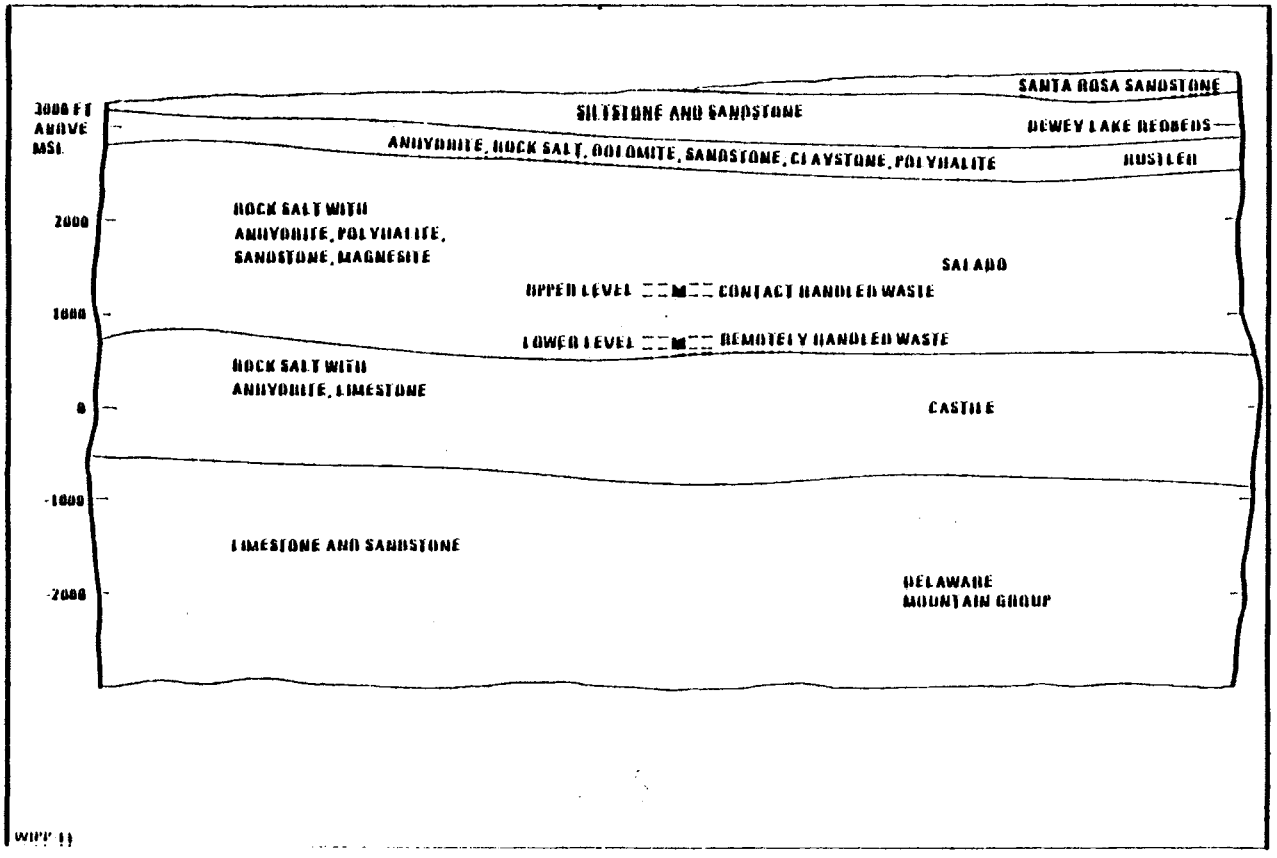


FIGURE 1. Geologic Section of the Los Medanos Area (WIPP EIS/ER 1978)

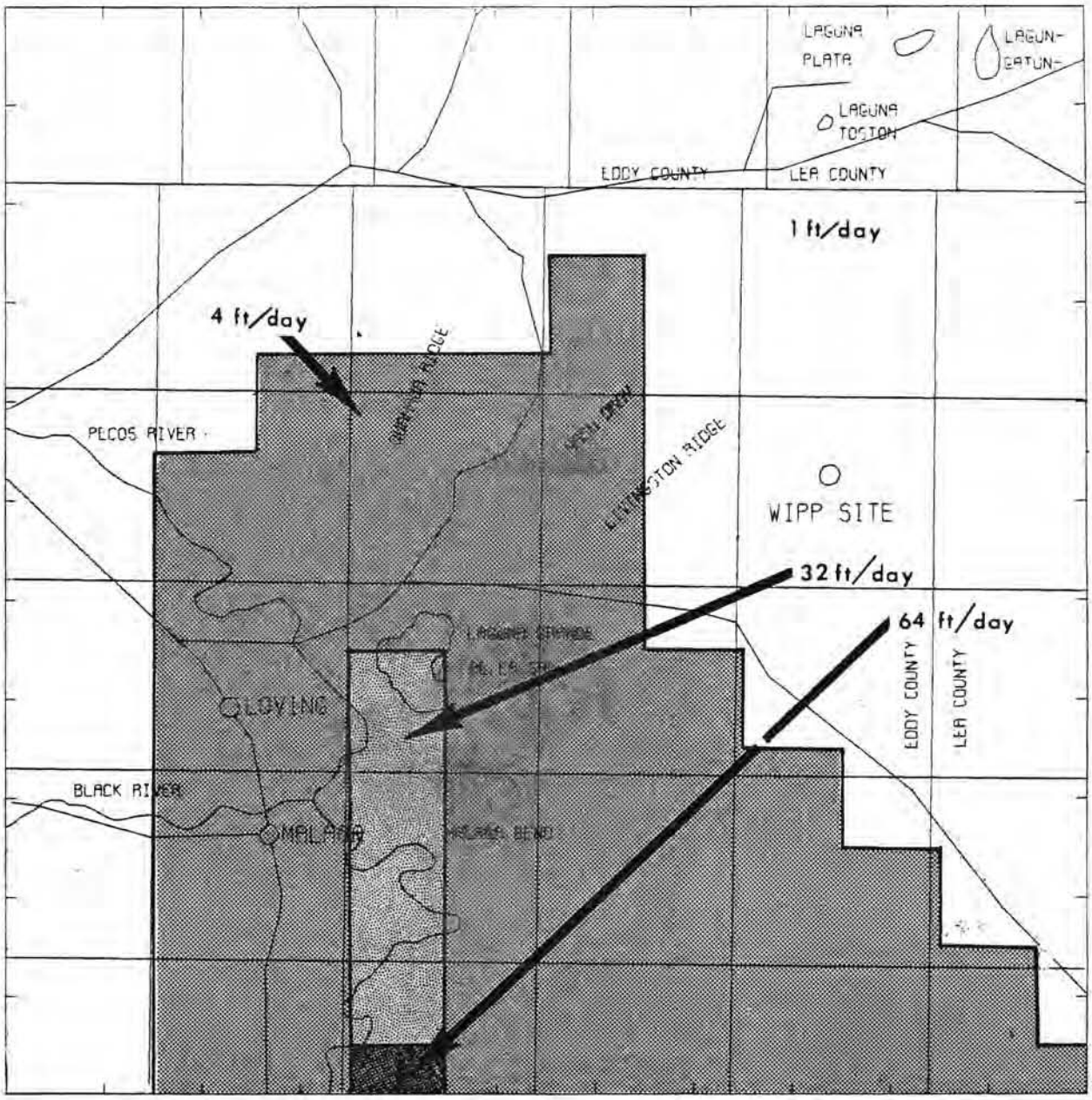


FIGURE 2. Rustler Aquifer Hydraulic Conductivity Distribution (WIPP EIS/ER 1978) Used in the Intera and WISAP Modeling of the WIPP Site

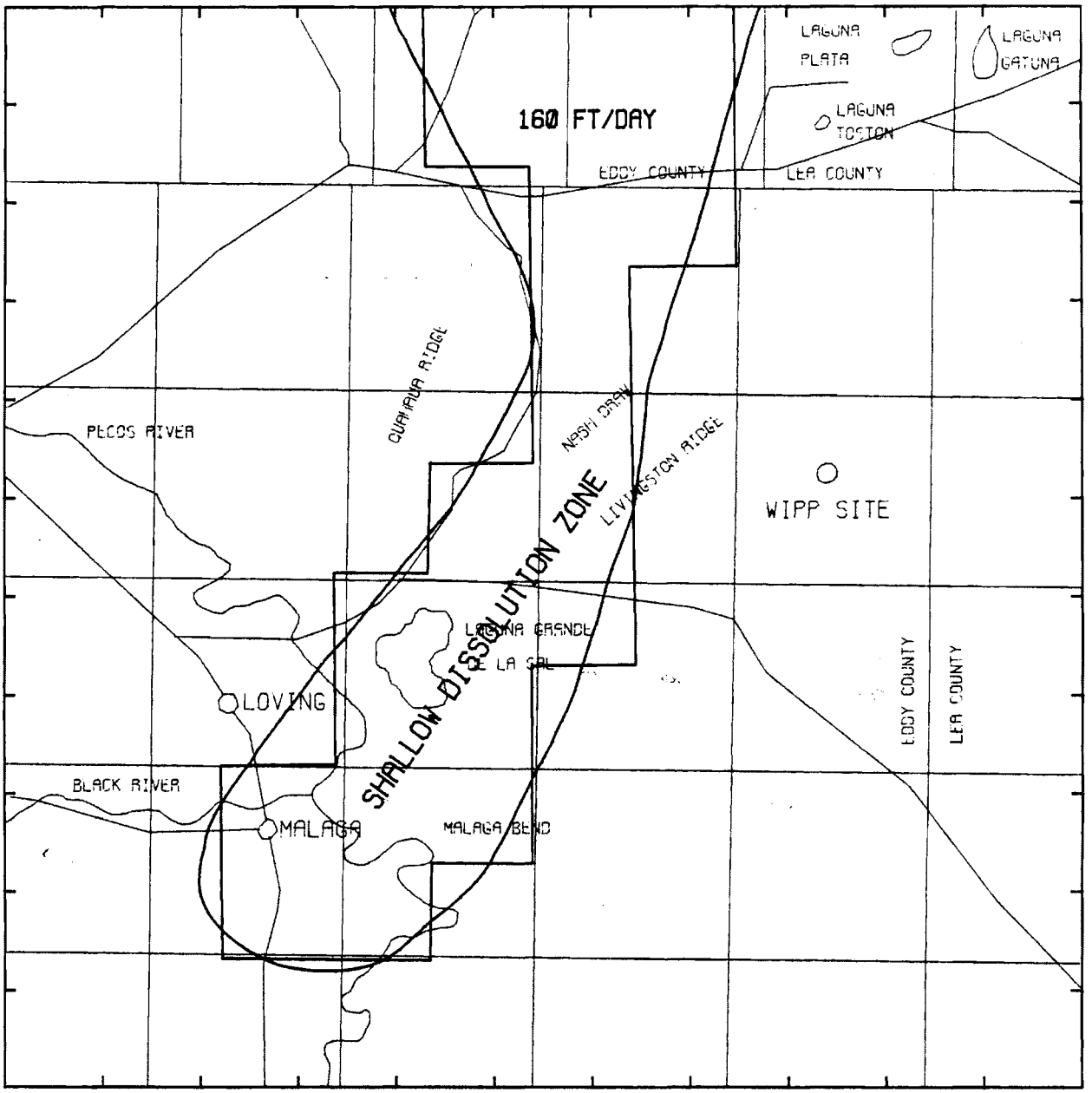


FIGURE 3. Shallow Dissolution Zone Hydraulic Conductivity Distribution (WIPP EIS/ER 1978) Used in the Intera and WISAP Modeling of the WIPP Site

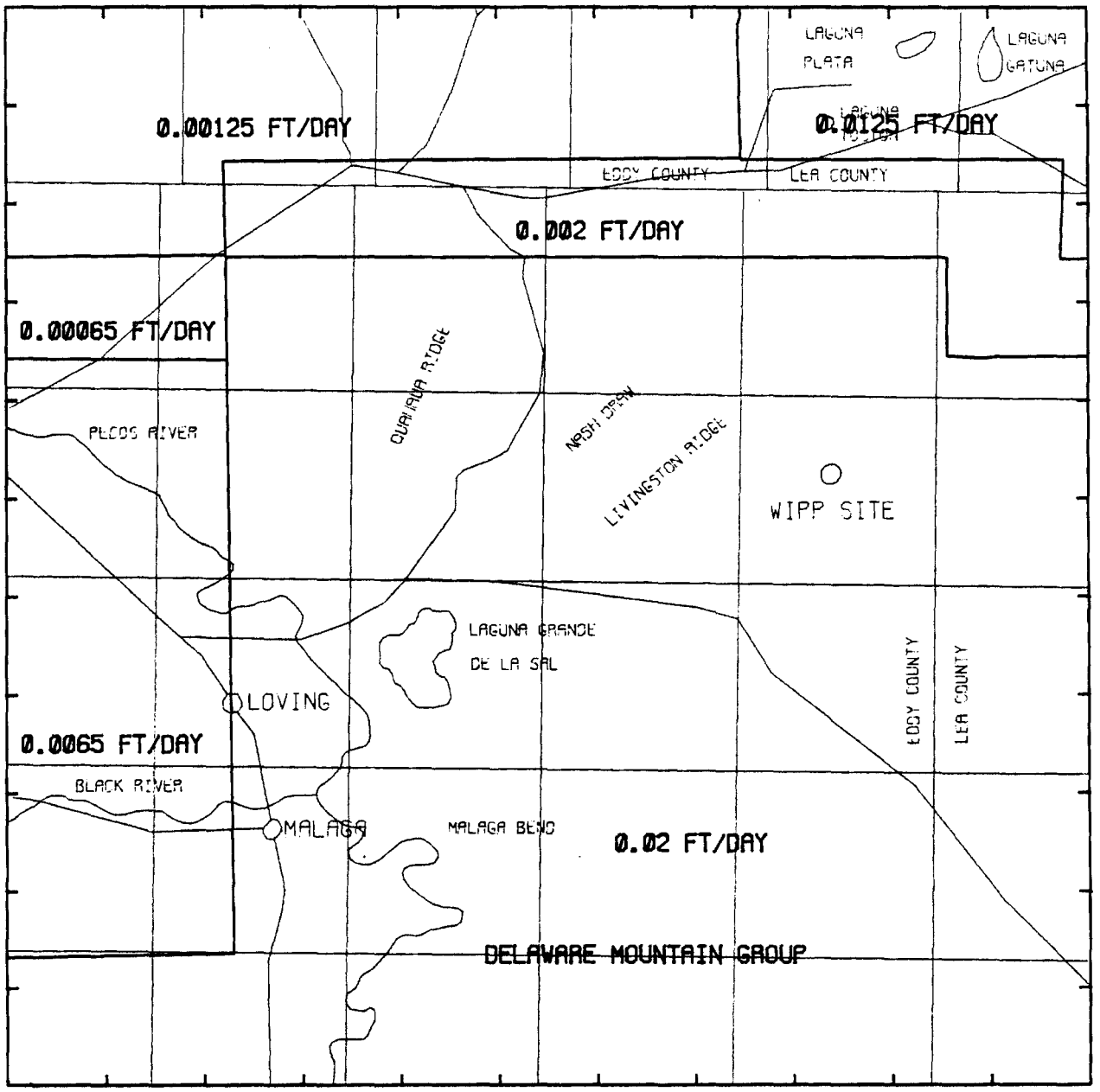


FIGURE 4. Delaware Mountain Group Hydraulic Conductivity Distribution (WIPP EIS/ER 1978) Used in the Intera and WISAP Modeling of the WIPP Site

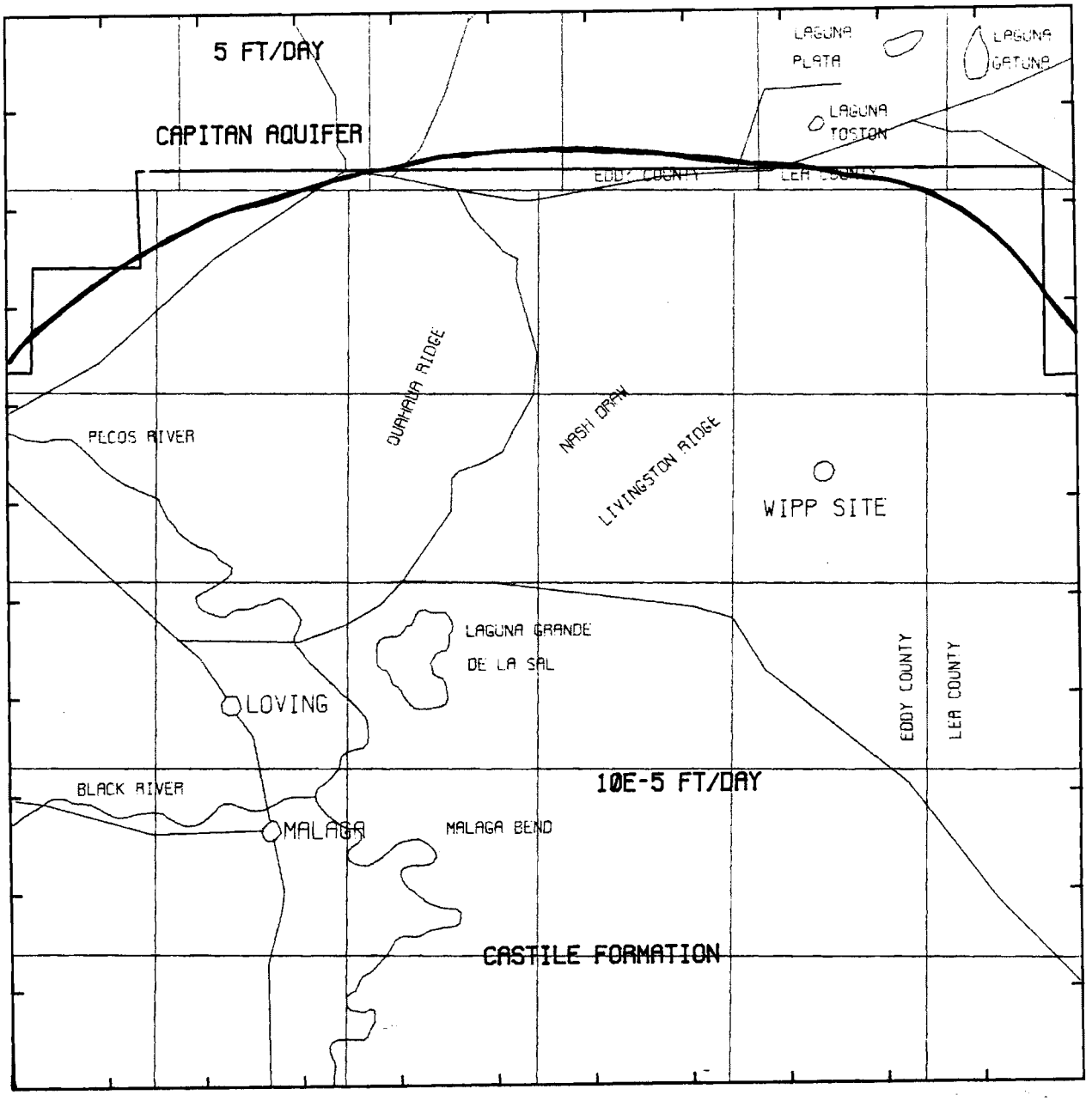
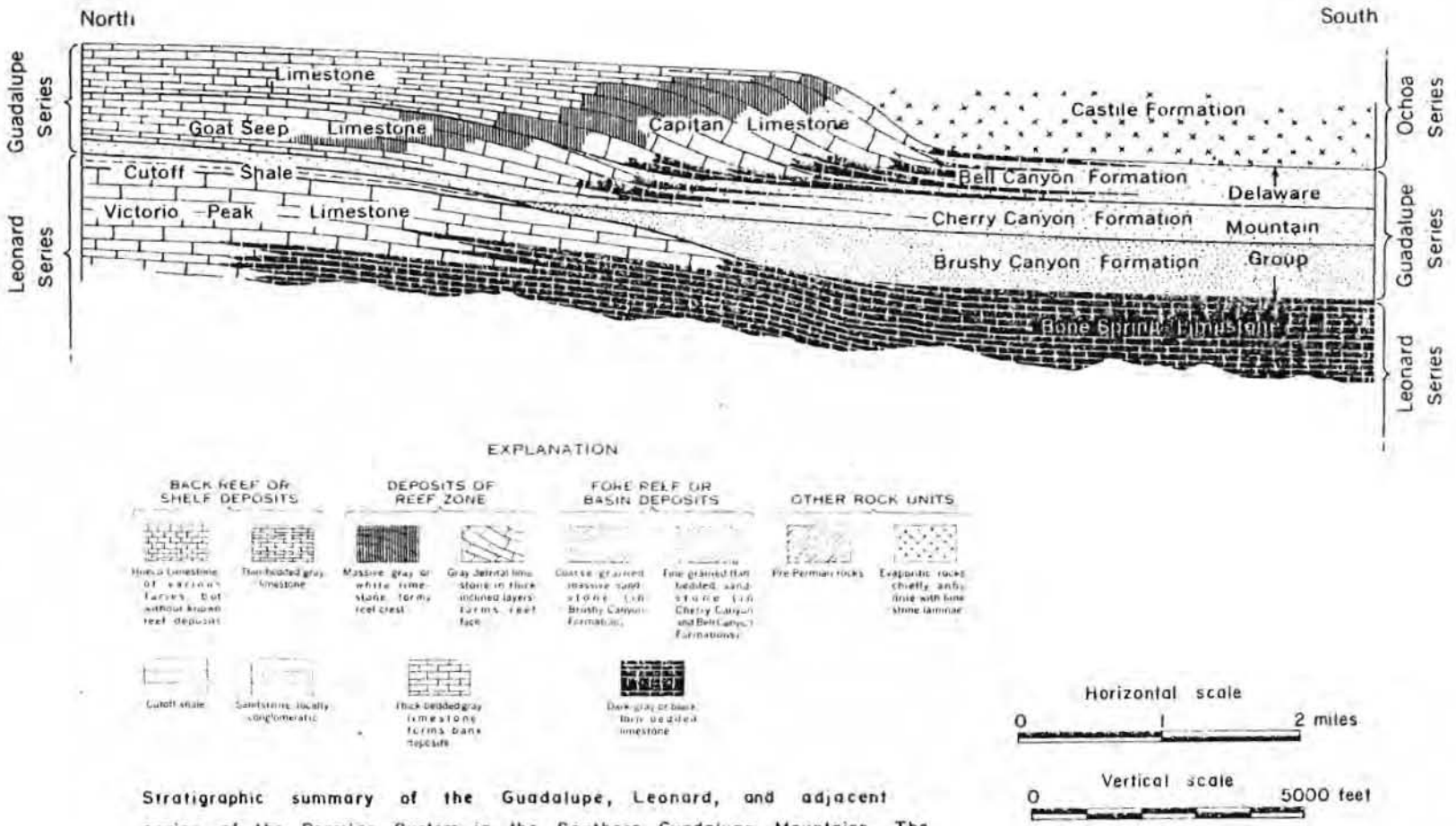


FIGURE 5. Capitan Aquifer Hydraulic Conductivity Distribution (WIPP EIS/ER 1978) Used in the Intera and WISAP Modeling of the WIPP Site



Stratigraphic summary of the Guadalupe, Leonard, and adjacent series of the Permian System in the Southern Guadalupe Mountains. The Delaware basin area is to the right and the shelf or platform area is to to the left. Rock facies are greatly generalized.

REFERENCE:

Adapted from E. D. McKee, et al. (1967).
(Originally compiled from P. B. King (1942, 1948)).

FIGURE 6. Cross Section of Capitan Reef Area (Powers et al. 1979)

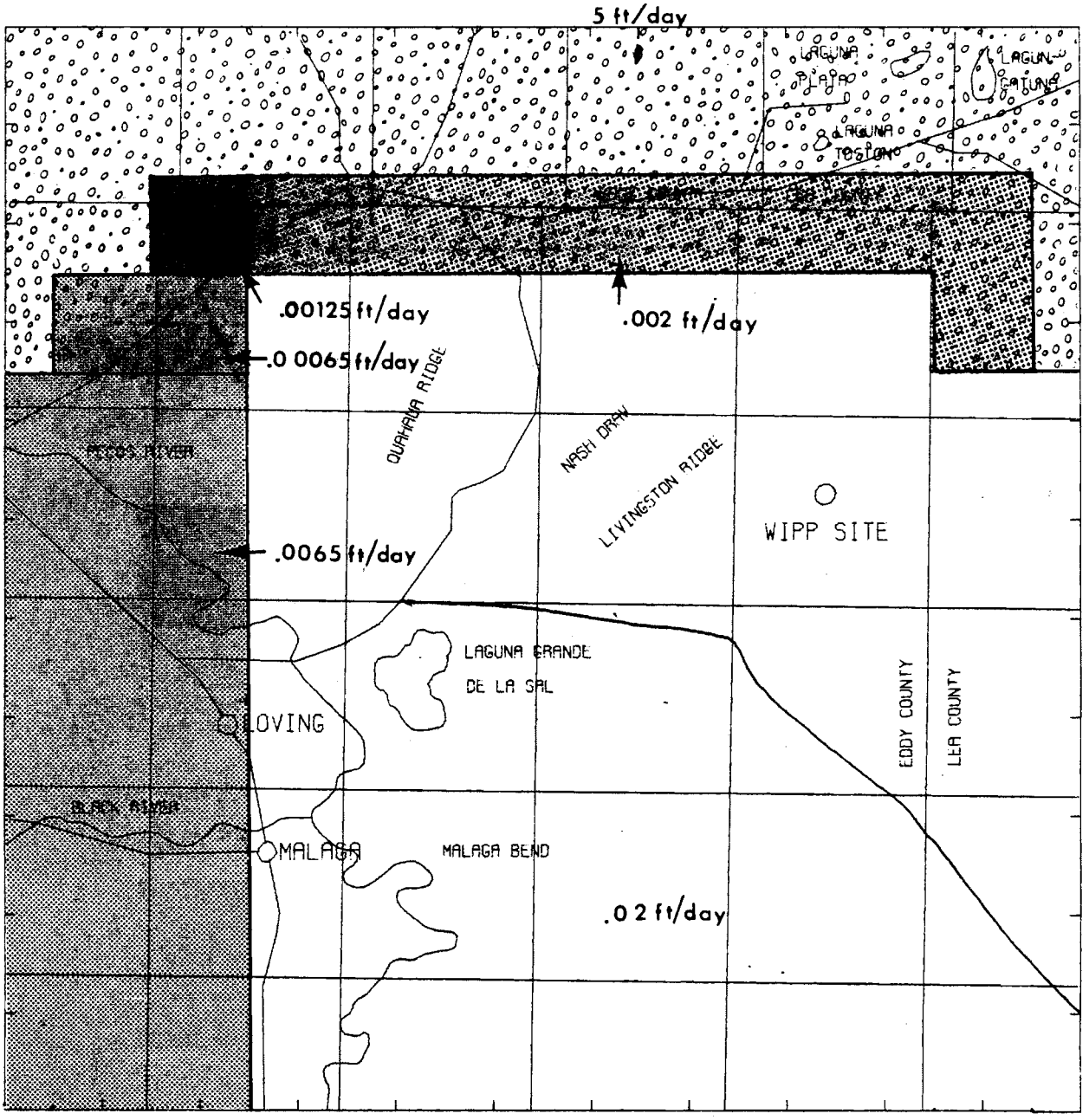


FIGURE 7. WISAP Hydraulic Conductivity Distribution Used to Model the Delaware Mountain-Capitan Aquifer Group

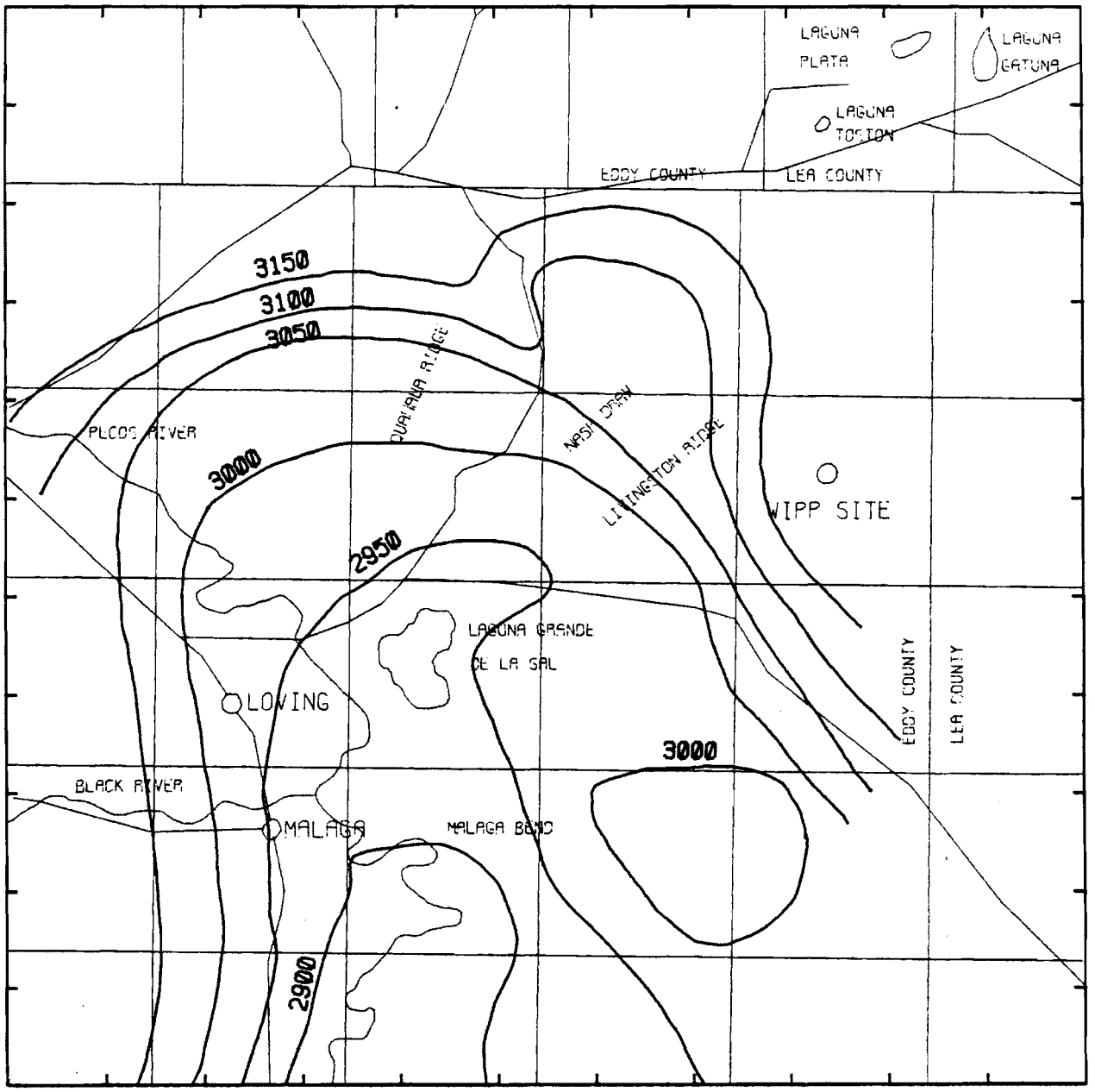


FIGURE 8. Rustler Formation Interpreted or Measured Hydraulic Potentials (WIPP EIS/ER 1978). Contours are in feet referenced to mean sea level.

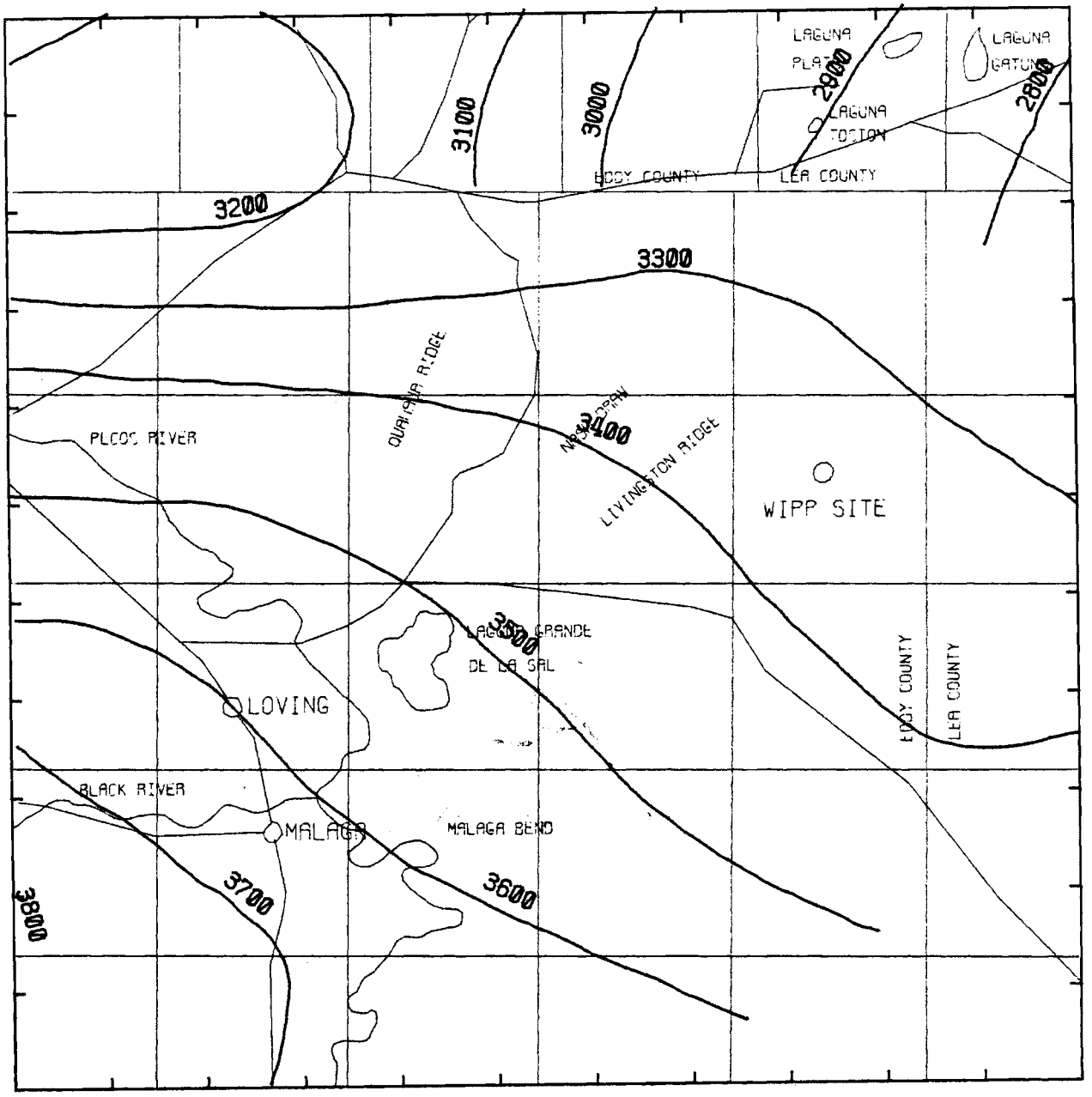


FIGURE 9. Delaware Mountain Group and Capitan Interpreted or Measured Hydraulic Potentials (WIPP EIS/ER 1978). Contours are in feet referenced to mean sea level.

compared to these measured potentials. Intera's model-predicted results for the Rustler and Delaware Mountain Group are shown in Figures 10 and 11, respectively.

WISAP HYDROLOGIC MODEL RESULTS

The WISAP two dimensional multiaquifer Variable Thickness Transient (VTT) model was used to model the Rustler and Delaware Mountain Group Capitan system. The hydraulic conductivity distributions shown in Figures 2 and 7 were used in this WISAP modeling effort. The thickness of the Rustler, Capitan and Delaware Mountain are 40 ft, 1600 ft, and 3000 ft, respectively (WIPP EIS/ER 1978). Porosity was fixed at 0.1 (WIPP EIS/ER 1978). A twelve by twelve grid with a 1.5 mile spacing was used to model each of the two systems as was done in the Intera analysis. Only Dirichlet (held potential) boundary conditions, supplied by Intera for the Rustler, were used in the WISAP analysis. These boundary conditions are indicated by the crossed boxes (nodes) in Figures 12 and 13 for the Rustler and Delaware Mountain-Capitan respectively. Figures 12 and 13 also display the WISAP VTT model-predicted potentials for the Rustler and Delaware Mountain-Capitan aquifer systems. In addition, Figure 12 shows the streamlines from the WIPP site to the discharge site along the Pecos River. The model predicted travel times for these streamlines are shown in Table 1. For the Rustler Formation, the WISAP predicted travel time from the WIPP site to the discharge site is 3600 years. Note that the streamlines shown in Figure 12 converge as they go from regions of low transmissivity to high transmissivity. Table 2 shows the transmissivity distribution used in this WISAP modeling effort. Table 3 shows a node by node comparison between WISAP model predicted potentials and the measured potentials for the two different aquifers. Since the held potential boundary conditions for the Rustler were not taken from Figure 8, the differences shown in Table 2 along the Rustler boundary are not zero.

CONCLUSIONS ON WISAP AND INTERA HYDROLOGIC MODELING COMPARISON

The WISAP hydrologic modeling methodology includes various levels of modeling capability from simple one- and two-dimensional analytical methods

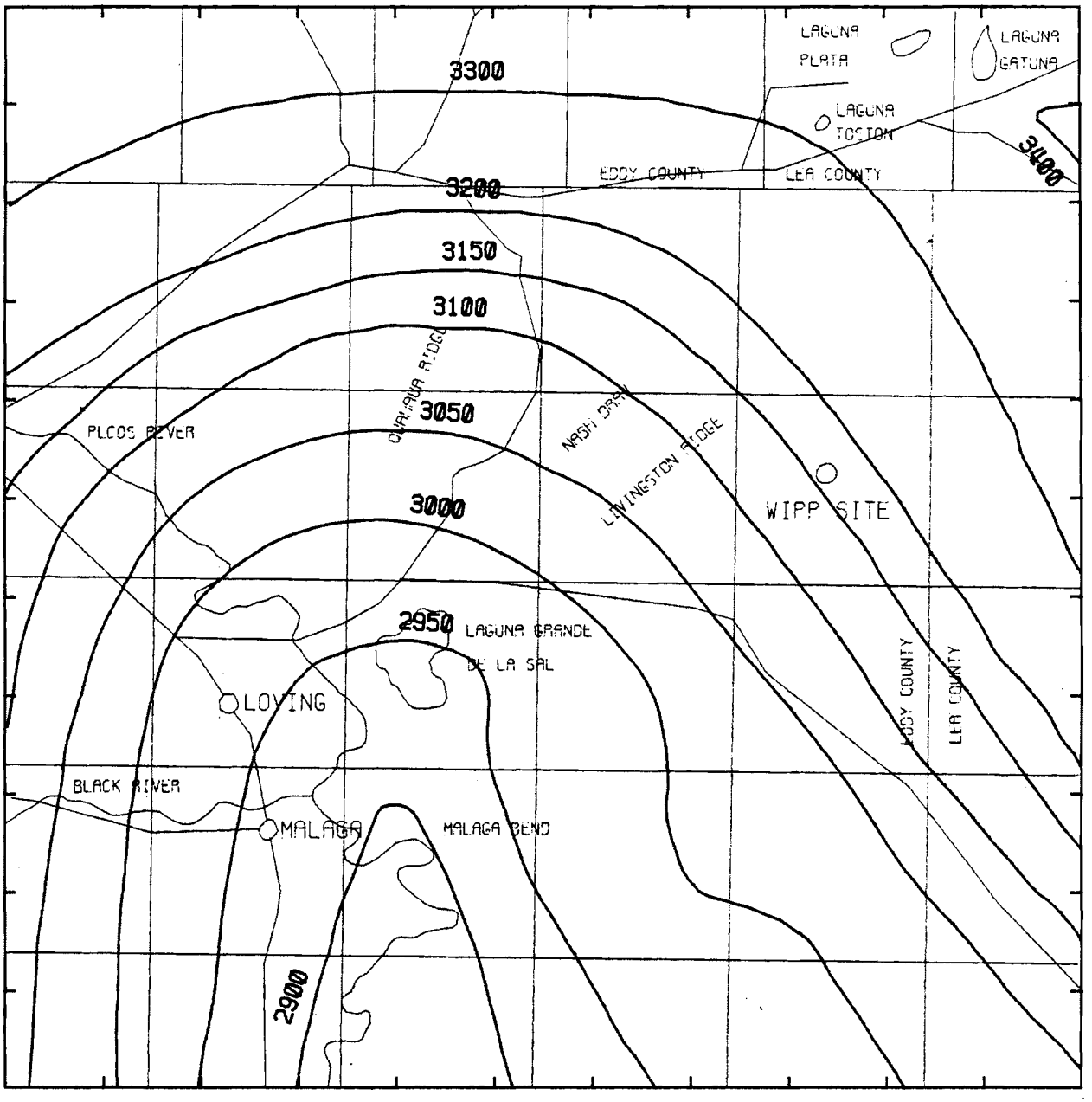


FIGURE 10. Rustler Formation Hydraulic Potentials (WIPP EIS/ER 1978) Calculated by the Intera Model. Contours are in feet referenced to mean sea level.

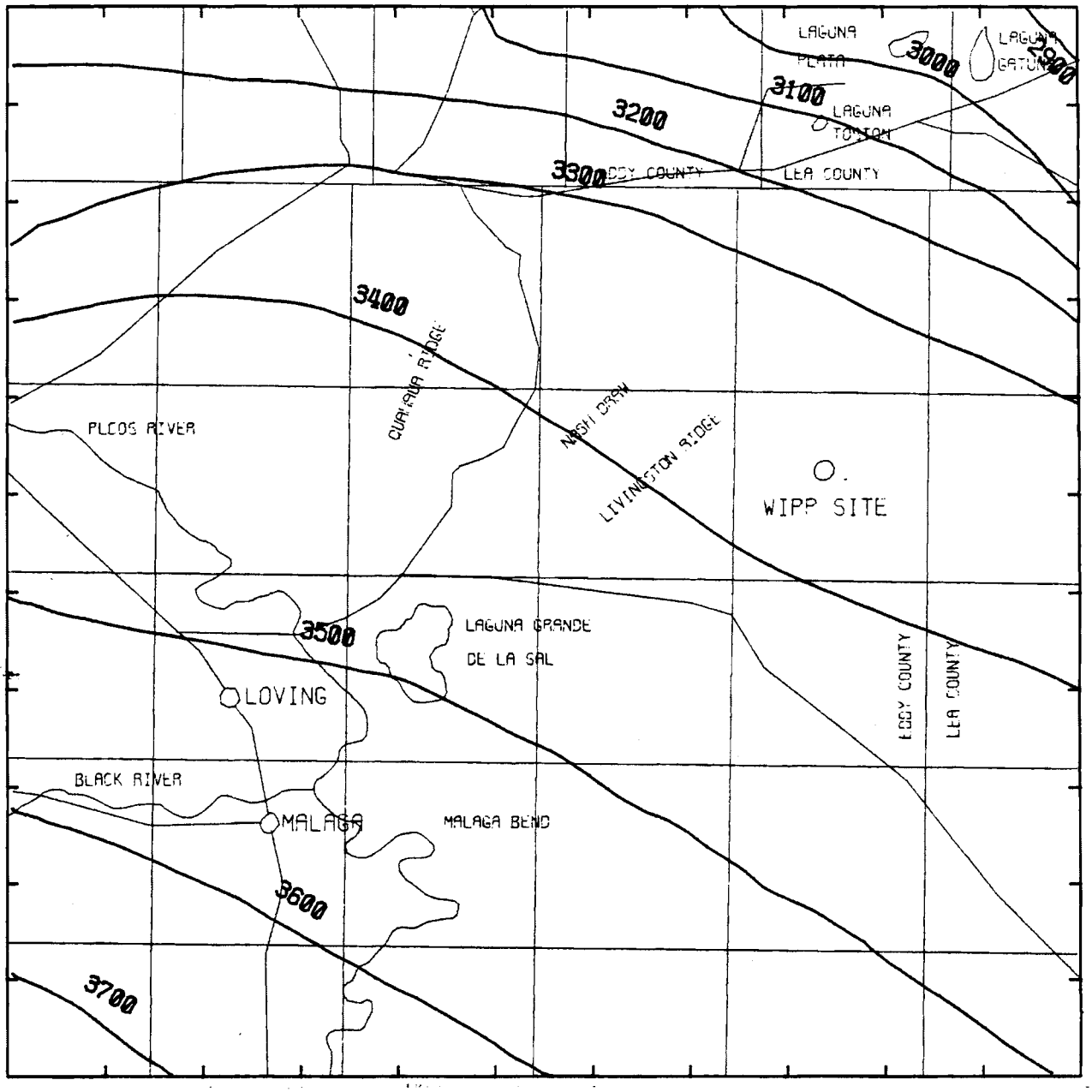


FIGURE 11. Delaware Mountain Group and Capitan Hydraulic Potentials (WIPP EIS/ER 1978) Calculated by the Intera Model. Contours are in feet referenced to mean sea level.

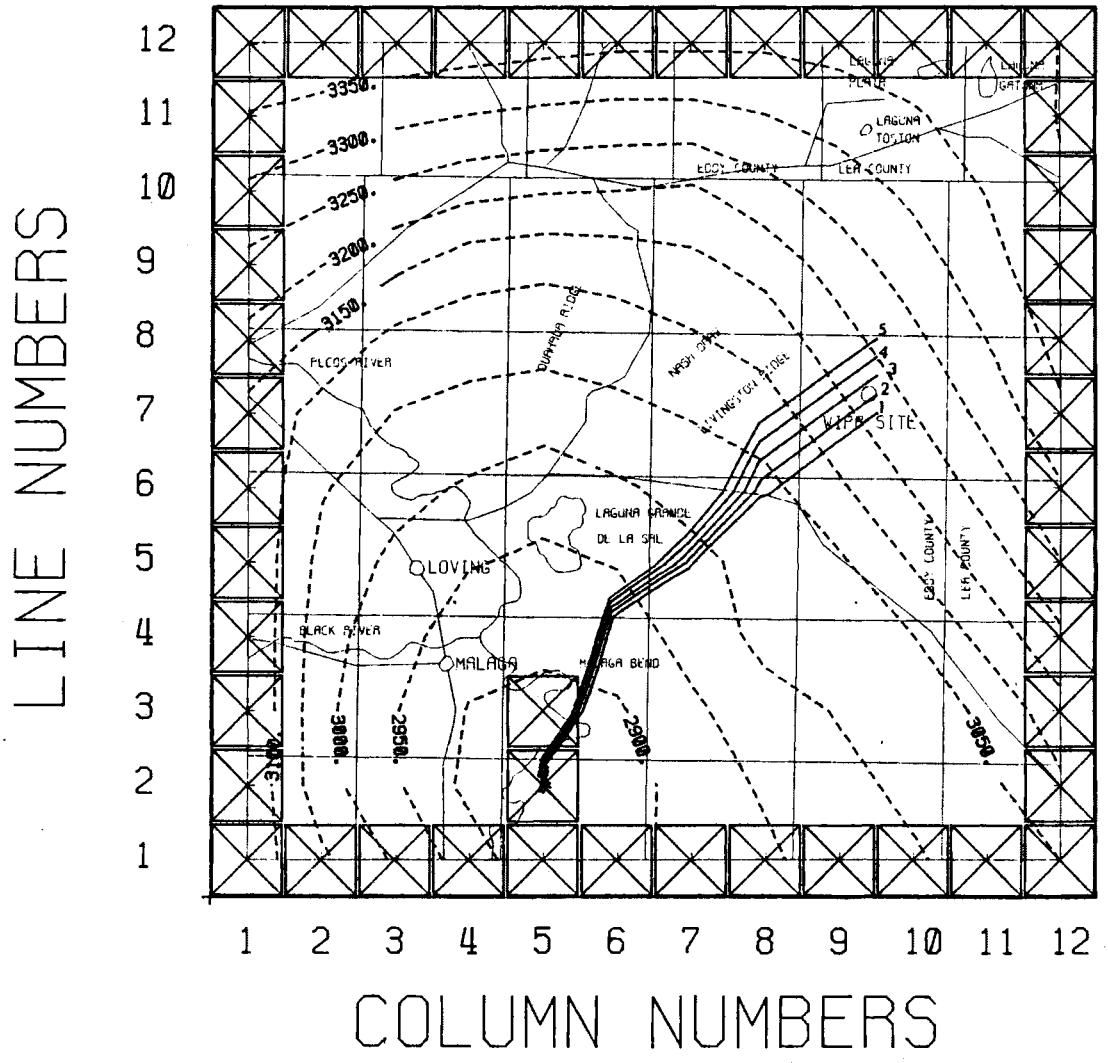


FIGURE 12. Diagram of the Nodal System WISAP Used to Model the Rustler Aquifer. The crossed nodes represent Dirichlet boundary nodes. WISAP model predicted potential distribution is illustrated by the heavy dashed lines and travel paths from the WIPP site are illustrated by the heavy solid lines. Contours are in feet referenced to mean sea level.

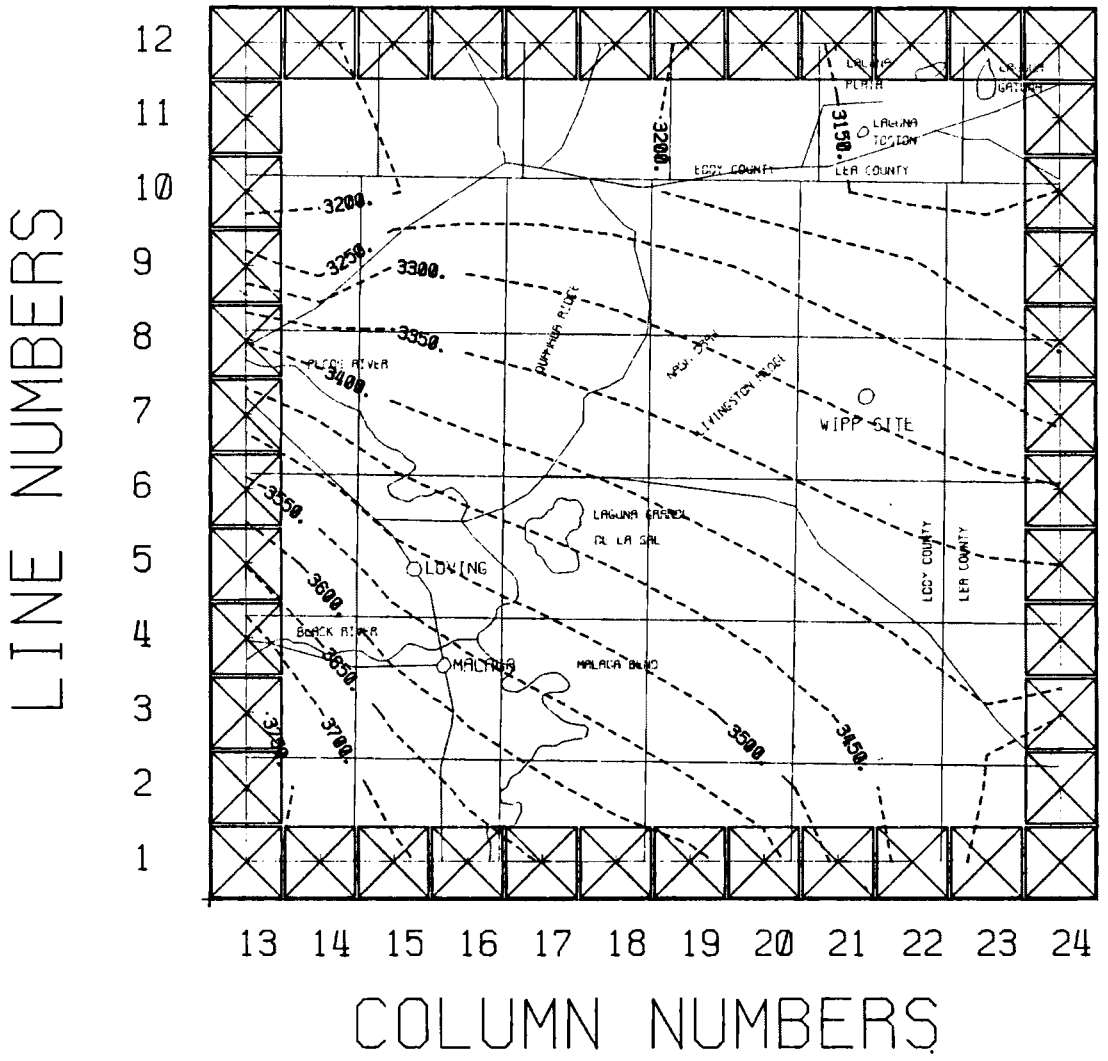


FIGURE 13. Diagram of the Nodal System WISAP Used to Model the Delaware Mountain-Capitan Aquifer System. The crossed nodes represent Dirchlet boundary nodes. WISAP model predicted potential distribution is illustrated by the heavy dashed lines. Contours are in feet referenced to mean sea level.

TABLE 1. WISAP VTT Model Predicted Travel Time for the Five Streamlines Shown in Figure 12

Streamline Data

Aquifer 1

Porosity = 0.1000
Endpoints of Starting Boundary
In Node Coordinates

X1 = 9.5000 Y1 = 7.0000
X2 = 9.5000 Y2 = 8.0000

No.	X-END (node)	Y-END (node)	Time (years)	Distance (feet)
1	4.9438	1.9239	3434.95	114048.0
2	4.9500	1.9654	3572.41	116424.0
3	5.0743	1.9259	3668.15	121176.0
4	5.0888	1.9721	3720.74	123552.0
5	4.9939	1.9056	3824.73	128304.0

Average Time (years) = 3644.20
Average Distance (feet) = 120701.
Average Velocity (feet/year) = 33.1214

All starting (X1, Y1, X2, Y2) and ending (X-END, Y-END) coordinates for streamlines are referenced to the line (Y's) and column (X's) coordinate system shown in Figure 12.

through complex three dimensional models, with heat and solute transport. The conceptual model of the WIPP site hydrogeology required the use of the intermediate level VTT model, which is a two-dimensional multilayer finite difference model which solves the Boussinesq equations for ground-water flow and allows the various layers to be connected via an interaquifer transfer coefficient.

Figure 14 shows the comparison between the WISAP VTT hydrologic model results for the Rustler aquifer potential (dashed lines) and the interpreted or measured potentials (solid lines). Figure 15 shows a similar comparison of the WISAP model results for the Delaware Mountain-Capitan aquifer. Figures 16 and 17 show the same kinds of comparisons, but for the Intera model-predicted

TABLE 2. WISAP Transmissivity Distribution Used to Model the Rustler and Delaware Mountain-Capitan Aquifer Systems

RUSTLER

TRANSMISSIVITY FT**2/DAY

	1	2	3	4	5	6	7	8	9	10	11	12
12	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.
11	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.
10	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.	40.
9	40.	40.	40.	40.	40.	40.	160.	40.	40.	40.	40.	40.
8	40.	40.	40.	160.	160.	160.	160.	40.	40.	40.	40.	40.
7	40.	40.	160.	160.	160.	160.	160.	40.	40.	40.	40.	40.
6	40.	40.	160.	160.	160.	160.	160.	40.	40.	40.	40.	40.
5	40.	40.	160.	160.	1280.	160.	160.	160.	40.	40.	40.	40.
4	40.	40.	160.	160.	1280.	160.	160.	160.	160.	40.	40.	40.
3	40.	40.	160.	160.	1280.	160.	160.	160.	160.	160.	40.	40.
2	40.	40.	160.	160.	1280.	160.	160.	160.	160.	160.	160.	40.
1	40.	40.	160.	160.	2560.	160.	160.	160.	160.	160.	160.	160.

DELAWARE MOUNTAIN-CAPITAN

TRANSMISSIVITY FT**2/DAY

	13	14	15	16	17	18	19	20	21	22	23	24
12	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
11	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
10	8000.	8000.	4.	6.	6.	6.	6.	6.	6.	6.	6.	8000.
9	8000.	2.	2.	60.	60.	60.	60.	60.	60.	60.	6.	8000.
8	20.	20.	20.	60.	60.	60.	60.	60.	60.	60.	60.	60.
7	20.	20.	20.	60.	60.	60.	60.	60.	60.	60.	60.	60.
6	20.	20.	20.	60.	60.	60.	60.	60.	60.	60.	60.	60.
5	20.	20.	20.	60.	60.	60.	60.	60.	60.	60.	60.	60.
4	20.	20.	20.	60.	60.	60.	60.	60.	62.	60.	60.	60.
3	20.	20.	20.	60.	60.	60.	60.	60.	60.	60.	60.	60.
2	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.
1	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.

TABLE 3. Node by Node Comparison Between WISAP VTT Model Predicted Potential Distributions in the 2 Aquifers (Figures 12 and 13) and the Measured or Interpreted Potentiometric Distribution (Figures 8 and 9). The maximum and minimum differences as well as the root mean square (R.M.S.) deviations are illustrated. All differences are in feet.

Rustler Max.=44.8 Min.=-116.5 R.M.S.=37.0

COLUMN → / LINE ↓	1	2	3	4	5	6	7	8	9	10	11	12
12*	12	24	39	31	35	35	34	25	17	5	-13	-19
11*	-4	3	0	-7	-4	3	8	15	11	6	-3	-4
10*	-19	-19	-31	-49	-49	-18	-17	-6	-7	-8	-9	-3
9*	-34	-31	-39	-62	-77	6	16	-14	-39	-30	-19	0
8*	-21	2	15	27	16	-12	11	-27	-72	-56	-35	-8
7*	-6	20	34	39	32	33	-8	-79	-101	-85	-53	-4
6*	17	1	32	32	21	44	24	-76	-116	-108	-66	-17
5*	17	-24	9	14	0	-15	4	-19	-84	-89	-81	-28
4*	6	-47	-17	-1	-9	-47	-36	0	-33	-72	-58	-40
3*	1	-61	-39	-14	-15	-52	-63	-30	7	-36	-62	-31
2*	6	-52	-31	-9	-29	-45	-37	-26	1	1	-40	-33
1*	16	3	32	45	-22	-28	-26	-24	-1	1	-24	-45

Deleware Mountain-Capitan Max.=45.4 Min.=-75.8 R.M.S.=27.5

COLUMN → / LINE ↓	1	2	3	4	5	6	7	8	9	10	11	12
12*	0	0	0	0	0	0	0	0	0	0	0	0
11*	0	21	20	17	-5	-6	5	-2	-14	-19	-13	0
10*	0	20	12	16	-10	-14	-3	-24	-40	-44	-28	0
9*	0	-30	45	39	21	5	-12	-24	-22	-13	-18	0
8*	0	-15	-20	-26	-28	-33	-43	-48	-43	-18	-2	0
7*	0	-37	-64	-60	-54	-53	-51	-44	-34	-23	-3	0
6*	0	-44	-76	-70	-57	-52	-45	-34	-22	-11	-5	0
5*	0	-42	-70	-64	-51	-42	-34	-23	-9	1	-5	0
4*	0	-28	-56	-48	-39	-32	-22	-14	-6	-3	-15	0
3*	0	-14	-43	-40	-30	-26	-19	-15	-21	-28	-28	0
2*	0	-13	-32	-28	-22	-24	-30	-34	-40	-25	-13	0
1*	0	0	0	0	0	0	0	0	0	0	0	0

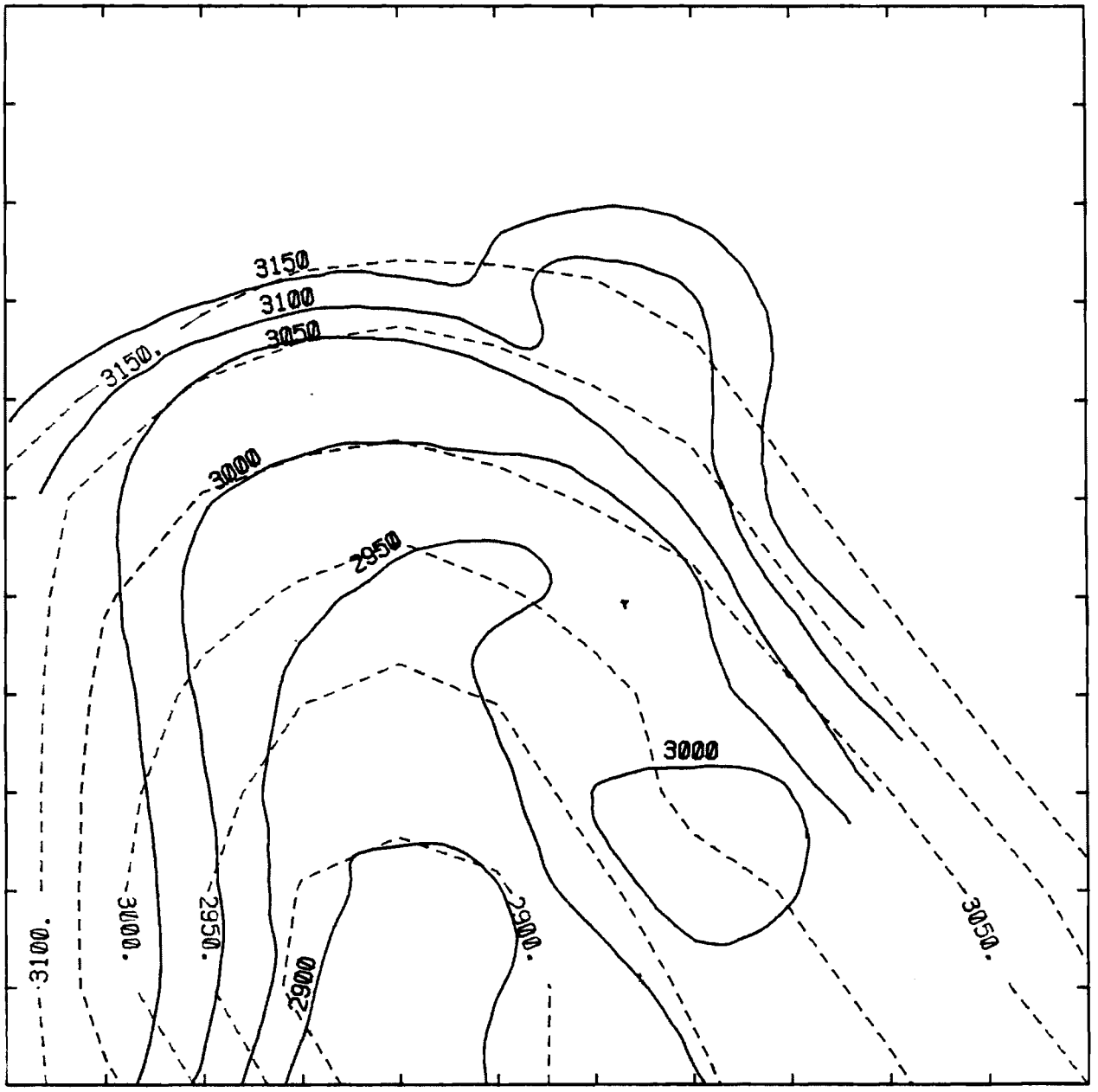


FIGURE 14. Plot Showing the Comparison Between the WISAP VTT Model Predicted Potentials for the Rustler (dashed lines) and the Measured or Interpreted Potentials (WIPP EIS/ER 1978) (solid lines). All contours are in feet referenced to mean sea level.

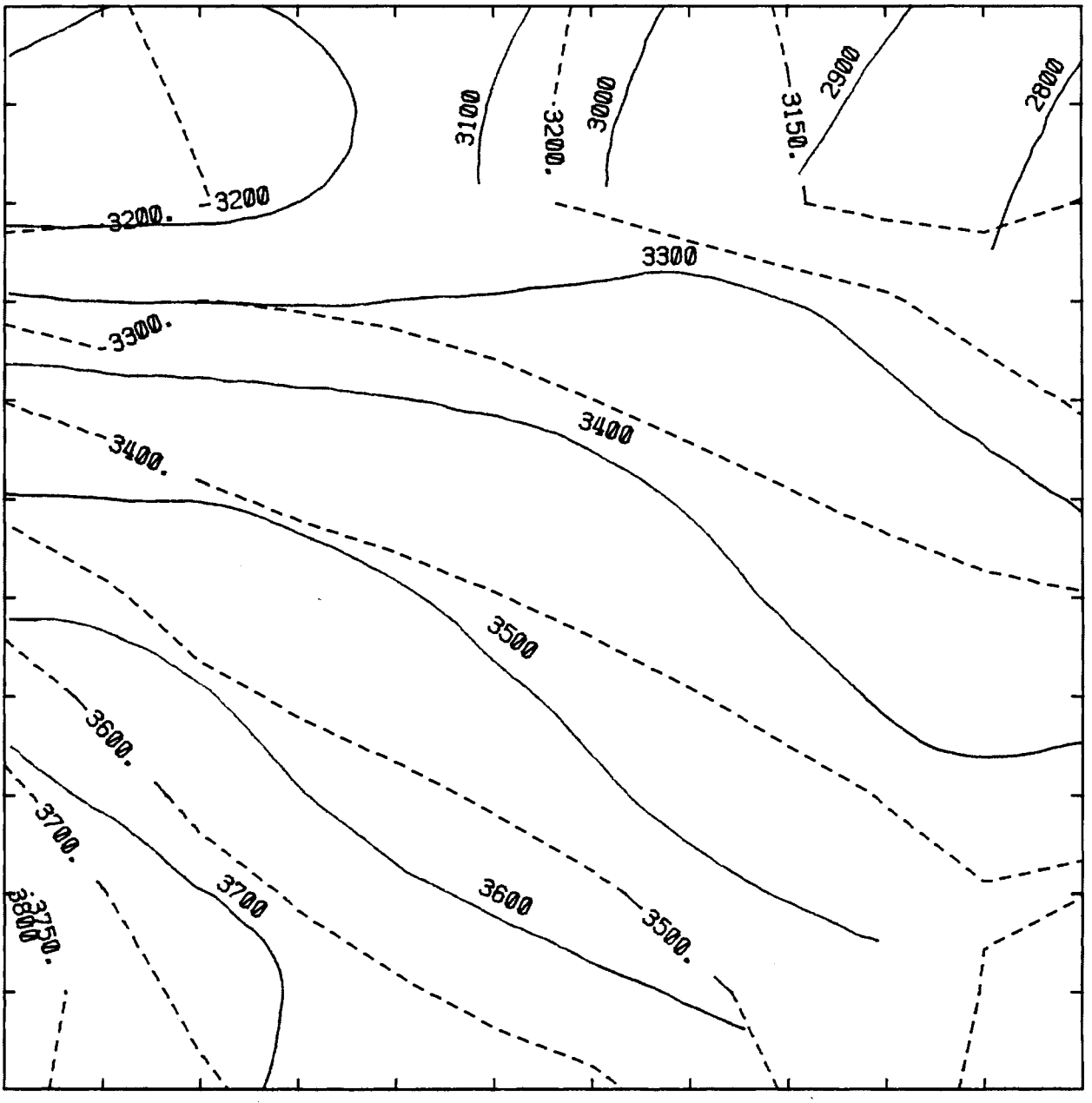


FIGURE 15. Plot Showing the Comparison Between the WISAP VTT Model Predicted Potentials for the Delaware Mountain-Capitan (dashed lines) and the Measured or Interpreted Potentials (WIPP EIS/ER 1978) (solid lines). All contours are in feet referenced to mean sea level.

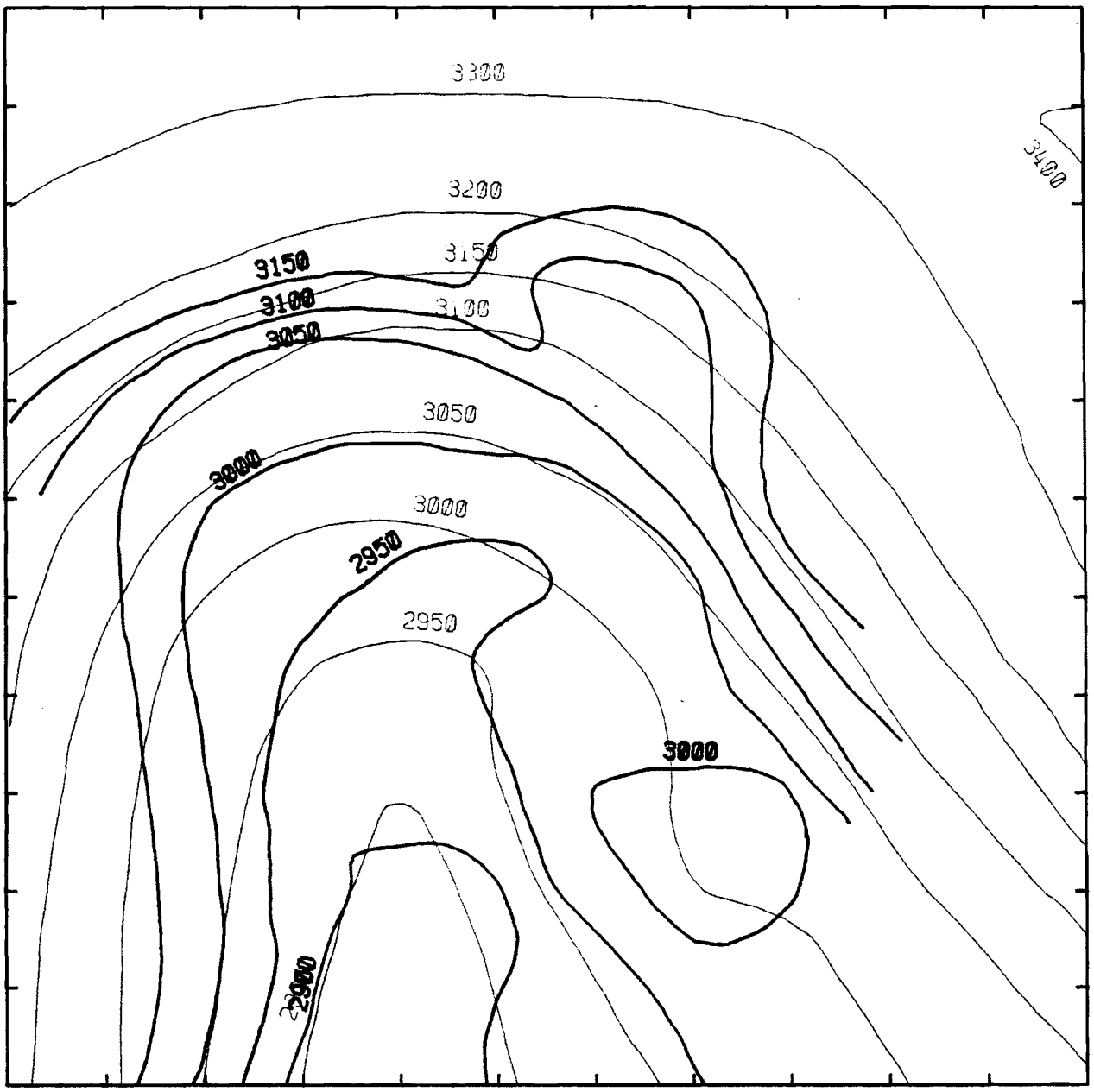


FIGURE 16. Plot Showing the Comparison Between the WIPP Intera Model Predicted Potentials (WIPP EIS/ER 1978) for the Rustler (light lines) and the Measured or Interpreted Potentials (WIPP EIS/ER 1978) (heavy lines). All contours are in feet referenced to mean sea level.

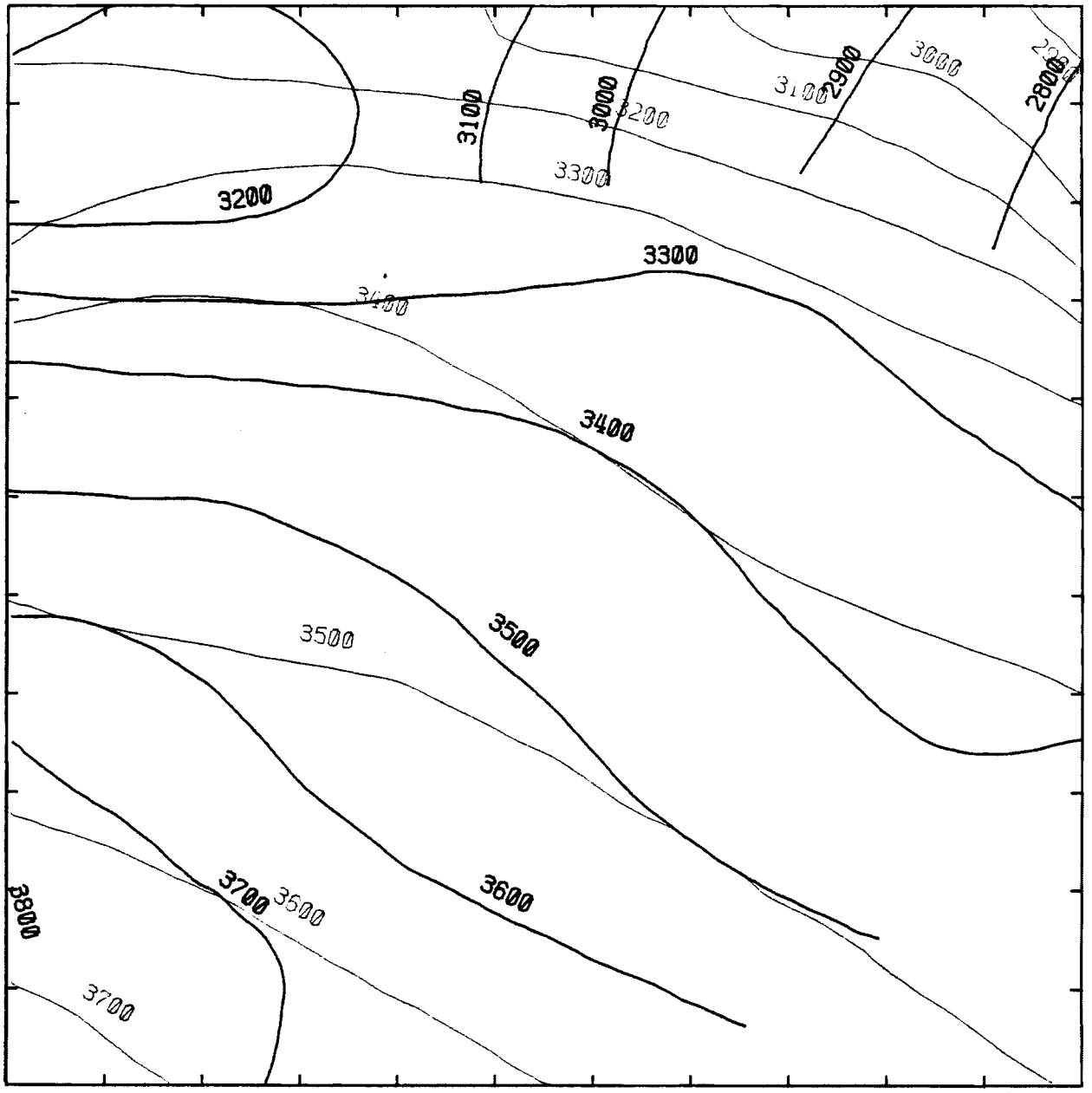


FIGURE 17. Plot Showing the Comparison Between the Intera Model Predicted Potentials (WIPP EIS/ER 1978) for the Delaware Mountain-Capitan (light lines) and the Measured or Interpreted Potentials (WIPP EIS/ER 1978) (heavy lines). All contours are in feet referenced to mean sea level.

potentials for the Rustler and Delaware Mountain-Capitan, respectively. Heavy solid lines represent the interpreted data and light solid lines represent the Intera model results. A comparison between the WISAP VTT model results (dashed lines) and the Intera model results (solid lines) for the Rustler and Delaware Mountain-Capitan are shown in Figures 18 and 19, respectively. The slight differences between the WISAP VTT model results and the Intera model results for the Rustler can be most likely attributed to the slightly different methods used for the boundary conditions. Dirichlet (held potential) boundaries were used for the WISAP VTT model at each of the crossed nodes in Figures 12 and 13, whereas the Intera model used aquifer influence functions along the boundary. Differences between WISAP VTT model results and Intera model results for this Delaware Mountain-Capitan are due to the somewhat different conceptual model explained earlier.

In order to make a comparison between the WISAP and Intera travel times, the Intera potential distribution shown in Figure 10 was digitized on a 12 by 12 grid and the streamline and travel times were calculated for this potential distribution and the hydraulic conductivity distribution shown in Figure 2. Figure 20 shows the contours of the digitized Intera potential distribution and five predicted streamlines originating at the WIPP area. Table 4 shows the node by node comparison between the measured or interpreted potentials (Figures 8 and 9) and the digitized Intera model predicted potentials. Table 5 lists the travel times and path lengths for the 5 streamlines shown in Figure 20.

The Rustler potential comparison between WISAP and Intera agree fairly well. The Delaware Mountain-Capitan are different but this was because of the different conceptual interpretation used for this aquifer system. Table 6 shows a comparison between the WISAP VTT and Intera travel time results. Travel times for the Rustler streamlines agree very well. The average distances and velocities show some deviation, but this can be explained by noting that the VTT streamlines terminate farther downstream and thus travel an additional 27,000 ft in the higher hydraulic conductivity zone. Since the velocity is averaged along the path length this results in the greater average velocity.

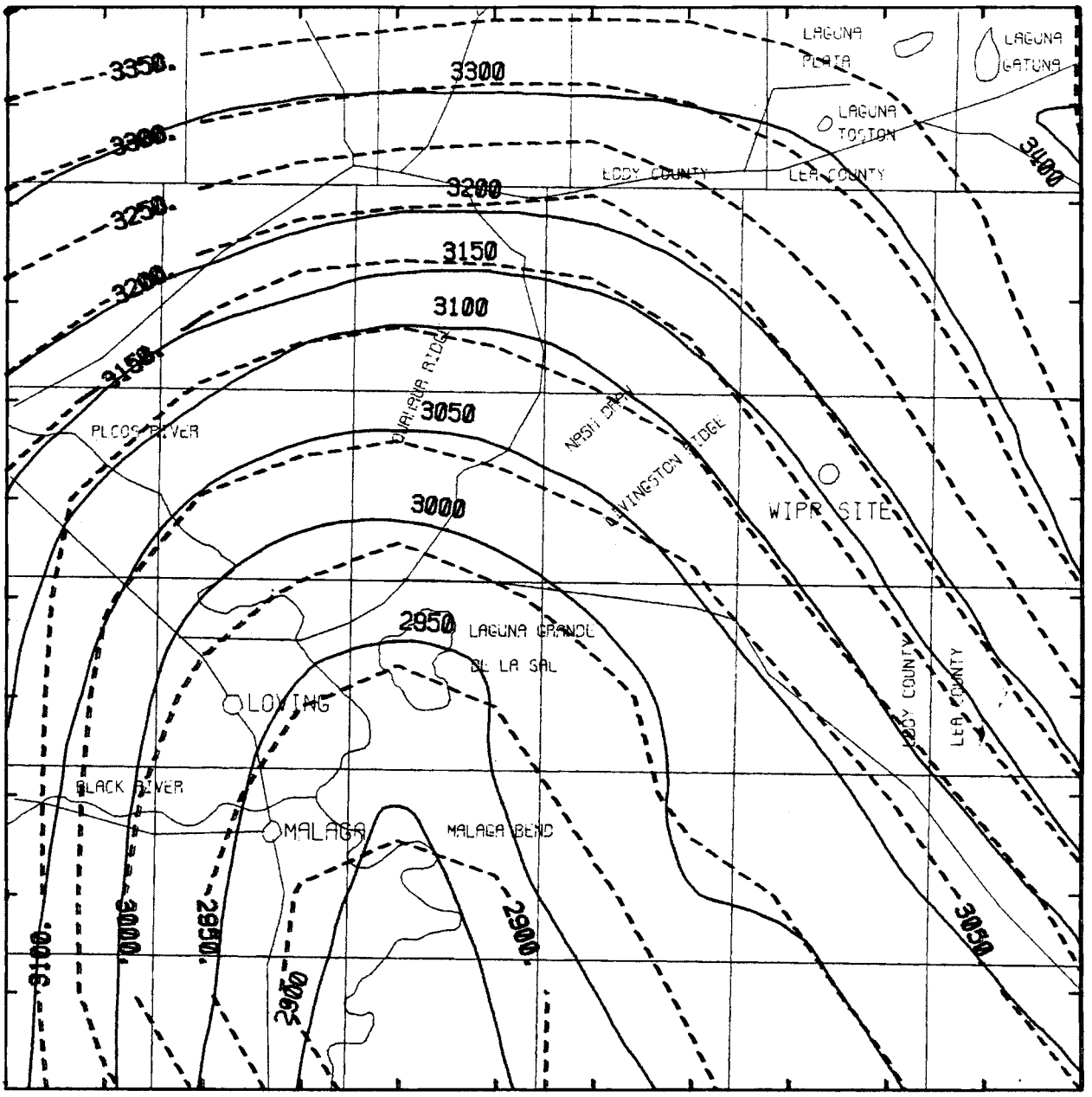


FIGURE 18. Plot Showing the Comparison Between the WISAP VTT Model Predicted Potentials for the Rustler (dashed lines) and the Intera Model Predicted Potentials (WIPP EIS/ER 1978) (solid lines). All contours are in feet referenced to mean sea level.

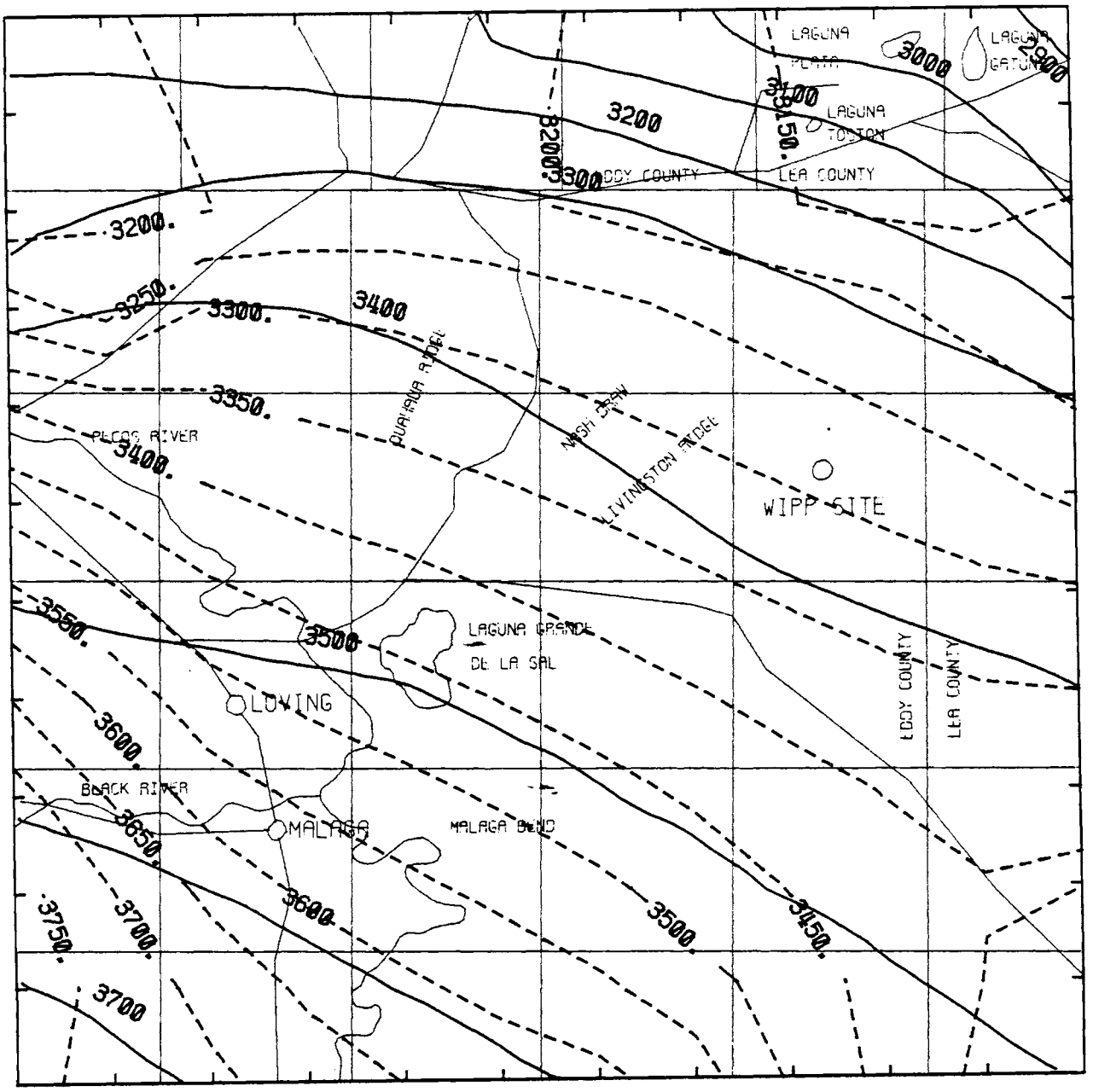


FIGURE 19. Plot Showing the Comparison Between the WISAP VTT Model Predicted Potentials for the Delaware Mountain-Capitan (dashed lines) and the Intera Model Predicted Potentials (WIPP EIS/ER 1978) (solid lines). All contours are in feet referenced to mean sea level.

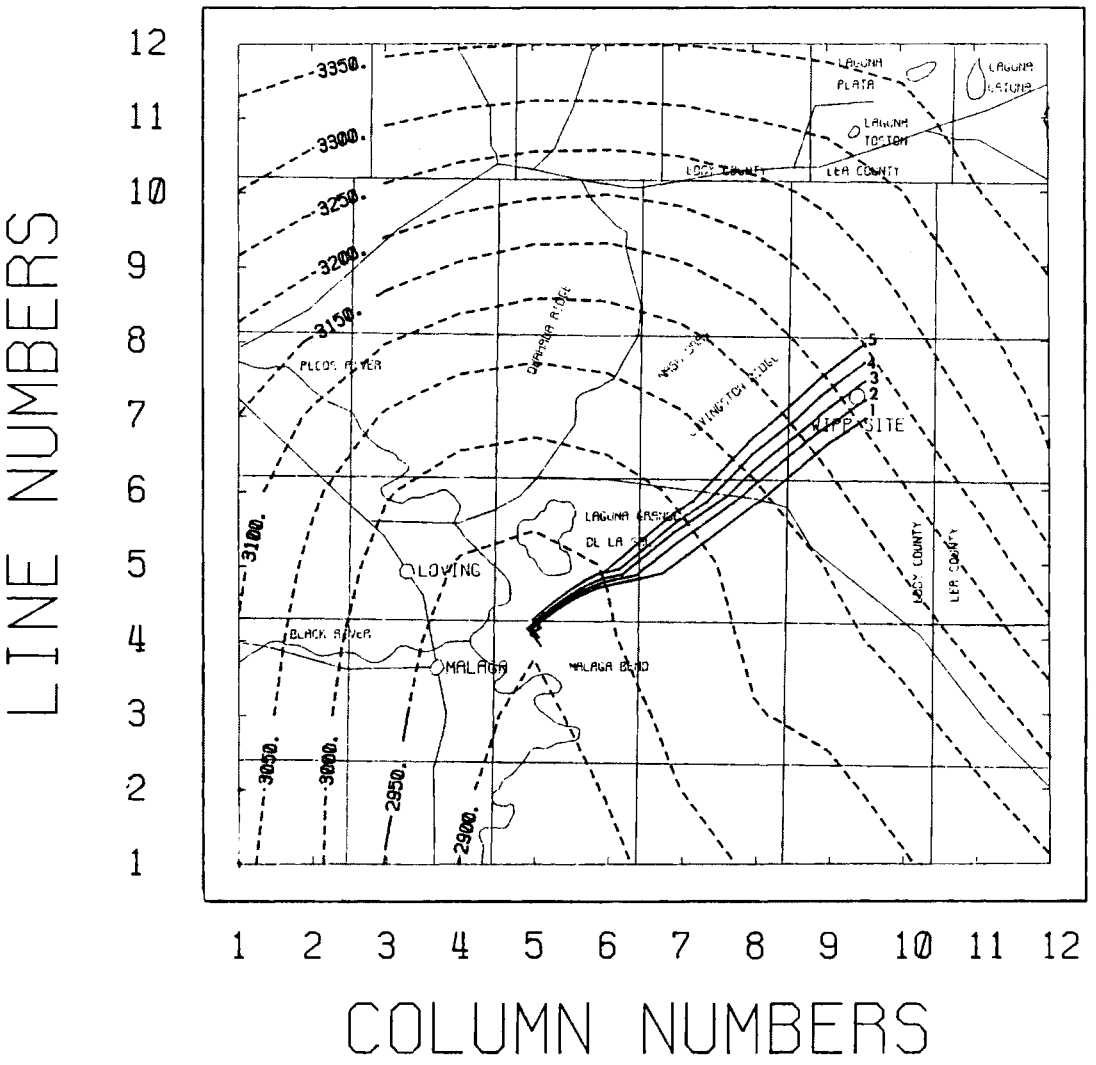


FIGURE 20. Intera Predicted Potentials and the Associated Streamlines from the WIPP Site. All contours are in feet referenced to mean sea level.

The results of the WISAP modeling of the WIPP hydrologic system indicate that for the same conceptual model (i.e., hydrologic interpretation), essentially the same results are achieved as those obtained with the Intera model. This result was expected since the various hydrologic codes essentially utilize and solve the same flow equations.

TABLE 4. Node by Node Comparison Between the Intera Model Predicted Potential Distributions (WIPP EIS/ER 1978) in the 2 Aquifers (Figures 10 and 11) and the Measured or Interpreted Potential Distributions (WIPP EIS/ER 1978) (Figures 8 and 9). The maximum difference and minimum difference as well as the root mean square (R.M.S.) deviations are illustrated. All differences are in feet.

Rustler Max.=31.0 Min.=-119.2 R.M.S.=37.5

COLUMN / LINE	1	2	3	4	5	6	7	8	9	10	11	12
12*	-10	-2	5	9	18	26	26	22	12	-1	-21	-34
11*	-13	-4	-6	-13	-7	6	14	18	4	-6	-2	-3
10*	-12	-17	-29	-44	-45	-16	3	-5	-17	-20	-14	-14
9*	-31	-26	-28	-39	-63	11	24	-6	-45	-41	-34	-38
8*	-23	9	31	29	14	-17	3	-26	-78	-63	-50	-47
7*	7	30	31	24	18	19	-15	-77	-110	-92	-66	-36
6*	-1	5	18	16	23	30	16	-67	-119	-119	-77	-25
5*	-19	-21	1	6	-9	-15	0	-19	-74	-89	-92	-38
4*	-46	-46	-14	4	-20	-26	-26	-7	-22	-55	-60	-49
3*	-66	-60	-30	8	-11	-21	-36	-11	13	-25	-46	-38
2*	-62	-62	-33	13	-21	-16	-7	-9	4	4	-36	-42
1*	-49	-49	-13	17	-44	-28	-9	-6	0	4	-25	-48

Delaware Mountain-Capitan Max.=145.5 Min.=-226.5 R.M.S.=76.0

COLUMN / LINE	1	2	3	4	5	6	7	8	9	10	11	12
12*	-11	-17	-35	-54	-81	-130	-126	-142	-161	-160	-186	-227
11*	58	61	49	30	-4	-17	-16	-39	-73	-101	-151	-200
10*	107	129	138	128	93	87	105	70	30	-2	-48	-159
9*	96	132	145	137	112	90	71	59	63	64	48	-7
8*	29	39	51	57	59	54	40	32	37	63	84	107
7*	-19	-22	-15	4	16	20	23	29	38	49	75	94
6*	-68	-67	-53	-27	-5	6	16	27	40	52	58	63
5*	-107	-93	-68	-38	-17	1	16	29	46	57	49	50
4*	-135	-99	-70	-38	-18	-2	14	30	45	52	35	29
3*	-121	-93	-79	-46	-26	-12	4	21	31	34	35	51
2*	-135	-68	-66	-46	-33	-27	-23	-8	16	52	78	101
1*	-1	-22	-18	-17	-16	-18	-20	4	64	100	126	136

TABLE 5. Predicted Travel Times for the Five Streamlines Which Were Derived from the Intera Model Potentiometric Distribution (WIPP EIS/ER 1978) in Figure 20 and the Hydraulic Conductivity Distribution Used in the Intera Model and Shown in Figure 2

Streamline Data

Aquifer 1

Porosity = 0.1000
Endpoints of Starting Boundary
In Node Coordinates

X1 = 9.5000 Y1 = 7.0000
X2 = 9.5000 Y2 = 8.0000

No.	X-END (node)	Y-END (node)	Time (years)	Distance (feet)
1	5.0611	4.0785	3387.31	87912.0
2	5.0204	4.0765	3384.51	90288.0
3	5.0895	3.9701	3448.30	95040.0
4	4.9629	4.1209	3502.28	95040.0
5	4.9939	4.1131	3492.96	97416.0

Average Time (years) = 3443.07
Average Distance (feet) = 93139.
Average Velocity (feet/year) = 27.0512

All starting (X1, Y1, X2, Y2) and ending (X-END, Y-END) coordinates for streamlines are referenced for the line (Y's) and column (X's) coordinate system shown in Figure 20.

TABLE 6. Comparison Between the WISAP and Intera Travel Time Results

	VTT	Intera
Average travel for the five Rustler streamlines from the WIPP area, years	3644.	3443.
Average velocity for the five Rustler streamlines from the WIPP area, feet/year	33.12	27.1
Average travel distance for the five Rustler streamlines from the WIPP area, feet	120701.	93139.

TRANSPORT MODELING

In modeling the transport of nuclides from WIPP to the discharge site, Intera used a one-dimensional transport model. Based on the streamlines analyzed for the two-dimensional model runs, this should give an adequate representation of transport.

Intera's one-dimensional transport model is coupled with the flow model. After Intera ran the two-dimensional flow model to predict water travel times, a one-dimensional flow model was set up to simulate transport of the nuclides. The Intera one-dimensional simulation was set up by modeling the flow path from the WIPP Site to the Pecos River, which had been predicted with their 3-D model. Intera set up the 1-D model, by utilizing the hydraulic conductivity distribution along the 3-D model flow path. The potentials at the ends of the flow path from the three-dimensional model were also preserved. The Intera transport simulation was then run using the hydrologic conditions described in this 1-D flow tube. Table 7 illustrates the characteristics of the one dimensional flow tube use by Intera.

Although Intera ran various scenarios at upper and lower permeability bounds, WISAP comparison runs were made only for the upper permeability bound

TABLE 7. Characteristics of the One-Dimensional Flow Tube Used by Intera to Simulate the Transport From WIPP to Malaga Bend. These same values were used in the WISAP transport modeling.

1-D flow tube velocity	14.78 ft/yr
1-D flow tube length	78,000 ft
1-D flow tube width	750 ft
1-D flow tube height	40 ft
1-D flow tube velocity	0.1
1-D flow tube dispersivity	300 ft
1-D flow tube bulk density	120 lb/ft^3
β = bulk density/porosity	17.3 g/ml
1-D water travel time	5,277 years

and only for transport of wastes from the spent fuel repository and for repository breach or failure scenario 1 (WIPP EIS/ER 1978). This breach scenario, developed at Sandia, involves flow through the repository as a result of interconnection of the Rustler and Delaware Mountain aquifers through an uncased bore hole centered in the spent fuel repository. The Sandia-Intera analysis indicated a slight head differential between these two aquifer systems, which resulted in a calculated bore hole flow of 600 ft^3/day (WIPP EIS/ER 1978). Waters entering the bore hole from the Delaware Mountain aquifer at 230,000 ppm salt (WIPP EIS/ER 1978) were assumed to pick up salt uniformly along the 2,700 ft (WIPP EIS/ER 1978) of uncased salt and exit to the Rustler aquifer at 410,000 ppm salt (WIPP EIS/ER 1978). The 600 ft^3/day of water flow would thus result in the loss of 54 ft^3 (WIPP EIS/ER 1978) of salt per day from the sides of the bore hole over the entire 2,700 ft of bedded salt (2×10^{-2} ft^3 of salt/ft of bore hole/day). The waste in the spent fuel repository (which is 16.5 ft thick and 1,076 ft by 1112 ft in area) was assumed to dissolve at the same rate as the salt and thus would take 164,000 yr to leach into Rustler aquifer waters.

Repository failure for scenario 1 was assumed to occur 1,000 yr after repository sealing. Table 8 lists the spent fuel and TRU inventories (WIPP EIS/ER 1978) in the repository after 1000 years, and the Kd and half-life numbers (WIPP EIS/ER 1978) used in the Intera and WISAP transport modeling. The WISAP 1-D MTT model was used to analyze the transport of wastes from the WIPP site to Malaga Bend for comparison to Intera results. The data in Tables 7 and 8, considering the 164,000 yr leach time, represent all the data necessary to run the WISAP transport model.

For this failure scenario only the 3 fission products (^{99}Tc, ^{129}I, and ^{135}Cs) and the four actinide chains shown in Table 8 are of interest for WISAP transport model studies. Only the longer lived members of the four actinide chains are modeled. Shorter lived members are assumed to be in secular equilibrium with their parents.

TABLE 8. WIPP Repository Inventory at 1,000 yr, for the Modeled Nuclides Along With the Half Life and Kd Values Used in the Intera and WISAP Transport Model (WIPP EIS/ER 1978)

ISOTOPE	HALF LIFE (YEARS)	UNCONTROLLED WATER RADIATION STANDARD (M.P.C.)	KD (ML/G)	TRU WASTE (MICRO-CURIES/ LITER)*	TRU WASTE CURIES	SPENT FUEL (MICRO-CURIES/ LITER)**	SPENT FUEL CURIES
99-TC	2.13E5	3.0E-4	0.	0.	0.	1.36E-2	6.59E3
129-I	1.59E7	6.0E-8	0.	0.	0.	3.09E-2	1.50E1
135-CS	2.3 E6	1.0E-4	15.	0.	0.	3.23E-4	1.56E2
244-PU	8.3 E7	4.0E-6	2100.	0.	0.	7.62E-15	3.69E-9
240-PU	6.54E3	5.0E-6	2100.	6.13E7	9.28E6	.419	2.03E5
236-U	2.34E7	3.0E-5	10.	1.94E-2	2.79E2	2.89E-4	1.40E2
232-TH	1.4 E10	2.0E-6	2200.	4.50E-10	6.81E-6	1.38E-11	6.68E-6
237-NP	2.14E6	3.0E-6	700.	8.67E-2	1.31E3	9.08E-4	439.74
233-U	1.58E5	3.0E-5	10.	2.2E-4	3.33	2.97E-6	1.44
229-TH	7.3 E3	7.0E-6	2200.	7.23E-6	1.10E-1	1.21E-7	5.86E-2
242-PU	3.87E5	5.0E-6	2100.	0.	0.	1.37E-3	6.64E2
238-U	4.47E9	4.0E-5	10.	0.	0.	2.96E-4	1.43E2
238-PU	8.78E1	5.0E-6	2100.	1.03E-1	1.56E3	0.	0.
234-U	2.44E5	3.0E-5	10.	8.51E-2	1.29E3	1.79E-3	8.67E2
230-TH	7.7 E4	2.0E-6	2200.	6.28E-4	9.51	1.43E-5	6.93
226-RA	1.6 E3	3.0E-8	25.	1.05E-4	1.59	2.58E-6	1.25
243-AM	7.37E3	4.0E-6	1450.	0.	0.	1.72E-2	8.33E3
239-PU	2.4 E4	5.0E-6	2100.	2.72E3	4.12E7	0.304	1.47E5
235-U	7.04E8	3.0E-5	10.	2.65E-3	4.01E1	1.6E-5	7.75
231-PA	3.25E4	9.0E-7	10.	0.	0.	0.	0.

* CONVERSION FACTOR TO CONVERT MICRO-CURIES/LITER TO CURIES (1.514E4). TRU WASTES.

** CONVERSION FACTOR TO CONVERT MICRO-CURIES/LITER TO CURIES (4.843E5). SPENT FUEL WASTES.

TRANSPORT MODEL RESULTS

The WISAP one-dimensional MMT transport model was run for the 3 fission products and 4 actinide chains shown in Table 8. The results of the WISAP transport model are shown in Figures 21 through 35 in the form of Malaga Bend arrival curves. These graphs illustrate the concentration versus time of the various nuclides in the groundwater, which is being discharged at Malaga Bend into the Pecos River. Isotopes not displayed have decayed before reaching Malaga Bend. Table 9 summarizes the WISAP MMT transport model results. This table indicates the minimum and maximum times of discharge (years), the total number of curies released to the environment (Ci), the time of peak arival (years), peak concentration (μCi/mℓ) in the groundwater and Pecos River water along with the respective ratios to maximum permissable concentration (MPC) (U.S. ERDA 1975), and the peak release rate (Ci/yr) to the Pecos River. For purposes of these calculations, the Pecos River flow rate was assumed to be 0.736 cubic meters per second (WIPP EIS/ER 1978). Only two isotopes arrived at Malaga Bend with ground-water concentration above the maximum permissible uncontrolled water radiation standard (MPC). These isotopes were 129-I (1.23 times MPC) and 226-Ra (4.83 times MPC). Dilution by the Pecos River brought both of these concentrations in the biosphere river below MPC.

TRANSPORT MODELING CONCLUSIONS

Transport model comparisons will be made when the Intera transport model results are received. Preliminary runs, made earlier in this study with a different leach time and a slightly different flow tube description, indicated that the transport models give comparable results.

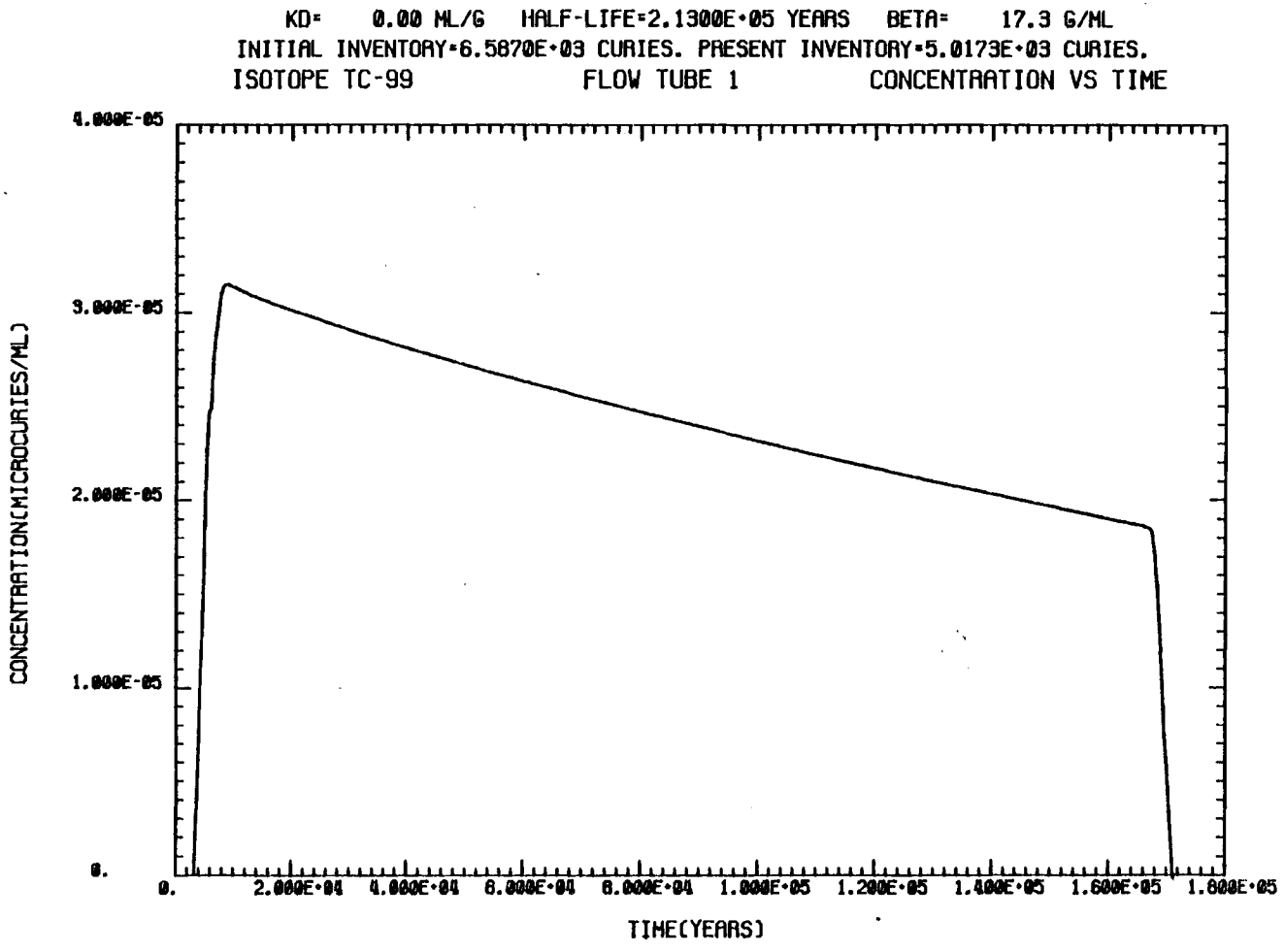


FIGURE 21. WISAP Predicted Malaga Bend Arrival Curve for Tc-99

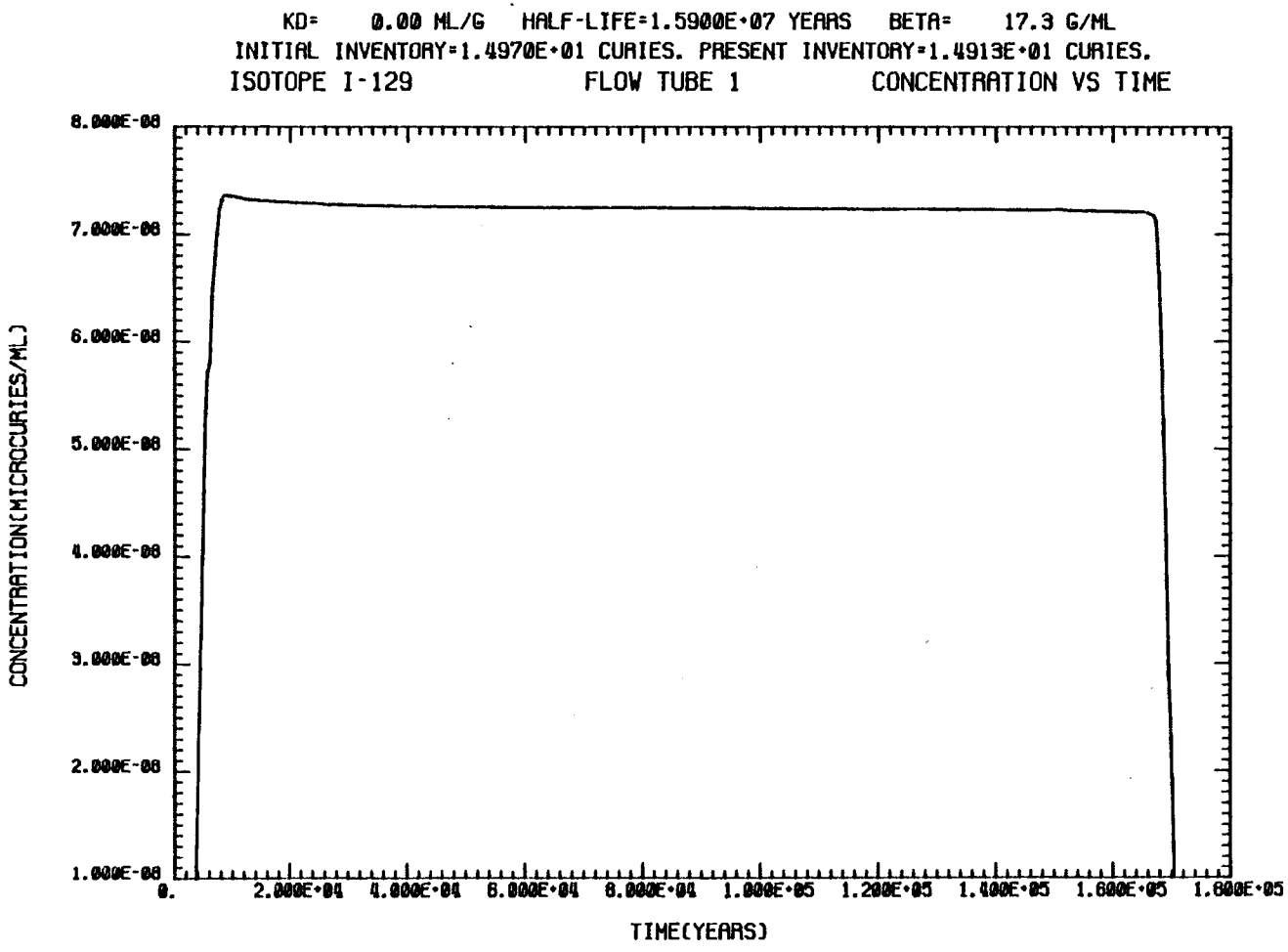


FIGURE 22. WISAP Predicted Malaga Bend Arrival Curve For I-129

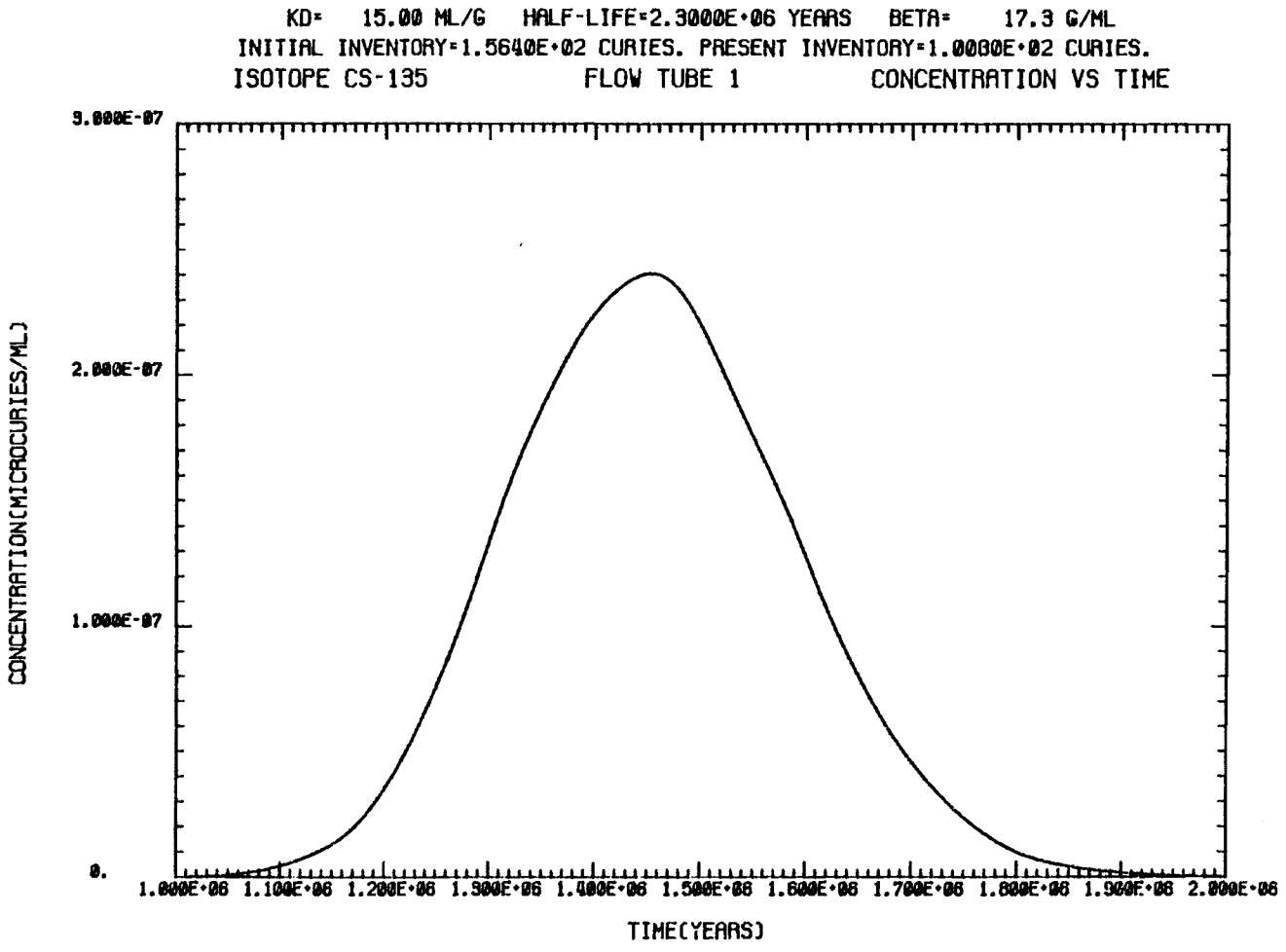


FIGURE 23. WISAP Predicted Malaga Bend Arrival Curve for Cs-135

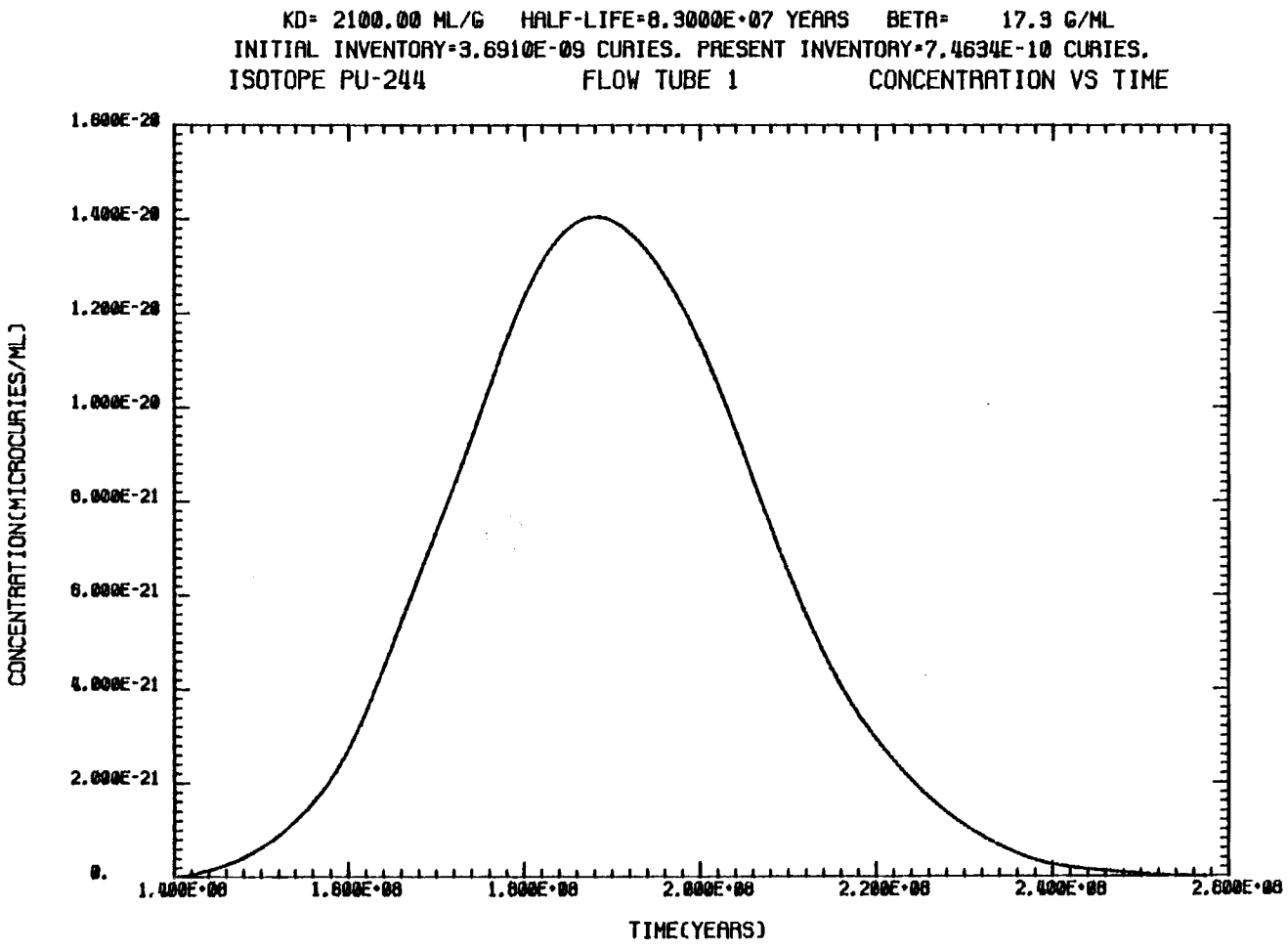


FIGURE 24. WISAP Predicted Alaga Bend Arrival Curve for Actinide Chain 1

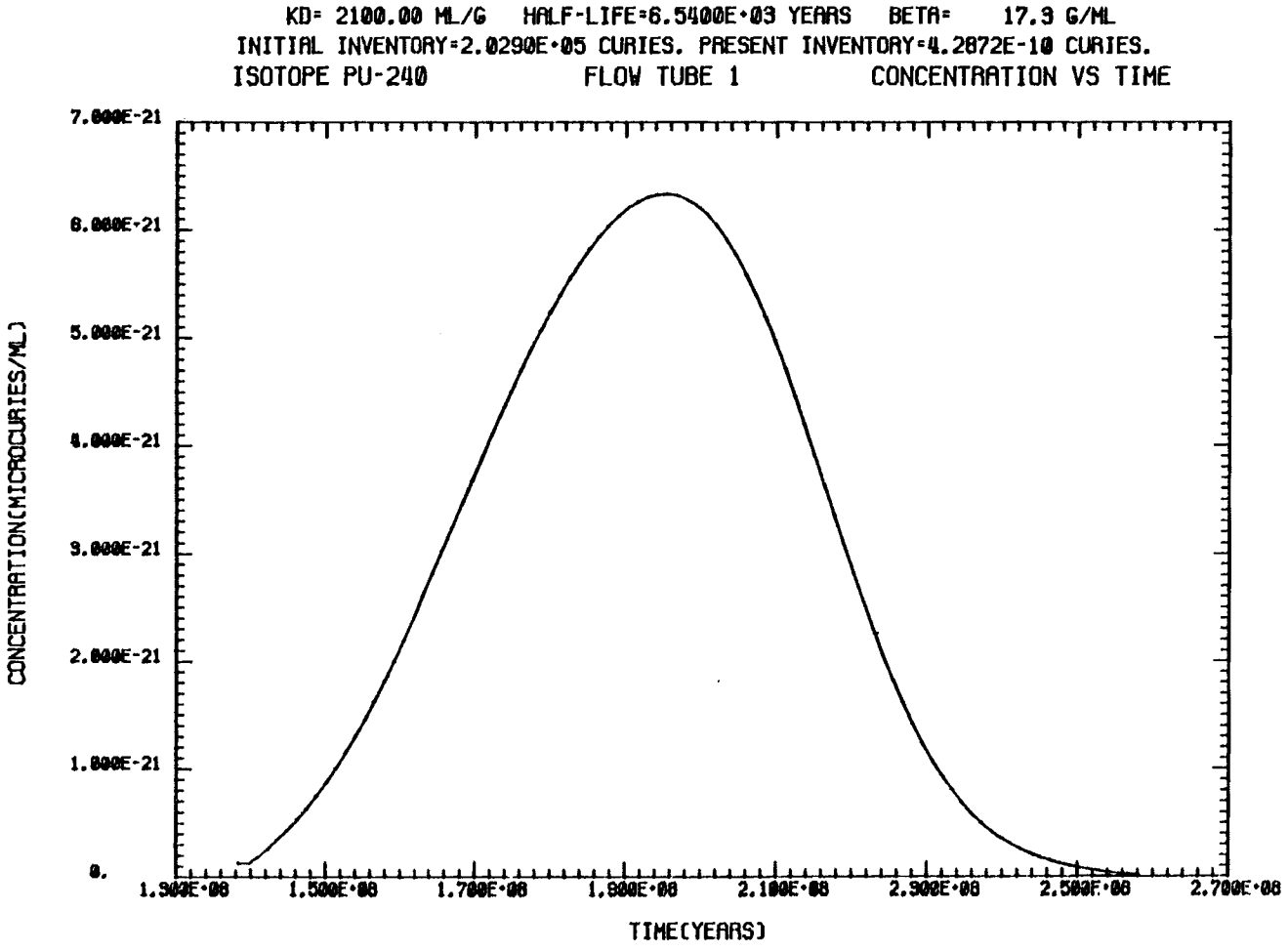


FIGURE 25. WISAP Predicted Malaga Bend Arrival Curve for Actinide Chain 1

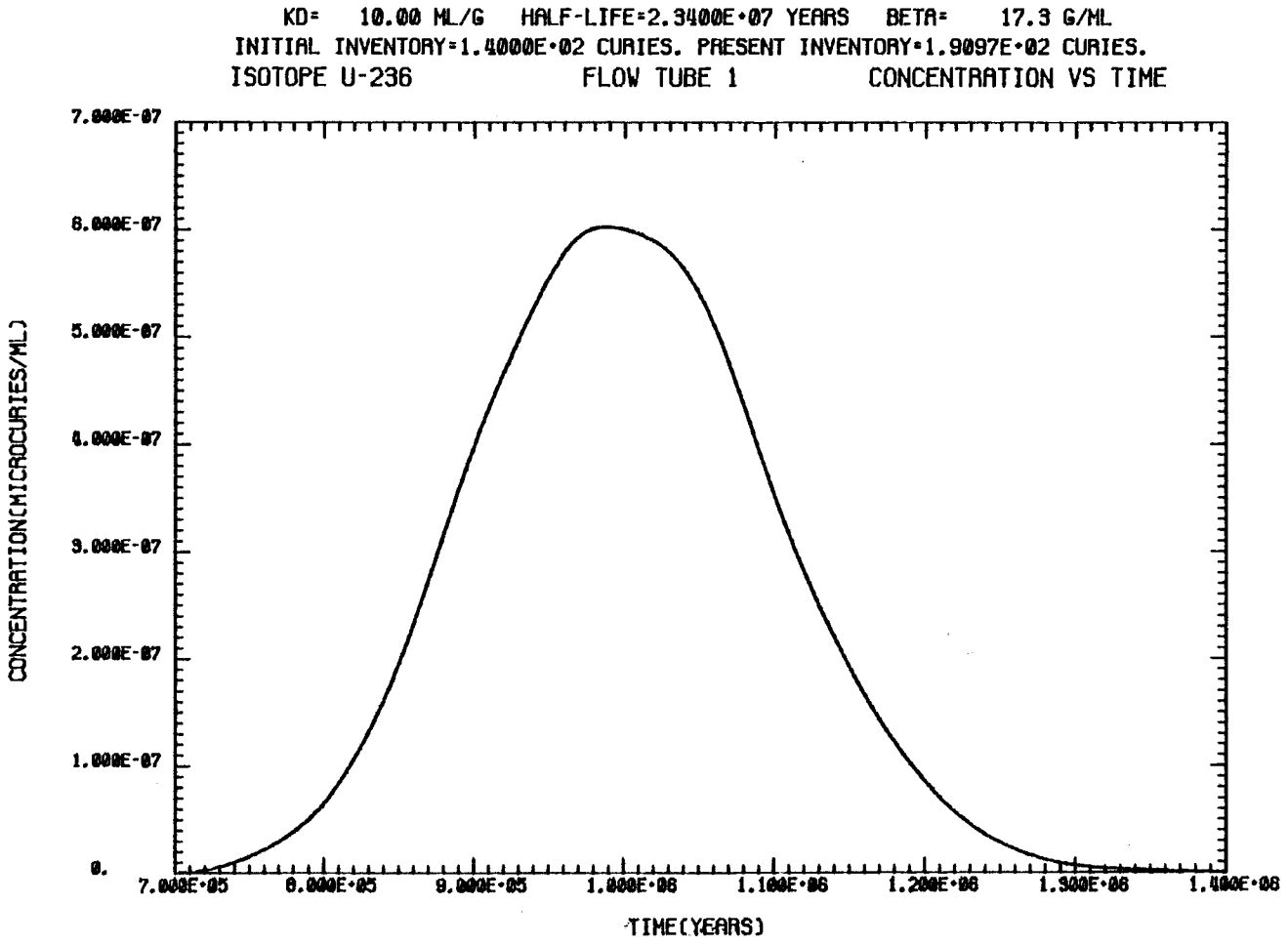


FIGURE 26. WISAP Predicted Malaga Bend Arrival for Actinide Chain 1

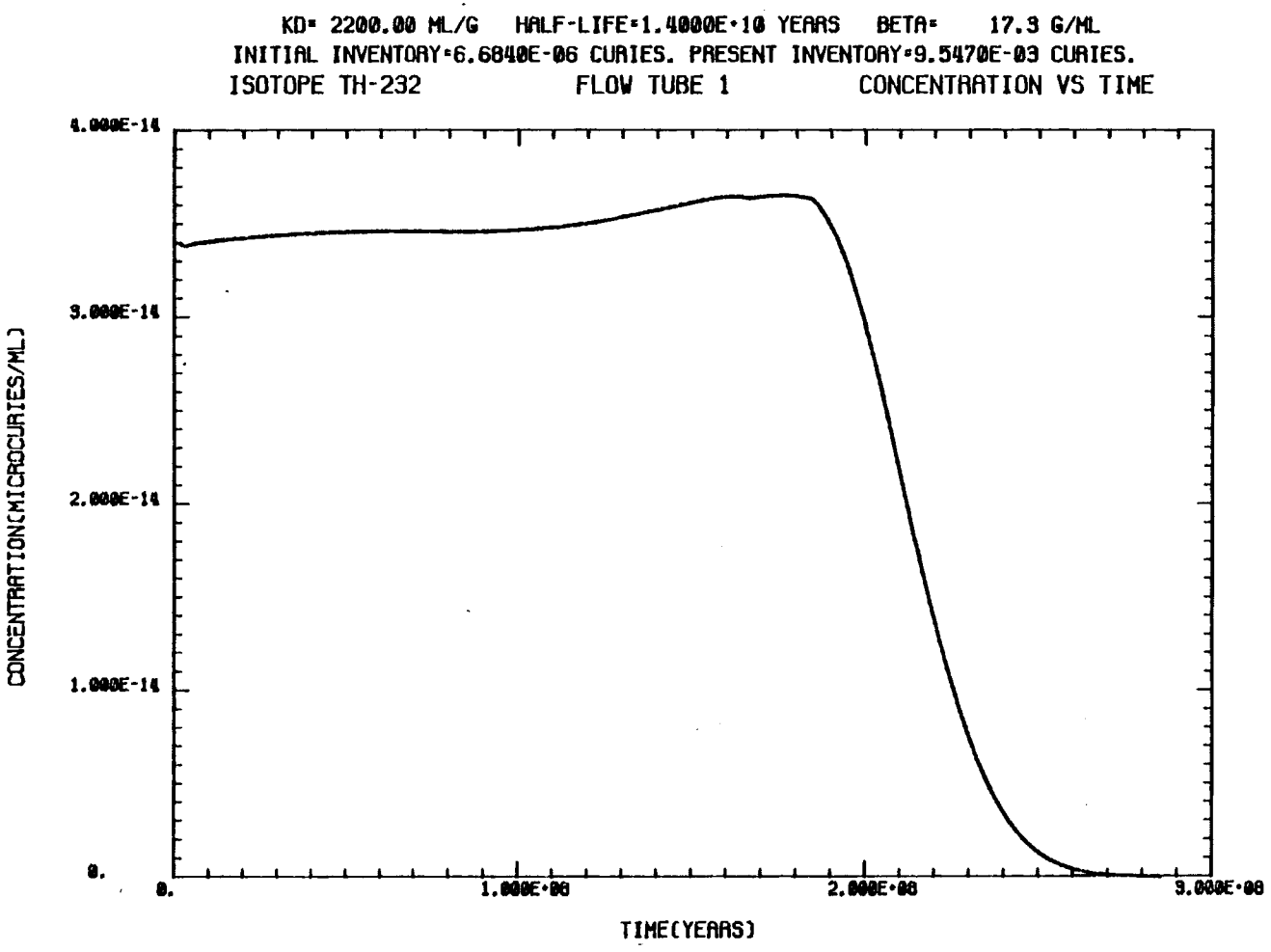


FIGURE 27. WISAP Predicted Malaga Bend Arrival for Actinide Chain 1

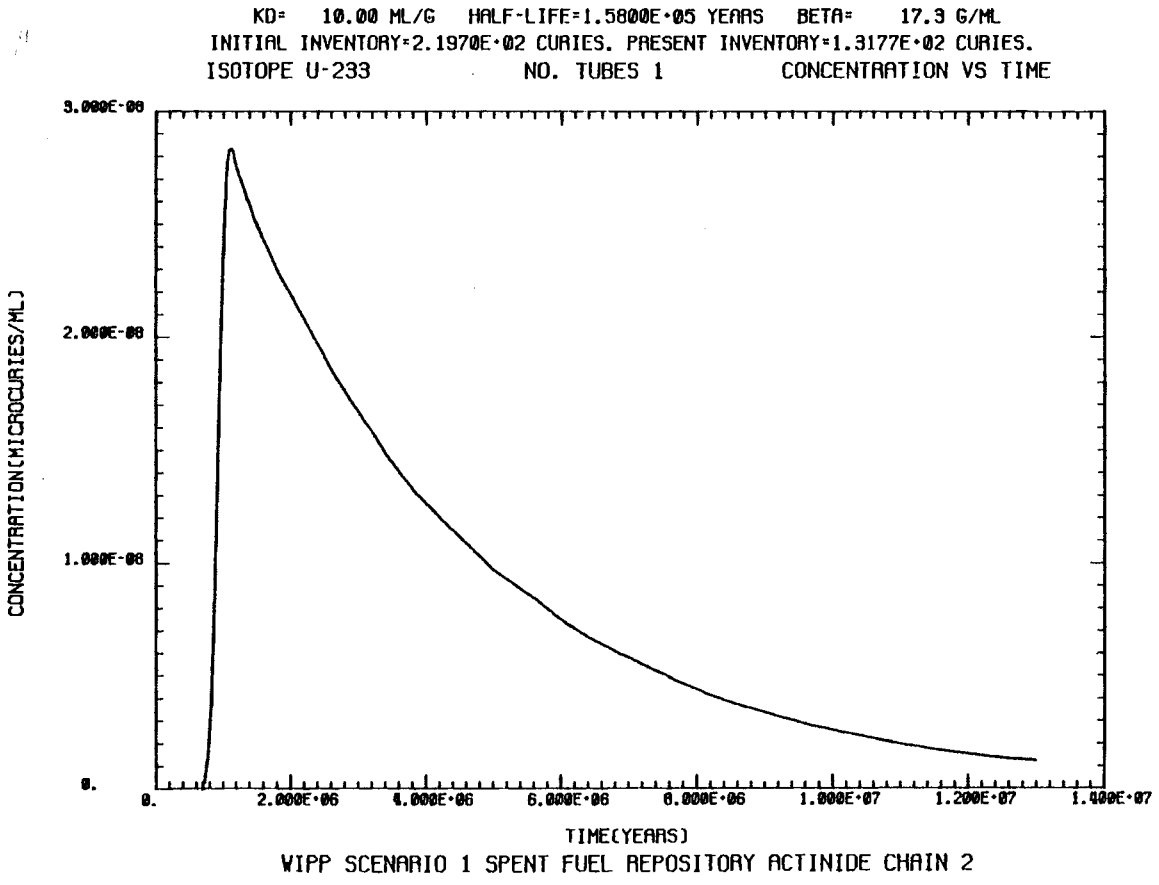


FIGURE 28. WISAP Predicted Malaga Bend Arrival for Actinide Chain 2

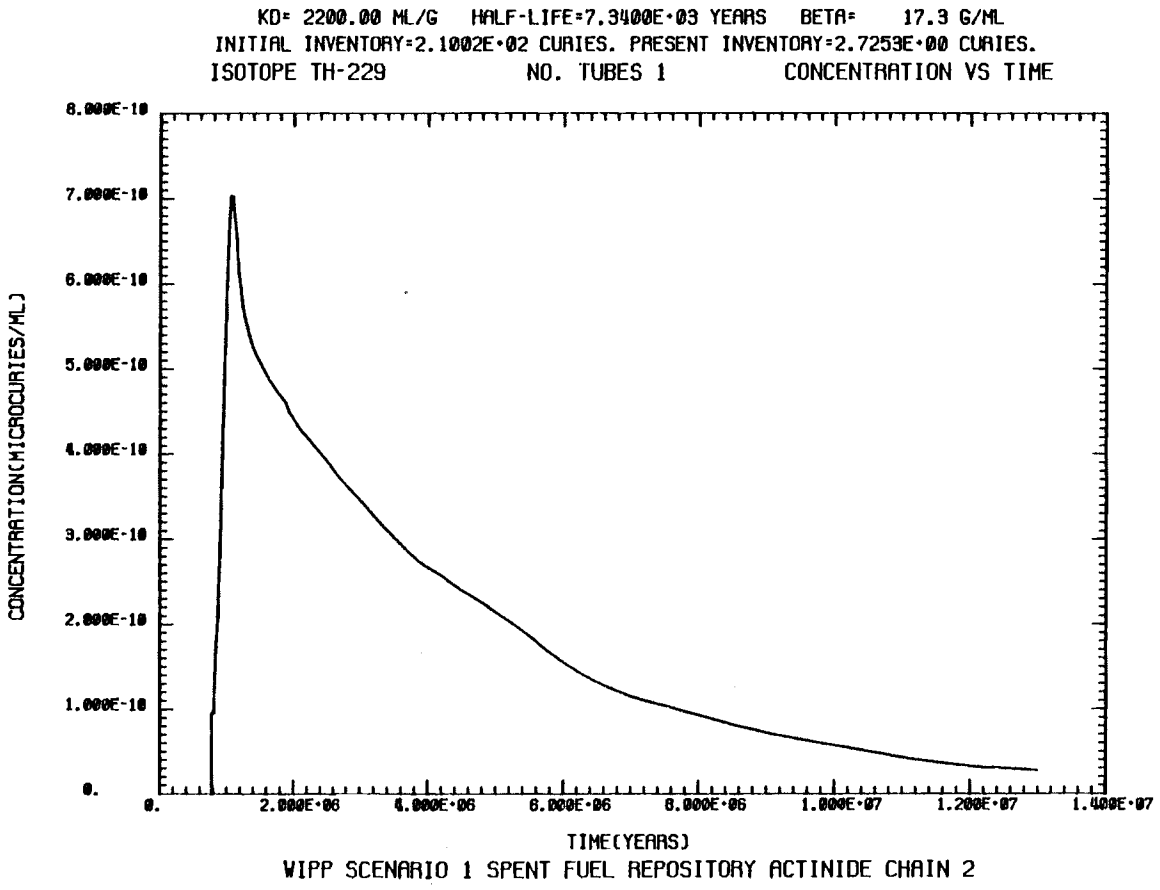


FIGURE 29. WISAP Predicted Malaga Bend Arrival for Actinide Chain 2

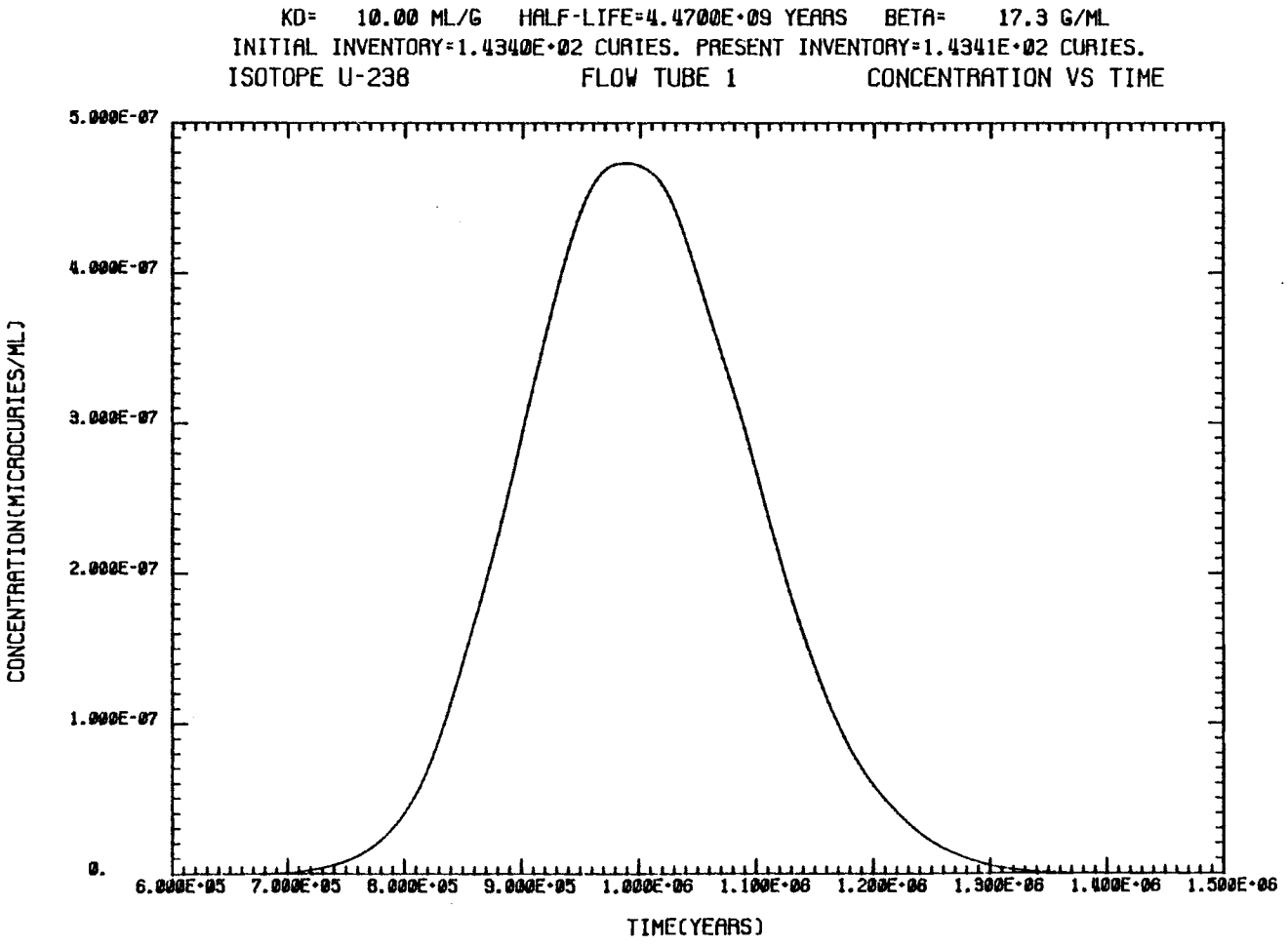


FIGURE 30. Malaga Bend Arrival for Actinide Chain 3

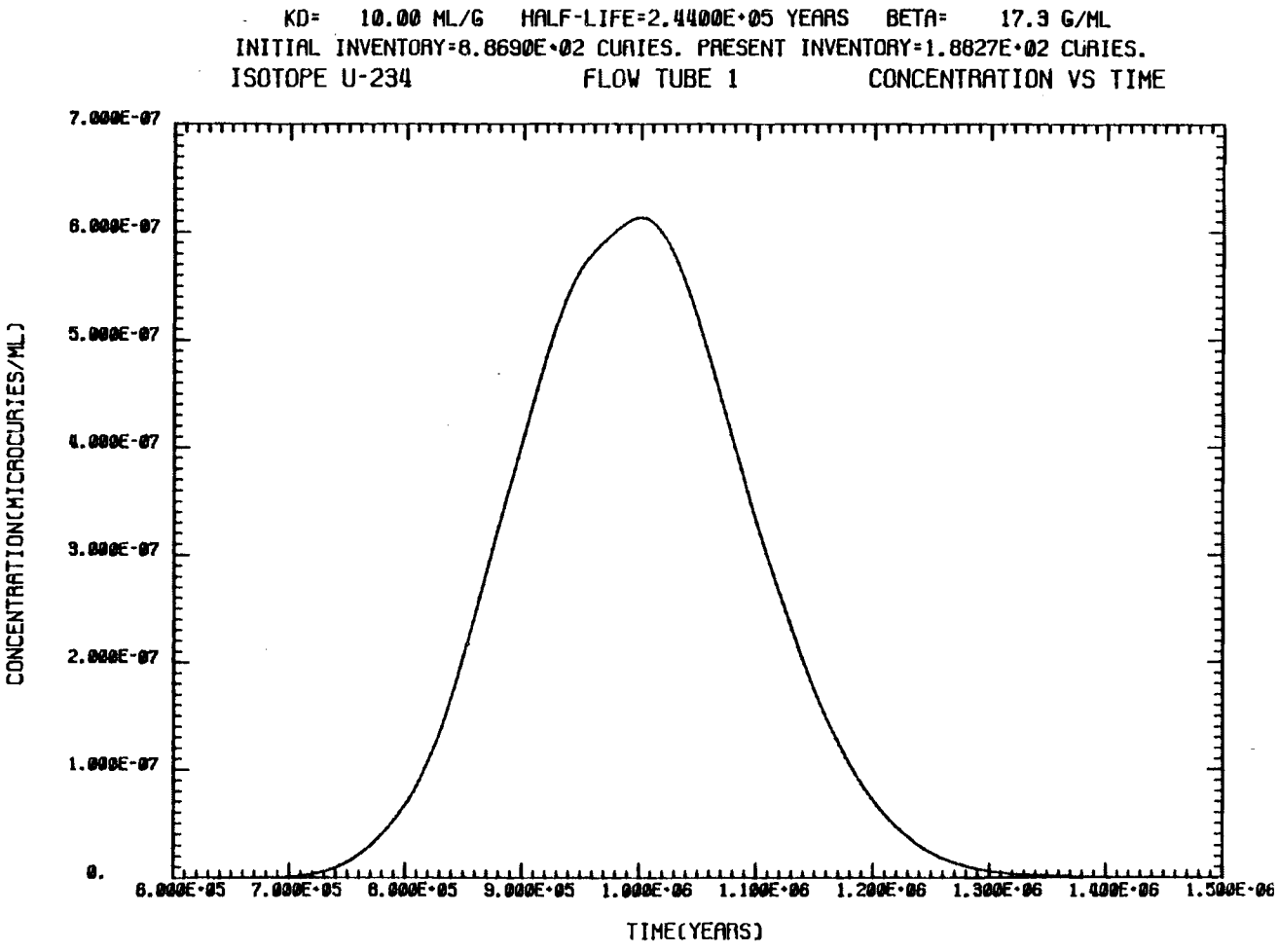


FIGURE 31. WISAP Predicted Malaga Bend Arrival for Actinide Chain 3

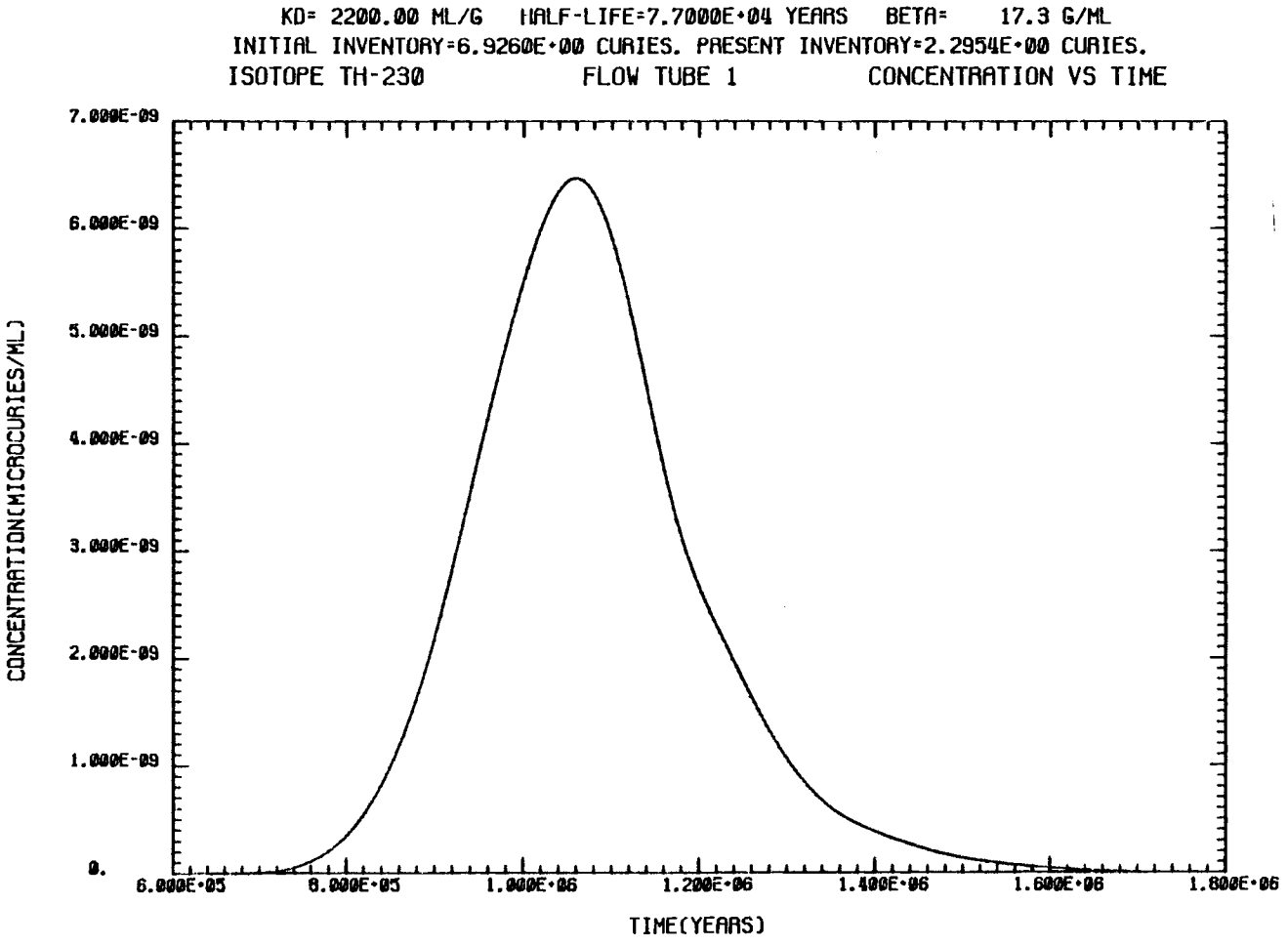


FIGURE 32. WISAP Predicted Malaga Bend Arrival for Actinide Chain 3

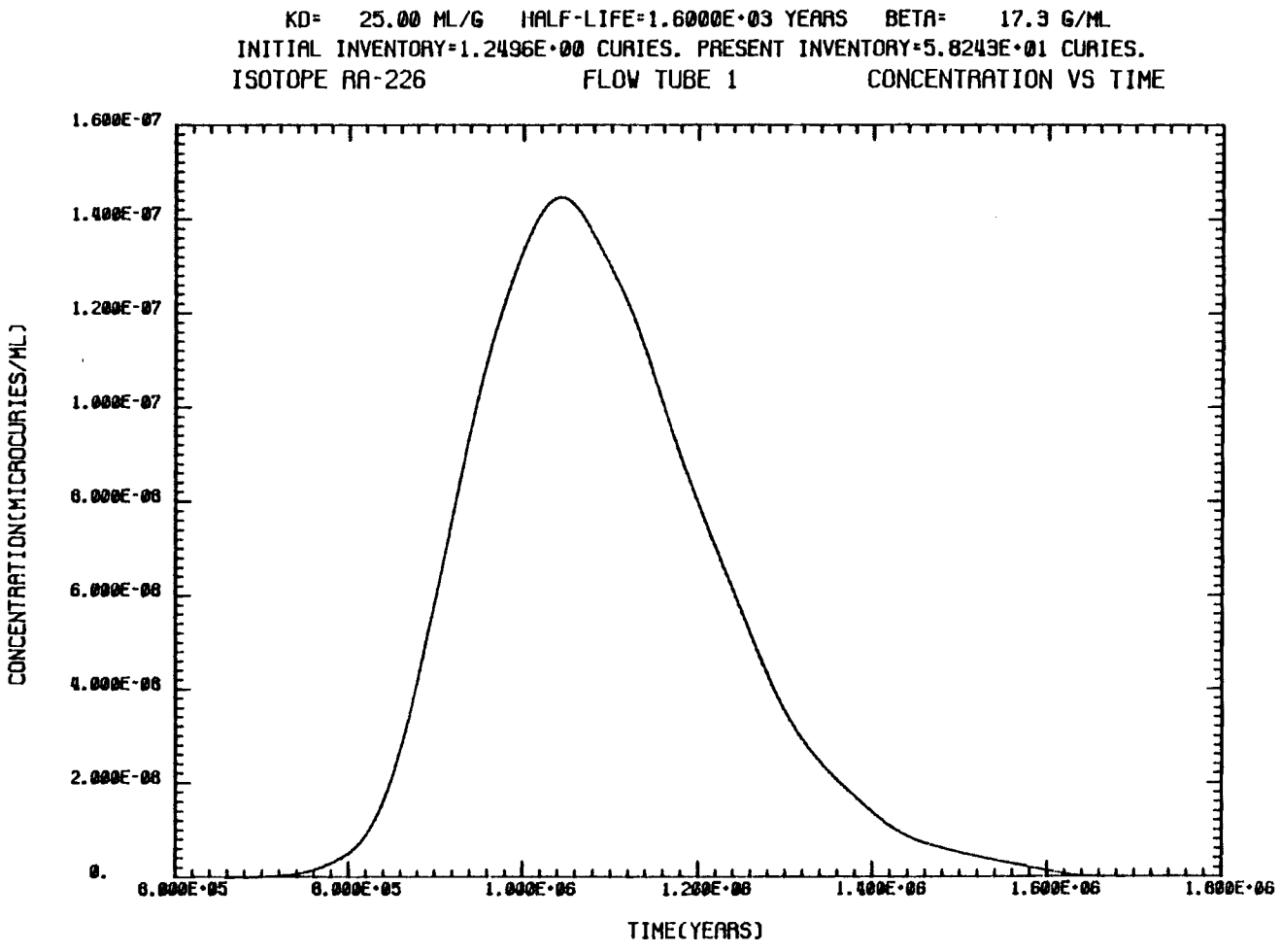


FIGURE 33. WISAP Predicted Malaga Bend Arrival for Actinide Chain 3

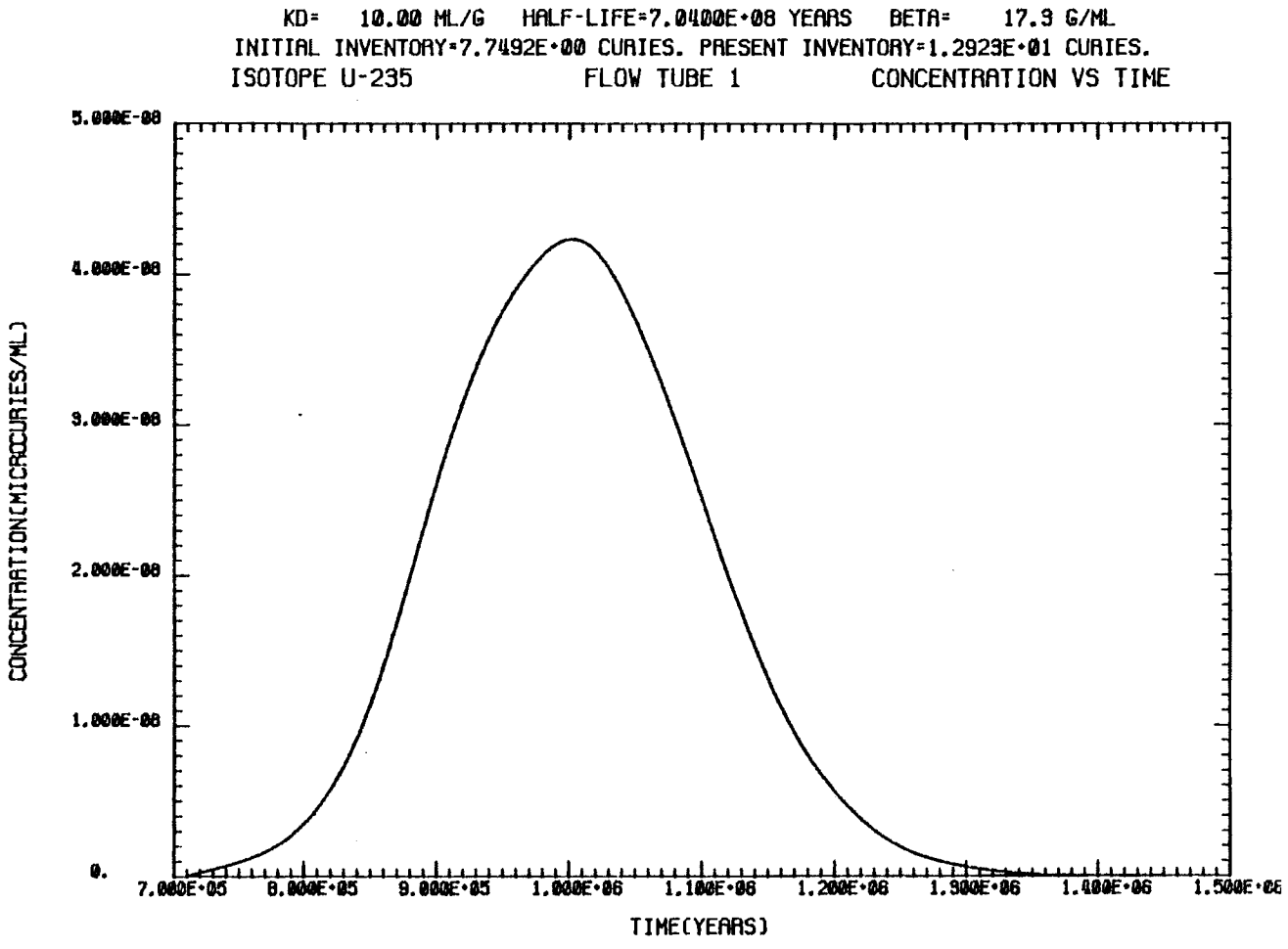


FIGURE 34. WISAP Predicted Malaga Bend Arrival for Actinide Chain 4

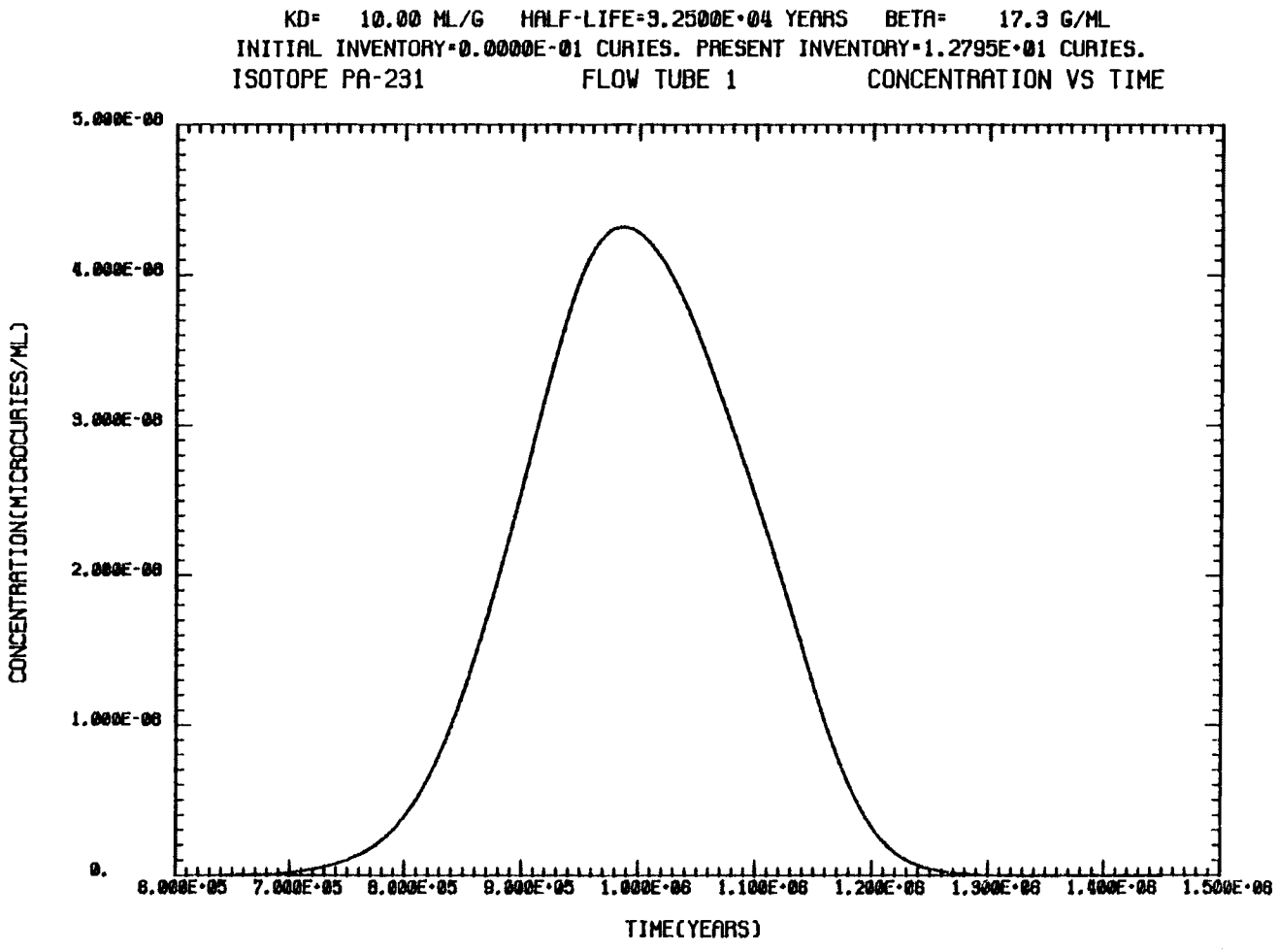


FIGURE 35. WISAP Predicted Malaga Bend Arrival for Actinide Chain 4

TABLE 9. Summary of the WISAP Transport Model Results for Malaga Bend Arrival

ISOTOPE	TOTAL CURIES RELEASED TO BIOSPHERE	RELEASE PERIOD (YEARS) MINIMUM TIME	RELEASE PERIOD (YEARS) MAXIMUM TIME	TIME OF PEAK RELEASE (YEARS)	MAXIMUM RATE OF RELEASE TO BIOSPHERE (CURIES/YEAR)	MAXIMUM CONCENTRATION IN GROUND WATER (MICRO-CURIES/ML)	RATIO OF GROUND WATER CONCENTRATION TO MPC**	MAXIMUM CONCENTRATION IN THE BIOSPHERE RIVER (MICRO-CURIES/ML)	RATIO OF BIOSPHERE RIVER CONCENTRATION TO MPC**
99-TC	5.02E+03	4.38E+03	1.70E+05	8.70E+03	3.97E-02	3.16E-05	1.05E-01	1.71E-06	5.70E-03
129-I	1.49E+01	4.38E+03	1.70E+05	8.70E+03	9.28E-05	7.39E-08	1.23E+00*	4.00E-09	6.66E-02
135-CS	1.01E+02	1.01E+06	2.00E+06	1.45E+06	3.02E-04	2.41E-07	2.41E-03	1.30E-08	1.30E-04
244-PU	7.46E-10	1.41E+08	2.57E+08	1.88E+08	1.76E-17	1.41E-20	3.52E-15	7.58E-22	1.90E-16
240-PU	4.29E-10	1.39E+08	2.60E+08	1.95E+08	7.96E-18	6.34E-21	1.27E-15	3.43E-22	6.86E-17
236-U	1.91E+02	7.02E+05	2.58E+08	9.88E+05	7.57E-04	6.03E-07	2.01E-02	3.26E-08	1.09E-03
232-TH	9.55E-03	7.66E+05	2.85E+08	1.76E+08	4.59E-11	3.65E-14	1.83E-08	1.98E-15	9.89E-10
237-NP	--------	--------	--------	--------	--------	--------	--------	--------	--------
233-U	1.40E+02	7.68E+05	3.33E+07	1.12E+06	3.56E-05	2.83E-08	9.43E-04	1.53E-09	5.11E-05
229-TH	2.80E+00	7.68E+05	3.33E+07	1.12E+06	8.80E-07	7.10E-10	1.01E-04	3.79E-11	5.42E-06
242-PU	--------	--------	--------	--------	--------	--------	--------	--------	--------
238-U	1.43E+02	6.75E+05	3.30E+07	9.86E+05	5.94E-04	4.73E-07	1.16E-02	2.56E-08	6.40E-04
234-U	1.89E+02	6.34E+05	3.30E+07	9.99E+05	7.70E-04	6.13E-07	2.04E-02	3.92E-08	1.11E-03
230-TH	2.30E+00	6.46E+05	3.30E+07	1.06E+06	8.12E-06	6.47E-07	3.23E-01	3.50E-10	1.75E-04
226-RA	6.20E+01	6.59E+05	3.30E+07	1.04E+06	1.82E-04	1.45E-07	4.83E+00*	7.84E-09	2.61E-01
243-AM	--------	--------	--------	--------	--------	--------	--------	--------	--------
239-PU	--------	--------	--------	--------	--------	--------	--------	--------	--------
235-U	1.29E+01	7.11E+05	3.51E+06	1.00E+06	5.31E-05	4.23E-08	1.41E-03	2.29E-09	7.63E-05
231-PA	1.28E+01	6.38E+05	3.44E+06	1.00E+06	5.40E-05	4.32E-08	4.80E-02	2.33E-09	2.59E-03

* INDICATES THAT THE ISOTOPE IS ABOVE MPC.
** MPC MAXIMUM PERMISSIBLE WATER CONCENTRATION
UNCONTROLLED WATER RADIATION STANDARD (MICRO-CI/ML).
-------- INDICATES THAT THE ISOTOPE DECAYED BEFORE REACHING BIOSPHERE.

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