Waste Isolation Pilot Plant

Compliance Certification Application

Reference 115

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Submitted in accordance with 40 CFR §194.13, Submission of Reference Materials.

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GROUND-WATER FLOW MODELING OF THE CULEBRA DOLOMITE - VOLUME II: DATA BASE

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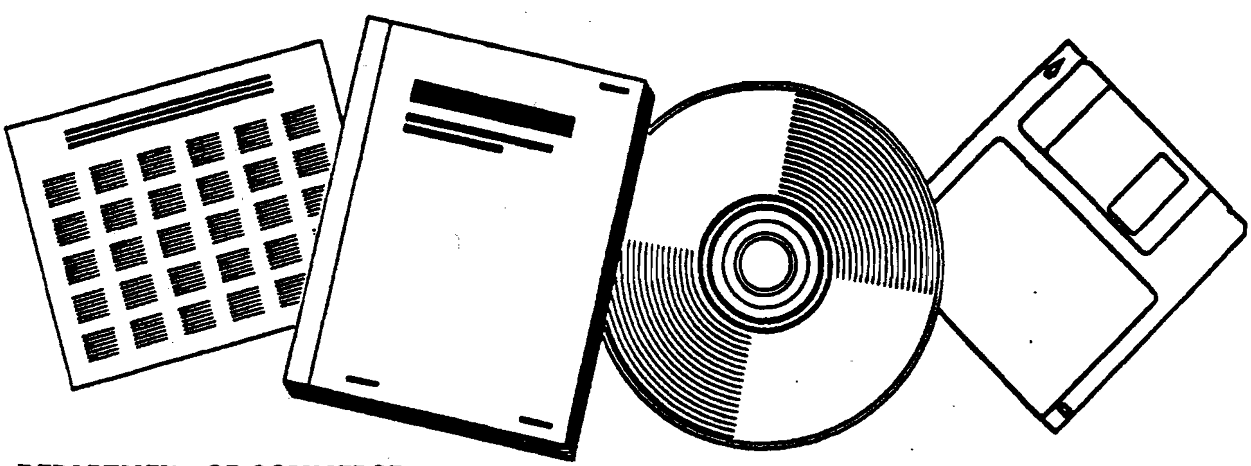

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Ground-Water Flow Modeling of the Culebra Dolomite

Volume II: Data Base

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6850 Austin Center Boulevard, Suite 300
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Prepared by Sandia National Laboratories Albuquerque, New Mexico 87185
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GROUND-WATER FLOW MODELING OF THE CULEBRA DOLOMITE

VOLUME II: DATA BASE*

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Austin, Texas 78731

* The work described in this report was done for Sandia National Laboratories under Contract No. 32-1025.

PREFACE

The objective of this report is to present and discuss the hydrogeologic data base for the Culebra dolomite at the WIPP site. The data base includes:

- coordinates of the WIPP-area boreholes,
- Culebra elevations,
- Culebra transmissivities,
- Culebra storativities,
- Culebra formation-fluid densities,
- borehole fluid-density histories for the WIPP-site boreholes,
- estimates of the uncertainty in the borehole-fluid densities and the uncertainty in the related equivalent-freshwater heads,
- transient freshwater heads,
- estimates of an undisturbed freshwater head, and the uncertainty in this value for the WIPP-site boreholes, and
- shaft construction, grouting, and inflow histories.

This report documents the hydrogeologic data base subsequently used in a study which modeled ground-water flow in the Culebra dolomite. The modeling study is given in a companion report "Ground-Water Flow Modeling of the Culebra Dolomite: Volume I - Model Calibration", SAND89-7068/1, by A.M. LaVenue, T.L. Cauffman, and J.F. Pickens

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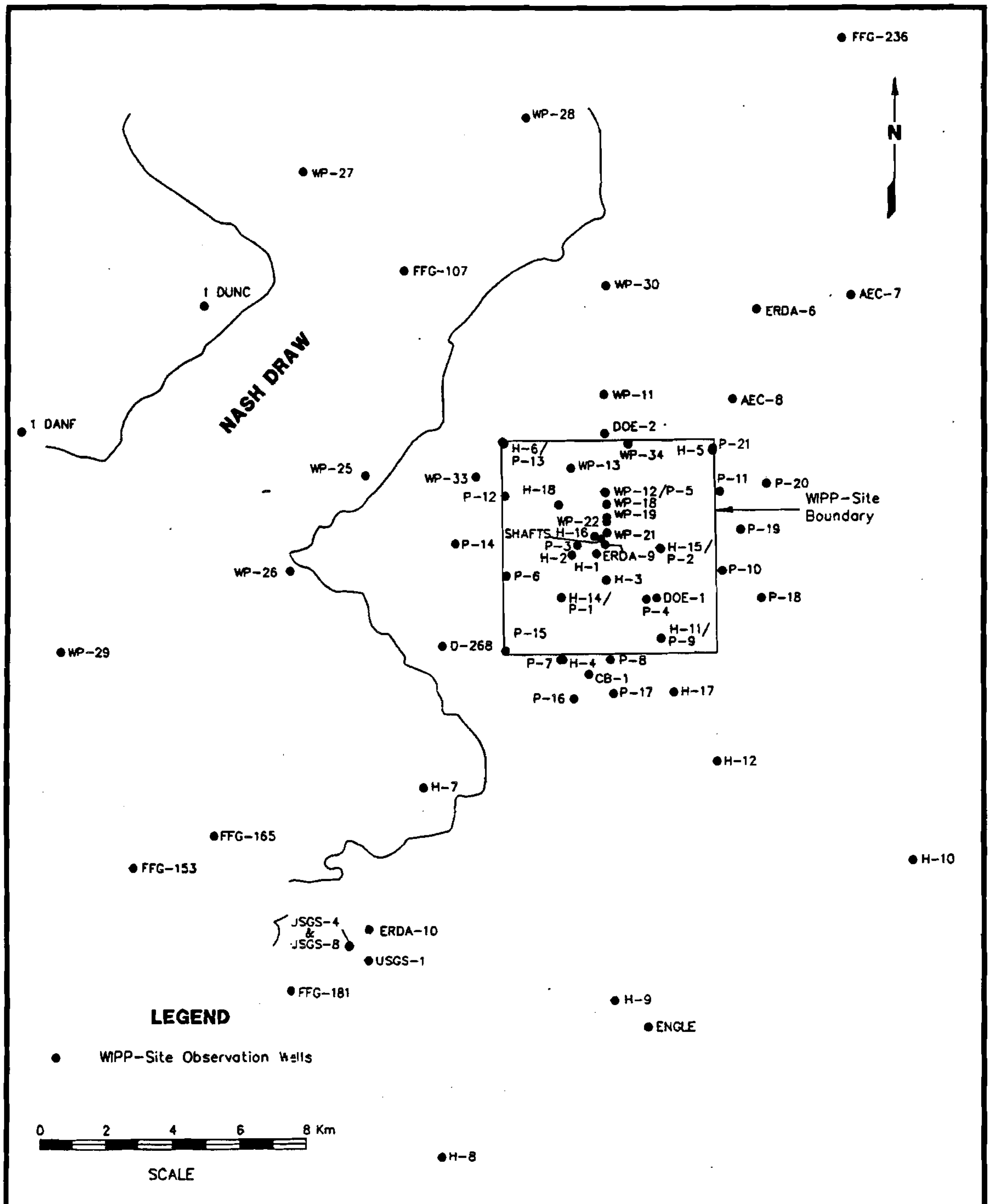
APPENDIX A: BOREHOLE COORDINATES

The Universal Transverse Mercator (UTM) coordinates for the WIPP-area boreholes (Figure A.1) are presented in Table A.1a-e. The UTM system is an internationally recognized coordinate system providing uniform world coverage using metric units. A comprehensive discussion of the UTM system is provided in Gonzales (1989). Most of the borehole coordinates were obtained from Gonzales (1989). The coordinates presented in Gonzales (1989) were calculated using the nearest NE section corner as a reference point. The U.S. Geological Survey provided the section-corner coordinates. These were obtained by digitizing and processing map data (Gonzales, 1989). An estimate of the accuracy of this process is +/-10 m (Gonzales, 1989).

The coordinates for boreholes having names beginning with FFG were calculated from the state coordinates presented in Richey (1989). The UTM's for the #1 Danforth and #1 Duncan boreholes were calculated from the section coordinates presented in Jones (1959).



Drawn by	ABW	Date	11/15/89	WIPP-Area Boreholes
Checked by	T.C.	Date	11/15/89	
Revisions		Date		
H09700R869			11/15/89	

INTERA Technologies

Figure A.1

WIPP-SITE OBSERVATION-WELL COORDINATES
Updated 02/01/90

OBSERVATION WELL	LOCATION SEC	T	R	UTM (1) COORDINATES m EAST	m NORTH
H-1	29	T22S	R31E	613423	3581684
H-2a	29	T22S	R31E	612663	3581641
H-2b1	29	T22S	R31E	612651	3581651
H-2b2	29	T22S	R31E	612661	3581649
H-2c	29	T22S	R31E	612666	3581668
H-3b1	29	T22S	R31E	613729	3580895
H-3b2	29	T22S	R31E	613701	3580906
H-3b3	29	T22S	R31E	613705	3580876
H-3d	29	T22S	R31E	613721	3580890
H-4a	5	T23S	R31E	612407	3578469
H-4b	5	T23S	R31E	612380	3578483
H-4c	5	T23S	R31E	612406	3578499
H-5a	15	T23S	R31E	616888	3584776
H-5b	15	T23S	R31E	616872	3584801
H-5c	15	T23S	R31E	616903	3584802
H-6a	18	T22S	R31E	610580	3584982
H-6b	18	T22S	R31E	610594	3585008
H-6c	18	T22S	R31E	610610	3584983
H-7a	14	T23S	R30E	608102	3574670
H-7b1	14	T23S	R30E	608124	3574648
H-7b2	14	T23S	R30E	608116	3574619
H-7c	14	T23S	R30E	608095	3574640
H-8a	23	T24S	R30E	608658	3563566
H-8b	23	T24S	R30E	608683	3563556
H-8c	23	T24S	R30E	608664	3563537
H-9a	4	T24S	R31E	613958	3568260
H-9b	4	T24S	R31E	613989	3568261
H-9c	4	T24S	R31E	613974	3568234
H-10a	20	T23S	R32E	622949	3572457
H-10b	20	T23S	R32E	622975	3572473
H-10c	20	T23S	R32E	622976	3572443

Drawn by T.C.	Date 10/12/89	WIPP-Area Borehole UTM Coordinates
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table A.1a

OBSERVATION WELL	LOCATION SEC	T	R	UTM (1) COORDINATES m EAST	m NORTH
H-11b1	33	T22S	R31E	615346	3579130
H-11b2	33	T22S	R31E	615348	3579107
H-11b3	33	T22S	R31E	615367	3579127
H-11b4	33	T22S	R31E	615301	3579131
H-12	15	T23S	R31E	617023	3575452
H-14	29	T22S	R31E	612341	3580354
H-15	28	T22S	R31E	615315	3581859
H-16	20	T22S	R31E	613369	3582212
H-17	3	T23S	R31E	615718	3577513
H-18	20	T22S	R31E	612264	3583166
DOE-1	28	T22S	R31E	615203	3580333
DOE-2	8	T22S	R31E	613683	3585294
P-1	29	T22S	R31E	612338	3580341
P-2	28	T22S	R31E	615316	3581848
P-3	20	T22S	R31E	612799	3581898
P-4	28	T22S	R31E	614935	3580319
P-5	17	T22S	R31E	613684	3583540
P-6	30	T22S	R31E	610609	3581084
P-7	5	T23S	R31E	612308	3578478
P-8	4	T23S	R31E	613830	3578467
P-9	33	T22S	R31E	615356	3579125
P-10	26	T22S	R31E	617087	3581203
P-11	23	T22S	R31E	617016	3583457
P-12	24	T22S	R30E	610456	3583452

Drawn by T.C.	Date 10/12/89	WIPP-Area Borehole UTM Coordinates
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table A.1b

OBSERVATION WELL	LOCATION SEC	T	R	UTM (1) COORDINATES m EAST	m NORTH
P-13	18	T22S	R31E	610531	3585029
P-14	24	T22S	R30E	609084	3581976
P-15	31	T22S	R31E	610624	3578747
P-16	5	T23S	R31E	612695	3577321
P-17	4	T23S	R31E	613926	3577466
P-18	26	T22S	R31E	618367	3580350
P-19	23	T22S	R31E	617681	3582418
P-20	14	T22S	R31E	618532	3583768
P-21	15	T22S	R31E	616898	3584849
WIPP-11	9	T22S	R31E	613791	3586475
WIPP-12	17	T22S	R31E	613710	3583524
WIPP-13	17	T22S	R31E	612644	3584247
WIPP-18	20	T22S	R31E	613735	3583179
WIPP-19	20	T22S	R31E	613739	3582782
WIPP-21	20	T22S	R31E	613743	3582319
WIPP-22	20	T22S	R31E	613739	3582653
WIPP-25	15	T22S	R30E	606385	3584028
WIPP-26	29	T22S	R30E	604014	3581162
WIPP-27	21	T21S	R30E	604426	3593079
WIPP-28	18	T21S	R31E	611266	3594680
WIPP-29	34	T22S	R29E	596981	3578694
WIPP-30	33	T21S	R31E	613721	3589701
WIPP-33	13	T22S	R30E	609630	3584019

Drawn by T.C.	Date 10/12/89	WIPP-Area Borehole UTM Coordinates
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table A.1c

OBSERVATION WELL	LOCATION SEC	T	R	UTM (1) COORDINATES m EAST	m NORTH
WIPP-34	9	T22S	R31E	614334	3585142
ERDA-6	35	T21S	R31E	618220	3589008
ERDA-9	20	T22S	R31E	613696	3581958
ERDA-10	34	T23S	R30E	606685	3570515
CABIN BABY-1	5	T23S	R31E	613191	3578049
ENGLE	4	T24S	R31E	614953	3567454
USGS-1	34	T23S	R30E	606462	3569459
USGS-4	34	T23S	R30E	605841	3569887
USGS-8	34	T23S	R30E	605879	3569888
D-268	35	T22S	R30E	608702	3578877
AEC-7	31	T21S	R32E	621126	3589381
AEC-8	11	T22S	R31E	617525	3586442
WH. SHAFT	20	T22S	R31E	613579	3582079
C&SH SHAFT	20	T22S	R31E	613571	3582201
EX. SHAFT	20	T22S	R31E	613717	3582080
AI. SHAFT	20	T22S	R31E	613381	3582200
FFG-107	26	T21S	R30E	607461	3590055
FFG-153	24	T23S	R29E	599239	3572224
FFG-165	19	T23S	R30E	601859	3573206
FFG-181	5	T24S	R30E	604215	3568693
FFG-188*	20	T24S	R30E	603881	3562585
FFG-225*	1	T21S	R32E	629277	3596967
FFG-236	6	T21S	R32E	620854	3597026
FFG-244*	35	T21S	R32E	627179	3589332

Drawn by T.C.	Date 10/12/89	WIPP-Area Borehole UTM Coordinates
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table A.1d

OBSERVATION WELL	LOCATION SEC	T	R	UTM (1) COORDINATES m EAST	m NORTH
FFG-426*	19	T21S	R29E	592523	3591566
1 DANF	9	T22S	R29E	595800	3585222
1 DUNC	31	T21S	R30E	601312	3588916
WIPP-SITE BOUNDARY					
NE CORNER				616941	3585109
NW CORNER				610495	3585068
SE CORNER				617015	3578681
SW CORNER				610567	3578623

(1) UTM abbreviates Universal Transverse Mercator

* Not plotted on Figure A.1 because they fall beyond the boundary of the figure. These wells were used to improve Culebra contouring along the margins of the model area.

Drawn by T.C.	Date 10/12/89	WIPP-Area Borehole UTM Coordinates
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table A.1e

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Gonzales, M.M., 1989. Compilation and Comparison of Test-Hole Location Surveys in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site. Sandia National Laboratories, SAND88-1065.

Jones, C.L., 1959. Thickness, Character, and Structure of the Upper Permian Evaporites in Part of Eddy County, Southeast New Mexico. U.S. Geological Survey, Trace Elements Memorandum Report #1033, 19 p.

Richey, S., 1989. Geologic and Hydrologic Data for the Rustler Formation Near the Waste Isolation Pilot Plant, Southeastern New Mexico. U.S. Geological Survey, Open File Report 89-32.

APPENDIX B: CULEBRA ELEVATIONS

The Culebra elevations, in meters above mean sea level (m amsl), in the WIPP-area boreholes are presented in Table B.1a-d. The elevations are calculated from the referenced ground-surface elevations and the stratigraphic information taken from data sources for these particular boreholes. Gonzales (1989) was the reference used for the ground-surface-elevation values.

The depths below ground surface (BGS) to the Culebra top, center, and bottom are listed in Table B.1a-d and were obtained from INTERA (1987) for most boreholes. These values are presented in meters below ground surface. The elevations of the top, center, and bottom of the Culebra in meters above mean sea level are also listed in Table B.1a-d. These values are calculated from the surface elevations and depth values.

The depths to the top of the Culebra for FFG-107, FFG-165, FFG-181, FFG-225, FFG-236, FFG-244, and FFG-426 and to the base of the Culebra for FFG-153 and FFG-188 were obtained from Richey (1989). The depths to the Culebra top in the #1 Danforth and #1 Duncan boreholes were taken from Jones (1959). A Culebra thickness equal to that at the nearest borehole at which the Culebra thickness is known was assumed for the FFG, #1 Danford, and #1 Duncan wells. The actual Culebra thicknesses at the FFG wells range from 5.5 to 10.6 m.

ELEVATION DATA BASE Updated 02/01/90

WELL	REFERENCE ELEVATION m amsl(1)	CULEBRA DEPTH m bgs(2) Top	Center	Bottom	CULEBRA ELEVATION m amsl(1) Top	Center	Bottom	CULEBRA THICKNESS m
H-1	1035.68	206.04	209.55	213.06	829.64	826.13	822.62	7.01
H-2a	1029.55	189.89	193.24	196.60	839.66	836.31	832.95	6.71
H-2b1	1029.50	190.20	192.94	195.68	839.30	836.56	833.82	5.49
H-2b2	1029.49	189.89	193.24	196.60	839.60	836.25	832.90	6.71
H-2c	1029.52	190.20	192.94	195.68	839.32	836.58	833.84	5.49
H-3b1	1033.04	204.22	207.87	211.53	828.82	825.17	821.51	7.32
H-3b2	1033.07	206.04	209.70	213.36	827.03	823.37	819.71	7.32
H-3b3	1032.71	205.13	208.64	212.14	827.58	824.07	820.57	7.01
H-4a	1015.84	151.18	154.84	158.50	864.66	861.01	857.35	7.32
H-4b	1015.80	149.35	153.31	157.28	866.45	862.48	858.52	7.92
H-4c	1016.04	149.35	153.31	157.28	866.69	862.73	858.76	7.92
H-5a	1068.49	273.41	276.91	280.42	795.09	791.58	788.08	7.01
H-5b	1068.44	273.41	276.91	280.42	795.03	791.53	788.02	7.01
H-5c	1068.56	274.02	277.83	281.64	794.55	790.74	786.93	7.62
H-6a	1020.24	184.10	187.60	191.11	836.15	832.64	829.14	7.01
H-6b	1020.34	184.10	187.60	191.11	836.24	832.73	829.23	7.01
H-6c	1020.45	184.10	187.60	191.11	836.35	832.84	829.34	7.01
H-7b1	964.25	72.24	77.88	83.52	892.01	886.37	880.73	11.28
H-7b2	964.35	72.24	77.88	83.52	892.11	886.47	880.83	11.28
H-7c	964.21	72.24	77.88	83.52	891.97	886.33	880.69	11.28
H-8b	1046.34	179.22	183.18	187.15	867.12	863.16	859.19	7.92
H-8c	1046.14	179.22	183.18	187.15	866.92	862.96	858.99	7.92
H-9a	1038.16	197.21	201.78	206.35	840.95	836.38	831.81	9.14
H-9b	1038.21	197.21	201.78	206.35	841.00	836.43	831.86	9.14
H-9c	1038.31	197.21	201.78	206.35	841.10	836.53	831.96	9.14
H-10b	1124.32	414.53	419.25	423.98	709.79	705.07	700.34	9.45
H-10c	1124.14	414.53	419.25	423.98	709.61	704.89	700.16	9.45
H-11b1	1039.68	222.50	226.47	230.43	817.18	813.21	809.25	7.92
H-11b2	1039.75	223.42	227.08	230.73	816.33	812.67	809.02	7.32
H-11b3	1039.99	223.72	227.53	231.34	816.27	812.46	808.65	7.62
H-11b4	1039.32	220.37	223.88	227.38	818.95	815.44	811.94	7.01

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Ground-Surface and Culebra Dolomite Elevations for WIPP-Area Boreholes

INTERA Technologies

Table B.1a

WELL	REFERENCE ELEVATION m amsl(1)	CULEBRA DEPTH m bgs(2) Top	Center	Bottom	CULEBRA ELEVATION m amsl(1) Top	Center	Bottom	CULEBRA THICKNESS m
H-12	1044.24	250.85	254.97	259.08	793.39	789.27	785.16	8.23
H-14	1019.70	166.12	170.23	174.35	853.58	849.47	845.35	8.23
H-15	1060.77	262.43	265.79	269.14	798.34	794.98	791.63	6.71
H-16	1039.25	214.12	217.46	220.80	825.13	821.79	818.45	6.68
H-17	1031.45	215.13	219.03	222.93	816.32	812.42	808.52	7.80
H-18	1040.39	209.89	213.57	217.26	830.50	826.82	823.13	7.37
DOE-1	1056.16	249.94	253.44	256.95	806.23	802.72	799.22	7.01
DOE-2	1041.89	251.16	254.51	257.86	790.73	787.38	784.03	6.71
P-1	1019.50	163.98	168.10	172.21	855.52	851.40	847.29	8.23
P-2	1060.00	261.21	265.18	269.14	798.79	794.82	790.86	7.92
P-3	1031.00	195.68	199.19	202.69	835.32	831.81	828.31	7.01
P-4	1048.90	236.22	240.33	244.45	812.68	808.57	804.45	8.23
P-5	1058.20	245.06	248.56	252.07	813.14	809.64	806.13	7.01
P-6	1022.20	163.68	167.18	170.69	858.52	855.02	851.51	7.01
P-7	1015.50	151.18	155.14	159.11	864.32	860.36	856.39	7.92
P-8	1016.90	171.60	175.41	179.22	845.30	841.49	837.68	7.62
P-9	1038.90	223.72	227.23	230.73	815.18	811.67	808.17	7.01
P-10	1069.40	283.77	287.73	291.69	785.63	781.67	777.71	7.92
P-11	1068.60	277.98	281.94	285.90	790.62	786.66	782.70	7.92
P-12	1029.00	192.94	196.44	199.95	836.06	832.56	829.05	7.01
P-13	1019.70	184.10	187.60	191.11	835.60	832.10	828.59	7.01
P-14	1024.05	174.65	178.00	181.36	849.40	846.05	842.69	6.71
P-15	1008.82	125.88	129.24	132.59	882.94	879.58	876.23	6.71

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Ground-Surface and Culebra Dolomite Elevations for WIPP-Area Boreholes

INTERA Technologies

Table B.1b

WELL	REFERENCE ELEVATION m amsl(1)	CULEBRA DEPTH m bgs(2) Top	Center	Bottom	CULEBRA ELEVATION m amsl(1) Top	Center	Bottom	CULEBRA THICKNESS m
P-16	1012.80	152.40	155.91	159.41	860.40	856.89	853.39	7.01
P-17	1016.74	170.08	173.89	177.70	846.66	842.85	839.04	7.62
P-18	1059.88	277.98	282.24	286.51	781.90	777.64	773.37	8.53
P-19	1080.90	294.74	299.31	303.89	786.16	781.59	777.01	9.14
P-20	1082.90	290.47	294.44	298.40	792.43	788.46	784.50	7.92
P-21	1069.90	274.02	277.83	281.64	795.88	792.07	788.26	7.62
WIPP-11	1044.25	257.25	260.76	264.26	787.00	783.49	779.99	7.01
WIPP-12	1058.05	246.89	250.70	254.51	811.16	807.35	803.54	7.62
WIPP-13	1037.96	213.66	217.17	220.68	824.30	820.79	817.28	7.01
WIPP-18	1053.51	239.88	243.08	246.28	813.63	810.43	807.23	6.40
WIPP-19	1046.40	230.43	233.93	237.44	815.97	812.47	808.96	7.01
WIPP-21	1041.53	222.20	225.86	229.51	819.33	815.68	812.02	7.32
WIPP-22	1044.18	226.16	229.51	232.87	818.02	814.67	811.31	6.71
WIPP-25	979.16	136.25	140.06	143.87	842.91	839.10	835.29	7.62
WIPP-26	960.65	56.69	60.20	63.70	903.95	900.45	896.94	7.01
WIPP-27	968.40	89.00	92.96	96.93	879.40	875.43	871.47	7.92
WIPP-28	1020.05	128.02	131.98	135.94	892.03	888.07	884.11	7.92
WIPP-29	907.37	3.66	8.23	12.80	903.72	899.14	894.57	9.14
WIPP-30	1044.70	192.33	195.68	199.03	852.37	849.01	845.66	6.71
ERDA-6	1079.05	216.41	220.22	224.03	862.64	858.83	855.02	7.62
ERDA-9	1039.00	214.58	218.08	221.59	824.42	820.92	817.41	7.01
ERDA-10	1027.50	145.08	149.35	153.62	882.42	878.15	873.88	8.53
CB-1	1014.15	153.31	157.28	161.24	860.84	856.88	852.91	7.92

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INTERA Technologies		Table B.1c

WELL	REFERENCE ELEVATION m amsl(1)	CULEBRA DEPTH m bgs(2)			CULEBRA ELEVATION m amsl(1)			CULEBRA THICKNESS m
		Top	Center	Bottom	Top	Center	Bottom	
ENGLE	1042.00	200.86	204.22	207.57	841.14	837.78	834.43	6.71
USGS-1	1044.12	157.58	162.46	167.33	886.54	881.66	876.79	9.75
USGS-4	1040.22	142.88	148.03	153.18	897.34	892.19	887.04	10.30
USGS-6	1036.32	151.79	156.97	162.15	884.53	879.35	874.17	10.36
USGS-7	1036.93	156.67	161.39	166.12	880.26	875.54	870.81	9.45
USGS-8	1039.52	140.21	145.39	150.57	899.31	894.13	888.95	10.36
D-268	999.30	112.47	115.97	119.48	886.83	883.32	879.82	7.01
AEC-7	1114.73	265.18	269.14	273.10	849.55	845.59	841.63	7.92
AEC-8	1076.60	253.90	257.86	261.82	822.70	818.74	814.78	7.92
FFG-107	987.6	99.70	103.66	107.62	887.90	883.94	879.98	7.92
FFG-153	917.1	7.50	11.35	15.20	909.60	905.75	901.90	7.7
FFG-165	935.7	22.90	28.54	34.18	912.80	907.16	901.52	11.3
FFG-181	1016.5	86.00	89.96	93.92	930.50	926.54	922.58	7.92
FFG-188	979.0	133.71	137.56	141.41	845.29	841.44	837.59	7.7
FFG-225	1138.3	534.80	538.76	542.72	603.50	599.54	595.58	7.92
FFG-236	1101.2	418.50	422.46	426.42	682.70	678.74	674.78	7.92
FFG-244	1120.0	398.70	402.66	406.62	721.30	717.34	713.38	7.92
FFG-426	996.1	69.20	73.16	77.12	926.90	922.94	918.98	7.92
1 DANF	989.4	24.38	28.19	32.00	965.02	961.21	957.40	7.62
1 DUNC	1011.9	39.62	42.67	45.72	972.28	969.23	966.18	6.10

(1) amsl abbreviates above mean sea level
(2) bgs abbreviates below ground surface

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Checked by T.C.	Date 10/12/89	
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INTERA Technologies		Table B.1d

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Jones, C.L., 1959. Thickness, Character, and Structure of the Upper Permian Evaporites in Part of Eddy County, Southeast New Mexico. U.S. Geological Survey, Trace Elements Memorandum Report #1033, 19 p.

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APPENDIX C: CULEBRA TRANSMISSIVITIES

The Culebra transmissivity data base is presented in Table C.1a-g. For each borehole or hydropad location, Table C.1a-g contains:

- The reference for the cited transmissivity value
- The types of tests performed
- The transmissivity value in ft^2/day as presented in the literature
- The transmissivity converted to m^2/s and its $\log_{10}$ value
- The selected transmissivity values used in determining the representative value (see below for explanation)
- The average log transmissivity of the selected values
- The representative borehole or hydropad transmissivity value (and associated log value) used in the modeling
- Comments
- Specification, where appropriate, of interference-test transmissivity values which may be considered for use at pilot-points (denoted by a plus sign)

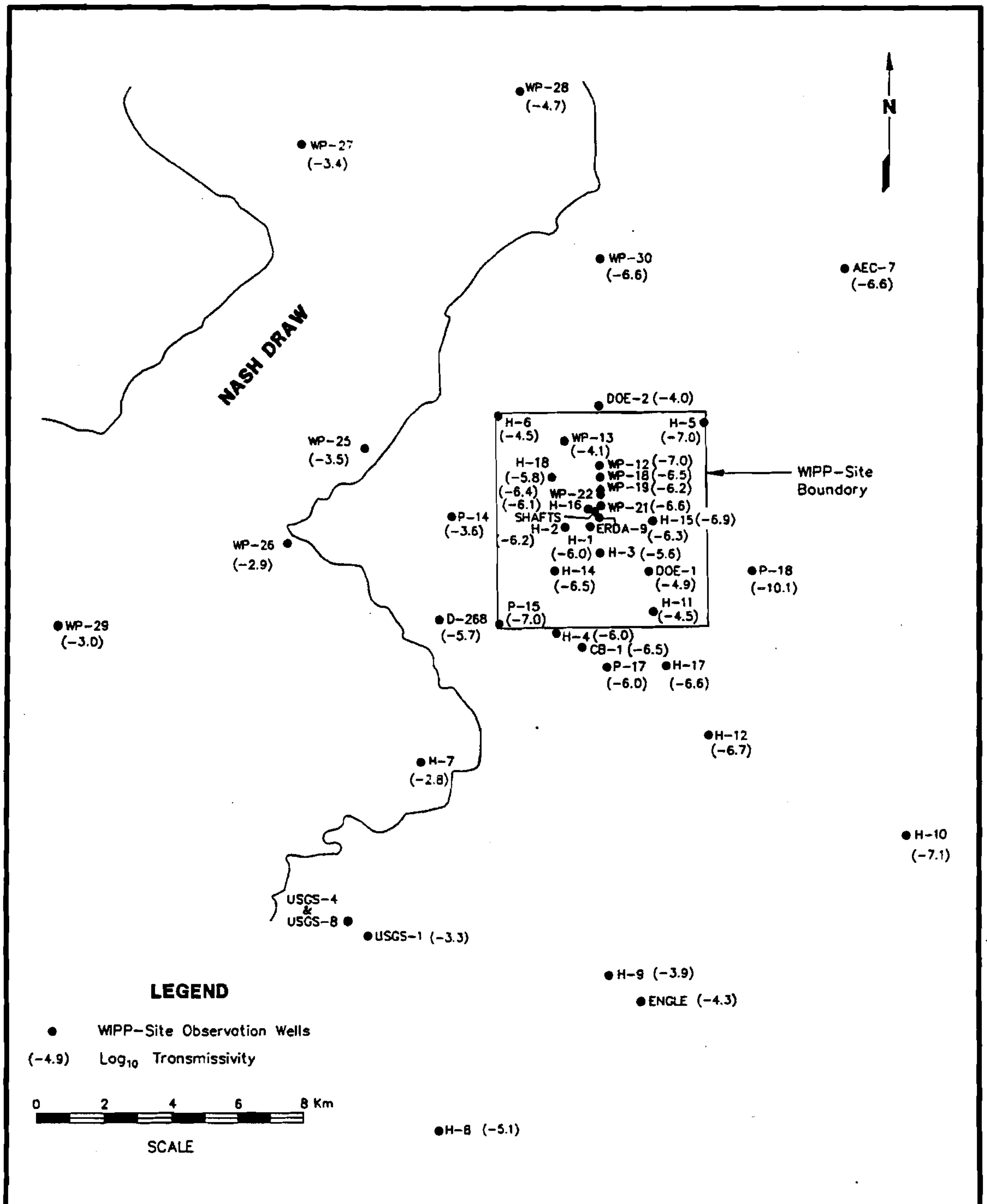
The transmissivity values are tabulated based upon the type of hydraulic test performed. Interpretations of pumping and slug test data provide transmissivity values best suited for the kriging analyses used to prepare data for the finite-difference model. These tests produce intermediate-scale hydraulic stresses (on the order of tens of meters) which are consistent with the typical model grid block size in the immediate WIPP-site area. Thus, transmissivity values determined from regional-scale interference tests, which stress hundreds of meters (large-scale tests), or from drill-stem tests (DST's), which stress only a few meters or less of the formation (small-scale tests), are not considered to represent the transmissivity at the intermediate scale. The values determined from these large- and small-scale tests were, therefore, not used to calculate the representative transmissivity for each borehole or hydropad location. Transmissivities derived from hydropad-interference tests are considered representative of intermediate-scale values. For example, several pumping tests have been performed at each of the three wells at the H-6 hydropad. The interference values of transmissivity determined at the hydropad are considered to represent intermediate-scale conditions and were included as selected values. At locations such as H-6, transmissivity values provided by R.L. Beauheim (1988b) were, in general, selected as being more representative than other values reported in earlier publications. Thus, at H-6 the Gonzalez (1983) transmissivity values are not selected. The Beauheim (1988b) values were considered more representative because they were determined using an analysis technique that was more sophisticated than earlier analyses (e.g., able to incorporate double porosity, wellbore storage effects, and skin effects). In addition, for those cases where new tests were conducted, the quality of the test and the resultant field data was considered to be superior to earlier tests.

The second selection criterion is the quality of the value from the intermediate-scale test. On several occasions, various tests at a borehole have produced several consistent values of transmissivity and one value that is inconsistent. This latter value could result from either a poor test or a poor test analysis. One example of this is at borehole H-3b1. Transmissivity values of 12 and 27 ft^2/day were determined from bailer and slug tests, respectively, and then averaged and presented as 19 ft^2/day in Mercer (1983). Since the other six values at this well, and at the other wells at the hydropad, are between 1 and 3 ft^2/day (Beauheim, 1987a) based on pumping tests, the higher number was not considered consistent and was not selected for use in calculating the mean and standard deviation of the log transmissivity value for the H-3 hydropad.

The above criteria were used as guidelines, and were not strictly adhered to in all cases. DST values were selected on several occasions in order to have more than a single value at a borehole (e.g., H-14, H-15). The selected DST values were, however, consistent with the other values at the boreholes.

After selecting transmissivity values for each well and/or hydropad, the mean of the log of the selected transmissivity values was calculated. The mean of the log value was used for several reasons. First, and most important, the arithmetic mean of log transmissivity values is a better estimator of the true average than is the arithmetic mean of actual transmissivity values (de Marsily, 1986). Also, because transmissivity is commonly considered log normally distributed (Law, 1944; Freeze, 1975) and because the spatial structure implicit in the semi-variogram used for kriging assumes a normal distribution, the log of transmissivity must be taken prior to computing the mean. Therefore, LaVenue et al. (1990) uses the mean of the log transmissivities reported in

Table C.1. These calculations do not include reported regional-interference test values. Figure C.1 shows the calculated mean $\log_{10}$ transmissivity assigned at each borehole.



Drawn by	ABW	Date	11/15/89	Mean Log_{10} Transmissivity Values of the Culebra Dolomite
Checked by	T.C.	Date	11/15/89	
Revisions		Date		
H09700R869			11/15/89	
INTERA Technologies				Figure C.1

CULEBRA TRANSMISSIVITY DATABASE AND TRANSMISSIVITY UNCERTAINTIES   Updated 02/02/90

WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	REPORTED CULEBRA TRANSMISSIVITY m2/s	REPORTED CULEBRA TRANSMISSIVITY log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING m2/s	COMMENTS
H-1	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	0.62	6.667E-07 +	-6.1761	NO				
	BEAUHEIM	'87b	SLUG	0.87	9.355E-07	-6.0290	YES				
	BEAUHEIM	'87a	I - OB(H3b2)	0.46	4.946E-07 +	-6.3057	NO				
	MERCER	'83	SLUG	0.07	7.527E-08	-7.1234	NO				
	SEWARD	'82	DST	0.08	8.602E-08	-7.0654	NO				
	BEAUHEIM	'87c	I - OB(W-13)	20	2.151E-05 +	-4.6674	NO	NA	-6.0290	9.355E-07	VALUE ASSIGNED AT H-1 BOREHOLE
H-2b1	BEAUHEIM	'88b	I - OB(H2a)R	0.64	6.882E-07	-6.1623	YES				
	MERCER	'83	SLUG	0.4	4.301E-07	-6.3664	YES				
	GONZALEZ	'83	PUMPING	0.7	7.527E-07	-6.1234	YES				
	SEWARD	'82	DST	0.5	5.376E-07	-6.2695	YES				
H-2b2	BEAUHEIM	'88b	I - OB(H2a)R	0.62	6.667E-07	-6.1761	YES				
	BEAUHEIM	'87a	I - OB(H3b2)	1.2	1.290E-06 +	-5.8893	NO				
	BEAUHEIM	'87c	I - OB(W-13)	16	1.720E-05 +	-4.7644	NO				
H-2c	BEAUHEIM	'88b	I - OB(H2a)R	0.73	7.850E-07	-6.1051	YES	-6.2005	-6.2005	6.303E-07	VALUE ASSIGNED AT H-2 HYDROPAD
H-3b1	BEAUHEIM	'87a	I - OB(H3b2)	1.8	1.936E-06	-5.7132	YES				
	BEAUHEIM	'87a	I - OB(H3b3)	3.0	3.226E-06	-5.4913	YES				
	MERCER	'83	SLUG	19.0	2.043E-05	-4.6897	NO				
	SEWARD	'82	DST	0.7	7.527E-07	-6.1234	NO				
H-3b2	BEAUHEIM	'87a	I - OB(H3b3)	3.0	3.226E-06	-5.4913	YES				
	BEAUHEIM	'87a	PUMPING '85	1.7	1.828E-06	-5.7380	YES				
H-3b3	BEAUHEIM	'87a	I - OB(H3b2)	1.8	1.936E-06	-5.7132	YES				
	BEAUHEIM	'87a	PUMPING '84	2.9	3.118E-06	-5.5061	YES	-5.6089	-5.6089	2.461E-06	VALUE ASSIGNED AT H-3 HYDROPAD
H-4a	GONZALEZ	'83	I - OB(H4b)O	1.7	1.828E-06	-5.7380	YES				
	GONZALEZ	'83	I - OB(H4b)R	0.9	9.678E-07	-6.0142	YES				
	GONZALEZ	'83	I - OB(H4c)O1	1.1	1.183E-06	-5.9271	YES				
	GONZALEZ	'83	I - OB(H4c)R1	1.3	1.398E-06	-5.8545	YES				
	GONZALEZ	'83	I - OB(H4c)O2	1.3	1.398E-06	-5.8545	YES				
	GONZALEZ	'83	I - OB(H4c)R2	1.6	1.720E-06	-5.7644	YES				

INTERA Technologies | Culebra Dolomite Transmissivity Data Base | Table C.1a

#1050-000 T.C. 10/12/89

WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	m2/s	log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	m2/s	COMMENTS
H-4b	GONZALEZ	'83	PUMPING D	0.3	3.226E-07	-6.4913	YES				
	GONZALEZ	'83	PUMPING R	0.4	4.301E-07	-6.3664	YES				
	MERCER et al.	'81	SLUG	0.9	9.678E-07	-6.0142	YES				
	GONZALEZ	'83	I - OB(H4c)D1	0.8	8.602E-07	-6.0654	YES				
	GONZALEZ	'83	I - OB(H4c)R1	1.3	1.398E-06	-5.8545	YES				
	GONZALEZ	'83	I - OB(H4c)D2	1.2	1.290E-06	-5.8893	YES				
	GONZALEZ	'83	I - OB(H4c)R2	1.8	1.936E-06	-5.7132	YES				
	SEWARD	'82	DST	0.86	9.248E-07	-6.0340	YES				
H-4c	BEAUHEIM	'87b	SLUG	0.65	6.989E-07	-6.1556	YES				
	GONZALEZ	'83	I - OB(H4b)D	1.5	1.613E-06	-5.7924	YES				
	GONZALEZ	'83	I - OB(H4b)R	0.7	7.527E-07	-6.1234	YES				
	GONZALEZ	'83	PUMPING D1	0.6	6.452E-07	-6.1903	YES				
	GONZALEZ	'83	PUMPING R1	1.0	1.075E-06	-5.9685	YES				
	GONZALEZ	'83	PUMPING D2	0.4	4.301E-07	-6.3664	YES				
	GONZALEZ	'83	PUMPING R2	1.7	1.828E-06	-5.7380	YES	-5.9960	-5.9960	1.009E-06	VALUE ASSIGNED AT H-4 HYDROPAD
H-5a	BEAUHEIM	'88b	I - OB(H5b)R	0.051	5.484E-08	-7.2609	YES				
	BEAUHEIM	'88b	I - OB(H5c)R	0.09	9.678E-08	-7.0142	YES				
	GONZALEZ	'83	I - OB(H5c)D	0.15	1.613E-07	-6.7924	NO				
	GONZALEZ	'83	I - OB(H5c)R	0.19	2.043E-07	-6.6897	NO				
	GONZALEZ	'83	I - OB(H5b)D	0.11	1.183E-07	-6.9271	NO				
	GONZALEZ	'83	I - OB(H5b)R	0.20	2.151E-07	-6.6674	NO				
H-5b	BEAUHEIM	'88b	I - OB(H5c)R	0.063	6.774E-08	-7.1691	YES				
	BEAUHEIM	'88b	PUMPING R	0.20	2.151E-07	-6.6674	YES				
	GONZALEZ	'83	PUMPING R	0.22	2.366E-07	-6.6260	NO				
	GONZALEZ	'83	I - OB(H5c)D	0.12	1.290E-07	-6.8893	NO				
	GONZALEZ	'83	I - OB(H5c)R	0.24	2.581E-07	-6.5883	NO				
	DENN. & MERCER	'82	SLUG	0.20	2.151E-07	-6.6674	YES				
	SEWARD	'82	DST	0.86	9.248E-07	-6.0340	NO				
H-5c	BEAUHEIM	'88b	I - OB(H5b)R	0.046	4.946E-08	-7.3057	YES				
	BEAUHEIM	'88b	PUMPING R	0.094	1.011E-07	-6.9953	YES				
	GONZALEZ	'83	PUMPING D	0.04	4.301E-08	-7.3664	NO				
	GONZALEZ	'83	PUMPING R	0.11	1.183E-07	-6.9271	NO				
	GONZALEZ	'83	I - OB(H5b)D	0.16	1.720E-07	-6.7644	NO				
	GONZALEZ	'83	I - OB(H5b)R	0.11	1.183E-07	-6.9271	NO	-7.0115	-7.0115	9.740E-08	VALUE ASSIGNED AT H-5 HYDROPAD

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	REPORTED CULEBRA TRANSMISSIVITY m2/s	REPORTED CULEBRA TRANSMISSIVITY log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING m2/s	COMMENTS
H-6a	BEAUHEIM	'88b	I - OB(H6c)D2	33	3.548E-05	-4.4500	YES				
	BEAUHEIM	'88b	I - OB(H6c)R2	33	3.548E-05	-4.4500	YES				
	BEAUHEIM	'87c	I - OB(W-13)	71	7.635E-05 +	-4.1172	NO				
	GONZALEZ	'83	I - OB(H6b)D	67	7.205E-05	-4.1424	NO				
	GONZALEZ	'83	I - OB(H6b)R	77	8.280E-05	-4.0820	NO				
	GONZALEZ	'83	I - OB(H6c)D1	87	9.355E-05	-4.0290	NO				
	GONZALEZ	'83	I - OB(H6c)R1	66	7.097E-05	-4.1489	NO				
	GONZALEZ	'83	I - OB(H6c)D2	70	7.527E-05	-4.1234	NO				
	GONZALEZ	'83	I - OB(H6c)R2	69	7.420E-05	-4.1296	NO				
H-6b	BEAUHEIM	'88b	I - OB(H6c)D2	33	3.548E-05	-4.4500	YES				
	BEAUHEIM	'88b	I - OB(H6c)R2	33	3.548E-05	-4.4500	YES				
	BEAUHEIM	'87c	I - OB(W-13)	69	7.420E-05 +	-4.1296	NO				
	BEAUHEIM	'86	I - OB(DOE2)	61	6.559E-05 +	-4.1831	NO				
	GONZALEZ	'83	PUMPING D	79	8.495E-05	-4.0708	NO				
	GONZALEZ	'83	PUMPING R	88	9.463E-05	-4.0240	NO				
	GONZALEZ	'83	I - OB(H6c)D1	86	9.248E-05	-4.0340	NO				
	GONZALEZ	'83	I - OB(H6c)R1	63	6.774E-05	-4.1691	NO				
	GONZALEZ	'83	I - OB(H6c)D2	69	7.420E-05	-4.1296	NO				
	GONZALEZ	'83	I - OB(H6c)R2	67	7.205E-05	-4.1424	NO				
	DENNEHY	'82	PUMPING D '79	73	7.850E-05	-4.1051	NO				
	DENNEHY	'82	PUMPING R '79	83	8.925E-05	-4.0494	NO				
	SEWARD	'82	DST	75	8.065E-05	-4.0934	NO				
H-6c	BEAUHEIM	'88b	PUMPING 2	33	3.548E-05	-4.4500	YES				
	GONZALEZ	'83	PUMPING R1	71	7.635E-05	-4.1172	NO				
	GONZALEZ	'83	I - OB(H6b)D	70	7.527E-05	-4.1234	NO				
	GONZALEZ	'83	I - OB(H6b)R	77	8.280E-05	-4.0820	NO				
	GONZALEZ	'83	PUMPING D2	72	7.742E-05	-4.1111	NO				
	GONZALEZ	'83	PUMPING R2	72	7.742E-05	-4.1111	NO	-4.4500	-4.4500	3.548E-05	VALUE ASSIGNED AT H-6 HYDROPAD
H-7b1	BEAUHEIM	'88b	PUMPING	2000	2.151E-03	-2.6674	YES				
	MERCER	'83	PUMPING	1000	1.075E-03	-3.0000	YES				
	BARR et al.	'83	PUMPING	2320	2.495E-03	-2.6030	NO				
H-7b2	BEAUHEIM	'88b	I - OB(H7b1)R	1000	1.075E-03	-2.9685	YES				
H-7c	BEAUHEIM	'88b	I - OB(H7b1)D	1800	1.936E-03	-2.7132	YES				
	BEAUHEIM	'88b	I - OB(H7b1)R	1800	1.936E-03	-2.7132	YES	-2.8125	-2.8125	1.540E-03	VALUE ASSIGNED AT H-7 HYDROPAD

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	m2/s	log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	m2/s	COMMENTS
H-8b	BEAUHEIM	'87b	PUMPING	8.2	8.817E-06	-5.0547	YES				
	MERCER	'83	PUMPING	16	1.720E-05	-4.7644	NO				
	BARR et al.	'83	PUMPING	97.2	1.045E-04	-3.9808	NO	NA	-5.0547	8.817E-06	VALUE ASSIGNED AT H-8 HYDROPAD
H-9a	BEAUHEIM	'88b	I - OB(H9c)R1	120	1.290E-04	-3.8893	YES				
	BEAUHEIM	'88b	I - OB(H9c)R2	110	1.183E-04	-3.9271	YES				
H-9b	BEAUHEIM	'88b	I - OB(H9c)D2	120	1.290E-04	-3.8893	YES				
	MERCER	'83	PUMPING	231	2.484E-04	-3.6049	NO				
	BARR et al.	'83	PUMPING	893	9.600E-04	-3.0177	NO	-3.9019	-3.9019	1.253E-04	VALUE ASSIGNED AT H-9 HYDROPAD
H-10b	MERCER	'83	SLUG	0.07	7.527E-08	-7.1234	YES	NA	-7.1234	7.527E-08	VALUE ASSIGNED AT H-10 HYDROPAD
H-11b1	BEAUHEIM	'89	PUMPING '88R	27	2.903E-05	-4.5371	YES				
	BEAUHEIM	'89	I - OB(H11b4)'88R	41	4.409E-05	-4.3557	YES				
	SAULNIER	'87	PUMPING '84	11.3	1.215E-05	-4.9154	NO				
	SAULNIER	'87	I - OB(H11b3)'84	25.5	2.742E-05	-4.5619	YES				
	SAULNIER	'87	I - OB(H11b3)'85	24.8	2.667E-05	-4.5740	YES				
	SAULNIER	'87	I - OB(H11b2)'84	25.4	2.731E-05	-4.5636	YES				
	BEAUHEIM	'87a	I - OB(H3b2)	6.8	7.312E-06 +	-5.1360	NO				
H-11b2	SAULNIER	'87	I - OB(H11b3)'84	23.8	2.559E-05	-4.5919	YES				
	SAULNIER	'87	I - OB(H11b3)'85	26.4	2.839E-05	-4.5469	YES				
	SAULNIER	'87	I - OB(H11b1)'84	23.4	2.516E-05	-4.5993	YES				
H-11b3	BEAUHEIM	'89	I - OB(H11b1)'88R	27	2.903E-05	-4.5371	YES				
	SAULNIER	'87	PUMPING '84	26.1	2.807E-05	-4.5518	YES				
	SAULNIER	'87	PUMPING '85	30.7	3.301E-05	-4.4813	YES				
	SAULNIER	'87	I - OB(H11b1)'84	26.0	2.796E-05	-4.5535	YES				
	SAULNIER	'87	I - OB(H11b2)'84	23.9	2.570E-05	-4.5901	YES				
H-11b4	BEAUHEIM	'89	PUMPING'88	42	4.516E-05	-4.3452	YES				
	BEAUHEIM	'89	I - OB(H11b1)'88R	29	3.118E-05	-4.5061	YES				
	BEAUHEIM	'89	SLUG 1	40	4.301E-05	-4.3664	YES				
	BEAUHEIM	'89	SLUG 2	43	4.624E-05	-4.3350	YES	-4.5057	-4.5057	3.121E-05	VALUE ASSIGNED AT H-11 HYDROPAD

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	REPORTED CULEBRA TRANSMISSIVITY m2/s	REPORTED CULEBRA TRANSMISSIVITY log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING m2/s	COMMENTS
H-12	BEAUHEIM	'87b	SLUG	0.18	1.936E-07	-6.7132	YES	NA	-6.7132	1.936E-07	VALUE ASSIGNED AT H-12 BOREHOLE
H-14	BEAUHEIM	'87b	SLUG	0.30	3.226E-07	-6.4913	YES				
	BEAUHEIM	'87b	DST	0.31	3.333E-07	-6.4771	YES	-6.4842	-6.4842	3.279E-07	VALUE ASSIGNED AT H-14 BOREHOLE
H-15	BEAUHEIM	'87b	SLUG	0.10	1.075E-07	-6.9685	YES				
	BEAUHEIM	'87b	DST	0.15	1.613E-07	-6.7924	YES	-6.8804	-6.8804	1.317E-07	VALUE ASSIGNED AT H-15 BOREHOLE
H-16	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	0.62	6.667E-07	-6.1761	YES				
	BEAUHEIM	'87b	DST	0.85	9.140E-07	-6.0391	YES				
	BEAUHEIM	'87b	SLUG	0.69	7.420E-07	-6.1296	YES	-6.1149	-6.1149	7.675E-07	VALUE ASSIGNED AT H-16 BOREHOLE
H-17	BEAUHEIM	'87b	DST	0.21	2.258E-07	-6.6463	YES				
	BEAUHEIM	'87b	SLUG	0.22	2.366E-07	-6.6260	YES	-6.6361	-6.6361	2.311E-07	VALUE ASSIGNED AT H-17 BOREHOLE
H-18	BEAUHEIM	'88b	PUMPING	1.0	1.075E-06	-5.9685	YES				
	BEAUHEIM	'87b	SLUG	1.7	1.828E-06	-5.7380	YES				
	BEAUHEIM	'87b	DST	2.2	2.366E-06	-5.6260	YES	-5.7775	-5.7775	1.669E-06	VALUE ASSIGNED AT H-18 BOREHOLE
DOE-1	BEAUHEIM	'89	I - OB(H11b1)'88	9.0	9.678E-06 +	-5.0142	NO				
	BEAUHEIM	'89	I - OB(H3b2)	5.8	6.237E-06 +	-5.2050	NO				
	BEAUHEIM	'87a	I - OB(H3b3)	12	1.290E-05 +	-4.8893	NO				
	BEAUHEIM	'87b	PUMPING D	28	3.011E-05	-4.5213	NO				
	BEAUHEIM	'87b	PUMPING R	11	1.183E-05	-4.9271	YES	NA	-4.9271	1.183E-05	VALUE ASSIGNED AT DOE-1 BOREHOLE
DOE-2	BEAUHEIM	'86	PUMPING	89	9.570E-05	-4.0191	YES				
	BEAUHEIM	'88a	I - OB(W-13)	38	4.086E-05 +	-4.3887	NO	NA	-4.0191	9.570E-05	VALUE ASSIGNED AT DOE-2 BOREHOLE
P-14	MERCER	'83	PUMPING	140	1.505E-04	-3.8223	YES				
	BEAUHEIM	'87c	I - OB(W-13)	265	2.850E-04 +	-3.5452	NO				
	BARR et al.	'83	PUMPING	475	5.108E-04	-3.2918	YES	-3.5571	-3.5571	2.773E-04	VALUE ASSIGNED AT P-14 BOREHOLE
P-15	BEAUHEIM	87b	SLUG	0.09	9.678E-08	-7.0142	YES				
	MERCER	'83	SLUG	0.07	7.527E-08	-7.1234	YES				
	SEWARD	'82	DST	0.1	1.075E-07	-6.9685	YES	-7.0354	-7.0354	9.218E-08	VALUE ASSIGNED AT P-15 BOREHOLE
P-17	BEAUHEIM	'87b	SLUG	1.0	1.075E-06	-5.9685	YES				
	MERCER	'83	SLUG	1.0	1.075E-06	-5.9685	YES	-5.9685	-5.9685	1.075E-06	VALUE ASSIGNED AT P-17 BOREHOLE

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	m2/s	log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	m2/s	COMMENTS
P-18	BEAUHEIM	'87b	SLUG	0.00007	7.527E-11	-10.1234	YES				
	MERCER	'83	SLUG	0.001	1.075E-09	-8.9685	NO	NA	-10.1234	7.527E-11	VALUE ASSIGNED AT P-18 BOREHOLE
WIPP-12	BEAUHEIM	'87b	SLUG	0.10	1.075E-07	-6.9685	YES				
	BEAUHEIM	'87c	I - OB(W-13)	7.9	8.495E-06 +	-5.0708	NO	NA	-6.9685	1.075E-07	VALUE ASSIGNED AT WIPP-12 BOREHOLE
WIPP-13	BEAUHEIM	'87c	PUMPING	69	7.420E-05	-4.1296	YES				
	BEAUHEIM	'86	I - OB(DOE2)	72	7.742E-05 +	-4.1111	NO	NA	-4.1296	7.420E-05	VALUE ASSIGNED AT WIPP-13 BOREHOLE
WIPP-18	BEAUHEIM	'87b	SLUG	0.30	3.226E-07	-6.4913	YES				
	BEAUHEIM	'87c	I - OB(W-13)	23	2.473E-05 +	-4.6067	NO	NA	-6.4913	3.226E-07	VALUE ASSIGNED AT WIPP-18 BOREHOLE
WIPP-19	BEAUHEIM	'87b	SLUG	0.60	6.452E-07	-6.1903	YES				
	BEAUHEIM	'87c	I - OB(W-13)	24	2.581E-05 +	-4.5883	NO	NA	-6.1903	6.452E-07	VALUE ASSIGNED AT WIPP-19 BOREHOLE
WIPP-21	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	0.62	6.667E-07 +	-6.1761	NO				
	BEAUHEIM	'87b	SLUG	0.25	2.688E-07	-6.5705	YES				
	BEAUHEIM	'87c	I - OB(W-13)	22	2.366E-05 +	-4.6260	NO	NA	-6.5705	2.688E-07	VALUE ASSIGNED AT WIPP-21 BOREHOLE
WIPP-22	BEAUHEIM	'87b	SLUG	0.37	3.979E-07	-6.4003	YES				
	BEAUHEIM	'87c	I - OB(W-13)	19	2.043E-05 +	-4.6897	NO	NA	-6.4003	3.979E-07	VALUE ASSIGNED AT WIPP-22 BOREHOLE
WIPP-25	MERCER	'83	PUMPING	270	2.903E-04	-3.5371	YES				
	BEAUHEIM	'87c	I - OB(W-13)	650	6.989E-04 +	-3.1556	NO				
	BARR et al.	'83	PUMPING	265	2.850E-04	-3.5452	YES	-3.5412	-3.5412	2.876E-04	VALUE ASSIGNED AT WIPP-25 BOREHOLE
WIPP-26	MERCER	'83	PUMPING	1250	1.344E-03	-2.8716	YES				
	BARR et al.	'83	PUMPING	1030	1.108E-03	-2.9556	YES	-2.9136	-2.9136	1.220E-03	VALUE ASSIGNED AT WIPP-26 BOREHOLE
WIPP-27	MERCER	'83	PUMPING	650	6.989E-04	-3.1556	YES				
	BARR et al.	'83	PUMPING	243	2.613E-04	-3.5829	YES	-3.3692	-3.3692	4.274E-04	VALUE ASSIGNED AT WIPP-27 BOREHOLE
WIPP-28	MERCER	'83	PUMPING	18	1.936E-05	-4.7132	YES				
	BARR et al.	'83	PUMPING	20.6	2.215E-05	-4.6546	YES	-4.6839	-4.6839	2.071E-05	VALUE ASSIGNED AT WIPP-28 BOREHOLE
WIPP-29	MERCER	'83	PUMPING	1000	1.075E-03	-2.9685	YES	NA	-2.9685	1.075E-03	VALUE ASSIGNED AT AT WIPP-29 BOREHOLE

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA TRANSMISSIVITY ft2/day	m2/s	log m2/s	SELECTED VALUES (YES or NO)	AVERAGE OF SELECTED VALUES (PER HYDROPAD OR WELL LOCATION) log m2/s	TRANSMISSIVITY VALUES USED FOR KRIGING log m2/s	m2/s	COMMENTS
WIPP-30	BEAUHEIM	'87b	SLUG	0.18	1.936E-07	-6.7132	YES				
	MERCER	'83	SLUG	0.3	3.226E-07	-6.4913	YES				
	GONZALEZ	'83	PUMPING	0.02	2.151E-08	-7.6674	NO				
	BEAUHEIM	'87c	I - OB(W-13)	28	3.011E-05 +	-4.5213	NO				
	BARR et al.	'83	PUMPING	19.0	2.043E-05	-4.6897	NO	-6.6023	-6.6023	2.499E-07	VALUE ASSIGNED AT WIPP-30 BOREHOLE
ERDA-9	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	0.24	2.581E-07 +	-6.5883	NO				
	BEAUHEIM	'87b	SLUG	0.47	5.054E-07	-6.2964	YES				
	BEAUHEIM	'87c	I - OB(W-13)	22	2.366E-05 +	-4.6260	NO	NA	-6.2964	5.054E-07	VALUE ASSIGNED AT ERDA-9 BOREHOLE
CABIN BABY-1	BEAUHEIM	'87b	SLUG	0.28	3.011E-07	-6.5213	YES	NA	-6.5213	3.011E-07	VALUE ASSIGNED AT CABIN BABY BOREHOLE
ENGLE	BEAUHEIM	'87b	PUMPING	43	4.624E-05	-4.3350	YES				
	BEAUHEIM	'88b	I - OB(H9c)	96	1.032E-04	-3.9862	NO	NA	-4.3350	4.624E-05	VALUE ASSIGNED AT ENGLE BOREHOLE
USGS-1	COOPER	'62	PUMPING '60D	543	5.839E-04	-3.2337	YES				
	COOPER	'62	PUMPING '60R	531	5.710E-04	-3.2434	YES				
	COOPER & GLANZ.	'71	PUMPING '63	468	5.032E-04	-3.2982	YES	-3.2584	-3.2584	5.515E-04	VALUE ASSIGNED AT USGS-1 BOREHOLE
D-268	BEAUHEIM	'88b	SLUG	1.90	2.043E-06	-5.6897	YES	NA	-5.6897	2.043E-06	VALUE ASSIGNED AT D-268 BOREHOLE
AEC-7	BEAUHEIM	'88b	SLUG	0.26	2.796E-07	-6.5535	YES	NA	-6.5535	2.796E-07	VALUE ASSIGNED AT AEC-7 BOREHOLE
EX. SHFT.	BEAUHEIM	'87c	I - OB(W-13)	28	3.011E-05 +	-4.5213	NO				

ABBREVIATIONS ;

I = INTERFERENCE
R# = RECOVERY OF TEST #
D# = DRAWDOWN OF TEST #
OB = OBSERVATION
(WELL) = PUMPING WELL
DST = DRILL-STEM TEST
SLUG = SLUG TEST
NA = NOT APPLICABLE
+ = POSSIBLE VALUE FOR PILOT POINT POSITIONED BETWEEN PUMPING AND OBSERVATION WELL

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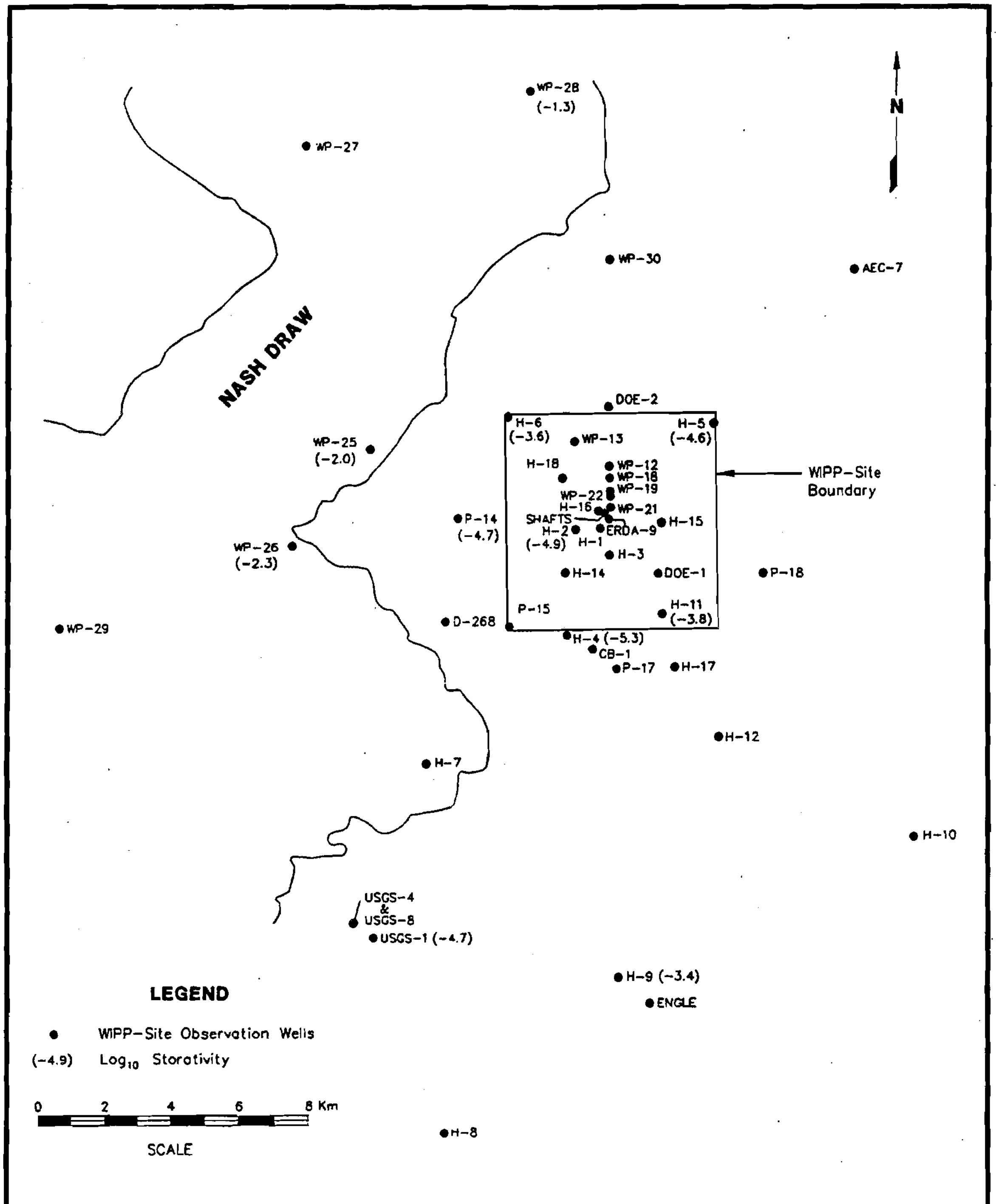
APPENDIX D: CULEBRA STORATIVITIES

The Culebra storativity data base is listed in Table D.1a-g. The table format is very similar to that of Table C.1a-g. The values listed for each borehole and/or hydropad were evaluated to determine the most representative values on a scale of tens of meters. Figure D.1 lists these values next to their associated boreholes. The storativity values determined from regional-scale interference tests, slug tests, or DST's were not considered to be representative values on a scale of tens of meters.



Drawn by ABW	Date 11/15/89	Mean Log_{10} Storativity Values of the Culebra Dolomite
Checked by T.C.	Date 11/15/89	
Revisions	Date	
H09700R869	11/15/89	
INTERA Technologies		Figure D.1

CULEBRA STORATIVITY DATABASE Updated 02/02/90

WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
H-1	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	1.0E-05 +	-5.0000	NO				
	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87a	I - OB(H3b2)	2.7E-05 +	-4.5686	NO				
	MERCER	'83	SLUG	1.0E-04	-4.0000	NO				
	SEWARD	'82	DST	NR						
	BEAUHEIM	'87c	I - OB(W-13)	1.3E-04 +	-3.8861	NO				
H-2b1	BEAUHEIM	'88b	I - OB(H2a)R	1.4E-05	-4.8539	YES				
	MERCER	'83	SLUG	1.0E-09	-9.0000	NO				
	GONZALEZ	'83	PUMPING	1.2E-05	-4.9208	YES				
	SEWARD	'82	DST	1.0E-09	-9.0000	NO				
H-2b2	BEAUHEIM	'88b	I - OB(H2a)R	2.1E-05	-4.6778	YES				
	BEAUHEIM	'87a	I - OB(H3b2)	3.0E-05 +	-4.5229	NO				
	BEAUHEIM	'87c	I - OB(W-13)	7.3E-05 +	-4.1367	NO				
H-2c	BEAUHEIM	'88b	I - OB(H2a)R	7.7E-06	-5.1135	YES	-4.8915	-4.8915	1.28E-05	VALUE ASSIGNED AT H-2 HYDROPAD
H-3b1	BEAUHEIM	'87a	I - OB(H3b2)	NR						
	BEAUHEIM	'87a	I - OB(H3b3)	NR						
	MERCER	'83	SLUG	NR						
	SEWARD	'82	DST	NR						
H-3b2	BEAUHEIM	'87a	I - OB(H3b3)	NR						
	BEAUHEIM	'87a	PUMPING '85	NR						
H-3b3	BEAUHEIM	'87a	I - OB(H3b2)	NR						
	BEAUHEIM	'87a	PUMPING '84	NR						
H-4a	GONZALEZ	'83	I - OB(H4b)D	3.1E-06	-5.5045	YES				
	GONZALEZ	'83	I - OB(H4b)R	NR						
	GONZALEZ	'83	I - OB(H4c)D1	8.0E-06	-5.0947	YES				
	GONZALEZ	'83	I - OB(H4c)R1	NR						
	GONZALEZ	'83	I - OB(H4c)D2	5.6E-06	-5.2503	YES				
	GONZALEZ	'83	I - OB(H4c)R2	NR						

INTERA Technologies | Culebra Dolomite Storativity Data Base | Table D.1a

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
H-4b	GONZALEZ	'83	PUMPING D	NR						
	GONZALEZ	'83	PUMPING R	NR						
	MERCER et al.	'81	SLUG	1.0E-09	-9.0000	NO				
	GONZALEZ	'83	I - OB(H4c)D1	1.0E-06	-6.0000	YES				
	GONZALEZ	'83	I - OB(H4c)R1	8.6E-06	-5.0635	YES				
	GONZALEZ	'83	I - OB(H4c)D2	NR						
	GONZALEZ	'83	I - OB(H4c)R2	6.5E-06	-5.1884	YES				
	SEWARD	'82	DST	1.0E-06	-6.0000	NO				
H-4c	BEAUHEIM	'87b	SLUG	NR						
	GONZALEZ	'83	I - OB(H4b)D	5.7E-06	-5.2464	YES				
	GONZALEZ	'83	I - OB(H4b)R	NR						
	GONZALEZ	'83	PUMPING D1	NR						
	GONZALEZ	'83	PUMPING R1	NR						
	GONZALEZ	'83	PUMPING D2	NR						
	GONZALEZ	'83	PUMPING R2	NR			-5.3354	-5.3354	4.62E-06	VALUE ASSIGNED AT H-4 HYDROPAD
H-5a	BEAUHEIM	'88a	I - OB(H5c)R	3.1E-05	-4.5086	YES				
	BEAUHEIM	'88a	I - OB(H5b)R	1.7E-05	-4.7696	YES				
	GONZALEZ	'83	I - OB(H5c)D	2.5E-05	-4.6021	NO				
	GONZALEZ	'83	I - OB(H5c)R	NR						
	GONZALEZ	'83	I - OB(H5b)D	9.3E-06	-5.0297	NO				
	GONZALEZ	'83	I - OB(H5b)R	NR						
H-5b	BEAUHEIM	'88a	I - OB(H5c)R	3.3E-05	-4.4815	YES				
	GONZALEZ	'83	PUMPING R	NR						
	GONZALEZ	'83	I - OB(H5c)D	2.6E-05	-4.5850	NO				
	GONZALEZ	'83	I - OB(H5c)R	NR						
	DENN. & MERCER	'82	SLUG	1.0E-05	-5.0000	NO				
	SEWARD	'82	DST	1.0E-05	-5.0000	NO				
H-5c	BEAUHEIM	'88a	I - OB(H5b)R	3.5E-05	-4.4559	YES				
	GONZALEZ	'83	PUMPING D	NR						
	GONZALEZ	'83	PUMPING R	NR						
	GONZALEZ	'83	I - OB(H5b)D	2.9E-05	-4.5346	NO				
	GONZALEZ	'83	I - OB(H5b)R	NR			-4.5539	-4.5539	2.79E-05	VALUE ASSIGNED AT H-5 HYDROPAD

INTERA Technologies | Culebra Dolomite Storativity Data Base | Table D.1b

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
H-6a	BEAUHEIM	'88b	I - OB(H6c)D2	2.8E-04	-3.5528	YES				
	BEAUHEIM	'88b	I - OB(H6c)R2	2.7E-04	-3.5686	YES				
	BEAUHEIM	'87c	I - OB(W-13)	8.2E-06 +	-5.0862	NO				
	GONZALEZ	'83	I - OB(H6b)D	2.2E-05	-4.6576	NO				
	GONZALEZ	'83	I - OB(H6b)R	NR						
	GONZALEZ	'83	I - OB(H6c)D1	2.5E-05	-4.5952	NO				
	GONZALEZ	'83	I - OB(H6c)R1	NR						
	GONZALEZ	83	I - OB(H6c)D2	2.3E-05	-4.6345	NO				
	GONZALEZ	'83	I - OB(H6c)R2	NR						
H-6b	BEAUHEIM	'88b	I - OB(H6c)D2	2.0E-04	-3.6990	YES				
	BEAUHEIM	'88b	I - OB(H6c)R2	2.0E-04	-3.6990	YES				
	BEAUHEIM	'87c	I - OB(W-13)	7.9E-06 +	-5.1024	NO				
	BEAUHEIM	'86	I - OB(DOE2)	6.0E-06 +	-5.2218	NO				
	GONZALEZ	'83	PUMPING D	NR						
	GONZALEZ	'83	PUMPING R	NR						
	GONZALEZ	'83	I - OB(H6c)D1	1.4E-05	-4.8477	NO				
	GONZALEZ	'83	I - OB(H6c)R1	NR						
	GONZALEZ	'83	I - OB(H6c)D2	1.5E-05	-4.8386	NO				
	GONZALEZ	'83	I - OB(H6c)R2	NR						
	DENNEHY	'82	PUMPING D '79	NR						
	DENNEHY	'82	PUMPING R '79	NR						
	SEWARD	'82	DST	NR						
H-6c	BEAUHEIM	'88a	PUMPING	NR						
	GONZALEZ	'83	PUMPING R1	NR						
	GONZALEZ	'83	I - OB(H6b)D	1.3E-05	-4.8996	NO				
	GONZALEZ	'83	I - OB(H6b)R	NR						
	GONZALEZ	'83	PUMPING D2	NR						
	GONZALEZ	'83	PUMPING R2	NR			-3.6299	-3.6299	2.35E-04	VALUE ASSIGNED AT H-6 HYDROPAD
H-7b1	BEAUHEIM	'88b	PUMPING	NR						
	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	5.0E-07	-6.3010	NO				
H-7b2	BEAUHEIM	'88b	I - OB(H7b1)R	NR						
H-7c	BEAUHEIM	'88b	I - OB(H7b1)D	NR						
	BEAUHEIM	'88b	I - OB(H7b1)R	NR						

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
H-8b	BEAUHEIM	'87b	PUMPING	NR						
	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	1.0E-02	-2.0000	NO				
H-9a	BEAUHEIM	'88b	I - OB(H9c)R1	4.7E-04	-3.3279	YES				
H-9b	BEAUHEIM	'88b	I - OB(H9c)D2	3.1E-04	-3.5086	YES				
	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	3.5E-04	-3.4559	NO				
H-9c	BEAUHEIM	'88b	PUMPING	NR			-3.4183	-3.4183	3.82E-04	VALUE ASSIGNED AT H-9 HYDROPAD
H-10b	MERCER	'83	SLUG	1.0E-04	-4.0000	NO				
H-11b1	BEAUHEIM	'89	PUMPING'88	NR						
	BEAUHEIM	'89	I - OB(H11b4)'88R	3.4E-05	-4.4685	YES				
	SAULNIER	'87	PUMPING '84	NR						
	BEAUHEIM	'89	I - OB(H11b3)'84	1.9E-04	-3.7212	YES				
	BEAUHEIM	'89	I - OB(H11b3)'85	2.0E-04	-3.6990	YES				
	BEAUHEIM	'89	I - OB(H11b2)'84	2.6E-04	-3.5850	YES				
	BEAUHEIM	'87a	I - OB(H3b2)	7.4E-06 +	-5.1308	NO				
H-11b2	BEAUHEIM	'89	I - OB(H11b3)'84	2.2E-04	-3.6576	YES				
	BEAUHEIM	'89	I - OB(H11b3)'85	1.8E-04	-3.7447	YES				
	BEAUHEIM	'89	I - OB(H11b1)'84	2.8E-04	-3.5528	YES				
H-11b3	BEAUHEIM	'89	I - OB(H11b1)'88R	1.5E-04	-3.8239	YES				
	SAULNIER	'87	PUMPING '84	NR						
	SAULNIER	'87	PUMPING '85	NR						
	BEAUHEIM	'89	I - OB(H11b1)'84	1.9E-04	-3.7212	YES				
	BEAUHEIM	'89	I - OB(H11b2)'84	1.8E-04	-3.7447	YES				
H-11b4	BEAUHEIM	'89	I - OB(H11b1)'88R	8.2E-05	-4.0862	YES				
	BEAUHEIM	'89	SLUG 1	NR						
	BEAUHEIM	'89	SLUG 2	NR						
	BEAUHEIM	'89	PUMPING'88	NR			-3.8005	-3.8005	1.58E-04	VALUE ASSIGNED AT H-11 HYDROPAD
H-12	BEAUHEIM	'87b	SLUG	NR						

WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
H-14	BEAUHEIM	'87b	SLUG	NR.						
	BEAUHEIM	'87b	DST	NR						
H-15	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87b	DST	NR						
H-16	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	1.0E-05	-5.0000	NO				
	BEAUHEIM	'87b	DST	NR						
	BEAUHEIM	'87b	SLUG	NR						
H-17	BEAUHEIM	'87b	SLUG	NR						
H-18	BEAUHEIM	'88b	PUMPING	NR						
	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'88b	DST	NR						
DOE-1	BEAUHEIM	'89	I - OB(H11b1)'88D	2.4E-06 +	-5.6198	NO				
	BEAUHEIM	'89	I - OB(H3b2)	1.1E-05 +	-4.9586	NO				
	BEAUHEIM	'87a	I - OB(H3b3)	1.2E-05 +	-4.9208	NO				
	BEAUHEIM	'87b	PUMPING D	NR						
	BEAUHEIM	'87b	PUMPING R	NR						
DOE-2	BEAUHEIM	'86	PUMPING	NR						
	BEAUHEIM	'88a	I - OB(W-13)	5.2E-06 +	-5.2840	NO				
P-14	BEAUHEIM	'87c	I - OB(W-13)	5.2E-05 +	-4.2840	NO				
	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	2.0E-05	-4.6990	YES	NA	-4.6990	2.00E-05	VALUE ASSIGNED AT P-14 BOREHOLE
P-15	MERCER	'83	SLUG	1.0E-04	-4.0000	NO				
	SEWARD	'82	DST	1.0E-04	-4.0000	NO				
	BEAUHEIM	87b	SLUG	NR						
P-17	BEAUHEIM	'87b	SLUG	NR						
	MERCER	'83	SLUG	1.0E-06	-6.0000	NO				
P-18	BEAUHEIM	'87b	SLUG	NR						
	MERCER	'83	SLUG	NR						
WIPP-12	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87c	I - OB(W-13)	3.6E-05 +	-4.4437	NO				
WIPP-13	BEAUHEIM	'86	I - OB(DOE2)	3.0E-06 +	-5.5229	NO				

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
WIPP-18	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87b	I - OB(W-13)	4.0E-05 +	-4.3979	NO				
WIPP-19	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87b	I - OB(W-13)	4.0E-05 +	-4.3979	NO				
WIPP-21	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	1.0E-05 +	-5.0000	NO				
	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87c	I - OB(W-13)	5.3E-05 +	-4.2757	NO				
WIPP-22	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87c	I - OB(W-13)	4.7E-05 +	-4.3279	NO				
WIPP-25	MERCER	'83	PUMPING	NR						
	BEAUHEIM	'87c	I - OB(W-13)	6.4E-05 +	-4.1938	NO				
	BARR et al.	'83	PUMPING	1.0E-02	-2.0000	YES	NA	-2.0000	1.00E-02	VALUE ASSIGNED AT WIPP-25 BOREHOLE
WIPP-26	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	4.8E-03	-2.3188	YES	NA	-2.3188	4.80E-03	VALUE ASSIGNED AT WIPP-26 BOREHOLE
WIPP-27	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	1.0E-06	-6.0000	NO				
WIPP-28	MERCER	'83	PUMPING	NR						
	BARR et al.	'83	PUMPING	5.0E-02	-1.3010	YES	NA	-1.3010	5.00E-02	VALUE ASSIGNED AT WIPP-28 BOREHOLE
WIPP-29	MERCER	'83	PUMPING	NR						
WIPP-30	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87c	I - OB(W-13)	5.6E-06 +	-5.2518	NO				
	MERCER	'83	SLUG	1.0E-04	-4.0000	NO				
	GONZALEZ	'83	PUMPING	1.0E-04	-4.0000	NO				
	BARR et al.	'83	PUMPING	5.0E-05	-4.3010	NO				
ERDA-9	AVIS & SAULNIER	'90	I - OB(A.I.SHFT)	1.0E-05 +	-5.0000	NO				
	BEAUHEIM	'87b	SLUG	NR						
	BEAUHEIM	'87c	I - OB(W-13)	5.4E-05 +	-4.2676	NO				
CABIN BABY-1	BEAUHEIM	'87b	SLUG	NR						

INTERA Technologies | Culebra Dolomite Storativity Data Base | Table D.1f

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WELL	REFERENCES	YEAR OF REFERENCE	TYPE OF TEST	REPORTED CULEBRA S	LOG OF STORATIVITY	SELECTED S VALUE (YES OR NO)	AVERAGE OF SELECTED S VALUES (PER HYDROPAD OR WELL LOCATION) log S	CULEBRA STORATIVITY VALUE log S	CULEBRA STORATIVITY VALUE S	COMMENTS
ENGLE	BEAUHEIM	'88b	I - OB(H9c)	4.8E-06	-5.3188	NO				
	BEAUHEIM	'87b	PUMPING	NR						
USGS-1	COOPER	'62	PUMPING '60D	NR						
	COOPER	'62	PUMPING '60R	NR						
	COOPER & GLANZ.	'71	PUMPING '63	2.0E-05	-4.6990	YES	NA	-4.6990	2.00E-05	VALUE ASSIGNED AT USGS-1 BOREHOLE
D-268	BEAUHEIM	'88a	SLUG	NR						
AEC-7	BEAUHEIM	'88a	SLUG	NR						
EX.SHFT	BEAUHEIM	'87c	I - OB(W-13)	5.5E-05 +	-4.2596	NO				

ABBREVIATIONS ;

I = INTERFERENCE
R# = RECOVERY OF TEST #
D# = DRAWDOWN OF TEST #
OB = OBSERVATION
(WELL) = PUMPING WELL

DST = DRILL-STEM TEST
SLUG = SLUG TEST
NA = NOT APPLICABLE
NR = NOT REPORTED
+ = POSSIBLE VALUE FOR PILOT POINT POSITIONED BETWEEN PUMPING AND OBSERVATION WELL

INTERA Technologies | Culebra Dolomite Storativity Data Base | Table D.1g

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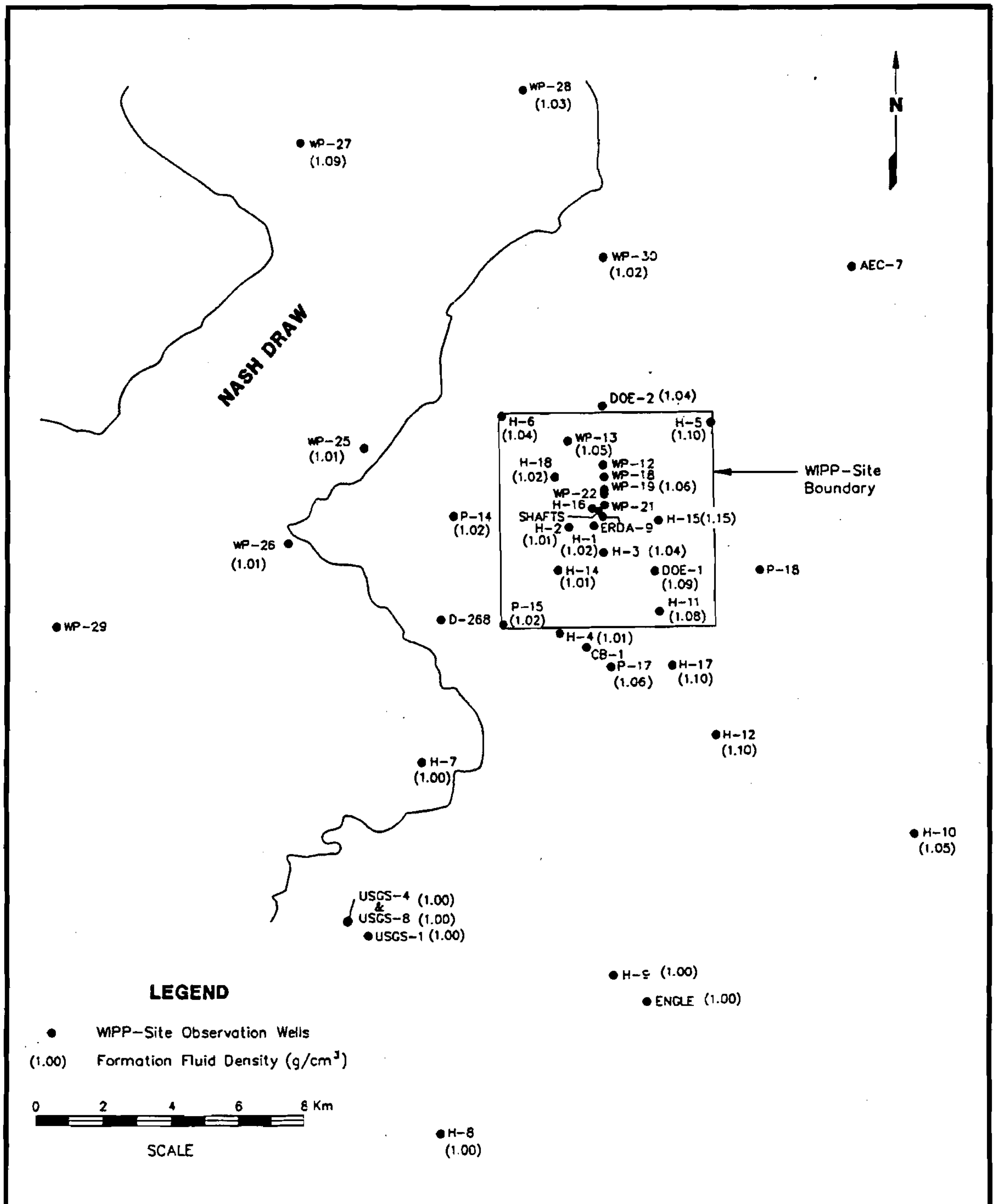
APPENDIX E: CULEBRA FORMATION-FLUID DENSITIES

The densities of water samples from boreholes open to a given formation will be the same as the densities of the formation water only if the samples are not contaminated. Contamination can result from the mixing of formation water with drilling fluids, with fluids used in borehole construction, and with water from other formations connected by the borehole. Knowledge of the extent of such contamination, if any, is required to evaluate the composition and density of formation fluids.

The density and chemical analytical data on Culebra samples included in the data base have been evaluated for their internal consistency and for indications of how well they may represent the density and chemistry of Culebra formation waters. The evaluation procedures used for samples collected prior to April 1986 are described in Haug et al. (1987). This detailed evaluation was not performed on samples collected after April 1986. However, a comparison of the latter samples with those presented in Haug et al. (1987) indicate similar formation-fluid densities.

Table E.1a-d lists the density data base. The table lists the source of the sample data, the date the sample was taken, and the values of specific gravity or density of the sample. The calculated densities were determined using the methodology described in Haug et al. (1987). The densities recommended for modeling purposes are presented in the table and on Figure E.1. The recommended density values for most wells or hydropads are an average of the values from the Water Quality Sampling Program (WQSP) for water samples taken at that well or hydropad location. For wells that did not have WQSP data, calculated values reported and discussed in Haug et al. (1987) were selected.



Drawn by	ABW	Date	11/15/89	Formation-Fluid Density Values of the Culebra Dolomite
Checked by	T.C.	Date	11/15/89	
Revisions		Date		
H09700R869			11/15/89	
INTERA Technologies				Figure E.1

FORMATION-FLUID DENSITIES Updated 06/01/89

Well Number	Date Sampled	Mercer, 1983 sp.grv.	Mercer, 1983 density g/cm3	Robinson, 1986 sp.grv.	Robinson, 1986 density g/cm3	Uhland & Randall, 1986 sp.grv.	Uhland & Randall, 1986 density g/cm3	Uhland et al., 1987 sp.grv.	Uhland et al., 1987 density g/cm3	Randall et al., 1988 sp.grv.	Randall et al., 1988 density g/cm3	Lyon, 1989 sp.grv.	Lyon, 1989 density g/cm3	HydroGeoChem Field Logbooks sp.grv.	HydroGeoChem Field Logbooks density g/cm3	INTERA Field Logbooks sp.grv.	INTERA Field Logbooks density g/cm3	Calculated Density(2) g/cm3	Recommended Density g/cm3
H-1	06/02/76	1.016	1.014(1)															1.022	1.022
H-2a	04/21/86					1.009	1.007												
	08/12/87									1.008	1.006								
H-2b1	02/22/77	1.012	1.010																
H-2b2	11/16/83													1.006	1.004				1.006(3)
H-3b1	03/17/77	1.024	1.022																
H-3b2	12/16/85															1.037	1.034		
H-3b3	06/11/84																		1.035(3)
	02/04/85																		
	05/05/86							1.038	1.036										
	08/24/87									1.037	1.035								
H-4b	05/29/81			1.010	1.008														
	07/25/85					1.015	1.013												
	11/09/86							1.018	1.016										
	09/25/87									1.015	1.013								
H-4c	08/10/84																		1.014(3)
	unknown													1.012	1.010				
H-5b	06/01/81			1.100	1.097														
	08/27/85					1.105	1.102												
	05/21/86							1.105	1.102										
H-5c	10/15/81			1.100	1.097														1.102(3)

INTERA Technologies | Culebra Dolomite Formation-Fluid-Density Data Base | Table E.1a

#1050-000 T.C. 10/12/89

Well Number	Date Sampled	Mercer, 1983 sp.grv.	Mercer, 1983 density g/cm3	Robinson, 1986 sp.grv.	Robinson, 1986 density g/cm3	Uhland & Randall, 1986 sp.grv.	Uhland & Randall, 1986 density g/cm3	Uhland et al., 1987 sp.grv.	Uhland et al., 1987 density g/cm3	Randall et al., 1988 sp.grv.	Randall et al., 1988 density g/cm3	Lyon, 1989 sp.grv.	Lyon, 1989 density g/cm3	HydroGeoChem Field Logbooks sp.grv.	HydroGeoChem Field Logbooks density g/cm3	INTERA Field Logbooks sp.grv.	INTERA Field Logbooks density g/cm3	Calculated Density(2) g/cm3	Recommended Density g/cm3
H-6b	05/02/81			1.040	1.038														1.038
	09/15/85					1.042	1.039												
	07/28/86							1.040	1.037										
	11/16/87									1.040	1.038								
H-7b	03/20/80	1.001	0.999																0.999
	02/21/86															1.000	0.998		
	03/26/86					1.001	0.999												
	02/25/87									1.001	0.999								
H-8b	02/11/80	1.000	0.998																1.000
	12/09/85															1.002	1.000		
	01/22/86					1.002	1.000												
	02/11/87									1.002	1.000								
H-9b	11/14/85					1.003	1.001												1.000
	01/28/87									1.002	1.000								
H-10b	03/21/80	1.045	1.043															1.047	1.047
H-11b3	10/13/84													1.087	1.085				1.078
	05/23/85					1.091	1.089(1)												
	06/04/86							1.081	1.078										
	09/15/87									1.080	1.078								
H-12	08/09/85					1.096	1.093												1.095
	01/16/87									1.100	1.097								
H-14	12/11/86															1.010	1.008		1.010
	05/26/87									1.012	1.010								
H-15	05/11/87															1.160	1.157		1.154
	05/11/87							1.156(4)											
	05/11/87									1.156	1.153								
H-17	10/27/87									1.103	1.100								1.100
	11/26/87															1.107			
H-18	11/10/87									1.018	1.016								1.017
	04/07/88											1.020	1.018						

INTERA Technologies | Culebra Dolomite Formation-Fluid-Density Data Base | Table E.1b

#1050-000 T.C. 10/12/89

Well Number	Date Sampled	Mercer, 1983 sp.grv.	Mercer, 1983 density g/cm3	Robinson, 1986 sp.grv.	Robinson, 1986 density g/cm3	Uhland & Randall, 1986 sp.grv.	Uhland & Randall, 1986 density g/cm3	Uhland et al., 1987 sp.grv.	Uhland et al., 1987 density g/cm3	Randall et al., 1988 sp.grv.	Randall et al., 1988 density g/cm3	Lyon, 1989 sp.grv.	Lyon, 1989 density g/cm3	HydroGeoChem Field Logbooks sp.grv.	HydroGeoChem Field Logbooks density g/cm3	INTERA Field Logbooks sp.grv.	INTERA Field Logbooks density g/cm3	Calculated Density(2) g/cm3	Recommended Density g/cm3
DOE-1	04/12/85						1.110												1.088
	07/03/86							1.091	1.088(5)										
	07/28/87									1.091	1.088								
DOE-2	03/12/85						1.060												1.041
	07/04/86															1.040	1.037		
	08/27/86							1.043	1.041										
P-14	02/26/86					1.019	1.017												1.018
	06/18/87									1.020	1.018								
P-15	05/10/77	1.080	1.078(1)															1.015	1.015
P-17	03/17/86					1.065	1.063												1.061
	12/18/86							1.063	1.061										
	10/21/87									1.062	1.060								
WIPP-13	02/16/87									1.048	1.046								1.046
	02/18/87															1.046			
WIPP-19	07/14/87									1.072	1.070(5)								1.059
	02/12/88											1.061	1.059						
	08/29/88											1.061	1.059						
WIPP-25	08/20/80			1.010	1.008														1.009
	02/12/86					1.010	1.008												
	04/15/87									1.011	1.009								
WIPP-26	08/24/80			1.005	1.003														1.009
	11/25/85					1.012	1.010												
	04/01/87									1.010	1.008								
WIPP-27	08/22/80	1.094	1.092(1)															1.091	1.093
	09/05/80			1.090	1.088													1.096	
WIPP-28	09/11/80			1.030	1.028													1.032	1.032
WIPP-29	08/20/80	1.178	1.175(1)																(6)
	08/28/80			1.160	1.158														
	12/14/85					1.216	1.213												
	03/11/87									1.187	1.184								

INTERA Technologies | Culebra Dolomite Formation-Fluid-Density Data Base | Table E.1c

#1050-000 T.C. 10/12/89

Well Number	Date Sampled	Mercer, 1983 sp.grv.	Mercer, 1983 density g/cm3	Robinson, 1986 sp.grv.	Robinson, 1986 density g/cm3	Uhland & Randall, 1986 sp.grv.	Uhland & Randall, 1986 density g/cm3	Uhland et al., 1987 sp.grv.	Uhland et al., 1987 density g/cm3	Randall et al., 1988 sp.grv.	Randall et al., 1988 density g/cm3	Lyon, 1989 sp.grv.	Lyon, 1989 density g/cm3	HydroGeoChem Field Logbooks sp.grv.	HydroGeoChem Field Logbooks density g/cm3	INTERA Field Logbooks sp.grv.	INTERA Field Logbooks density g/cm3	Calculated Density(2) g/cm3	Recommended Density g/cm3
WIPP-30	09/06/80			1.020	1.018														1.018
	03/04/88											1.020	1.018						
ENGLE	03/04/85						1.015											1.001	1.001
C.B.-1	10/03/86															1.031	1.029		(7)
USGS-1	05/15/85																	1.000(8)	1.000
USGS-4	03/23/75																	1.000(8)	1.000
USGS-8	03/23/75																	1.000(8)	1.000

(1) These samples were determined to have suspect density and/or chemical data. Discussion is given in Haug et al. (1987).
(2) Unless otherwise noted, densities were calculated based on chemical composition of samples using Pitzer ion-interaction theory for the Cl-salt component of the solution and stoichiometric addition of densities of pure solutions for the SO4-salt components.
(3) Value assigned to the hydropad.
(4) Personal communication with W.S. Randall on 10/26/87
(5) These samples were not considered representative of the formation fluid. Samples taken during subsequent WQSP rounds are considered more representative.
(6) A density is not recommended due to contamination from nearby potash tailings dumps.
(7) A value was not recommended due to the limited data at this well.
(8) Density calculated based on total dissolved solid and specific conductance measurements made on fluid collected from the borehole.

INTERA Technologies | Culebra Dolomite Formation-Fluid-Density Data Base | Table E.1d

#1050-000 T.C. 10/12/89

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APPENDIX F: BOREHOLE FLUID-DENSITY HISTORIES AND ESTIMATION OF UNCERTAINTIES IN BOREHOLE-FLUID DENSITIES AND RELATED EQUIVALENT-FRESHWATER HEADS

Calculation of the transient equivalent-freshwater heads discussed in Appendix G requires a knowledge of the average borehole-fluid density. For each borehole used in the Culebra flow model, a review of published literature and original field records was conducted to compile a summary of the activities at that borehole, to gather available water-quality data from fluid withdrawn from the borehole, and to gather results of borehole pressure-density surveys. The literature and field records used in this search are given in the bibliography at the end of this appendix. An estimate of borehole-fluid density as a function of time was then determined based on this research. In addition, this review was used to estimate the uncertainty of the borehole-fluid density. As used in this report, the term uncertainty refers to upper and lower bound estimates and is not intended to have a rigorous statistical meaning.

The literature sources used in constructing the borehole-fluid density histories are:

1) basic data reports (borehole-specific reports, e.g., Sandia Laboratories and U.S. Geological Survey, 1979, 1980; Sandia National Laboratories and D'Appolonia Consulting Engineers, 1982, 1983; Sandia National Laboratories and U.S. Geological Survey, 1983; Beauheim et al., 1983; D'Appolonia Consulting Engineers, 1983);
2) hydrologic data reports (Hydro Geo Chem, 1985; INTERA and Hydro Geo Chem, 1985; INTERA, 1986; Saulnier et al., 1987; Stensrud et al., 1987, 1988a, 1988b);
3) hydrogeologic interpretive reports (e.g., Beauheim, 1987; Christensen and Peterson, 1981; Gonzalez, 1983a; Haug et al., 1987; Mercer, 1983; Mercer and Orr, 1977, 1979; Richey, 1986, 1987);
4) water-quality data and geochemical interpretive reports (e.g. Gonzalez, 1983b; Lambert and Robinson, 1984; Lyon, 1989; Randall et al., 1988; Uhland and Randall, 1986; Uhland et al., 1987);
5) potash resources reports (e.g., Jones, 1978);

6) Project Gnome reports (e.g., Cooper, 1961; Cooper and Glanzman, 1971; U.S. Department of Energy, 1982);
7) pressure-density survey literature (Crawley, 1988a, 1988b; Kehrman, 1989);
8) logbooks for the field hydrology program (Hydro Geo Chem, 1979-1985; INTERA, 1985-1989).

The most direct data for determining the borehole-fluid density was from the results of the pressure-density surveys. Unfortunately, pressure-density surveys were not initiated at the WIPP site until late 1986 and many of the WIPP wells have histories which begin in 1977. For time periods when pressure-density survey data was not available, construction of the borehole-fluid density history utilized limited indirect information obtained from well activities and water-quality sampling exercises. The ideal condition for determining histories of the borehole-fluid density would have been to conduct pressure-density surveys periodically and before and after each well activity.

For each well, this appendix provides a summary of the activities affecting the borehole-fluid density. These activities include well development, hydraulic testing (slug, drill-stem, and pumping test), and water-quality sampling. The following paragraphs describe general guidelines used to estimate borehole-fluid density.

The best data for determining the average borehole-fluid densities were those obtained from the three rounds of borehole pressure-density surveys, conducted by International Technologies, Inc., reported in Crawley (1988a) and from the results of other pressure-density surveys, conducted by Westinghouse Electric Corporation, reported in Crawley (1988b) and Kehrman (1989). The survey dates and calculated densities are tabulated in Table F.1a-c. In these surveys, a downhole transducer was lowered to various depths in the borehole, including the center of the Culebra interval if possible. At each depth, the pressure was recorded by the transducer and the depth to water below the casing top was measured. A direct calculation of the average borehole-fluid density of the fluid column above the center of the Culebra interval is made using the relationship:

$$\rho = \frac{P_{fc} - P_{atm}}{g(d_c - d_w)} \qquad \text{(F.1)}$$

where

- ρ = average borehole-fluid density,
- P_{fc} = absolute pressure measured with the transducer located at the center of the Culebra interval,
- P_{atm} = atmospheric pressure,
- g = the local acceleration of gravity,
- d_c = depth to the center of the Culebra interval below ground surface (BGS), and
- d_w = depth to water (BGS) with the transducer located at the center of the Culebra.

In wells with a production-injection packer (PIP) set above the Culebra interval, the fluid column accessible for surveying ranges from 7 to 73 percent of the total fluid column. For these wells, the pressure measured immediately above the PIP is extrapolated to the center of the Culebra interval using the relationship:

$$P_{fc} = P + \rho g (d_c - d_p) \qquad (F.2)$$

where

- P_{fc} = pressure at the center of the Culebra interval,
- P = absolute pressure measured with the transducer located immediately above the PIP,
- ρ = estimated fluid density for the section of the borehole surveyed immediately above the PIP,
- g = the local acceleration of gravity,
- d_c = depth to the center of the Culebra interval (BGS), and
- d_p = transducer depth (BGS).

This extrapolated pressure is then used to calculate an average borehole-fluid density using Equation F.1. Table F.1a-c summarizes the survey dates and calculated borehole-fluid densities for each well for which pressure-density surveys have been conducted.

A variety of activities and combinations of activities have been conducted in the wells of the WIPP site during their early histories. These activities include, but are not limited to, well completion, cleaning, acidization, well recompletion, and interval perforation. Two generalizations can be made concerning the early borehole histories. First, the activities conducted in the boreholes were unique to each well. That is, a summary of typical activities conducted in all WIPP-site wells during their early histories cannot be developed. For example, some wells were left filled with drilling fluid for months or years after drilling while others were perforated, cleaned, and acidized within a short period of time after drilling was completed. Second, water-quality data are limited and no pressure-density surveys were conducted for the early times resulting in large uncertainties for the estimated borehole-fluid densities.

Well-development at tested wells was designed to clean the perforated intervals and to establish good hydraulic connection to the formation. Typically, well development was conducted with the entire borehole open to the formation. Fluid pumped from the formation during surge and development periods entered the borehole and mixed with the existing borehole fluid. The pumped fluid consisted of a combination of the pre-pumping wellbore fluid, the formation fluid, or fluid lost to the formation during drilling. In some cases, a sample was collected during the initial stages of well development and then again during the final stages. The density of the former sample is considered to be representative of the borehole-fluid density from the time the well was completed or the interval was perforated until the well development began. In the absence of other data, the latter sample is considered for most cases to be representative of the fluid present in the borehole after well development was completed. The degree of representativeness of each of these samples with respect to the fluid column in the borehole is dependent on the amount of the total fluid column removed during the well-development exercise.

Slug-injection tests were used in some of the wells to obtain estimates of the hydrologic parameters for the tested interval. Two downhole-equipment configurations were used for these tests. The first (Figure F.1) consisted of an inflatable packer installed on tubing inside the casing above the tested interval. For this configuration, the mechanics of the test are as follows. Once the packer was inflated and the pressure in the test interval stabilized, a measured volume of fluid was added to the annulus between the tubing and casing. When the fluid level in the annulus had stabilized, the packer was deflated, transmitting a near-instantaneous pressure increase to the formation. Due to the addition of fluid directly into the borehole, tests of this type can affect the borehole-fluid density. The slug-injection fluid was either freshwater or formation fluid previously removed from the tested well or a nearby well. In general, when freshwater was added to the borehole the borehole-fluid density decreased and when formation fluid was added the density increased. The second configuration for slug-injection tests (Figure F.2) is similar to the first with the addition of a minipacker installed and inflated inside the tubing. A measured quantity of fluid is added to the tubing once the pressure in the packer-isolated test interval has stabilized. The minipacker is then deflated, transmitting a near-instantaneous pressure increase to the formation. Since the volume of fluid added to the tubing is usually a small percentage of the pre-test borehole-fluid volume, tests of this type are considered to have a less significant effect on the borehole-fluid density.

Pumping tests were conducted in some of the WIPP-site wells to obtain estimates of the hydrologic parameters for the tested interval. In addition, a few long-term pumping tests were conducted to evaluate the formation's hydrologic parameters on a regional scale, including estimations of areal variations in permeability. Most of these tests were conducted with a packer located above the tested interval in the pumping well to reduce the effect of borehole storage during testing. The pump intake was positioned within the packer-isolated interval a short distance below the packer. Tests of this type are assumed to have a minor effect on the borehole-fluid density for most cases. The pumped fluid is contained within the packer isolated interval before it is removed from the borehole and does not come into contact with the stagnant borehole fluid above the packer. Some pumping tests were conducted without isolating the tested interval. In these cases, the pre-pumping borehole fluid may be modified as a result of the pumping. The extent of modification is dependent upon the volume of pre-existing borehole fluid replaced and/or mixed with pumped fluid.

A water-quality sampling program (WQSP) was initiated in January 1985 to sample wells in the vicinity of the WIPP site. Twenty-six wells have been included in the sampling program, which was conducted by International Technologies, Inc. from 1985 to 1988 and is currently conducted by Westinghouse Electric Corporation. Data for the rounds of sampling are reported in Uhland and Randall (1986), Uhland et al. (1987), Randall et al. (1988), and Lyon (1989). The primary goal of the WQSP is to obtain representative formation-fluid samples from the more transmissive hydrogeologic units.

The interval to be sampled is purged for a period of time prior to the initiation of serial sampling. A final sample is collected once the serial samples indicate that steady-state chemical conditions of the ground water appear to have been reached. In estimating the borehole-fluid density, water-quality sampling was considered to have an effect on the borehole-fluid density only in cases where a packer was not used, or the packer failed, and the transmissivity of the Culebra interval is low.

The following pages of this appendix contain a well-by-well discussion of the borehole-fluid density estimates for the WIPP-site wells used in the Culebra flow model. These discussions are divided into four sections: (1) a brief introductory paragraph on the drilling history of the well, (2) a chronological list of activities affecting interpretation of borehole-fluid densities, (3) a paragraph summarizing the estimates of borehole-fluid density as a function of time, the source of the estimate (i.e., pressure-density survey, field measurement, etc.), and the activities which appear to have caused the density to change from one time period to the next, and (4) estimates of borehole-fluid density uncertainty and related head uncertainty for each time period. A table summarizing the estimated borehole-fluid densities and related density and freshwater-head uncertainties is also included.

The uncertainty of the estimate of the borehole-fluid density for any given time period was based on an extensive review of all the fluid-density measurements and borehole activities at the monitoring well. The value for the uncertainty in borehole-fluid density was reported to two significant figures. The following general guidelines were used to estimate the borehole-fluid density uncertainty.

- In cases where the selected borehole-fluid density was based on the average of two or more density measurements and/or pressure-density survey results, the uncertainty was assumed to be the range of differences between the average fluid density calculated from these measurements and the individual density measurements or ±0.01 g/cm^3, whichever was greater. The sources for the density measurements include, but are not limited to, fluid bailed or swabbed from the borehole and fluid pumped from the borehole during well development, pumping exercises and tests, or water-quality sampling.

- When the selected borehole-fluid density was based on the results of a single pressure-density survey or on vertical sampling in the borehole, the borehole-fluid density uncertainty was estimated to be ±0.01 g/cm^3.
- An uncertainty of ±0.02 g/cm^3 was typically estimated if the selected borehole-fluid density was based on a single measured value, other than the results of a pressure-density survey, or on an average value determined from measurements made during a single activity. Single activities include, but are not limited to, one episode of bailing or swabbing, pumping tests or exercises, one slug-injection test, and well-development pumping.
- If most of the density measurements at a borehole were consistent, the average of these consistent values was selected as representative of the borehole-fluid density and the inconsistent values were used to define the uncertainty. If there were no inconsistent values, an uncertainty of ±0.01 g/cm^3 was used.
- The uncertainty in the selected borehole-fluid density was considered to fall within the range of up to +0.05 to -0.05 g/cm^3 when the selected value applied to a time period during which there was heavy activity in the borehole and/or when there was one or no density measurements made during the time period.

The limits to the possible values for the borehole-fluid density were defined as ranging from a minimum of 0.995 g/cm^3, the midpoint between the lowest reported borehole-fluid density (0.990 g/cm^3) and the density of freshwater (1.000 g/cm^3) and a maximum of 1.200 g/cm^3 corresponding to the density of 10-lb/gal brine. Therefore, the guidelines were modified, if necessary, so that the lowest density value indicated by the range of the uncertainty was greater than 0.995 g/cm^3 and the highest density value was less than 1.200 g/cm^3.

In addition to estimating the uncertainty of the borehole-fluid density estimate, a related freshwater-head uncertainty was calculated. An average column of fluid in the borehole above the center of the Culebra interval was assumed for these calculations. Multiplying the fluid column height by the borehole-fluid density uncertainty yields the uncertainty in freshwater head. The values for the freshwater-head uncertainty were reported to two significant figures.

As used in this appendix and in Appendix G, the term uncertainty refers to the upper and lower bound in the estimates of the borehole-fluid density and freshwater heads. This term is not intended to have a rigorous statistical meaning. Because of the many different factors affecting selection of the estimates at each well, a rigorous statistical approach was not considered feasible.

Table F.2a-d summarizes the chronology of borehole-fluid densities for each well used in the model. For each well, the table gives (1) average borehole-fluid density (g/cm^3), (2) a quantitative estimate of uncertainty in the borehole-fluid density (g/cm^3), (3) the appropriate time period, and (4) the approximate date of the water-level measurement used to calculate the undisturbed freshwater head.

WELL HISTORIES

H-1

H-1 was drilled in May and June 1976 as the first hydrologic test hole for the Rustler Formation at the WIPP site (Mercer and Orr, 1979). The borehole was drilled and reamed to a 9-5/8-inch diameter to a total depth of 261.0 m below ground surface (BGS) and then cased from the surface to a total depth of 258.5 m BGS using 7-inch casing. A cement plug was left in the casing from 253.4 to 258.5 m BGS. In January 1977, the casing in H-1 was perforated across the Rustler-Salado contact from 244.8 to 252.1 m BGS. In March 1977, the casing across the Culebra dolomite interval was perforated from 205.8 to 214.3 m BGS. In April of the same year, the Magenta dolomite interval was perforated from 171.3 to 179.9 m BGS. Following hydrologic testing, a bridge plug was set in the casing about 240.9 m BGS to isolate the Rustler-Salado contact, and a production-injection packer (PIP) was set on 2-3/8-inch tubing about 198.5 m BGS. Water levels in the Culebra and Magenta dolomites have been monitored in H-1 since that time.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

- 03/07/77: Casing perforation at the Culebra interval.
- 03/08/77: Bailed approximately 1640 L of fluid from the Culebra interval.
- 03/17/77: Bailed approximately 680 L of fluid from the Culebra interval. The density of a sample collected was 1.016 g/cm^3.
- 03/24/77: Conducted a tracer and a temperature survey on the Culebra interval. Approximately 6190 L of fluid were injected into the borehole during the surveys. After tracer injection, the borehole was bailed dry. The source of the injected fluid and the volume of fluid removed by bailing were not reported.
- 04/06/77: Installed a PIP between the Culebra and Magenta perforations. The center of the packer was set 7.2 m above the perforated Culebra interval.

10/22/86: Pressure-density survey; calculated ρ = 1.066 g/cm^3. The borehole was blocked off at 146.3 m BGS, therefore, only 18.6 m (7.0 percent) of the total fluid column could be accessed.

05/18/87: Removed the PIP. Evacuated the borehole using compressed air. Approximately 1890 L of fluid were removed. A fluid sample obtained near the end of this operation had a specific gravity of 1.058 at 20.0°C (ρ = 1.056 g/cm^3). [NOTE: Both the Magenta and Culebra intervals were open to the borehole.]

05/28/87: Evacuated the borehole using compressed air. Approximately 1890 L of fluid were removed. A fluid sample obtained near the end of this operation had a specific gravity of 1.055 at 25.0°C (ρ = 1.052 g/cm^3). [NOTE: Both the Magenta and Culebra intervals were open to the borehole.]

06/04/87 - 07/06/87: Attempted eight pumping tests using a pump and packer assembly. A total of approximately 70 L of fluid were removed from the borehole (about 8.5 L per test). During pumping, the bottom of the packer seal was located 6.5 m above the top of the perforated Culebra interval.

07/14/87: Reinstalled the PIP with the bottom of the packer seal set 8.0 m above the top of the perforated Culebra interval. The PIP was set by filling the tubing with freshwater and then blowing out or knocking out the plug.

08/27/87: Swabbed approximately 150 L of fluid from the tubing connected to the Culebra interval. The specific gravity of the swabbed fluid was 1.000 at 22.0°C (ρ = 0.998 g/cm^3) at the start of swabbing and 1.000 at 23.0°C (ρ = 0.998 g/cm^3) at the end of swabbing.

09/01/87: Swabbed approximately 530 L of fluid from the tubing connected to the Culebra interval (swabbed dry). The specific gravity of the swabbed fluid ranged from 1.000 at 22.0°C (ρ = 0.998 g/cm^3) at the start of swabbing to 1.020 at 24.0°C (ρ = 1.017 g/cm^3) at the end of swabbing.

09/15/87: Swabbed approximately 420 L of fluid from the tubing connected to the Culebra interval. The specific gravity of the swabbed fluid ranged from 1.019 at 23.0°C (ρ = 1.017 g/cm^3) at the start of swabbing to 1.021 at 23.0°C (ρ = 1.019 g/cm^3) at the end of swabbing. After swabbing, a minipacker was set inside the tubing, 22.6 m above the top of the perforated Culebra interval. The minipacker was immediately inflated in preparation for a slug-withdrawal test.

09/21/87: Conducted a slug-withdrawal test. The test was initiated by deflating the minipacker located inside the tubing, 22.6 m above the top of the perforated Culebra interval.

09/22/87 - 09/28/87: Conducted three slug-injection tests. These tests consisted of inflating the minipacker, adding approximately 60 L of formation fluid to the tubing, and then deflating the minipacker. A total of about 190 L of formation fluid were injected into the tested interval.

09/16/88: Removed the PIP separating the Magenta and Culebra intervals.

09/19/88 - 10/08/88: Water-quality sampling. Three different pump and packer configurations were used during sampling due to a series of equipment failures. The total volume of fluid pumped from the borehole was approximately 2.01 x 10^4 L at a flow rate which declined from 0.02 to 0.01 L/s. The specific gravity of the pumped fluid was 1.024 at 22.4°C (ρ =1.022 g/cm^3) on 10/04/88.

10/19/88: Reinstalled a PIP between the Magenta and Culebra intervals. The bottom of the packer seat is located about 8.4 m above the top of the Culebra interval.

05/11/89: Pressure-density survey; calculated ρ = 1.002 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 58.1 m or 75.3 percent of the total fluid column.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-1 is estimated as follows. For the time period of 03/07/77 (initial completion of the Culebra interval) through 07/14/87, a density of 1.036 g/cm^3 is estimated to be representative of the borehole fluid. This density is the average of the densities measured on 03/17/77 and 05/18/87. A density of 0.998 g/cm^3, based on field-density measurements on 08/27/87, is estimated for the time period of 07/14/87 to 09/01/87. Fluid collected at the end of swabbing on 09/15/87 had a density of 1.019 g/cm^3. The average of this value and the results of the pressure-density survey conducted in May 1989 is assumed to be representative of the borehole fluid for the time period of 09/01/87 to 06/16/89.

The borehole-fluid density uncertainty for the first and third time periods is estimated to be ±0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±1.9 m. The borehole-fluid density and freshwater-head uncertainties for the second period are +0.02 g/cm^3 and +1.9 m, respectively. The freshwater-head uncertainties were calculated assuming an approximate borehole fluid column height above the center of the Culebra interval of 93.5 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/07/77 - 07/14/87	1.036	±0.02	±1.9
07/14/87 - 09/01/87	0.998	+0.02	+1.9
09/01/87 - 06/16/89	1.011	±0.02	±1.9

H-2a

H-2a was drilled in mid-February 1977 as a Magenta monitoring well. The borehole was originally drilled to the top of the Magenta dolomite at a depth of 156.4 m BGS, cased with 6-5/8-inch casing, and cemented. H-2a was then cored through the Magenta and left open for later hydrologic testing and sampling. In July 1983, the borehole was deepened through the Culebra dolomite to the top of the unnamed lower member of the Rustler Formation at a depth of 204.9 m BGS. H-2a was then converted to a dual-completion borehole with the installation of a production-injection packer (PIP) and tubing to separate the Magenta and Culebra dolomites. In April and May 1984, the borehole was re-entered and cleaned, then 4-1/2-inch casing was installed to the top of the Culebra interval (189.9 m BGS) and cemented. A lead-coned packer with an attached well screen and bottom cap was installed across the Culebra dolomite interval from 189.9 to 196.6 m BGS.

The significant borehole activities affecting interpretations of Culebra equivalent-freshwater heads are:

07/12/83 - 07/15/83: Drilled the Culebra interval.

08/01/83 - 08/03/83: Cleaned the borehole and circulated fluid in the borehole. Installed a PIP between the Magenta and Culebra intervals. The bottom of the packer seal was set 11.2 m above the top of the Culebra interval.

04/25/84 - 05/01/84: Recompleted the borehole. Set and cemented 4-1/2-inch casing to the top of the Culebra dolomite and then set well screen across the Culebra interval.

12/14/83-04/19/84: The borehole was open to both the Magenta and Culebra. Water-level measurements during this time period are composite values.

06/07/84: Bailed approximately 190 L of fluid from the borehole. The specific gravity of the fluid collected with the first bail was 1.070 at 28.0°C (ρ = 1.066 g/cm^3) and with the last bail was 1.066 at 27.0°C (ρ = 1.062 g/cm^3).

06/22/84: Bailed approximately 190 L of fluid from the borehole. The fluid collected with the last bail had a specific gravity of 1.068 at 24.0°C (ρ = 1.065 g/cm^3).

07/09/84: Bailed approximately 270 L of fluid from the borehole. The specific gravity of the fluid collected near the end of bailing was 1.054 at 25.0°C (ρ = 1.051 g/cm^3).

07/20/84: Installed a packer and tubing in the borehole. The packer was set in the casing approximately 30.0 m above the Culebra interval.

08/31/84 - 09/04/84: Conducted three slug-injection tests. The tests consisted of inflating the packer, adding fluid to the annulus, and then deflating the packer to initiate the test. For each test, approximately 140 L of fluid were added to the borehole. The source of the slug was fluid pumped from H-2b2 (ρ = 1.016 g/cm^3). After completion of these tests, the packer and tubing were removed from the borehole.

04/04/86 - 04/21/86: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. Problems were encountered with the packer and it failed to seal. The location of the pump intake was not reported. About 1630 L of fluid were pumped prior to sampling. The specific gravity of the pumped fluid decreased from 1.049 at 22.4°C (ρ = 1.046 g/cm^3) on 04/04/86 to 1.009 at 21.7°C (ρ = 1.007 g/cm^3) on 04/21/86. Approximately 3.67 x 10^4 L of fluid were pumped prior to final sampling at an average rate of 0.02 L/s.

07/23/87 - 08/12/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra for sampling. The pump intake was located 4.1 m above the top of the Culebra interval. Approximately 2.04 x 10^4 L of fluid were pumped prior to sampling. The specific gravity of the pumped fluid remained constant at 1.008 at 22.7°C (ρ = 1.007 g/cm^3). Approximately 3.33 x 10^4 L of fluid were pumped prior to final sampling at an average rate of 0.02 L/s.

01/04/89-01/19/89: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 12.8 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.011 at 20.6°C (ρ = 1.009 g/cm^3) on 01/11/89 and 1.014 at 19.4°C (ρ = 1.012 g/cm^3) on 01/19/89. Approximately 1.81 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.017 L/s.

For the time period of 07/15/83 (initial completion of the Culebra interval) to 07/09/84, a density of 1.064 g/cm^3 is estimated to be representative of the borehole fluid. This fluid density is based on an average of the specific-gravity measurements of samples obtained from bailing operations on 06/07/84 and 06/22/84. For the time period from 07/09/84 to 06/16/89, a density of 1.012 g/cm^3 is estimated to be representative of the borehole fluid. This value is an average of the density for water added to the borehole during the slug testing in August and September 1984 and the density of the water pumped during the final stages of water-quality sampling in April 1986. Because the Culebra interval is relatively tight in the vicinity of the H-2 hydropad and the interval was not effectively isolated during the water-quality sampling conducted in April 1986, it is assumed that this pumping resulted in drawdown at the well and subsequent mixing of the formation fluid (ρ = 1.007 g/cm^3) with the wellbore fluid.

The borehole-fluid density uncertainty for the first time period is +0.01 to -0.02 g/cm^3. This uncertainty value translates to a head uncertainty of +0.9 to -1.7 m. For the second time period, the borehole-fluid density uncertainty is +0.02 to -0.01 g/cm^3 and the freshwater-head uncertainty is +1.7 to -0.9 m. The freshwater-head uncertainties were calculated assuming an approximate borehole fluid column height above the center of the Culebra interval of 86.3 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-2a

Time Period	Borehole-Fluid Density (g/cm³)	Density Uncertainty (g/cm³)	Related Head Uncertainty (m)
07/15/83 - 07/09/84	1.064	+0.01/-0.02	+0.9/-1.7
07/09/84 - 06/16/89	1.012	+0.02/-0.01	+1.7/-0.9

H-2b1

H-2b1 (also referred to as H-2b) was drilled in early February 1977 as a Culebra monitoring well. The borehole was originally drilled to near the top of the Culebra (185.7 m BGS), cased, and cemented. The borehole was then cored through the Culebra from 189.9 to 196.6 m BGS to a total depth of 201.5 m BGS, and left open for later hydrologic testing and sampling. In April and May 1977, H-2b1 was perforated across the Magenta dolomite interval from 155.5 to 164.0 m BGS and converted to a dual-completion borehole with the installation of a production-injection packer (PIP) to separate the Magenta and Culebra dolomites. The bottom seal of the PIP was located at a depth of 180.8 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

02/12/77: Cored the Culebra interval.

02/13/77 - 02/21/77: Bailed an unknown volume of fluid from the Culebra interval. (No water-quality data.)

02/22/77: Bailed an unknown volume of fluid from the Culebra interval. The density of the bailed fluid was 1.010 g/cm^3.

04/04/77 - 05/13/77: Installed a retrievable bridge plug 178.6 m BGS. Perforated the Magenta interval from 155.5 to 164.0 m BGS. Bailed an unknown volume of fluid from the Magenta interval.

05/13/77: Removed the bridge plug from the borehole and installed a PIP between the Magenta and Culebra intervals. The bottom seal of the PIP was located at a depth of 180.8 m BGS.

01/80: Installed a pump-jack assembly in the tubing (the exact date and details of the installation were not reported).

01/07/80 - 01/11/80: Conducted a pumping exercise of unspecified duration on the Culebra interval at an approximate discharge rate of 0.008 L/s. (No water-quality data.)

01/30/80 - 02/01/80: Conducted a 40-hour pumping test on the Culebra interval at an approximate discharge rate of 0.019 L/s. (No water-quality data.)

02/06/80 - 02/11/80: Pumped fluid from the borehole for approximately 123 hours at a rate of 0.016 L/s. The pumped fluid was injected, along with a tracer(s), into H-2c.

02/13/80 - 03/20/80: Pumped fluid from the borehole for 865.5 hours at an approximate pumping rate of 0.019 L/s.

03/27/80 - 06/18/80: Pumped fluid from the borehole.

06/23/80: Removed the pump-jack assembly from the tubing.

07/07/80 - 04/07/81: Fluid pumped from H-2c was injected through the tubing into the Culebra interval at an approximate injection rate of 0.018 L/s. Tracer was added to the injected fluid from 07/10/80 to 08/07/80. A total of approximately 4.20×10^5 L of fluid were injected. The specific gravity of the injected fluid was reported to be 1.002, however, this value was not considered to be representative.

12/14/83: Removed the PIP located between the Magenta and Culebra intervals.

12/14/83 - 02/06/84: The borehole was open to both the Magenta and Culebra. Water-level measurements during this time period are composite values.

01/09/84 - 01/10/84: Circulated fluid in the borehole and cleaned the borehole.

06/07/84 - 06/22/84: Bailed approximately 2000 L of fluid from the borehole. [NOTE: Both the Magenta perforations and Culebra open-hole intervals contributed fluid.] The specific gravity of the fluid collected with the initial bail was 1.056 at 23.0°C (ρ = 1.053 g/cm^3) and with the final bail was 1.126 at 24.0°C (ρ = 1.123 g/cm^3).

07/09/84: Installed a PIP between the Magenta and Culebra intervals. The bottom of the packer seal was set 10.5 m above the top of the Culebra interval. Freshwater was introduced into the borehole during installation of the PIP.

07/25/84: The borehole was evacuated with compressed air to try to remove the freshwater introduced into the borehole during PIP installation. Removed approximately 8 L of fluid.

07/26/84 - 08/01/84: Added approximately 170 L of formation fluid from H-2b2 to the tubing. Released the fluid into the Culebra interval.

08/29/84: Slug-injection test. The slug consisted of approximately 70 L of fluid added to the tubing. The test was initiated by releasing the fluid into the Culebra interval. The source of the slug was fluid pumped from H-2b2.

10/28/87: Pulled the PIP which was suspected to have deflated.

12/17/87: Installed a PIP between the Magenta and Culebra intervals. The bottom of the packer element was set at 182.9 m below top of casing (BTC). The packer was inflated using formation fluid.

03/01/88: Pulled the PIP from the borehole to inspect it for possible damage. Installed another PIP. The bottom of the packer element was set at 183.1 m BTC. The packer was inflated using freshwater.

03/07/88: Pulled the PIP from the borehole.

03/15/88: Installed a PIP between the Magenta and Culebra intervals. The bottom of the packer element was set at 183.0 m BTC. The packer was inflated using approximately 160 L of freshwater. After inflating the packer, approximately 160 L of fluid were swabbed from the tubing.

07/13/88: Pulled the PIP from the borehole to inspect it for possible damage. Reinstalled the PIP in the borehole. The bottom of the packer element was set at 173.5 m BTC. The packer was inflated using formation fluid to load the tubing and approximately 60 L of freshwater to pressure up.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-2b1 is estimated as follows. For the time period of 02/12/77 (initial completion of the Culebra interval) to 01/09/84, a density of 1.010 g/cm^3 is estimated to be representative of the borehole fluid. The borehole probably filled with formation fluid from the Culebra interval as a result of the extensive pumping and formation-fluid injection in the borehole over this time period. An estimate of 1.010 g/cm^3 for the formation fluid was determined from water-quality data reported in Mercer (1983). For the time period of 01/09/84 to 07/09/84, a density of 1.053 g/cm^3 is assumed. This value is based on the density measured for fluid bailed from the borehole during June 1984. After 07/09/84, the borehole-fluid density is assumed to be 1.010 g/cm^3

consisting of a combination of water from the formation and H-2b2 water used in the slug-injection test conducted in August 1984.

The borehole-fluid density uncertainty for the first and third time periods is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.7 to -0.9 m. During the second time period, H-2b1 had a very complex borehole history. This results in large uncertainties associated with this estimate. The borehole-fluid density uncertainty for the second period is ±0.04 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±3.5 m. The freshwater-head uncertainties were calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 86.3 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-2b1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
02/12/77 - 01/09/84	1.010	+0.02/-0.01	+1.7/-0.9
01/09/84 - 07/09/84	1.053	±0.04	±3.5
07/09/84 - 06/16/89	1.010	+0.02/-0.01	+1.7/-0.9

H-2b2

H-2b2 was drilled in July 1983 to allow monitoring and hydrologic testing of the Culebra dolomite. The well was originally drilled to the top of the Culebra dolomite, cased, and cemented. H-2b2 was then cored through the Culebra from 189.9 to 196.6 m BGS into the unnamed lower member of the Rustler Formation to a total depth of 201.2 m BGS. In April 1984, the borehole was re-entered and cleaned. After completion, a lead-coned packer with an attached well screen and bottom cap was installed across the Culebra dolomite. The screened interval is from 190.2 to 197.6 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/06/83: Completed the Culebra interval.

10/13/83: Installed tubing and a pump-jack assembly in the borehole. The top of the seating valve was located approximately 15.0 m above the top of the Culebra interval.

10/13/83 - 10/16/83: Pumped the borehole for 68.8 hours at an approximate discharge rate of 0.019 L/s. The specific gravity of fluid collected at the start of pumping was 1.098. The specific gravity of fluid collected at the end of pumping was 1.052 at 25.0°C (ρ = 1.049 g/cm^3).

11/08/83 - 11/17/83: Conducted a 212.5-hour pumping test at a discharge rate of approximately 0.017 L/s. The specific gravity of the pumped fluid was 1.050 at the start of pumping and 1.006 at 20.0°C (ρ = 1.004 g/cm^3) at the end of pumping.

12/05/83: Pulled the tubing and pump-jack assembly from the borehole.

01/08/84: Cleaned the borehole and circulated fluid in the borehole.

05/02/84 - 05/03/84: Set a well screen over the open-hole Culebra interval.

06/07/84 - 07/09/84: Bailed approximately 1780 L of fluid from the borehole. The specific gravity of the bailed fluid was 1.042 at 31.0°C (ρ = 1.037 g/cm^3) at the start of bailing and 1.068 at 25.0°C (ρ = 1.065 g/cm^3) at the end of bailing.

07/16/84: Installed tubing, a packer, and a pump-jack assembly in the borehole. The bottom seal of the packer was set approximately 20.0 m above the top of the Culebra interval.

07/17/84 - 08/02/84: Conducted eight 4-hour pumping exercises at an average discharge rate of 0.017 L/s. (No water-quality data.)

08/21/84 - 08/22/84: Pumped approximately 760 L of fluid from the borehole. (No water-quality data.)

08/27/84: Pulled the pump-jack assembly from the tubing.

08/28/84 - 08/30/84: Conducted two slug-injection tests. The tests consisted of inflating the packer, adding approximately 40 L of fluid to the annulus, and then deflating the packer to initiate the test. The source of the slug was fluid previously pumped from the borehole.

07/86: A water sample taken at the Culebra depth had a specific gravity of 1.016.

05/17/89: Pressure-density survey; calculated ρ = 1.008 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-2b2 is estimated as follows. For the time period of 08/06/83 (initial completion of the Culebra interval) to 10/13/83, a density of 1.095 g/cm^3 is assumed to be representative of the borehole fluid. This value was based on the density measured for fluid produced during the early stages of well-development pumping conducted in October 1983. For the time period of 10/13/83 to 08/22/84, a density of 1.051 g/cm^3 is assumed. This value is the average of the densities measured for fluid bailed from the borehole in June and July 1984. The decrease in density from the first time period appears to be the result of well-development pumping. During pumping between 07/16/84 and 08/21/84, the Culebra interval was isolated with a packer. This configuration and the low pumping rate suggests that pumping during this period probably had only a minor impact on the borehole fluid. Based on the results of the pressure-density survey conducted in May 1989, a borehole-fluid density of 1.008 g/cm^3 is assumed for the time period of 08/22/84 to 06/16/89.

The borehole-fluid density uncertainty for the first time period is ±0.05 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±4.3 m. The borehole-fluid density uncertainty for the second time period is ±0.03 g/cm^3 which is ±2.6 m when expressed as freshwater-head uncertainty. The borehole-fluid density and freshwater-head uncertainties for the third time period are +0.01 g/cm^3 and +0.9 m, respectively. The freshwater-head uncertainties were calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 86.3 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-2b2

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/06/83 - 10/13/83	1.095	±0.05	±4.3
10/13/83 - 08/22/84	1.051	±0.03	±2.6
08/22/84 - 06/16/89	1.008	+0.01	+0.9

H-2c

H-2c was drilled in February and March 1977 as a Rustler-Salado contact test borehole. The borehole was originally drilled to a depth of 226.2 m BGS. Following casing and cementing, H-2c was cored through the Rustler-Salado contact to a total depth of 242.4 m BGS. A retrievable bridge plug was then installed between the Rustler-Salado contact and the Culebra interval (190.2 to 198.8 m BGS), and the Culebra interval was perforated. After perforation of the Culebra, the bridge plug was retrieved and a production-injection packer (PIP) was set at a depth of 223.2 m BGS to allow long-term monitoring of both the Rustler-Salado contact and the Culebra interval.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

03/07/77: Casing perforation at the Culebra interval.

03/08/77: Bailed approximately 1000 L fluid from the borehole. (No water-quality data).

03/16/77: Bailed an unknown volume of fluid from the borehole and sampled the Culebra interval. (No water-quality data.)

03/21/77: Conducted a tracer and a temperature survey in the borehole. The pumping rate was about 0.5 L/s. A total of approximately 2640 L of fluid were injected into the borehole.

03/23/77: Bailed the borehole dry. (No water-quality data.)

03/25/77: Placed the well on long-term dual-completion monitoring of the Culebra and Rustler-Salado contact intervals.

11/79 - 1/80: Pulled the PIP and installed a retrievable bridge plug between the perforated Culebra interval and the open-hole Rustler-Salado contact interval. The top of the bridge plug was set 202.3 m BGS.

01/80: Installed tubing and a PIP in the borehole. The bottom seal of the PIP was set approximately 1.0 m above the top of the Culebra interval.

02/06/80 - 02/11/80: Formation fluid pumped from H-2b1 was injected through the tubing into the Culebra interval for approximately 70 hours at an average rate of 0.017 L/s.

02/13/80 - 03/20/80: Formation fluid pumped from H-2b1 was injected through the tubing into the Culebra interval for approximately 900 hours at an average rate of 0.019 L/s. The tracers pentafluorobenzoate and flourocarbon were added to the injected fluid between 02/22/80 and 02/25/80.

03/27/80 - 06/18/80: Several attempts were made to continue pumping fluid from H-2b1 into H-2c without success.

06/30/80 - 07/02/80: Recompleted H-2c by installing a sucker-rod pump assembly into the tubing. Pumped fluid from the Culebra interval for 48 hours at an average rate of 0.014 L/s. (No water-quality data.)

07/07/80 - 04/07/81: Pumped fluid from the Culebra interval at an average discharge rate of 0.018 L/s. A total of approximately 4.20 x 10^5 L of fluid were pumped. A sample of the pumped fluid, collected on 12/10/80, had a specific gravity of 1.002 at 19.0°C (ρ = 1.000 g/cm^3). The representativeness of this sample was considered to be questionable.

04/29/81 - 05/02/81: Pumped fluid from the Culebra interval for 95 hours at an approximate discharge rate of 0.017 L/s. (No water-quality data.)

06/06/84: Removed the tubing and PIP from the borehole. The pump-jack assembly had been removed at some earlier, unreported date.

06/07/84: Set a bridge plug in the casing approximately 4.0 m below the base of the Culebra interval.

06/07/84 - 07/02/84: Swabbed approximately 2180 L of fluid from the borehole. The specific gravity of the swabbed fluid was 1.172 at 28.0°C (ρ = 1.168 g/cm^3) at the start of swabbing and 1.114 at 23.0°C (ρ = 1.111 g/cm^3) at the end of swabbing.

07/29/86: Pressure-density survey; calculated ρ = 1.055 g/cm^3.

04/13/87: Pressure-density survey; calculated ρ = 1.042 g/cm^3.

09/30/87: Pressure-density survey; calculated ρ = 1.035 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

05/16/89: Pressure-density survey; calculated ρ = 1.035 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-2c is estimated as follows. For the time period of 03/23/77 (initial completion of the Culebra interval) to 07/02/84, a borehole-fluid density of 1.023 g/cm^3 was estimated. This value was determined assuming consistency with the equivalent-freshwater heads for H-2b1 where borehole-fluid density data are available for estimating confident head values. A density of 1.044 g/cm^3 is estimated to be representative of the borehole-fluid density for the time period of 07/02/84 to 06/16/89. This value is an average of the densities calculated from the results of the pressure-density surveys conducted in July 1986, April 1987, and May 1989.

The borehole-fluid density uncertainty is +0.02 g/cm^3 for the first time period. This uncertainty value translates to a freshwater-head uncertainty of +1.7 m. The borehole-fluid density and freshwater-head uncertainties for the second time period are ±0.01 g/cm^3 and ±0.9 m, respectively. The freshwater-head uncertainties were calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 86.3 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-2c

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/23/77 - 07/02/84	1.023	+0.02	+1.7
07/02/84 - 06/16/89	1.044	±0.01	±0.9

H-3b1

H-3b1 was drilled in July and August 1976 through the Rustler Formation and into the upper part of the Salado Formation to a total depth of 275.0 m BGS. During drilling, drill-stem tests were conducted on the Magenta, Culebra, unnamed lower member, and Rustler-Salado contact intervals. After drilling, the borehole was cased with 6-5/8-inch casing and cemented to a depth of 271.6 m BGS. The Rustler-Salado contact, the Culebra, and the Magenta intervals were then perforated, tested, and sampled. The Culebra interval from 205.8 to 214.3 m BGS was perforated on March 7, 1977. After testing was completed on all the intervals, a bridge plug was set between the Rustler-Salado contact and Culebra perforations at a depth of 242.4 m BGS and a production-injection packer (PIP) was set between the Culebra and Magenta perforations at a depth of 199.7 m BGS. In this configuration, H-3b1 was a testing and monitoring borehole for both the Magenta and Culebra intervals until April 1986.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

03/07/77 - 03/23/77: Perforated, developed, and tested the Culebra interval. The specific gravity of the fluid removed during the final phases of well development was 1.038 at 21.5°C (ρ = 1.036 g/cm^3). Conducted a tracer and a temperature survey. Approximately 1700 L of formation fluid were added to the borehole during the surveys. Bailed fluid from the borehole. The volume removed by bailing and the specific gravity of the bailed fluid were not reported.

03/23/77 - 05/13/77: Installed a bridge plug 198.7 m BGS, then perforated and tested the Magenta dolomite interval.

05/13/77: Retrieved the bridge plug and installed a PIP with the bottom seal set approximately 4.6 m above the top of the Culebra interval.

03/09/84 - 04/06/84: Conducted five slug-injection tests. A total of 170 L of formation fluid were injected down the tubing.

04/06/84: Pumped fluid from the borehole using an air-lift pump. The pump intake was set approximately 35.0 m above the top of the Culebra interval. A packer was not utilized. A total of approximately 210 L of fluid were pumped from the borehole.

05/09/84: Injected about 80 L of the tracer meta-trifluoromethylbenzoate followed by approximately 300 L of formation fluid into the Culebra interval.

04/17/86: Removed the PIP and set a bridge plug between the Culebra and Magenta intervals. The top of the nipple on the bridge plug was installed at 184.1 m BGS. Discontinued water-level monitoring of the Culebra interval.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-3b1 is estimated to be 1.036 g/cm^3 from the time the Culebra dolomite interval was perforated (03/07/77) to 04/17/86 (date PIP was removed prior to recompleting H-3b1 as a Magenta testing and monitoring borehole). This density value was measured during the final stages of well development conducted in March 1977.

The borehole-fluid density uncertainty is assumed to be on the order of ±0.02 g/cm^3 which translates to a freshwater-head uncertainty of ±1.8 m. The freshwater-head uncertainty was calculated assuming an average of 89.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-3b1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/07/77 - 04/17/86	1.036	±0.02	±1.8

H-3b2

H-3b2 was cored to a total depth of 221.0 m BGS using a 4-3/4-inch core bit, then reamed to a diameter of 7-7/8 inches to an approximate depth of 206.0 m BGS. 5-1/2-inch casing was set and cemented to a depth of 205.2 m BGS. The borehole was then cleaned to total depth and completed as an open-hole testing and monitoring borehole for the Culebra interval which is located 206.1 to 213.1 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

11/11/83: Culebra interval completed open hole.

02/28/84 - 03/01/84: Conducted two pumping exercises. The pump intake was set approximately 35.0 m above the top of the Culebra interval. A packer was not utilized. The first exercise was 8 hours in duration with an approximate discharge rate of 0.32 L/s. The second exercise was 18 hours in duration with an approximate discharge rate of 0.13 L/s. (No water-quality data.)

03/09/84: Conducted slug-injection and slug-withdrawal tests using a volume-displacement tool. No fluid was added or withdrawn from the borehole.

03/13/84: Bailed fluid from the borehole. The volume and specific gravity of the fluid removed were not reported.

04/03/84: Pumped approximately 400 L of fluid from the borehole. The pump intake was set approximately 25.0 m above the top of the Culebra interval. A packer was not utilized. (No water-quality data.)

05/09/84: Installed an inflatable packer and tracer-injection system in the borehole. The bottom seal of the packer was set just above the Culebra interval. Injected approximately 80 L of the tracer pentafluorobenzoate followed by 200 L of formation fluid into the Culebra interval.

05/23/84: Pumped fluid from the borehole. The pump intake was located approximately 2.0 m above the top of the Culebra interval. The volume and specific gravity of the fluid removed by pumping were not reported.

06/17/85 - 06/18/85: Installed a pump and packer assembly in the borehole. The pump intake was set approximately 7.0 m above the top of the Culebra interval. The depth of the packer was not reported.

06/20/85 - 07/10/85: Conducted a step-drawdown pumping exercise. The volume of fluid removed during the exercise was approximately 4.55×10^5 L. (No water-quality data.)

10/11/85 - 10/13/85: Conducted two 1-hour pumping exercises at an average discharge rate of 0.32 L/s. (No water-quality data.)

10/15/85 - 12/16/85: Conducted a long-term pumping test at an average discharge rate of 0.32 L/s. The total estimated volume of fluid pumped was 1.63×10^6 L. The specific gravity of the fluid pumped at the beginning of the test was 1.039 at 22.0°C (ρ = 1.037 g/cm^3). The specific gravity of the fluid pumped at the end of the test was 1.037 at 23.0°C (ρ = 1.035 g/cm^3).

04/17/86: Removed the pump and packer assembly from the borehole.

08/07/86: Pressure-density survey; calculated ρ = 1.037 g/cm^3.

02/24/87: Pressure-density survey; calculated ρ = 1.039 g/cm^3.

09/21/87: Pressure-density survey; calculated ρ = 1.021 g/cm^3. [Note: These data were reported as uncertain because of equipment problems.]

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-3b2 is estimated to be 1.038 g/cm^3 for the time period of 11/11/83 (date Culebra interval was completed) to 06/16/89. The results of the pressure-density surveys conducted on 08/07/86 and 02/24/87 were averaged to obtain this value.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 89.0 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-3b2

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
11/11/83 - 06/16/89	1.038	±0.01	±0.9

H-3b3

H-3b3 was cored and reamed in November and December 1983. After setting surface casing, the borehole was cored to a total depth of approximately 222.6 m BGS using a 4-3/4-inch core bit and then reamed to a diameter of 7-7/8 inches to an approximate depth of 205.2 m BGS. 5-1/2-inch casing was then run, set, and cemented to a depth of 204.4 m BGS. The borehole was then cleaned to a total depth of 222.6 m BGS and completed as an open-hole testing and monitoring borehole for the Culebra interval which is located 205.2 to 212.2 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

02/03/84: Culebra interval completed open hole.

03/08/84: Conducted two slug-injection and slug-withdrawal tests using a volume-displacement tool. No fluid was added or withdrawn from the borehole.

03/12/84: Bailed fluid from the borehole. The volume of fluid removed was not reported. (No water-quality data.)

04/03/84: Conducted three slug-injection tests. Approximately 80 L of formation fluid were added to the borehole during each test.

04/07/84 - 04/16/84: Conducted several slug-injection and slug-withdrawal tests using a volume-displacement tool. No fluid was added or withdrawn from the borehole.

04/17/84: Installed a pump and packer assembly in the borehole. The pump intake was located approximately 30.0 m above the top of the Culebra interval. The bottom packer seal was set approximately 33.0 m above the top of the Culebra interval.

04/17/84 - 04/18/84: Conducted three 1-hour pumping exercises at discharge rates of 0.05 to 0.40 L/s. (No water-quality data.)

04/19/84: Conducted a 13-hour pumping exercise. The average discharge rate was 0.4 L/s. The specific gravity of the first fluid sample was 1.042 at 24.0°C (ρ = 1.039 g/cm^3). The specific gravity of the final fluid sample was 1.038 at 23.0°C (ρ = 1.036 g/cm^3).

<u>04/23/84 - 06/12/84</u>: Conducted a long-term pumping test. For the time period of 04/23/84 to 05/07/84, the average discharge rate was 0.25 L/s. For the time period of 05/07/84 to 06/12/84, the average discharge rate was reduced to 0.18 L/s. The volume of fluid pumped was approximately 9.00 x 10^5 L. The initial specific gravity of the produced fluid was 1.036 at 25.0°C (ρ = 1.033 g/cm^3). The final specific gravity of the produced flow was 1.034 at 27.0°C (ρ = 1.030 g/cm^3).

<u>07/19/84</u>: Removed the pump and packer assembly from the borehole.

<u>01/29/85 - 02/04/85</u>: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 20.0 m above the top of the Culebra interval. The volume of fluid pumped was approximately 6.20 x 10^4 L at an average rate of 0.15 L/s. No specific-gravity data were recorded.

<u>04/25/86 - 05/05/86</u>: Water-quality sampling. The Culebra interval was not isolated with a packer. The pump intake was located approximately 7.0 m above the top of the Culebra interval. The volume of fluid pumped was approximately 1.51 x 10^5 L at an average rate of 0.2 L/s. The initial specific gravity of the produced fluid was 1.037 at 22.5°C (ρ = 1.035 g/cm^3). The final specific gravity of the produced fluid was 1.038 at 22.1°C (ρ = 1.036 g/cm^3).

<u>08/07/87 - 08/24/87</u>: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 2.3 m above the top of the Culebra interval. About 2.37 x 10^5 L of fluid were pumped from the borehole prior to sampling. The average pumping rate was about 0.2 L/s. The specific gravity of the produced fluid was 1.026 at 23.5°C (ρ = 1.023 g/cm^3) on 08/17/87 and 1.037 at 22.4°C (ρ = 1.035 g/cm^3) on 08/24/87.

<u>02/14/89 - 03/02/89</u>: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 2.3 m above the top of the Culebra interval. The specific gravity of the pumped

fluid was 1.038 at 22.5°C (ρ = 1.036 g/cm^3) on 02/02/89 and 1.036 at 22.2° C (ρ = 1.034 g/cm^3) on 03/02/89. Approximately 3.86 x 10^5 L of fluid were pumped from the borehole during sampling at an average rate of 0.29 L/s.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-3b3 is estimated to be 1.033 g/cm^3 for the time period of 02/03/84 (date the Culebra interval was completed) to 06/16/89. This value is an average of all density measurements obtained in H-3b3.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 89.0 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-3b3

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
02/03/84 - 06/16/89	1.033	±0.01	±0.9

H-4a

H-4a was initially drilled in May 1978 through the Magenta (114.3 to 122.0 m BGS) to a depth of 129.6 m BGS using a 7-7/8-inch bit. The borehole was then cased and cemented with 5-1/2-inch casing set to a depth of 111.3 m BGS and completed as a Magenta test borehole. In February 1981, H-4a was re-entered and cored and reamed to a total depth of 162.2 m BGS. This cored interval included the Culebra dolomite located between 151.2 and 158.5 m BGS. After reaming, H-4a was completed as a dual-monitoring borehole by setting a production-injection packer (PIP) in the open-hole interval between the Magenta and Culebra dolomites. The top seal of the PIP was set 147.9 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

02/04/81: Completed the Culebra interval open hole. Installed a PIP between the Magenta and Culebra intervals.

04/81: Installed a pump-jack assembly and sucker rods in the Culebra interval tubing. The pump intake depth was not reported.

04/03/81 - 04/24/81: Conducted eight step-drawdown pumping exercises. The pumping rate varied from 0.01 to 0.03 L/s. The total volume discharged during pumping was estimated to have been approximately 4200 L. (No water-quality data.)

05/08/81: Removed the pump-jack assembly and sucker rods from the tubing.

11/05/82: Injected the tracers pentafluorobenzoate and para-fluorobenzoate into the Culebra interval using 1/2-inch injection line installed down the tubing to approximately 150.0 m BTC. The tracers were mixed with formation fluid collected from H-4c. A total of approximately 630 L of formation fluid were injected.

04/11/84: Injected the tracer benzene sulfonate into the Culebra interval. The tracer was mixed with formation fluid collected from H-4c. Approximately 300 L of formation fluid were injected.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-4a is estimated to be 1.015 g/cm^3 for the time period of 02/04/81 (initial completion of the Culebra interval) to 06/16/89. After well-development pumping in April 1981, the borehole is assumed to have filled with formation fluid.

The borehole-fluid density uncertainty is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.0 to -0.5 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 52.2 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-4a

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
02/04/81 - 06/16/89	1.015	+0.02/-0.01	+1.0/-0.5

H-4b

H-4b was drilled in May 1978. The borehole was rotary drilled to a depth of 145.4 m BGS using a 7-7/8-inch bit and cased with 5-1/2-inch casing. The borehole was then reamed to a depth of 145.4 m BGS and cored using a 4-3/4-inch core bit to a total depth of 161.3 m BGS. This cored interval included the Culebra dolomite located between 151.8 and 159.1 m BGS. After coring, H-4b was flushed with brine, evacuated with compressed air, and completed as an open-hole Culebra testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

05/15/78: Completed the Culebra interval open hole.

12/05/78: Bailed approximately 350 L of fluid from the borehole.

12/05/78: Installed a PIP, tubing, and a transducer assembly in the borehole. The PIP was set approximately 9.0 m above the top of the Culebra interval.

12/06/78: Slug-injection test. The slug consisted of approximately 250 L of formation fluid added to the tubing. Swabbed approximately 160 L of fluid from the tubing.

12/07/78: Removed the PIP, tubing, and transducer assembly from the borehole. Bailed approximately 640 L of fluid from the borehole. (No water-quality data.)

12/14/78: Bailed fluid from the borehole. The density of the bailed fluid was 1.024 g/cm^3.

05/08/81: Installed a pump-jack assembly and sucker rods in the borehole. The positive-displacement pump cylinder was set in open casing approximately 5.0 m above the top of the Culebra interval.

05/13/81: Conducted a 2-1/2-hour pumping exercise at a discharge rate of approximately 0.03 L/s. (No water-quality data.)

05/14/81 - 05/16/81: Conducted a 50-hour pumping exercise at a discharge rate of 0.02 L/s. The specific gravity of the pumped fluid was 1.010 at 19.5°C (ρ = 1.008 g/cm^3).

05/19/81 - 05/20/81: Conducted a 14-hour pumping exercise at a discharge rate of approximately 0.03 L/s. (No water-quality data.)

05/21/81 - 05/30/81: Conducted a 118-hour pumping test at a discharge rate of approximately 0.016 L/s. The specific gravity of the pumped fluid was 1.010 at 22.0°C (ρ = 1.008 g/cm^3).

06/09/81: Removed the pump-jack assembly and sucker rods from the borehole.

10/27/82: Injected the tracers thiocyanate and meta-trifluoromethylbenzoate into the Culebra interval through 1/2-inch injection tubing hung approximately 15.0 m BTC. Each tracer was mixed with about 110 L of formation fluid and followed by a 190 L chaser of formation fluid.

03/19/85: Installed a pump-jack assembly and sucker rods in the borehole. The pump intake was set approximately 10.0 m above the top of the Culebra interval.

03/25/85 - 05/03/85: Conducted eleven 3- to 8-hour pumping exercises at a discharge rate of approximately 0.025 L/s. The volume of fluid pumped is estimated to have been approximately 9000 L. (No water-quality data.)

06/14/85 - 07/05/85: Conducted daily 5-hour pumping exercises. The cumulative volume of fluid pumped during this period was approximately 5130 L. (No water-quality data.)

07/07/85: Removed the pump-jack assembly and sucker rods from the borehole.

07/08/85 - 07/25/85: Water-quality sampling. The pump intake was located approximately at the top of the Culebra interval at a depth of 151.8 m BGS. A packer was not utilized. Approximately 1280 L of fluid were pumped prior to sampling. The specific gravity of the initial sample was 1.015 at 22.0°C (ρ = 1.013 g/cm^3). The specific gravity of the final sample was 1.015 at 21.0°C (ρ = 1.013 g/cm^3). Approximately 1.78 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.02 L/s.

08/13/86: Pressure-density survey; calculated ρ = 1.021 g/cm^3.

11/06/86 - 11/13/86: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 0.7 m above the top of the Culebra interval. Approximately 1140 L of fluid were pumped prior to sampling. The specific gravity of the initial sample was 1.018 at 22.0°C (ρ = 1.016 g/cm^3). The specific gravity of the final sample was 1.021 at 18.2°C (ρ = 1.020 g/cm^3). Approximately 9270 L of fluid were pumped from the borehole during sampling.

02/17/87: Pressure-density survey; calculated ρ = 1.020 g/cm^3.

08/05/87: Pressure-density survey; calculated ρ = 0.997 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

09/16/87 - 09/25/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.7 m above the top of the Culebra interval. Approximately 4690 L of fluid were pumped prior to sampling. The specific gravity of the initial sample was 1.015 at 23.3°C (ρ = 1.013 g/cm^3). The specific gravity of the final sample was 1.015 at 20.9°C (ρ = 1.013 g/cm^3). Approximately 9460 L of fluid were pumped from the borehole during sampling at an average rate of 0.01 L/s.

04/04/89 - 04/06/89: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 6.3 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.017 at 22.4°C (ρ = 1.015 g/cm^3) on 04/04/89 and 1.016 at 21.4°C (ρ = 1.014 g/cm^3) on 04/06/89. Approximately 3970 L of fluid were pumped from the borehole during sampling at an average rate of 0.019 L/s.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-4b is estimated as follows. For the time period of 05/15/78 (initial completion of the Culebra interval) to 05/13/81, the density reported for a water sample obtained on 12/14/78 (1.024 g/cm^3) is assumed. For the time period of 05/13/81 to 03/25/85, a density of 1.008 g/cm³ is assumed to be representative of the borehole fluid. This density value was obtained from two separate samples collected during pumping tests conducted early in this time period. The decrease in density from the first time period is probably a result of well-development pumping conducted in May 1981. For the time period of 03/25/85 to 06/16/89, a density of 1.021 g/cm³ is assumed. This density is an average of the values obtained from the results of the pressure-density surveys conducted on 08/13/86 and 02/17/87. The effect of water-quality sampling conducted in July 1985, November 1986, and September 1987 on borehole-fluid density was considered to be minor.

The borehole-fluid density uncertainty for the first time period is ±0.02 g/cm³. This uncertainty value translates to a freshwater-head uncertainty of ±1.0 m. The borehole-fluid density uncertainty for the second and third time periods is ±0.01 g/cm³. This uncertainty value translates to a freshwater-head uncertainty of ±0.5 m. The freshwater-head uncertainties were calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 52.2 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-4b

Time Period	Borehole-Fluid Density (g/cm³)	Density Uncertainty (g/cm³)	Related Head Uncertainty (m)
05/15/78 - 05/13/81	1.024	±0.02	±1.0
05/13/81 - 03/25/85	1.008	±0.01	±0.5
03/25/85 - 06/16/89	1.021	±0.01	±0.5

H-4c

H-4c was drilled in May 1978 as the first test borehole on the H-4 hydropad. The borehole was drilled to a depth of 186.0 m BGS using a 7-7/8-inch bit and cased with 5-1/2-inch casing. The interval drilled included the Culebra dolomite located between 151.2 and 158.5 m BGS. The borehole was reamed to a depth of 186.3 m BGS and then cored with a 4-3/4-inch core bit through the Rustler-Salado contact to a total depth of 201.5 m BGS. After coring, the borehole was flushed with brine, evacuated with compressed air, and completed as an open-hole Rustler-Salado contact testing and monitoring borehole. In February 1981, H-4c was recompleted as a Culebra testing and monitoring borehole by setting a bridge plug at an estimated depth of 161.6 m BGS and then perforating the Culebra interval from 151.2 to 158.5 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

02/81: Casing perforation at the Culebra interval.

06/09/81: Installed a pump-jack assembly and sucker rods in the borehole. The positive-displacement pump assembly was set in open casing approximately 5.0 m above the top of the Culebra interval.

06/16/81 - 06/19/81: Conducted a 42.5-hour pumping test at a discharge rate of approximately 0.017 L/s. (No water-quality data.)

09/17/81 - 09/28/81: Conducted a 654-hour pumping test at a discharge rate of approximately 0.022 L/s. Field water-quality measurements were obtained for temperature, pH, and specific conductivity but not for specific gravity.

09/30/82 - 10/09/82: Conducted development pumping of the Culebra interval at an approximate discharge rate of 0.017 L/s. Approximately 1.32 x 10^4 L of fluid were pumped. (No water-quality data.)

10/24/82 - 06/10/83: Conducted a long-term convergent-flow tracer test on the H-4 hydropad with H-4c as the pumping well. The approximate discharge rate was 0.017 L/s. Numerous water samples were obtained for tracer analysis. However, there were no field water-quality measurements obtained. A total of approximately 3.60×10^5 L of fluid were pumped during this period.

06/10/83 - 10/15/84: Continuation of the long-term convergent-flow tracer test with the discharge rate increased to approximately 0.032 L/s. Water-quality samples obtained on 08/10/84 yielded a specific gravity of 1.010 at 21.5°C (ρ = 1.008 g/cm^3). A total of approximately 1.40×10^6 L of fluid were pumped during this period.

10/16/84: Removed the pump-jack assembly and sucker rods from the borehole.

07/16/86: Circulated approximately 160 L of 2-percent potassium-chloride solution in the borehole. Installed a packer and tubing. The packer was set approximately 2.0 m above the top of the Culebra interval. Acidized the Culebra interval by injecting approximately 640 L of a 20-percent hydrochloric acid solution. Deflated the packer and circulated approximately 2400 L of 2-percent potassium-chloride solution in the borehole. Swabbed approximately 1750 L of fluid from the tubing.

07/25/86 - 07/29/86: Attempted to run a step-drawdown pumping exercise. The pump intake was located approximately 2.0 m above the top of the Culebra interval. A packer was not utilized. Pump problems resulted in abandonment of this exercise.

07/31/86: Slug-injection test. A packer was set approximately 3.0 m above the top of the Culebra interval. The slug consisted of approximately 270 L of freshwater added to the annulus. The test was initiated by deflating the packer.

08/20/86 - 08/21/86: Recompleted the borehole as a Magenta testing and monitoring well and discontinued Culebra water-level monitoring.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-4c is estimated to be 1.008 g/cm^3 for the time period of 02/81 (initial completion of the Culebra interval) to 08/20/86 (date H-4c was recompleted as a Magenta testing and monitoring borehole). This value is based on the density measurements for samples collected on 08/10/84.

The borehole-fluid density uncertainty is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.0 to -0.5 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 52.2 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-4c

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
02/81 - 08/20/86	1.008	+0.02/-0.01	+1.0/-0.5

H-5a

H-5a was drilled and cored in June 1978. The borehole was initially drilled to a depth of 236.0 m BGS using a 7-7/8-inch bit, then cased and cemented using 5-1/2-inch casing. The borehole was then cleaned to a depth of 236.0 m BGS and cored through the Magenta dolomite, located 238.7 to 247.0 m BGS, to a total depth of 251.2 m BGS using a 4-3/4-inch core bit. After coring, H-5a was flushed with brine, evacuated with compressed air, and completed as an open-hole Magenta testing and monitoring borehole. The borehole remained in this configuration from June 6, 1978 through January 1, 1981 when it was recompleted by drilling through the Culebra dolomite, located 274.0 to 281.1 m BGS, to a total depth of 283.5 m BGS using a 4-3/4-inch drill bit. After the borehole was cleaned, a production-injection packer (PIP) was set in the open-hole section between the Magenta and Culebra intervals at a depth of 272.9 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

- 01/26/81 - 01/29/81: Drilled the Culebra interval.
- 03/30/81: Installed a pump-jack assembly and sucker rods in the Culebra interval tubing. The location of the pump intake was not reported.
- 04/28/81 - 05/07/81: Conducted two 15-hour pumping exercises at approximate discharge rates of 0.008 L/s. (No water-quality data.)
- 05/07/81: Removed the sucker rods and pump-jack assembly from the borehole.

Since the density of the fluid in the borehole is unknown, a value was determined by assuming consistency with the equivalent-freshwater heads from H-5b where borehole-fluid density data is available for estimating confident head values. For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-5a is estimated to be 1.092 g/cm^3 for the time period of 01/26/81 (initial penetration of the Culebra interval) to 06/16/89.

The borehole-fluid density uncertainty is ±0.05 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±6.4 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the top of the Culebra interval of 128.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-5a

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
01/26/81 - 06/16/89	1.092	±0.05	±6.4

H-5b

H-5b was drilled and cored in June 1978. The borehole was initially drilled to a depth of 268.8 m BGS using a 7-7/8-inch bit then cased and cemented using 5-1/2-inch casing. The borehole was then cleaned to a depth of 268.8 m BGS and cored through the Culebra dolomite interval, located 273.5 to 280.5 m BGS, to a total depth of 281.9 m BGS using a 4-3/4-inch core bit. After coring, H-5b was flushed with brine, evacuated with compressed air, and completed as an open-hole Culebra testing and monitoring borehole.

The significant borehole activities affecting the interpretation of Culebra equivalent-freshwater heads are:

06/13/78: Completed the Culebra open hole.

12/13/78: Installed a packer, tubing, and a transducer assembly in the borehole. The packer was inflated with formation fluid. The packer was set approximately 7.0 m above the top of the Culebra interval. Conducted a drawdown and recovery exercise initiated by swabbing fluid from the tubing. Approximately 1970 L of fluid were removed by swabbing. (No water-quality data.)

12/14/78: Slug-injection test. The slug consisted of 540 L of formation fluid added to the tubing above the packer. The test was initiated by knocking the plug out of the bottom of the packer.

12/15/78: Removed the packer, tubing, and transducer assembly from the borehole. Bailed approximately 670 L of fluid from the borehole. (No water-quality data.)

12/19/78: Bailed fluid from the borehole. The specific gravity of the bailed fluid was 1.106 at 20.0°C (ρ = 1.104 g/cm^3).

05/12/81: Installed a pump-jack assembly and sucker rods in the borehole. The pump intake was located approximately 2.0 m below the top of the Culebra interval.

05/22/81 - 05/23/81: Conducted a series of short pumping exercises to check the integrity of the pump. Fluid did not reach the surface during these exercises.

05/27/81 - 06/02/81: Conducted a 146.8-hour pumping test at an average discharge rate of 0.013 L/s. The initial specific gravity of the pumped fluid was 1.100 at 23.5°C (ρ = 1.097 g/cm^3). The final specific gravity of the pumped fluid was 1.100 at 21.5°C (ρ = 1.098 g/cm^3).

06/16/81: Removed the pump-jack assembly and sucker rods from the borehole.

08/22/85 - 08/30/85: Water-quality sampling. The Culebra interval was isolated with a packer for sampling. The pump intake was located 6.1 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.104 at 23.4°C (ρ = 1.101 g/cm^3) on 08/23/85 and 1.105 at 21.6°C (ρ = 1.104 g/cm^3) on 08/27/85. Approximately 4160 L of fluid were pumped during sampling at an average rate of 0.01 L/s.

05/09/86 - 05/21/86: Water-quality sampling. The Culebra interval was not isolated with a packer during sampling. The pump intake was located 11.2 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.103 at 22.8°C (ρ = 1.100 g/cm^3) on 05/09/86 and 1.105 at 23.7°C (ρ = 1.102 g/cm^3) on 05/21/86. Approximately 7570 L of fluid were pumped during sampling at an average rate of 0.01 L/s.

08/11/86: Pressure-density survey; calculated ρ = 1.108 g/cm^3.

04/15/87: Pressure-density survey; calculated ρ = 1.099 g/cm^3.

09/28/87: Pressure-density survey; calculated ρ = 1.090 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

02/17/88 - 02/24/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 6.6 m above the top of the Culebra interval. Prior to sampling, approximately 1510 L of fluid were pumped from the borehole at a rate of 0.009 L/s. The specific gravity of the pumped fluid was 1.102 at 19.7°C (ρ = 1.100 g/cm^3) on 02/19/88 and 1.102 at 19.3°C (ρ = 1.100 g/cm^3) on 02/24/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density for H-5b is estimated to be 1.104 g/cm^3 for the time period of 06/13/78 (date the Culebra interval was completed) to 06/16/89. This density value was obtained by averaging the densities of 1.108 and 1.099 g/cm^3 calculated from the results of the pressure-density surveys conducted in August 1986 and April 1987, respectively.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±1.3 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 128.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-5b

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
06/13/78 - 06/16/89	1.104	±0.01	±1.3

H-5c

H-5c was drilled and cored in May and June 1978. The borehole was initially drilled to a depth of 312.0 m BGS using a 7-7/8-inch bit, then cased and cemented using 5-1/2-inch casing. After cementing, the borehole was cleaned and cored to a total depth of 328.0 m BGS with a 4-3/4-inch core bit. After coring, H-5c was flushed with brine, evacuated with compressed air, and completed as an open-hole Rustler-Salado contact testing and monitoring borehole. From June 30, 1978 until January 1981, Rustler-Salado contact testing and monitoring were conducted in the borehole. In January 1981, H-5c was recompleted by placing a bridge plug near the bottom of the casing to isolate the borehole from the Rustler-Salado contact open-hole interval. The top seal of the bridge plug was set at a depth of 285.1 m BGS. The Culebra interval located between 274.1 and 281.7 m BGS was then perforated. From January 1981 until August 20, 1986, H-5c was a Culebra testing and monitoring borehole. On August 20, 1986, H-5c was again recompleted. During this recompletion operation, a second bridge plug was installed at a depth of 254.5 m BGS and the Magenta interval, located 240.2 to 247.6 m BGS, was perforated. Since August 1986, H-5c has been a Magenta testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

01/81: Casing perforation at the Culebra interval.

06/17/81: Installed a pump-jack assembly and sucker rods in the borehole. The pump intake depth was not reported.

09/18/81 - 09/21/81: Conducted a 81.2-hour pumping exercise. The discharge rate was highly variable ranging from 0.017 to 0.003 L/s. (No water-quality data.)

09/23/81 - 09/29/81: Conducted a 147.4-hour pumping exercise. The discharge rate varied from 0.021 to 0.008 L/s. (No water-quality data.)

10/07/81 - 10/16/81: Conducted a 215.7-hour pumping test. The average discharge rate was 0.008 L/s. The specific gravity of the fluid collected on 10/13/81 was 1.110 at 25.0°C (ρ = 1.107 g/cm^3). The specific gravity of the fluid collected on 10/14/81 was 1.102 at 24.0°C (ρ = 1.099 g/cm^3).

12/01/81: Removed the pump-jack assembly and sucker rods from the borehole sometime after this date. The exact date for this operation was not reported.

06/30/83 - 07/02/83: Conducted piston-pulse tests. No fluid was added or withdrawn from the borehole.

08/20/86: Recompleted the borehole as a Magenta testing and monitoring well and discontinued water-level monitoring of the Culebra interval.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-5c is estimated to be 1.103 g/cm^3 for the time period of 01/81 (initial completion of the Culebra interval) to 08/20/86 (date H-5c was recompleted as a Magenta testing and monitoring borehole). This density is an average of the density measurements obtained during the pumping test conducted in October 1981.

The borehole-fluid density uncertainty is ±0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±2.6 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 128.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-5c

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
01/81 - 08/20/86	1.103	±0.02	±2.6

H-6a

H-6a was drilled and cored in June and July 1978. The borehole was initially drilled to a depth of 144.6 m BGS using a 7-7/8-inch bit, then cased and cemented using 5-1/2-inch casing. The borehole was then cleaned to a depth of 144.8 m BGS and cored through the Magenta dolomite to a total depth of 160.0 m BGS. After coring, H-6a was flushed with brine, evacuated with compressed air, and completed as an open-hole Magenta testing and monitoring borehole. The borehole remained in this configuration from July 11, 1978 through January 20, 1981 when it was recompleted by coring through the Culebra interval, located 184.1 to 191.1 m BGS, to a total depth of 194.2 m BGS using a 4-3/4-inch core bit. After the borehole was cleaned, a production-injection packer (PIP) was set in the open-hole section between the Magenta and Culebra intervals at a depth of 181.1 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

01/20/81 - 01/22/81: Completed the Culebra interval open hole.

04/06/81 - 04/08/81: Installed a pump in the borehole. The pump intake was located approximately 40.0 m above the top of the Culebra interval. Conducted two short (10 to 30 minutes) well-development pumping exercises at a discharge rate of approximately 0.38 L/s. (No water-quality data.)

04/10/81: Pulled the pump from the borehole.

04/28/81: Cleaned fill from the borehole by circulating fluid pumped from H-6b.

04/30/81: Installed a PIP in the borehole at a depth of 181.1 m BGS.

08/23/81: Injected the tracers meta-trifluoromethylbenzoate and ortho-fluorobenzoate into the borehole using 200 L of formation fluid. The tracers were injected through 1/2-inch injection tubing that had been run down the feed-through tubing on the PIP.

10/27/82: Injected the tracers thiocyanate and meta-triflouromethylbenzoate into the borehole using 300 L of formation fluid.

04/12/83: Slug-injection test. The slug consisted of 100 L of fluid removed from H-6b added to the tubing. The test was initiated by adding the fluid to the tubing.

05/28/83 - 05/30/83: Conducted a preliminary recirculation-injection test by injecting fluid pumped from H-6b into the borehole at an average pumping and injection rate of 0.28 L/s.

06/03/83 - 06/09/83: Conducted a preliminary recirculation-injection test by injecting fluid pumped from H-6b into the borehole at an average pumping and injection rate of 0.28 L/s.

06/17/83 - 07/26/83: Conducted a recirculation-injection test by injecting fluid pumped from H-6b into the borehole at an average pumping and injection rate of 0.14 L/s. The tracers pentafluorobenzoate and meta-trifluoromethylbenzoate were added to the injected stream on 06/22/83.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-6a is estimated to be 1.038 g/cm^3 for the time period of 01/22/81 (initial completion of the Culebra interval) to 06/16/89. This density estimate assumes that the borehole was filled with the fluid that was pumped from H-6b and then circulated and injected into this borehole. This fluid has an assumed density of 1.038 g/cm^3.

The borehole-fluid density uncertainty is ±0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±1.8 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the top of the Culebra interval of 91.4 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-6a

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
01/22/81 - 06/16/89	1.038	±0.02	±1.8

H-6b

H-6b was drilled and cored in June and July 1978. The borehole was initially drilled to a depth of 179.8 m BGS using a 7-7/8-inch bit, then cased and cemented using 5-1/2-inch casing. The borehole was then cleaned to a depth of 180.4 m BGS and cored through the Culebra interval, located 184.1 to 191.1 m BGS, to a total depth of 195.1 m BGS using a 4-3/4-inch core bit. After coring, H-6b was flushed with brine, evacuated with compressed air, and completed as an open-hole Culebra testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

07/05/78: Completed the Culebra interval open hole.

12/19/78: Installed a packer and transducer assembly in the borehole. The packer was inflated with formation fluid. The packer was installed approximately 6.0 m above the top of the Culebra interval. Conducted a drawdown and recovery exercise and two slug-injection tests. The drawdown and recovery exercise was initiated by swabbing fluid from the tubing. Approximately 2080 L of fluid were removed by swabbing. Both slug-injection tests involved adding approximately 360 L of formation fluid to the tubing. The tests were initiated by knocking out a tubing plug at the bottom of the packer. After testing, the tubing was swabbed to obtain a sample of the formation fluid. The density reported for this sample was 1.040 g/cm^3.

09/18/79 - 09/25/79: Conducted a 72-hour pumping exercise at an average discharge rate of approximately 0.69 L/s. The pump intake depth was not reported. (No water-quality data.)

04/11/81 - 04/12/81: Installed a pump and transducer assembly in the borehole. The pump intake was located approximately 40.0 m above the top of the Culebra interval. Conducted a 23-hour pumping exercise at an average discharge rate of approximately 1.20 L/s. (No water-quality data.)

04/28/81 - 04/30/81: Pumped the borehole at approximately 1.64 L/s and injected fluid into H-6a to remove fill. A total of approximately 3.00×10^4 L of fluid were pumped during this operation. (No water-quality data.)

05/01/81 - 05/03/81: Conducted a 48-hour pumping test at an average discharge rate of approximately 1.45 L/s. The specific gravity of the pumped fluid was 1.040 at 23.0°C (ρ = 1.038 g/cm^3) on 05/01/81 and 1.040 at 22.0°C (ρ = 1.038 g/cm^3) on 05/02/81.

05/11/81: Pulled the pump and transducer assembly from the borehole.

08/20/81: Installed a packer and transducer assembly and a tracer-injection system in the borehole. The packer was installed in the casing immediately above the Culebra interval.

08/21/81: Tested the tracer-injection system by injecting approximately 100 L of formation fluid into the borehole.

08/23/81: Injected the tracers pentafluorobenzoate and meta-fluorobenzoate using 200 L of formation fluid.

09/02/81: Injected the tracer para-fluorobenzoate using 200 L of formation fluid.

09/30/82: Injected the tracer para-fluorobenzoate using 150 L of formation fluid.

10/05/82: Injected the tracers pentafluorobenzoate and thiocyanate using 150 L of formation fluid.

10/19/82: Pulled the packer, transducer assembly, and tracer-injection system from the borehole.

10/24/82 - 11/28/82: Conducted an 872-hour pumping exercise at an average discharge rate of approximately 1.01 L/s. The pump intake depth was not reported. (No water-quality data.)

04/10/83 - 04/14/83: Conducted four short pumping exercises to check the integrity of the pump, surface plumbing, and data-acquisition system. Repositioned the pump intake to approximately 22.0 m above the top of the Culebra interval on 04/11/83.

04/15/83 - 05/14/83: Conducted a 700-hour pumping exercise at an average discharge rate of 0.63 L/s. (No water-quality data.)

05/26/83: Conducted a 3-hour pumping exercise at a discharge rate of approximately 0.63 L/s. (No water-quality data.)

05/28/83 - 05/31/83: Conducted a 79.7-hour pumping exercise at a discharge rate of approximately 0.25 L/s. (No water-quality data.)

06/04/83 - 06/09/83: Conducted a 120-hour pumping exercise at a discharge rate of approximately 0.28 L/s. (No water-quality data.)

06/16/83 - 07/26/83: Conducted a 953-hour pumping exercise at a discharge rate of approximately 0.14 L/s. (No water-quality data.)

09/04/85 - 09/16/85: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 9.0 m above the top of the Culebra interval. Approximately 6.40 x 10^4 L of fluid were pumped prior to sampling. On 09/07/85, the specific gravity of the pumped fluid was 1.043 at 22.3°C (ρ = 1.041 g/cm^3). On 09/16/85, the specific gravity of the pumped fluid was 1.042 at 23.5°C (ρ = 1.039 g/cm^3). Approximately 3.62 x 10^5 L of fluid were pumped at an average rate of 0.03 L/s.

07/11/86 - 07/28/86: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 6.7 m above the top of the Culebra interval. Approximately 1.25 x 10^5 L of fluid were pumped prior to sampling. On 07/15/86, the specific gravity of the pumped fluid was 1.042 at 23.2°C (ρ = 1.039 g/cm^3). On 07/28/86, the specific gravity of the pumped fluid was 1.040 at 25.6°C (ρ = 1.037 g/cm^3). Approximately 4.77 x 10^5 L of fluid were pumped at an average rate of 0.32 L/s.

09/03/86: Pressure-density survey; calculated ρ = 1.040 g/cm^3.

05/11/87: Pressure-density survey; calculated ρ = 1.031 g/cm^3.

09/16/87: Pressure-density survey; calculated ρ = 1.029 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

11/04/87 - 11/16/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 4.3 m above the top of the Culebra interval. Approximately 2.46 x 10^5 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.041 at 20.8°C (ρ = 1.039 g/cm^3) on 11/12/87 and 1.040 at 20.9°C (ρ = 1.038 g/cm^3) on 11/16/87. Approximately 3.31 x 10^5 L of fluid were pumped at an average rate of 0.25 L/s.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-6b is estimated to be 1.038 g/cm^3 for the time period of 07/05/78 (initial completion of the Culebra interval) to 06/16/89. This value was determined by averaging the density measured during pumping conducted in May 1981 with the densities calculated from the results of the pressure-density surveys conducted in September 1986 and May 1987. Because the Culebra interval was isolated during the water-quality sampling exercises, this sampling was considered to have had a minor impact on the borehole-fluid density. Therefore, the specific gravities measured during sampling were not considered in the averaging discussed above.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 91.4 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-6b

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
07/05/78 - 06/16/89	1.038	±0.01	±0.9

H-6c

H-6c was drilled and cored in June 1978. The borehole was initially drilled to a depth of 213.1 m BGS using a 7-7/8-inch bit, then cased and cemented using 5-1/2-inch casing. After cementing, the borehole was cleaned and cored to a total depth of 225.9 m BGS using a 4-3/4-inch core bit. After coring, H-6c was flushed with brine, evacuated with compressed air, and completed as an open-hole Rustler-Salado contact testing and monitoring borehole. From June 26, 1978 until May 1981, the Rustler-Salado contact was tested and monitored. In May 1981, H-6c was recompleted by placing a bridge plug at a depth of 195.4 m BGS near the bottom of the casing to isolate the borehole from the Rustler-Salado contact. The Culebra interval was then perforated from 184.1 to 191.1 m BGS. On August 20, 1986, H-6c was again recompleted. A second bridge plug was set at a depth of approximately 162.1 m BGS and the Magenta interval was perforated from 149.4 to 156.7 m BGS. Since the date of this second recompletion, H-6c has been a Magenta observation well.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

05/81: Casing perforation at the Culebra interval.

05/11/81: Installed a pump in the borehole. The pump intake was located approximately 20.0 m above the top of the Culebra interval.

05/12/81 - 05/14/81: Conducted a 32.8-hour pumping exercise at an average discharge rate of 1.19 L/s. The specific gravity of the pumped fluid was 1.040 at 23.0°C (ρ = 1.038 g/cm^3) on 05/13/81.

05/21/81 - 05/27/81: Conducted a 148.5-hour pumping test at an average discharge rate of 1.03 L/s. The specific gravity of the pumped fluid was 1.040 at 23.5°C (ρ = 1.037 g/cm^3) on 05/27/81.

08/10/81 - 08/12/81: Conducted two short pumping exercises to check the integrity of the pump and sampling systems.

08/19/81 - 09/11/81: Conducted a 549-hour pumping exercise at an average discharge rate of approximately 1.06 L/s. (No water-quality data.)

09/30/82 - 10/18/82: Conducted a 357-hour pumping exercise at an average discharge rate of approximately 0.50 L/s. (No water-quality data.)

10/19/82: Removed the pump from the borehole.

11/05/82: Installed a tracer-injection system in the borehole. A packer was not utilized in this system. Injected the tracer para-fluorobenzoate using 250 L of formation fluid. Removed the tracer-injection system from the borehole after tracer injection was completed.

03/31/83: Bailed approximately 1700 L of fluid from the borehole. Installed injection tubing and a transducer assembly in the borehole. The bottom of the tubing was set approximately 90.0 m above the top of the Culebra interval.

04/15/83 - 05/14/83: Injected fluid pumped from H-6b and, on 04/19/86, the tracers pentafluorobenzoate and thiocyanate into the borehole for approximately 700 hours at a rate of 0.63 L/s.

07/19/83: Injected the tracer para-fluorobenzoate and about 430 L of formation fluid into the borehole.

08/20/86 - 08/22/86: Recompleted the borehole as a Magenta testing and monitoring well and discontinued water-level monitoring of the Culebra interval.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-6c is estimated to be 1.038 g/cm^3 for the time period of 05/81 (initial completion of the Culebra interval) to 08/20/86 (date the borehole was recompleted as a Magenta testing and monitoring borehole). This value is an average of the field measurement obtained from the 05/21/81 pumping test (1.037 g/cm^3) and the density of the injected water from H-6b (1.038 g/cm^3).

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 91.4 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-6c

Time Period	Borehole-Fluid Density (g/cm³)	Density Uncertainty (g/cm³)	Related Head Uncertainty (m)
05/81 - 08/20/86	1.038	±0.01	±0.9

H-7b1

H-7b1 was drilled and cored in September 1979. The borehole was initially drilled to a depth of 70.1 m BGS using a 7-7/8-inch bit, then reamed to a diameter of 9-7/8 inches and cased and cemented to a depth of 70.1 m BGS using 7-inch casing. After cleaning, H-7b1 was cored through the Culebra interval, located 72.2 to 83.4 m BGS, to a total depth of 87.2 m BGS using a 6-1/8-inch core bit. Following coring, H-7b1 was evacuated with compressed air and completed as an open-hole Culebra testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

09/18/79: Culebra interval completed open hole.

03/20/80: Bailed approximately 1060 L of fluid from the borehole. The density of the fluid collected at the end of bailing was 1.001 g/cm^3.

03/25/80 - 03/28/80: Conducted a pumping exercise. The exercise was aborted on 03/28/80 due to a pump malfunction. The length of the pumping period and the discharge rate were not reported. (No water-quality data.)

04/17/81 - 04/20/81: Conducted two 5-hour pumping exercises at an average discharge rate of approximately 2.52 L/s. The pump intake was located approximately 4.0 m above the top of the Culebra interval. (No water-quality data.)

09/16/81: Conducted a 2.7-hour pumping exercise at an average discharge rate of approximately 5.7 L/s. (No water-quality data.)

01/28/86: Installed a pump and packer assembly in the borehole. The pump intake was set approximately 4.0 m above the top of the Culebra interval.

01/28/86 - 02/17/86: Conducted six short pumping exercises to check the integrity of the pump. The cumulative pumping time was approximately 5 hours at an approximate discharge rate of 4.9 L/s. (No water-quality data.)

02/18/86 - 02/21/86: Conducted a 72-hour pumping test at an average discharge rate of approximately 5.13 L/s. The specific gravity of the pumped fluid was 1.001 at 21.5°C (ρ = 0.999 g/cm^3) at the end of pumping.

02/25/86: Pulled the pump and packer assembly from the borehole.

10/13/86: Pressure-density survey; calculated ρ = 1.004 g/cm^3.

02/18/87 - 02/25/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.2 m above the top of the Culebra interval. Approximately 3.10 x 10^4 L of fluid were pumped prior to sampling. The specific gravity of the pumped fluid was 1.001 at 21.3°C (ρ = 0.999 g/cm^3) on 02/19/87 and 1.001 at 20.2°C (ρ = 0.999 g/cm^3) on 02/25/87. The volume of fluid pumped during sampling was approximately 2.37 x 10^5 L.

03/23/87: Pressure-density survey; calculated ρ = 1.009 g/cm^3. [NOTE: The density profile for this survey indicates that there is a potential error related to the recorded atmospheric pressure. Therefore, the density for the borehole-fluid column is calculated using the data between probe depths of 53.3 m (4.6 m below the fluid surface) and 79.3 m (middle of the Culebra interval).]

10/01/87: Pressure-density survey; calculated ρ = 0.986 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

04/13/88 - 04/25/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 9.1 m above the top of the Culebra interval. Prior to sampling, approximately 2.62 x 10^5 L of fluid were pumped from the borehole at a rate of 0.38 L/s. The specific gravity of the pumped fluid was 1.002 at 23.2°C (ρ = 1.000 g/cm^3) on 04/20/88 and 1.002 at 21.2°C (ρ = 1.000 g/cm^3) on 04/25/88.

05/15/89 - 05/19/89: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 12.0 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.022 at 22.5°C (ρ = 1.020 g/cm^3) on 05/16/89 and 1.003 at 22.0°C (ρ = 1.001 g/cm^3) on 05/19/89. Approximately 1.48 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.044 L/s.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-7b1 is estimated to be 1.005 g/cm^3 for the time period of 09/18/79 (initial completion of the Culebra interval) to 06/16/89. The density measured on 03/20/80 and the densities calculated from the results of the first two pressure-density surveys were averaged to obtain this value.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +0.3 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 26.0 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-7b1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
09/18/79 - 06/16/89	1.005	+0.01	+0.3

H-7b2

H-7b2 was drilled and cored in August and September 1983. The borehole was initially drilled and cored to a depth of 70.7 m BGS using a 8-3/4-inch bit, then cased and cemented using 7-inch casing. After the borehole was cleaned, coring was continued through the Culebra interval, located 72.2 to 83.5 m BGS, using a 6-1/8-inch core bit to a total depth of 89.9 m BGS. H-7b2 was then completed by placing approximately 8.2 m of pea gravel at the bottom of the borehole and a 3-inch well screen across the Culebra interval.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

09/22/83: Completion of the Culebra interval.

09/23/83: Developed the Culebra interval using compressed air from the drilling rig. Approximately 1.60 x 10^4 L of fluid were produced during this development effort. (No water-quality data.)

12/14/83: Evacuated the borehole using compressed air. The volume of fluid produced was not reported. (No water-quality data.)

06/11/84 - 06/26/84: Evacuated the borehole using compressed air and bailed the borehole. The volume of fluid produced was not reported. (No water-quality data.)

03/20/86 - 03/27/86: Water-quality sampling. A packer was not used to isolate the Culebra interval. The depth of the pump intake was not reported. The specific gravity of the pumped fluid was 1.001 at 21.4°C (ρ = 0.999 g/cm^3) on 03/20/86 and 1.001 at 21.5°C (ρ = 0.999 g/cm^3) on 03/27/86. Approximately 1.47 x 10^5 L of fluid were pumped from the borehole during this sampling period at an average rate of 0.28 L/s.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-7b2 is estimated to be 0.999 g/cm^3 for the time period of 09/22/83 (initial completion of the Culebra interval) to 06/16/89. The borehole was assumed to have filled with formation fluid after the well-development activities conducted in September and December 1983. The stable fluid density of 0.999 g/cm^3 measured during water-quality sampling between 03/20/86 and 03/27/86 appears to be representative of the formation fluid.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +0.3 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 26.0 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-7b2

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
09/22/83 - 06/16/89	0.999	+0.01	+0.3

H-7c

H-7c was drilled and cored in September 1979. The borehole was initially drilled to a depth of 108.8 m BGS using a 7-7/8-inch bit then reamed to a diameter of 9-7/8 inches and cased and cemented using 7-inch casing. After cleaning, H-7c was cored through the Rustler-Salado contact to a total depth of 128.0 m BGS using a 6-1/8-inch core bit. Following this final coring, H-7c was evacuated using compressed air and completed as a Rustler-Salado contact testing and monitoring borehole. The borehole remained in this configuration until July 15, 1983, when it was recompleted as a Culebra testing and monitoring borehole. A bridge plug was set in the casing above the open-hole Rustler-Salado contact interval and the Culebra interval was perforated from 72.5 to 83.5 m BGS. The top seal of the bridge plug was set 92.8 m BGS.

The only borehole activity affecting interpretation of Culebra equivalent-freshwater heads was the casing perforation at the Culebra interval on 05/15/83.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-7c is estimated to be 1.000 g/cm^3 for the time period of 05/15/83 (initial completion of the Culebra interval) to 06/16/89. This density estimate assumes that the borehole is filled with formation fluid.

The borehole-fluid density uncertainty is +0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +0.5 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 26.0 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-7c

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
05/15/83 - 06/16/89	1.000	+0.02	+0.5

H-8b

H-8b was drilled and cored in August 1979. It was initially drilled and reamed to a diameter of 9-7/8 inches to a depth of 175.3 m BGS, then cased and cemented to a depth of 175.0 m BGS using 7-inch casing. After cleaning, H-8b was cored through the Culebra interval, located 179.2 to 187.1 m BGS, using a 6-1/8-inch core bit to a total depth of 190.2 m BGS. Following coring, H-8b was evacuated with compressed air and completed open hole as a Culebra observation well.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/12/79: Completed the Culebra interval open hole.

02/11/80 - 02/13/80: Conducted two bailing tests. A total of approximately 2140 L of fluid were bailed from the borehole. The density of a fluid sample collected near the end of bailing was reported to be 1.000 g/cm^3. A borehole-density profile conducted before the first bailing test indicated an average fluid-column density of 1.002 g/cm^3.

02/13/80: Installed a production-injection packer (PIP) and a transducer assembly in the borehole. The PIP was set approximately 9.0 m above the top of the Culebra interval.

02/13/80 - 02/14/80: Conducted three slug-injection tests. A total of approximately 1030 L of formation fluid were added to the tubing. The tests were initiated by filling the tubing with formation fluid to set the packer then pressuring up to shear the tubing plug.

03/23/80 - 03/24/80: Conducted a 24-hour pumping exercise at a discharge rate of approximately 1.0 L/s. The depth of the pump intake was not reported. (No water-quality data.)

11/26/85: Installed a pump, packer, and transducer assembly in the borehole. The pump intake was set approximately 6.0 m above the top of the Culebra interval.

11/27/85 - 12/05/85: Conducted three short pumping exercises to establish an optimum pumping rate and to check the data-acquisition system.

The total pumping time was 2.7 hours at an average rate of approximately 0.38 L/s. (No water-quality data.)

12/06/85 - 12/09/85: Conducted a 72-hour pumping test at a discharge rate of approximately 0.38 L/s. The specific gravity of the pumped fluid remained relatively constant at 1.002 at 23.0°C (ρ = 1.000 g/cm^3).

12/18/85: Removed the pump, packer, and transducer assembly from the borehole shortly after this date.

01/09/86 - 01/23/86: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The depths of the packer and pump intake were not reported. Approximately 9460 L of fluid were pumped prior to sampling. The specific gravity of the pumped fluid was 1.002 at 21.9°C (ρ = 1.000 g/cm^3) on 01/14/86 and 1.002 at 21.8°C (ρ = 1.000 g/cm^3) on 01/22/86. Approximately 3.26 x 10^4 L of fluid were pumped during sampling at an average rate of 0.04 L/s.

10/15/86: Pressure-density survey; calculated ρ = 1.000 g/cm^3.

02/04/87 - 02/11/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.8 m above the top of the Culebra interval. Approximately 2270 L of fluid were pumped prior to sampling. The specific gravity of the pumped fluid was 1.002 at 21.3°C (ρ = 1.000 g/cm^3) on 02/05/87 and 1.002 at 21.7°C (ρ = 1.000 g/cm^3) on 02/11/87. Approximately 2.08 x 10^4 L of fluid were pumped during sampling at an average rate of 0.03 L/s.

03/30/87: Pressure-density survey; calculated ρ = 1.001 g/cm^3.

10/07/87: Pressure-density survey; calculated ρ = 0.976 g/cm^3. [NOTE: These data were reported as uncertain due to equipment problems.]

06/01/88 - 06/08/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 1.4 m above the top of the Culebra interval. Approximately 4160 L of fluid were pumped prior to sampling at a rate of 0.03 L/s. The specific gravity of the pumped fluid was 1.001 at 22.6°C (ρ = 0.999 g/cm^3) on 06/03/88 and 1.001 at 22.1°C (ρ = 0.999 g/cm^3) on 06/08/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-8b is estimated to be 1.001 g/cm^3 for the time period of 08/12/79 (initial completion of the Culebra interval) to 06/16/89. This value is an average of the densities calculated from the results of the pressure-density surveys conducted in October 1986 and March 1987.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +0.5 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 48.3 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-8b

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/12/79 - 06/16/89	1.001	+0.01	+0.5

H-9a

H-9a was drilled and cored in July and September 1979. It was initially drilled to a depth of 156.1 m BGS using a 7-7/8-inch bit and then reamed to a diameter of 9-7/8 inches to a depth of 155.4 m BGS. Following reaming, 7-inch casing was set and cemented to a depth of 155.4 m BGS. H-9a was then cored through the Magenta interval, 159.4 to 168.9 m BGS, using a 6-1/8-inch core bit to a total depth of 170.4 m BGS. The borehole was then evacuated with compressed air and completed as an open-hole Magenta testing and monitoring borehole. From September 5, 1979 to July 22, 1983, H-9a remained in this configuration. From July 22, 1983 through July 28, 1983, H-9a was recompleted by drilling and coring through the Culebra interval from 197.2 to 206.3 m BGS with a 4-3/4-inch core bit to a total depth of 210.9 m BGS. After coring, a production-injection packer (PIP) was set in the open-hole section between the Magenta and Culebra intervals. The borehole remained in this configuration until April 5, 1984 when the borehole was recompleted. The open-hole Magenta interval was reamed to a diameter of 6-1/4 inches and 4-1/2-inch casing was set and cemented to a depth of 186.8 m BGS. The borehole was then cleaned to 208.2 m BGS and a well screen was set across the Culebra interval. In this current configuration, H-9a is a Culebra testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

07/22/83 - 07/28/83: Cored the Culebra interval. Set a PIP between the Magenta and Culebra intervals.

08/19/83: Swabbed fluid from the tubing. The volume of fluid recovered was not reported. (No water-quality data.)

09/17/83: Attempted to evacuate the borehole with compressed air. No fluid reached the surface.

04/05/84 - 04/19/84: Recompleted the borehole. Removed the PIP, reamed through the Magenta interval, and set and cemented casing to the top of the Culebra interval. Cleaned the borehole to 208.2 m BGS and set well screen across the Culebra interval. During recompletion, freshwater was circulated in the borehole. [NOTE:

When the PIP was removed, there was an indication that the packer had not inflated.]

06/24/84: Bailed approximately 1890 L of fluid from the borehole. (No water-quality data.)

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-9a is estimated to be 1.001 g/cm^3 for the time period of 07/22/83 (initial completion of the Culebra interval) to 06/16/89. After swabbing, recompletion, and bailing activities were conducted in H-9a, the borehole probably filled with formation fluid. An estimate of 1.001 g/cm^3 based on water-quality sampling at H-9b was selected as representative.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.1 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 111.1 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-9a

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
07/22/83 - 06/16/89	1.001	+0.01	+1.1

H-9b

H-9b was drilled and cored in August 1979. It was initially drilled to a depth of 195.1 m BGS using a 7-7/8-inch bit and then reamed to a diameter of 9-7/8 inches to a depth of 194.3 m BGS. After reaming, 7-inch casing was set and cemented to a depth of 194.3 m BGS. After cleaning, H-9b was completed by coring through the Culebra interval from 197.2 to 206.3 m BGS using a 6-1/8-inch core bit to a depth of 207.3 m BGS, then drilling to a total depth of 215.8 m BGS using a 6-1/8-inch bit. H-9b was then evacuated with compressed air and completed as an open-hole Culebra observation well.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/28/79: Completed the Culebra interval open hole.

02/05/80: Conducted density-profile sampling which yielded an average borehole-fluid density of 1.005 g/cm^3 for the fluid column above the middle of the Culebra interval. Conducted one bailing test. Approximately 1590 L of fluid were bailed from the borehole. Although water-quality samples were collected at the end of the bailing test, they were not analyzed for density or specific gravity.

02/06/80: Installed a PIP in the borehole and conducted two slug-injection tests. The packer was set approximately 7.0 m above the top of the Culebra interval using formation fluid. The slugs consisted of a total of about 770 L of formation fluid added to the tubing. The slugs were released into the isolated Culebra interval to initiate the tests. After the second test was completed, the PIP and tubing were removed from the borehole.

03/20/80: Conducted a 12-hour pumping exercise at a discharge rate of approximately 5.6 L/s. The pump intake was set approximately 13.0 m above the top of the Culebra interval. (No water-quality data.)

03/22/80: Slug-injection test. An unreported volume of formation fluid was added to the borehole.

08/31/83: Slug-injection test. A total of 150 L of formation fluid were added to the borehole.

09/19/83: Installed a pump and transducer assembly in the borehole. The pump intake was set approximately 1.0 m above the top of the Culebra interval.

09/20/83 - 09/29/83: Conducted a 212-hour pumping test at an average discharge rate of approximately 0.63 L/s. (No water-quality data.)

10/07/83: Conducted a 1.47-hour pumping exercise at an average discharge rate of approximately 0.63 L/s. The specific gravity of the pumped fluid was 1.000 at 24.1°C (ρ = 0.997 g/cm^3).

10/11/83: Pulled the pump and transducer assembly from the borehole.

10/30/85 - 11/14/85: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 2.7 m above the top of the Culebra interval. Approximately 4800 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.002 at 22.0°C (ρ = 1.000 g/cm^3) on 11/01/85 and 1.003 at 22.6°C (ρ = 1.000 g/cm^3) on 11/04/85. Approximately 2.71 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.04 L/s.

10/14/86: Pressure-density survey; calculated ρ = 1.002 g/cm^3.

01/20/87 - 01/28/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval during sampling. The pump intake was located approximately 4.0 m above the top of the Culebra interval. Approximately 3790 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.004 at 21.5°C (ρ = 1.002 g/cm^3) on 01/22/87 and 1.002 at 21.9°C (ρ = 1.000 g/cm^3) on 01/28/87. Approximately 1.25 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.02 L/s.

03/24/87: Pressure-density survey; calculated ρ = 0.999 g/cm^3.

10/05/87: Pressure-density survey; calculated ρ = 0.987 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

06/14/88 - 06/21/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.0 m above the top of the Culebra interval. Approximately 5110 L of fluid were pumped prior to sampling at a rate of 0.03 L/s. The specific gravity of the pumped fluid was 1.003 at 21.2°C (ρ = 1.001 g/cm^3) on 06/16/88 and 1.002 at 22.8°C (ρ = 1.000 g/cm^3) on 06/21/88.

06/05/89: Pressure-density survey; calculated ρ = 1.003 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole- fluid density in H-9b is estimated to be 1.001 g/cm^3 for the time period of 08/28/79 (initial completion of the Culebra interval) to 06/16/89. This value was obtained by averaging the densities calculated from the results of the pressure-density surveys conducted in October 1986, March 1987, and June 1989.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.1 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 111.1 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-9b

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/28/79 - 06/16/89	1.001	+0.01	+1.1

H-9c

H-9c was drilled and cored in August 1979. It was initially drilled and cored to a depth of 239.3 m BGS using a 7-7/8-inch bit and then reamed to a diameter of 9-7/8 inches to a depth of 238.7 m BGS. Following reaming, 7-inch casing was set and cemented to a depth of 238.7 m BGS. After cleaning out the borehole, it was cored through the Rustler-Salado contact from 240.5 to 248.7 m BGS using a 6-1/8-inch core bit to a total depth of 248.7 m BGS. H-9c was then evacuated with compressed air and completed as an open-hole Rustler-Salado contact testing and monitoring borehole. H-9c remained in this configuration until January 1983 when it was recompleted. The Culebra interval was perforated from 197.2 to 206.3 m BGS and a production-injection packer (PIP) was set near the bottom of the casing (230.4 m BGS) to enable monitoring of both the Rustler-Salado contact and the Culebra interval. The exact date of this recompletion is unknown.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

01/20/83 (estimate): Casing perforation at the Culebra interval. Set a PIP in the borehole between the Rustler-Salado contact and the Culebra interval at a depth of 230.4 m BGS.

03/02/83: Removed the PIP from the borehole. The bladder on the PIP was found to be partially ruptured.

03/02/83 - 03/09/83: Set a packer and transducer assembly in the borehole 230.4 m BTC.

07/22/83: Removed the packer and transducer assembly. Installed a bridge plug in the casing (top seal set 217.0 m BGS).

08/05/83: Installed a pump and transducer assembly in the borehole. The pump intake was set approximately 20.0 m above the top of the Culebra interval.

08/08/83: Tested the pump for five minutes at a discharge rate of 1.89 L/s. (No water-quality data.)

08/09/83: Conducted a 5.8-hour step-drawdown pumping exercise. Approximately 7480 L of fluid were pumped during this test. (No water-quality data.)

08/10/83: Repositioned the pump intake to approximately 1.0 m above the top of the Culebra interval.

08/11/83 - 08/12/83: Conducted a 22.5-hour pumping test at an average discharge rate of approximately 0.64 L/s. (No water-quality data.)

08/30/83: Pumped approximately 300 L of fluid from the borehole. (No water-quality data.)

09/19/83: Removed the pump and transducer assembly from the borehole.

10/11/83: Installed a pump and transducer assembly in the borehole. The pump intake was set approximately 1.0 m above the top of the Culebra interval.

12/02/83 - 12/13/83: Conducted a 266-hour pumping test at an average discharge rate of approximately 0.63 L/s. (No water-quality data.)

02/24/84: Removed the pump and transducer assembly from the borehole.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-9c is estimated to be 1.001 g/cm^3 for the time period of 01/20/83 (estimated date of casing perforation at Culebra interval) to 06/16/89. After the pumping activities conducted in August and December 1983, the borehole probably filled with formation fluid. A density estimate of 1.001 g/cm^3 was selected based on water-quality sampling at H-9b.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.1 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 111.1 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-9c

Time Period	Borehole-Fluid Density (g/cm³)	Density Uncertainty (g/cm³)	Related Head Uncertainty (m)
01/20/83 - 06/16/89	1.001	+0.01	+1.1

H-10b

H-10b was drilled and cored in October 1979. It was initially drilled and cored to a depth of 410.3 m BGS using a 7-7/8-inch bit and then reamed to a diameter of 9-7/8 inches. Following reaming, 7-inch casing was set and cemented to a depth of 410.3 m BGS. After cleaning, H-10b was cored through the Culebra interval from 414.5 to 422.8 m BGS using a 6-1/8-inch core bit to a total depth of 426.1 m BGS. H-10b was then evacuated with compressed air and completed as an open-hole Culebra testing and monitoring borehole.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/13/79: Completed the Culebra interval open hole.

02/25/80 - 02/26/80: Conducted density-profile sampling which indicated an average borehole-fluid density of about 1.035 g/cm^3 for the fluid column above the middle of the Culebra interval. Conducted one bailing test. A total of approximately 1780 L of fluid were bailed from the borehole. (No water-quality data.)

02/26/80 - 02/28/80: Installed a production-injection packer (PIP) approximately 25.0 m above the top of the Culebra interval. Conducted slug-injection testing. Approximately 1570 L of formation fluid were added to the tubing and then released into the isolated Culebra interval. After testing, the PIP and tubing were removed from the borehole.

03/21/80: Conducted a bailing test. A total of approximately 1100 L of fluid were bailed from the borehole. The density of fluid collected at the end of bailing was reported as 1.045 g/cm^3.

04/01/87: Pressure-density survey; calculated ρ = 1.048 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-10b is estimated to be 1.047 g/cm^3 for the time period of 10/13/79 (initial completion of the Culebra interval) to 06/16/89. This density is the average of the fluid density obtained at the end of bailing in March 1980 and the density calculated from the results of the pressure-density survey conducted in April 1987.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±2.1 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of 206.0 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-10b

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/13/79 - 06/16/89	1.047	±0.01	±2.1

H-11b1

H-11b1 was drilled and cored in August 1983. It was drilled, cored and reamed to a total depth of 239.3 m BGS using a 4-3/4-inch core bit and a 7-7/8-inch drill bit. Following the final coring sequence, the borehole was reamed to a diameter of 7-7/8 inches to the top of the Culebra interval located 223.1 m BGS. 5-1/2-inch casing was then set and cemented from the surface to 223.1 m BGS. The cement fill was drilled out and the borehole was cleaned. After cleaning, H-11b1 was completed as an open-hole Culebra (221.3 to 230.4 m BGS) testing and monitoring borehole. The fluid used during the drilling, reaming, and cleaning operations was a sodium-chloride brine (ρ = 1.2 g/cm^3).

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

09/02/83: Completed the Culebra interval open hole.

09/06/83: Bailed approximately 1670 L of fluid from the borehole. (No water-quality data.)

09/07/83 - 09/09/83: Conducted slug tests using a volume-displacement tool. No fluid was added or withdrawn from the borehole.

04/30/84: Installed a pump and transducer assembly in the borehole. The pump intake was located approximately 27.0 m above the top of the Culebra interval.

04/30/84 - 05/03/84: Conducted three short pumping exercises to develop the Culebra interval. The total pumping period was approximately 1.5 hours. A total of approximately 930 L of fluid were pumped from the borehole at discharge rates ranging from 0.22 to 0.15 L/s. (No water-quality data.)

05/07/84: Removed the pump and transducer assembly from the borehole.

05/25/84 - 05/29/84: Cleaned the borehole using sodium-chloride brine (ρ = 1.2 g/cm^3) as a circulating medium.

09/14/84: Installed a packer and transducer assembly in the borehole. The depth of the packer was not reported.

09/16/84 - 09/19/84: Conducted three slug-injection tests. The tests consisted of inflating the packer set above the Culebra interval, adding formation fluid to the annulus, and then deflating the packer to initiate the tests. A total of approximately 550 L of formation fluid were added to the annulus.

10/08/84: Installed a pump and transducer assembly in the borehole. The pump intake depth was not reported.

10/09/84: Pumped approximately 2830 L of fluid from the borehole. (No water-quality data.)

10/10/84 - 10/11/84: Conducted a 13-hour pumping test at a discharge rate of approximately 0.20 L/s. (No water-quality data.)

10/11/84: Pumped approximately 1140 L of fluid from the borehole. (No water-quality data.) Removed the pump and transducer assembly from the borehole.

10/13/84: Collected water-samples using a down-hole port sampler. Sample No. 1 was collected at a depth of 152.4 m BGS and had a specific gravity of 1.084. Sample No. 2 was collected at a depth of 182.9 m BGS and had a specific gravity of 1.083. Sample No. 3 was collected at a depth of 222.5 m BGS and had a specific gravity of 1.085. Sample No. 4, taken at the surface from a barrel of fluid pumped on 10/11/84, had a specific gravity of 1.084. Fluid temperature was not reported for any of the samples.

02/01/88 - 02/02/88: Installed a pump and packer assembly, with the pump intake set approximately 21.0 m above the top of the Culebra interval, in the borehole. Conducted a 5-hour step-drawdown pumping exercise at discharge rates ranging from 0.16 to 0.47 L/s. A total of approximately 5960 L of fluid were discharged during this test. The specific gravity of the pumped fluid was 1.077 at 24.0°C (ρ = 1.074 g/cm^3).

02/04/88: Conducted development pumping and surging. A total of approximately 8180 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid was 1.077 at 24.0°C (ρ = 1.074 g/cm^3).

02/05/88 - 02/08/88: Conducted a 71.5-hour pumping exercise at a discharge rate of approximately 0.36 L/s. The specific gravity of the pumped fluid was 1.077 at 24.0°C (ρ = 1.074 g/cm^3).

02/10/88 - 02/13/88: Conducted a 72-hour pumping exercise at a discharge rate of approximately 0.40 L/s. The specific gravity of the pumped fluid was 1.076 at 24.0°C (ρ = 1.073 g/cm^3).

02/19/88 - 02/22/88: Conducted a 70.7-hour pumping exercise at a discharge rate of approximately 0.44 L/s. The specific gravity of the pumped fluid was 1.077 at 23.0°C (ρ = 1.076 g/cm^3).

03/07/88: Removed the pump and packer assembly from the borehole.

04/13/88: Installed a pump and packer assembly, with the pump intake located approximately 21.0 m above the top of the Culebra interval, in the borehole. Conducted a 6-hour step-drawdown pumping exercise at discharge rates ranging from 0.13 to 0.38 L/s. A total of approximately 4850 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid was 1.078 at 27.5°C (ρ = 1.074 g/cm^3).

04/14/88 - 04/20/88: Conducted well-development pumping and surging. Approximately 3.50 x 10^4 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid was 1.077 at 27.0°C (ρ = 1.073 g/cm^3).

04/26/88: Lowered the pump intake to the top of the Culebra interval.

04/30/88: Conducted two short pumping exercises. Total pumping lasted approximately 3.62 hours at a discharge rate of approximately 0.38 L/s. The specific gravity of the pumped fluid was 1.077 at 27.0°C (ρ = 1.073 g/cm^3).

05/05/88 - 07/07/88: Conducted a 1512-hour pumping test at a discharge rate of approximately 0.38 L/s. The specific gravity of the pumped fluid was 1.076 at 26.0°C (ρ = 1.073 g/cm^3) on 05/14/88 and 1.076 at 26.0°C (ρ = 1.073 g/cm^3) on 06/27/88.

11/08/88: Pulled the pump and packer assembly from the borehole.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-11b1 is estimated as follows. For the time period of 09/02/83 (initial completion of the Culebra interval) to 02/01/88, a density of 1.080 g/cm^3 is estimated to be representative of the borehole fluid. This value was based on the results of the vertical sampling conducted on 10/13/84. For the time period of 02/01/88 to 06/16/89, a density of 1.074 g/cm^3 is assumed. This value was obtained from field measurements collected during development pumping. The decrease in density from the first time period appears to be the result of development pumping conducted in 1988.

The borehole-fluid density uncertainty for both time periods is ±0.01 g/cm^3 which is ±0.9 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of approximately 92.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-11b1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
09/02/83 - 02/01/88	1.080	±0.01	±0.9
02/01/88 - 06/16/89	1.074	±0.01	±0.9

H-11b2

H-11b2 was drilled and cored in November 1983. It was drilled, cored, and reamed to a total depth of 236.5 m BGS using a 4-3/4-inch core bit and a 7-7/8-inch drill bit. Following the final coring sequence, the borehole was reamed to a diameter of 7-7/8 inches to the top of the Culebra interval at 223.5 m BGS. 5-1/2-inch casing was then set and cemented from the surface to 223.5 m BGS. The cement fill was then drilled out, and the borehole was cleaned and evacuated with compressed air several times. After cleaning, H-11b2 was completed as an open-hole Culebra interval (223.4 to 230.7 m BGS) testing and monitoring borehole. The fluid used during the drilling, reaming, and cleaning operations was a sodium-chloride brine (ρ = 1.2 g/cm^3).

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

11/23/83: Completed the Culebra interval open hole.

05/21/84 - 05/24/84: Reamed the borehole and circulated sodium-chloride brine (ρ = 1.2 g/cm^3) in the borehole.

08/31/84: Bailed an unknown volume of fluid from the borehole. (No water-quality data.)

09/14/84: Installed a packer and transducer assembly in the borehole. The depth of the packer was not reported.

09/17/84: Slug-injection test. This test consisted of inflating the packer set above the Culebra interval, adding formation fluid to the annulus, and then deflating the packer to initiate the test. A total of approximately 130 L of formation fluid were added to the annulus.

10/01/84 - 10/02/84: Pulled the packer and transducer assembly and then installed a pump and transducer assembly in the borehole. The pump intake was set approximately 43.0 m above the top of the Culebra interval. Conducted a 12.3-hour pumping test at a discharge rate of approximately 0.14 L/s. (No water-quality data.)

10/08/84: Removed the pump and transducer assembly from the borehole.

10/13/84: Collected water samples using a down-hole port sampler. Sample No. 1 was collected at a depth of 152.4 m BGS and had a specific gravity of 1.088. Sample No. 2 was collected at a depth of 182.9 m BGS and had a specific gravity of 1.086. Sample No. 3 was collected at a depth of 222.5 m BGS and had a specific gravity of 1.083. Fluid temperature was not reported for any of the samples.

12/04/87: Cleaned the borehole and circulated formation fluid pumped from H-11b3 in the borehole.

01/08/88 - 01/12/88: Installed a pump and packer assembly in the borehole. The pump intake was set approximately 23.0 m above the top of the Culebra interval. Conducted a 3-hour step-drawdown pumping exercise at discharge rates of 0.19 and 0.35 L/s. A total of approximately 2250 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid was 1.081 at 25.0°C (ρ = 1.078 g/cm^3).

01/18/88 - 02/01/88: Conducted well-development pumping and surging. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. A total of approximately 7.92 x 10^4 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid was 1.080 at 22.0°C (ρ = 1.078 g/cm^3) on 01/18/88 and 1.076 at 25.0°C (ρ = 1.073 g/cm^3) on 02/01/88. Pulled the pump and packer assembly from the borehole.

04/26/88: Bailed approximately 570 L of fluid from the borehole. (No water-quality data.)

04/27/88: Installed a production-injection packer (PIP) in the borehole. The bottom seal of the packer was set approximately 2.0 m above the top of the Culebra interval.

04/28/88: Installed a tracer-injection system and transducer assembly in the tubing. Swabbed approximately 80 L of fluid from the tubing.

05/14/88: Injected the tracer pentafluorobenzoate mixed with 190 L of formation fluid followed by 190 L of formation fluid into the borehole.

11/09/88: Removed the tracer-injection system from the borehole.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-11b2 is estimated as follows. For the time period of 11/23/83 (initial completion of the Culebra interval) to 12/04/87, a density of 1.085 g/cm^3 is estimated to be representative of the borehole fluid. This value was based on the results of the vertical sampling conducted on 10/13/84. For the time period of 12/04/87 to 06/16/89, a borehole-fluid density of 1.076 g/cm^3 is assumed. The densities measured at the end of well-development pumping conducted in January 1988 and in February 1988 were averaged to obtain this value. The decrease in density from the first time period appears to be the result of well-development pumping which is assumed to have removed possible brine contamination from the borehole.

The borehole-fluid density uncertainty for both time periods is ±0.01 g/cm^3 which is ±0.9 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of approximately 92.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-11b2

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
11/23/83 - 12/04/87	1.085	±0.01	±0.9
12/04/87 - 06/16/89	1.076	±0.01	±0.9

H-11b3

H-11b3 was drilled and cored in December 1983 and January 1984. The borehole was drilled, cored, and reamed to a total depth of 239.9 m BGS using a 4-3/4-inch core bit and a 7-7/8-inch drill bit. Following the final coring sequence, the borehole was reamed to a diameter of 7-7/8 inches to the top of the Culebra interval. The Culebra is located 223.4 to 231.7 m BGS. 5-1/2-inch casing was then set and cemented from the surface to 223.4 m BGS. The cement fill was then drilled out and the borehole was cleaned and completed open hole as a Culebra observation well. The fluid used during the drilling, reaming, and cleaning operations was a sodium-chloride brine (ρ = 1.2 g/cm^3).

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

01/84: Completed the Culebra interval open hole.

05/30/84 - 06/01/84: Circulated sodium-chloride brine (ρ = 1.2 g/cm^3) in the borehole.

08/30/84: Bailed approximately 850 L of fluid from the borehole. (No water-quality data.)

08/31/84: Bailed an unknown volume of fluid from borehole. (No water-quality data.)

09/14/84: Installed a packer and transducer assembly in the borehole. The depth of the packer was not reported.

09/17/84: Slug-injection test. This test consisted of inflating the packer set above the Culebra interval, adding formation fluid to the annulus, and then deflating the packer to initiate the test. A total of approximately 270 L of formation fluid were added to the annulus.

10/02/84: Pulled the packer and transducer assembly and then installed a pump and transducer assembly in the borehole. The pump intake was set approximately 55.0 m above the top of the Culebra interval.

10/03/84: Conducted a 1.1-hour pumping exercise at a discharge rate of approximately 0.13 L/s. (No water-quality data.)

10/04/84 - 10/05/84: Conducted a 22-hour pumping exercise at a discharge rate of 0.27 L/s. (No water-quality data.)

10/06/84: Conducted a 4-hour pumping exercise at a discharge rate of 0.27 L/s. (No water-quality data.)

10/08/84: Pulled the pump and transducer assembly from the borehole.

10/13/84: Collected water samples using a down-hole port sampler. Sample No. 1 was collected at a depth of 152.4 m BGS and had a specific gravity of 1.098. Sample No. 2 was collected at a depth of 182.9 m BGS and had a specific gravity of 1.096. Sample No. 3 was collected at a depth of 222.5 m BGS and had a specific gravity of 1.087. Fluid temperature was not reported for any of the samples.

05/13/85 - 06/04/85: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 11.6 m above the top of the Culebra interval. Approximately 2.99×10^4 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.092 at 22.6°C (ρ = 1.089 g/cm^3) on 05/14/85 and 1.091 at 22.6°C (ρ = 1.088 g/cm^3) on 05/23/85. Approximately 4.47×10^5 L of fluid were pumped during sampling at an average rate of 0.35 L/s.

05/28/86 - 06/04/86: Water quality-sampling. The pump intake was located approximately 7.9 m above the top of the Culebra interval. A packer was not utilized. Approximately 1.93×10^4 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.083 at 23.4°C (ρ = 1.080 g/cm^3) on 05/29/86 and 1.081 at 24.0°C (ρ = 1.078 g/cm^3) on 06/04/83. Approximately 1.17×10^5 L of fluid were pumped during sampling at an average rate of 0.19 L/s.

09/12/86: Pressure-density survey; calculated ρ = 1.082 g/cm^3.

03/05/87: Pressure-density survey; calculated ρ = 1.076 g/cm^3.

09/09/87 - 09/15/87: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located approximately 0.6 m above the top of the Culebra interval. Approximately 1.93×10^4 L of fluid were pumped from the borehole prior to sampling. The specific gravity of the pumped fluid was 1.080 at 24.8°C (ρ = 1.077 g/cm^3)

on 09/10/87 and 1.080 at 23.2°C (ρ = 1.077 g/cm^3) on 09/15/87. Approximately 8.48 x 10^4 L of fluid were pumped during sampling at an average rate of 0.19 L/s.

09/23/87: Pressure-density survey; calculated ρ = 1.063 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

11/25/87 - 11/28/87: Conducted a 66.4-hour pumping exercise at a discharge rate of approximately 0.34 L/s. The pump intake was set approximately 3.0 m above the top of the Culebra interval. (No water-quality data.)

04/20/88: Bailed approximately 1510 L of fluid from the borehole. (No water-quality data.)

04/22/88: Installed a tracer-injection assembly in the borehole.

05/14/88: Injected the tracer meta-trifluoromethylbenzoate mixed with 190 L of formation fluid followed by 190 L of formation fluid into the borehole.

11/08/88: Removed the tracer-injection system from the borehole.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-11b3 is estimated to be 1.079 g/cm^3 for the time period of 01/84 (initial completion of the Culebra interval) to 06/16/89. The densities calculated from the results of the pressure-density surveys conducted in September 1986 and March 1987 were averaged to obtain this value.

The borehole-fluid density uncertainty is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.9 to -0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of approximately 92.9 m.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-11b3

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
01/84 - 06/16/89	1.079	+0.02/-0.01	+1.9/-0.9

H-11b4

H-11b4 was drilled in February and March 1988. It was initially drilled with a 7-7/8-inch bit to a depth of 217.6 m BGS using a sodium-chloride brine as the drilling fluid. 5-1/2-inch casing was then set and cemented from the surface to 217.6 m BGS. The cement plug was then drilled out and the borehole was cored through the Culebra interval from 220.4 to 227.4 m BGS to a total depth of 232.3 m BGS using a 4-1/2-inch core bit. Following coring, H-11b4 was reamed to a diameter of 4-3/4 inches to total depth and completed open hole as a Culebra observation well. Freshwater was used as the circulation fluid for this coring and reaming.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

03/20/88: Completed the Culebra interval open hole.

03/21/88 - 03/22/88: Conducted two drill-stem tests and two slug-withdrawal tests.

03/24/88: Installed a pump and packer assembly in the borehole. The pump intake was set approximately 6.0 m above the top of the Culebra interval.

03/26/88: Conducted a well-development step-drawdown exercise. The discharge rate ranged from 0.23 to 0.50 L/s. Approximately 7720 L of fluid were pumped from the borehole. Fluid collected at the beginning of the pumping period had a specific gravity of 1.034 at 22.0°C (ρ = 1.032 g/cm^3) and at the end of the pumping period had a specific gravity of 1.066 at 24.0°C (ρ = 1.063 g/cm^3).

03/27/88: Conducted a 4-hour pumping exercise at a discharge rate of approximately 0.38 L/s. The specific gravity of fluid collected at the beginning of the exercise was 1.063 at 24.5°C (ρ = 1.060 g/cm^3) and at the end of the exercise was 1.069 at 26.0°C (ρ = 1.066 g/cm^3).

04/04/88 - 04/06/88: Conducted a 50-hour pumping test at a discharge rate of approximately 0.38 L/s. The specific gravity of fluid collected at the beginning of the test was 1.064 at 25.5°C (ρ = 1.061 g/cm^3) and at the end of the test was 1.072 at 26.0°C (ρ = 1.069 g/cm^3).

04/11/88: Removed the pump and packer assembly from the borehole.

04/28/88: Bailed approximately 570 L of fluid from the borehole. (No water-quality data.) Installed a tracer-injection assembly in the borehole.

05/14/88: Injected the tracer ortho-trifluoromethylbenzate mixed with 190 L of formation fluid followed by 190 L of formation fluid into the borehole.

11/09/88: Removed the tracer-injection system from the borehole.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-11b4 is estimated to be 1.065 g/cm^3 for the time period of 03/20/88 (initial completion of the Culebra interval) to 06/16/89. The densities of 1.061 and 1.069 g/cm^3 measured for fluid collected at the beginning and at the end, respectively, of the pumping test conducted in April 1988 were averaged to obtain this value.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an estimated borehole fluid column height above the center of the Culebra interval of approximately 92.9 m.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-11b4

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/20/88 - 06/16/89	1.065	±0.01	±0.9

H-12

H-12 was drilled in October 1983 as a hydrologic test hole to evaluate the transmissivity of the Culebra dolomite. The borehole was originally drilled and reamed to a 7-7/8-inch diameter to a depth of approximately 249.9 m BGS where 5-1/2-inch casing was installed and fully cemented. The hole was then deepened by drilling and coring a 4-3/4-inch borehole to a total depth of 305.1 m BGS which included the Culebra interval located 250.9 to 259.1 m BGS. In December 1983, the borehole was plugged with cement from 271.3 to 305.1 m BGS. The well is completed open hole from 249.9 to 271.3 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

- 10/04/83 - 10/18/83: Drilled and reamed the borehole. Set casing from ground surface to 0.9 m above the top of the Culebra interval.
- 12/09/83: Plugged the borehole with cement from total depth to 12.2 m below the base of the Culebra interval. The cement, mixed with freshwater, was piped through the tubing. Residual cement was cleaned from the borehole with freshwater.
- 12/12/83: Evacuated the borehole with compressed air. (No water-quality data.)
- 12/19/83 - 12/30/83: Development pumping of the Culebra interval. Although a packer was installed in the borehole prior to pumping, it remained deflated. (No water-quality data.)
- 01/04/84: Conducted a 12-hour pumping exercise at an average rate of 0.02 L/s. The Culebra interval was not isolated with a packer. The density of the pumped fluid decreased from 1.122 g/cm^3 after 2 hours of pumping to 1.070 g/cm^3 at the end of pumping.
- 01/07/84 - 01/12/84: Conducted a pumping test at an average flow rate of 0.01 L/s. The pump intake was located 5.2 m above the top of the Culebra interval. A packer was not utilized. The density of the pumped fluid increased from 1.066 g/cm^3, 2 hours into pumping to

1.114 g/cm^3, 11.6 hours later and then gradually decreased to 1.090 g/cm^3 at the end of pumping.

01/23/84 - 01/25/84: Pumped fluid from the borehole at an average rate of 0.015 L/s. A packer was not utilized. (No water-quality data.)

07/05/84 - 07/06/84: Circulated 10-lb/gal brine in the borehole to clean out debris.

07/09/84: Bailed fluid from the borehole. (No water-quality data.)

07/26/84: Bailed approximately 470 L of fluid from the borehole. (No water-quality data.)

04/16/85 - 05/09/85: Conducted 13 separate pumping episodes lasting from 3 to 7 hours each. The pumping rate ranged from 0.03 to 0.06 L/s. The pump intake was located 0.5 m below the top of the Culebra interval. A packer was not utilized. (No water-quality data.)

05/28/85: Pumped fluid from the borehole at an average rate of 0.04 L/s for approximately 5.7 hours. (No water-quality data.)

06/03/85: Pumped fluid from the borehole at an average rate of 0.04 L/s for approximately 7.1 hours. (No water-quality data.)

06/10/85: Pumped fluid from the borehole at an average rate of 0.04 L/s for approximately 5.7 hours. (No water-quality data.)

07/14/85 - 07/22/85: Conducted 6 separate pumping episodes lasting from 4.5 to 7.6 hours each. The total volume of fluid pumping during each episode ranged from a low of 480 L to a high of 900 L. (No water-quality data.)

08/01/85 - 08/09/85: Water-quality sampling. The pump intake was located 0.1 m above the top of the Culebra interval. A packer was not utilized. Approximately 2650 L of fluid were pumped prior to sampling. The average flow rate was 0.02 L/s. The specific gravity of the pumped fluid was 1.096 at 24.5°C (ρ = 1.093 g/cm^3) throughout the sampling period.

09/30/86: Pressure-density survey; calculated ρ = 1.098 g/cm^3.

01/08/87 - 01/16/87: Water-quality sampling. A pump and packer assembly, with the pump intake located 4.6 m above the top of the Culebra interval, was utilized to isolate the Culebra interval for sampling. Approximately 570 L of fluid were pumped from the borehole prior to sampling. The average flow rate was 0.006 L/s. The specific gravity of the pumped fluid was 1.111 at 20.2°C (ρ = 1.109 g/cm^3) on 01/09/87 and 1.100 at 18.5°C (ρ = 1.098 g/cm^3) on 01/16/87.

03/06/87: Pressure-density survey; calculated ρ = 1.097 g/cm^3.

07/10/87 - 07/17/87: Bailed approximately 4920 L of fluid from the borehole. The specific gravity of the bailed fluid remained relatively constant at 1.100 at 23.0°C (ρ = 1.097 g/cm^3).

08/27/87: Slug-injection test. The bottom of the packer element was located 2.5 m above the top of the Culebra interval. A minipacker was installed and inflated inside the tubing, 103.2 m above the Culebra. The slug consisted of about 120 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to start the test.

09/01/87: Slug-injection test. The bottom of the packer element was located 2.5 m above the top of the Culebra interval. A minipacker was installed and inflated inside the tubing, 103.2 m above the Culebra. The slug consisted of about 120 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to start the test.

09/24/87: Pressure-density survey; calculated ρ = 1.083 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

12/01/88 - 12/14/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 4.6 m above the top of the Culebra interval. Approximately 950 L of fluid were pumped from the borehole prior to sampling at a rate of about 0.013 L/s. The specific gravity of the pumped fluid was 1.105 at 21.3°C (ρ = 1.103 g/cm^3) on 12/02/88 and 1.088 at 21.2°C (ρ = 1.086 g/cm^3) on 12/14/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-12 is estimated as follows. For the time period of 10/04/83 to 07/05/84, the densities measured at the end of two pumping activities conducted in January 1984

(1.070 and 1.090 g/cm^3) were averaged to obtained a borehole-fluid density estimate of 1.080 g/cm^3. The beginning of this time period corresponds to the date the Culebra interval was initially penetrated and the end corresponds to the date brine was circulated in the borehole. An average of the densities from the pressure-density surveys conducted in September 1986 and March 1987 was assumed representative of the borehole-fluid density for the time period of 07/05/84 to 06/16/89. This average is 1.098 g/cm^3. The increase in density from the first time period appears to be the result of well-development activities conducted from July 1984 to July 1985.

The borehole-fluid density uncertainty for the first time period is large due to the lack of water-quality data during the early history of the borehole. It is assumed that this uncertainty is on the order of ±0.03 g/cm^3 and translates to a freshwater-head uncertainty of ±3.4 m. The uncertainty in borehole fluid density for the second time period is ±0.01 g/cm^3 which is ±1.1 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainties were calculated assuming an average of 113.1 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-12

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/04/83 - 07/05/84	1.080	±0.03	±3.4
07/05/84 - 06/16/89	1.098	±0.01	±1.1

H-14

H-14 was drilled in October 1986 to provide a Culebra dolomite monitoring well in the southwest quadrant of the WIPP site. The borehole was drilled on the P-1 drilling pad about 15.2 m northeast of the P-1 location. A 7-7/8-inch borehole was drilled to a depth of 162.5 m BGS, 3.7 m above the Culebra dolomite. The Magenta Dolomite, Tamarisk, and Forty-niner Members of the Rustler Formation and the Dewey Lake Red Beds were tested with the Baker Service Tools (BST) hydrological test tool immediately after these units were drilled. A 5-1/2-inch casing was set and cemented from 162.2 m BGS to the surface. A 4-1/2-inch hole was then cored through the Culebra interval to 175.0 m BGS. After drill-stem testing of the Culebra, the borehole was reamed to a diameter of 4-3/4 inches, and deepened to a total depth of 179.5 m BGS. During the drilling of the Culebra dolomite, the drilling fluid was freshwater with a conservative organic tracer added to assist in estimating the degree of drilling-fluid contamination of the Culebra dolomite.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/21/86: Cored and reamed the upper Culebra interval. The electrolytic conductivity of the fluid collected from the drilling-rig-discharge line increased from 3400 to 3575 μS/cm. Conducted a drill-stem test on the upper Culebra interval using a BST hydrological test tool set between 5.2 and 3.7 m above the top of the Culebra interval. The Culebra was isolated with a packer during testing. The testing sequence consisted of a 16.9-minute flow period followed by an 87-minute pressure build-up period and then a second 27.3-minute flow period followed by a 111-minute pressure build-up period. The flow rate into the test zone during the flow periods was about 0.01 L/s.

10/22/86: Cored the remainder of the Culebra interval. The electrolytic conductivity of the fluid collected from the drilling-rig-discharge line increased from 3600 to 3800 μS/cm. Conducted a drill-stem, slug-test sequence on the entire Culebra interval using a BST hydrological test tool set between 5.2 and 3.7 m above the top of the Culebra interval. The Culebra was isolated with a packer during testing. The testing sequence consisted of a 14.3-minute flow period followed by a 77-minute pressure build-up period, a second 23.9-minute flow period followed by a 129.4-minute pressure build-up period, and a 204-minute slug-withdrawal test. The flow rate into the test zone during the flow periods was 0.01 to 0.02 L/s.

10/23/86: Reamed the borehole and drilled to total depth using freshwater as a circulating medium.

10/27/86 - 12/11/86: Development pumping of the Culebra dolomite interval. The pump intake was located 3.8 m above the top of the Culebra interval. A packer was not utilized. Conducted 20 separate pumping episodes lasting from 20 to 30 minutes each. The pumping rate ranged from a low of 0.28 L/s to a high of 0.49 L/s. The specific gravity of the pumped fluid was 1.004 after 10 minutes of pumping and 1.010 at 22.0°C (ρ = 1.008 g/cm^3) at the end of the last pumping episode.

05/19/87 - 05/26/87: Water-quality sampling. A pump and packer assembly, with the pump intake located 6.6 m above the top of the Culebra interval, was utilized to isolate the Culebra dolomite for sampling. Approximately 1140 L of fluid were pumped from the borehole prior to sampling. The average flow rate was 0.02 L/s during sampling. The specific gravity of the pumped fluid was constant at 1.012 at 22.2°C (ρ = 1.010 g/cm^3) from 05/20/87 to 05/26/87.

09/22/87: Pressure-density survey; calculated ρ = 1.002 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.] A water sample taken at the Culebra depth had a fluid density of 1.024 g/cm^3.

01/18/88 - 01/27/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 3.5 m above the top of the Culebra interval. Prior to sampling, approximately 3790 L of fluid were pumped from the borehole at a flow rate of 0.015 L/s. The specific gravity of the pumped fluid was 1.012 at 18.8°C

(ρ = 1.010 g/cm^3) on 01/21/88 and 1.012 at 19.7°C (ρ = 1.010 g/cm^3) on 01/27/88.

01/25/89 - 02/15/89: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 4.5 m above the top of the Culebra interval. The specific gravity of the pumped fluid was 1.014 at 22.0°C (ρ = 1.012 g/cm^3) on 01/31/89 and 1.014 at 20.5°C (ρ = 1.012 g/cm^3) on 02/14/89. Approximately 2.12 x 10^4 L of fluid were pumped from the borehole during sampling at an average rate of 0.015 L/s.

06/07/89: Pressure-density survey; calculated ρ = 1.018 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-14 is estimated to be 1.013 g/cm^3 for the time period of 10/21/86 (date the Culebra was initially penetrated) to 06/16/89. This value is the average of the density measurement for water collected during the final phases of well-development pumping in December 1986 and the results of the pressure-density survey conducted in June 1989.

The borehole-fluid density uncertainty is +0.01 g/cm^3 which is +0.6 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 64.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-14

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/21/86 - 06/16/89	1.013	+0.01	+0.6

H-15

H-15 was drilled in November 1986 on the P-2 drilling pad about 7.6 m north of the P-2 location. A 7-7/8-inch borehole was drilled to a depth of 260.3 m BGS, 2.1 m above the top of the Culebra dolomite. The borehole was cased and fully cemented from the surface to 260.0 m BGS with 5-1/2-inch casing. The Culebra interval was then cored to a depth of 271.6 m BGS and reamed to a diameter of 4-3/4 inches. After testing the Culebra dolomite, the borehole was deepened to a total depth of 274.3 m BGS using a 4-3/4-inch bit. During the drilling of the Culebra dolomite, the drilling fluid was freshwater with a conservative organic tracer added to assist in estimating the degree of drilling-fluid contamination of the Culebra dolomite.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

11/09/86 - 11/10/86: Cored and reamed the Culebra dolomite interval. The electrolytic conductivity of the fluid collected from the drilling-rig-discharge line increased from 560 to 3100 μS/cm.

11/11/86 - 11/13/86: Conducted a drill-stem, slug-test sequence using a Baker Service Tools (BST) hydrological test tool. The Culebra interval was isolated with a packer during testing. The testing sequence consisted of a 25.8-minute flow period followed by a 14.4-hour pressure build-up period, a second 40.1-minute flow period followed by a 5.2-hour pressure build-up period, and a 17.2-hour slug-withdrawal test. The flow rate into the test zone during the flow periods was about 0.01 L/s.

11/14/86: Drilled the borehole to total depth using freshwater as a circulating medium.

04/14/87 - 05/11/87: Water-quality sampling. Initially, the Culebra was not isolated with a packer and the pump intake was located 4.3 m below the top of the Culebra interval. After two days the pump was pumping dry so the flow rate was reduced. On 04/27/87 the pump failed and was removed. A pump and packer assembly, with the pump intake located 0.6 m above the top of the Culebra interval, was then installed in the borehole. The pump was later raised to 3.7 m above the top of the Culebra. A good packer seal was never achieved. Approximately 5680 L of fluid were pumped from the borehole prior to sampling. The average flow rate was 0.009 L/s. The specific gravity of the pumped fluid was 1.142 at 18.4°C (ρ = 1.140 g/cm^3) on 04/21/87 and 1.156 at 22.2°C (ρ = 1.153 g/cm^3) on 05/11/87.

08/31/87: Pressure-density survey; calculated ρ = 1.136 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

01/07/88 - 01/13/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.9 m above the top of the Culebra interval. Prior to sampling, approximately 3400 L of fluid were pumped from the borehole at a flow rate of 0.01 L/s. The specific gravity of the pumped fluid was 1.152 at 20.2°C (ρ = 1.150 g/cm^3) on 01/11/88 and 1.153 at 21.4°C (ρ = 1.151 g/cm^3) on 01/13/88.

08/24/88: Pressure-density survey; calculated ρ = 1.145 g/cm^3.

10/25/88 - 11/07/88: Water-quality sampling. The Culebra was not isolated with a packer. The location of the pump intake was varied in stages from 65.2 to 2.8 m above the top of the Culebra interval during the first three days of pumping. During sampling, the pump intake was located 2.8 m above the top of the Culebra interval. The volume of fluid removed was approximately 8330 L. The flow rate varied from about 0.005 to 0.007 L/s. The specific gravity of the pumped fluid was 1.159 at 22.4°C (ρ = 1.156 g/cm^3) on 11/01/88 and 1.160 at 23.4°C (ρ= 1.157 g/cm^3) on 11/07/88.

05/18/89: Pressure-density survey; calculated ρ=1.156 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-15 is estimated as follows. For the time period of 11/09/86 to 04/16/87, the borehole-fluid density is estimated to be 1.000 g/cm^3 based on the electrolytic-conductivity measurements made on the fluid collected from the rig-discharge line during coring and reaming of the Culebra interval. The beginning of the time period corresponds to the date the Culebra dolomite was initially penetrated and the end corresponds to the date the borehole was pumped dry during water-quality sampling. The average density of 1.151 g/cm^3 determined from the results of the pressure-density surveys conducted in August 1988 and May 1989 was assumed for the time period of 04/16/87 to 06/16/89. The increase in density from the first time period appears to be the result of the pumping during water-quality sampling in April and May 1987. Because the flow rate was low during the water-quality sampling conducted in October and November 1988, this pumping was considered to have had a minor effect on the borehole fluid.

The borehole-fluid density uncertainty for the first time period is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.2 m. For the second time period, the uncertainty in borehole-fluid density is ±0.01 g/cm^3 which is ±1.2 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainties were calculated assuming an average of 118.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-15

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
11/09/86 - 04/16/87	1.000	+0.01	+1.2
04/16/87 - 06/16/89	1.151	±0.01	±1.2

H-16

Drilling began at H-16 in July 1987. H-16 is located about 15.2 m northwest of the air-intake shaft (AIS) at the WIPP site. The well is an observation well for the AIS to monitor fluid pressures in the members of the Rustler Formation during the drilling of the AIS pilot hole and the excavation and construction of the AIS. The borehole was drilled, cored, and reamed to a diameter of 9-5/8 inches to a depth of 143.3 m BGS in the lower Dewey Lake Red Beds, 19.2 m above the top of the Rustler Formation. The borehole was cased to 143.0 m BGS with 7-inch casing, and then cored and reamed (in two stages) to a final diameter of 6-1/8 inches to a total depth of 259.4 m BGS, about 2.7 m into the upper halite of the Salado Formation. In late August 1987, a Baker Service Tools (BST) 5-packer long-term observation tool was installed in H-16. The tool is equipped with downhole-pressure transducers and is designed to monitor the formation-fluid pressures in the five members of the Rustler Formation isolated by the packers.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/05/87 - 08/11/87: Drilled the Culebra interval using freshwater as a circulating medium. Conducted a drill-stem, slug-test sequence using the BST hydrological test tool. The Culebra was isolated with a packer during testing. The testing sequence consisted of a 17-minute flow period followed by a 2.5-hour pressure build-up period, a second 14-minute flow period followed by a 3.5-hour pressure build-up period, and a 3-hour slug-withdrawal test.

08/11/87: Drilled the unnamed lower member using freshwater.

08/13/87: Evacuated the borehole with compressed air and converted to 10-lb/gal brine (ρ = 1.2 g/cm^3) as a circulating medium.

08/13/87 - 08/17/87: Conducted a drill-stem test on the unnamed lower member.

08/17/87 - 08/18/87: Reamed the borehole to total depth using brine and ran geophysical logs.

08/25/87 - 08/27/87: Cleaned the borehole with brine and installed the BST long-term observation tool.

09/02/87: Began collecting fluid-pressure data.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-16 is estimated to be 1.200 g/cm^3 for the time period of 08/11/87 to 06/16/89. The borehole fluid consisted of 10-lb/gal brine prior to installing the long-term observation tool and is assumed to be brine at the present.

The borehole-fluid density uncertainty is -0.05 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of -0.5 m. The freshwater-head uncertainty was calculated assuming the transducer collecting pressure data for the Culebra dolomite is located 10.9 m above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-16

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/11/87 - 06/16/89	1.200	-0.05	-0.5

H-17

H-17 was drilled and cored in September and October 1987 to provide an additional observation and test well to define further the hydrologic properties of the Culebra dolomite and to provide stratigraphic data on the entire Rustler Formation along the southern boundary of the WIPP site. The borehole was drilled, cored, and reamed to a 9-5/8-inch diameter to 211.2 m BGS in the lower anhydrite unit of the Tamarisk Member. The hole was cased to 210.9 m BGS with 7-inch casing and cemented; then cored and reamed to a 6-1/8-inch diameter to a total depth of 265.3 m BGS, 4.5 m into the top of the upper Salado Formation. In November 1987, a cement plug was placed in H-17 from the total depth to 235.6 m BGS, 12.8 m below the base of the Culebra dolomite. During the drilling of the Culebra dolomite, located 215.1 to 222.9 m BGS, the drilling fluid was freshwater with a conservative organic tracer added to assist in estimating the degree of drilling-fluid contamination of the Culebra dolomite.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/07/87 - 10/08/87: Cored and reamed the Culebra dolomite interval. The specific gravity of fluid collected from the circulation pit ranged from 0.999 at 20.0°C (ρ = 0.997 g/cm^3) to 1.002 at 24.0°C (ρ = 0.999 g/cm^3).

10/09/87 - 10/10/87: Conducted two drill-stem tests and one slug test using a Baker Service Tools (BST) hydrological test tool located 0.9 m above the top of the Culebra interval. The Culebra interval was isolated with a packer during the testing. The testing sequence consisted of a 16-minute flow period followed by an 8.5-hour pressure build-up period, a second 25-minute flow period followed by an 11.5-hour pressure build-up period and a 2-day slug withdrawal test. The flow rate into the test zone during the flow periods varied from 0.02 to 0.03 L/s.

10/16/87 - 10/18/87: Pumped approximately 3220 L of fluid from the borehole at an average flow rate of 0.08 L/s. The pump intake was located 0.1 m below the top of the Culebra interval which was not isolated with a packer. The specific gravity of the pumped fluid was 1.074 at 22.2°C (ρ = 1.071 g/cm^3) 30 minutes into pumping and increased to 1.104 at 24.0°C (ρ = 1.101 g/cm^3) at the end of pumping.

10/19/87 - 10/27/87: Water-quality sampling. The pump intake and the bottom of the packer element were located at the top of the Culebra interval and 0.5 m above the Culebra interval, respectively. Approximately 1330 L of fluid were pumped from the borehole prior to sampling. The average flow rate was 0.009 L/s. The specific gravity of the pumped fluid was 1.102 at 24.4°C (ρ = 1.099 g/cm^3) on 10/22/87 and 1.103 at 21.3°C (ρ = 1.101 g/cm^3) on 10/27/87.

11/04/87: Cored and reamed the borehole from just below the Culebra interval to total depth using 10-lb/gal brine (ρ = 1.2 g/cm^3) as a circulating medium.

11/06/87: Placed a cement plug in the borehole from total depth to 12.8 m below the Culebra interval.

11/23/87 - 11/24/87: Evacuated the borehole using compressed air. (No water-quality data.)

12/07/87: Pressure-density survey; calculated ρ = 1.179 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

08/03/88: Pressure-density survey; calculated ρ = 1.166 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-17 is estimated as follows. Based on the fluid density measured on 10/18/87, a value of 1.101 g/cm^3 is estimated for the time period of 10/07/87 (date the Culebra interval was initially penetrated) to 11/04/87 (date brine was circulated in the borehole). The water-quality sampling conducted in October 1987 is assumed to have had a minor effect on the borehole-fluid density since the Culebra interval was isolated during sampling. The density of 1.166 g/cm^3 determined from the pressure-density survey conducted in August 1988 is assumed for the time period of 11/24/87 to 06/16/89. The brief period from 11/04/87 to 11/24/87 affected by placing the cement plug in the borehole and jetting the borehole is also assigned a fluid density of

1.166 g/cm^3. The increase in density from the first time period appears to be the result of circulating brine in the borehole in November 1987.

The borehole-fluid density uncertainty for the first time period is ±0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±1.6 m. For the second time period, the uncertainty in borehole-fluid density is ±0.01 g/cm^3 which is ±0.8 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainties were calculated assuming an average of 81.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for H-17

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/07/87 - 11/04/87	1.101	±0.02	±1.6
11/04/87 - 06/16/89	1.166	±0.01	±0.8

H-18

H-18 was drilled and cored in October 1987 to define further the hydrologic properties of the Culebra dolomite and to provide stratigraphic data on the entire Rustler Formation in the area northwest of the center of the WIPP site. After coring and reaming to a 9-5/8-inch diameter to 205.4 m BGS in the lower anhydrite unit of the Tamarisk Member, 7-inch casing was installed and cemented to 205.1 m BGS. The hole was then cored and reamed to a 4-3/4-inch diameter through the Culebra interval, located 209.9 to 217.3 m BGS, to a depth of 217.7 m BGS. During drilling of the Culebra dolomite, the drilling fluid was freshwater with a conservative organic tracer added to assist in estimating the degree of drilling-fluid contamination of the Culebra dolomite. Drill-stem and slug tests were then performed on the Culebra. After testing, the borehole was cored and reamed to a 6-1/8-inch diameter to a depth of 253.1 m BGS, 2.9 m into the top of the Salado Formation, using brine as a circulation medium. In November 1987, a cement plug was placed in H-18 from total depth to 233.5 m BGS, 16.2 m below the base of the Culebra dolomite.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/30/87 - 10/31/87: Cored and reamed the Culebra dolomite interval. The specific gravity of the fluid collected from the rig-discharge line increased from 1.003 at 23.0°C (ρ = 1.001 g/cm^3) to 1.008 at 22.0°C (ρ = 1.006 g/cm^3). Conducted a drill-stem, slug-test sequence using a Baker Service Tools (BST) hydrological test tool located 1.1 m above the top of the Culebra interval. The Culebra was isolated with a packer during testing. The testing sequence consisted of an 11-minute flow period followed by a 64-minute pressure build-up period, a second 17-minute flow period followed by a 1.5-hour pressure build-up period, and a 1.6-hour slug-withdrawal test. The flow rate into the test zone during the flow periods varied from 0.05 to 0.09 L/s.

11/02/87: Reamed the borehole. The specific gravity of the fluid collected from the rig-discharge line increased from 1.003 at 22.5°C (ρ = 1.001 g/cm^3) to 1.004 at 22.5°C (ρ = 1.002 g/cm^3).

11/03/87 - 11/10/87: Water-quality sampling. The Culebra interval was isolated with a pump and packer assembly during sampling. The pump intake and the bottom of the packer element were located 4.5 and 5.9 m, respectively, above the top of the Culebra interval. The packer remained deflated during the first 19 hours of pumping. The specific gravity of a sample collected on 11/04/87, 15 minutes prior to inflating the packer, was 1.007 at 26.0°C (ρ = 1.004 g/cm^3). Approximately 8710 L of fluid were pumped from the borehole prior to sampling. The average flow rate was approximately 0.06 L/s. The specific gravity of the pumped fluid increased from 1.010 at 19.8°C (ρ = 1.008 g/cm^3) on 11/05/87 to 1.018 at 19.0°C (ρ = 1.016 g/cm^3) on 11/10/87.

11/16/87: Cored and reamed the borehole from just below the Culebra interval to total depth using 10-lb/gal brine (ρ = 1.2 g/cm^3) as a circulating medium.

11/19/87: Placed a cement plug in the borehole from total depth to 16.2 m below the base of the Culebra interval.

12/10/87: Pressure-density survey; calculated ρ = 1.181 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

02/26/88 - 03/01/88: Well development. Conducted a series of three pumping and recovery episodes, each consisting of 3- to 4-hour pumping periods, at rates of 0.15 to 0.21 L/s, followed by 12- to 15-hour recovery periods. The pump intake and the bottom of the packer element were located 0.4 and 1.8 m, respectively, above the top of the Culebra interval. The specific gravity of the pumped fluid decreased from 1.178 at 22.0°C (ρ = 1.175 g/cm^3) on 02/26/88 to 1.098 at 23.5°C (ρ = 1.095 g/cm^3) on 03/01/88.

03/03/88: Removed the pump and packer assembly from the borehole. Bailed approximately 250 L of fluid from the borehole. (No water-quality data.) Reinstalled the pump and packer assembly.

03/11/88 - 03/14/88: Conducted a 72-hour pumping test. The pump intake and the bottom of the packer element were located 0.1 and 1.5 m, respectively, above the top of the Culebra interval. About 1.54×10^4 L of fluid were pumped from the borehole. The specific gravity of the pumped fluid decreased from 1.061 at 22.0°C (ρ = 1.059 g/cm^3) on 03/11/88 to 1.030 at 18.5°C (ρ = 1.028 g/cm^3) on 03/14/88.

03/19/88 - 04/07/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 0.1 m above the top of the Culebra interval. Prior to sampling, about 3.63×10^4 L of fluid were pumped from the borehole at a flow rate of 0.06 L/s. The specific gravity of the pumped fluid was 1.027 at 26.1°C (ρ = 1.024 g/cm^3) on 03/21/88 and 1.020 at 20.2°C (ρ = 1.018 g/cm^3) on 04/07/88.

08/02/88: Pressure-density survey; calculated ρ = 1.044 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in H-18 is estimated as follows. For the time period of 10/30/87 (date the Culebra interval was initially penetrated) to 11/16/87 (date brine was circulated in the borehole), the borehole-fluid density is estimated to be 1.002 g/cm^3. This value was based on the density measurements for the fluid collected from the rig discharge line during coring and reaming of the Culebra interval. The density of 1.181 g/cm^3 determined from the results of the pressure-density survey conducted in December 1987 is assumed for the time period of 11/16/87 to 03/03/88 (date the borehole was bailed). The increase in density from the first time period appears to be the result of circulating brine in the borehole in November 1987 during the deepening of H-18 through the unnamed lower member of the Rustler Formation. Since the Culebra interval was isolated with a packer during the well-development activities conducted in February and March 1988, these activities are considered to have had a minor effect on the borehole-fluid density. For the time period of 03/03/88 to 06/16/89, the density of 1.044 g/cm^3 determined from the pressure-density survey conducted in August 1988 is assumed. The decrease in density from the second time period appears to be the result of the bailing on 03/03/88.

The borehole-fluid density uncertainty for the first time period is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.0 m. For the second time period, the uncertainty in borehole-fluid density is ±0.02 g/cm^3 which is ±1.9 m when expressed as freshwater-head uncertainty. The borehole-fluid density and freshwater-head uncertainties are ±0.01 g/cm^3 and ±1.0 m, respectively, for the third time period. The freshwater-head uncertainties were calculated assuming an average of 95.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for H-18

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/30/87 - 11/16/87	1.002	+0.01	+1.0
11/16/87 - 03/03/88	1.181	±0.02	±1.9
03/03/88 - 06/16/88	1.044	±0.01	±1.0

DOE-1

DOE-1 was drilled in July 1982 as a stratigraphic and hydrologic exploratory borehole. Its purpose was to investigate an anticlinal structure in the Castile Formation suggested by seismic-reflection surveys, to test for gas or fluid in the rocks associated with the anticline, and to examine the nature of the Castile Formation near the WIPP site. The well is located approximately 2.0 km southeast of the exploratory shaft at the WIPP site. The borehole was cased to 340.8 m BGS with 10-3/4-inch casing and cemented to the surface, then deepened to a total depth of 1236.7 m BGS at a diameter of 7-7/8 inches. In March 1983, DOE-1 was reconfigured to provide an additional Culebra dolomite well for the WIPP-site observation-well network. On March 8, 1983, the Culebra dolomite was perforated from 249.9 to 256.9 m BGS. The borehole was then configured for well development and hydrologic testing.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

03/08/83: Casing perforation at the Culebra interval.

04/13/83 - 04/29/83: Pumped the borehole using a pump and packer assembly installed above the perforated interval. The specific gravity of the pumped fluid was 1.090 at 21.5°C (ρ = 1.088 g/cm^3) on 04/18/85 and 1.092 at 21.5°C (ρ = 1.090) on 04/29/83.

05/02/83 - 05/03/83: Conducted a step-drawdown exercise at pumping rates of 0.19 to 0.95 L/s. For this exercise, a pump and packer assembly was installed above the perforated interval. (No water-quality data.)

05/06/83 - 05/24/83: Pumped the borehole using a pump and packer assembly installed above the perforated interval. The specific gravity of the pumped fluid decreased from 1.091 at 23.0°C (ρ = 1.088 g/cm^3) on 05/06/83 to 1.084 at 25.0°C (ρ = 1.081 g/cm^3) on 05/24/83.

04/12/85 - 04/25/85: Water-quality sampling. A bridge plug was installed below the Culebra interval to isolate the Culebra from the deeper water-bearing zones. A pump and packer assembly, with the pump intake located 1.5 m above the top of the perforated Culebra interval, was installed for sampling. Approximately 1.12 x 10^4 L of fluid were pumped from the borehole before sampling. The average pumping rate was 0.52 L/s. The samples were not analyzed for specific gravity.

06/20/86 - 07/03/86: Water-quality sampling. The pump intake was located 11.6 m above the top of the perforated interval. A packer was installed above the pump and a bridge plug was installed below the pump to isolate the Culebra interval for sampling. Approximately 1.20 x 10^5 L of fluid were pumped from the borehole before sampling. The average pumping rate was 0.29 L/s before sampling and 0.13 L/s during sampling. The specific gravity of the pumped fluid increased from 1.089 at 22.9°C (ρ = 1.086 g/cm^3) on 06/25/86 to 1.091 at 23.0°C (ρ = 1.088 g/cm^3) on 07/03/86.

09/10/86: Pressure-density survey; calculated ρ = 1.076 g/cm^3.

02/19/87: Pressure-density survey; calculated ρ = 1.108 g/cm^3.

07/17/87 - 07/29/87: Water-quality sampling. A pump and packer assembly, with the pump intake located 3.7 m above the top of the perforated interval, was used to isolate the Culebra for sampling. Approximately 1.02 x 10^5 L of fluid were pumped from the borehole before sampling. The packer was not inflated during the first 30 hours of pumping. The average pumping rate was 0.23 L/s. The specific gravity of the pumped fluid was 1.091 at 22.5°C (ρ = 1.088 g/cm^3) on 07/22/87 and 1.091 at 23.2°C (ρ = 1.089 g/cm^3) on 07/28/87.

09/02/87: Pressure-density survey; calculated ρ = 1.066 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

08/23/88: Pressure-density survey; calculated ρ = 1.069 g/cm^3.

05/10/89: Pressure-density survey; calculated ρ = 1.077 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in DOE-1 is estimated to be 1.083 g/cm^3 for the time period of 03/08/83 to 06/16/89.

This value is an average of the calculated densities determined from the pressure-density surveys conducted on 09/10/86, 02/19/87, 08/23/88, and 05/10/89.

The borehole-fluid density uncertainty is estimated to be ±0.02 g/cm^3. This uncertainty corresponds to ±2.0 m when expressed as a freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 101.8 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for DOE-1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/08/83 - 06/16/89	1.083	±0.02	±2.0

DOE-2

Well DOE-2 was drilled from August 1984 through July 1985 as a stratigraphic and hydrologic exploratory borehole. Its purpose was to examine all formations above and below the proposed WIPP-waste repository which could be affected if the repository were to be breached. DOE-2 is located immediately north of the northern WIPP-site boundary about 3.2 km from the center of the WIPP site. During the drilling phase, all formations were hydrologically tested by Sandia National Laboratories. The Rustler Formation was tested and then cemented behind casing before deepening the borehole to the Salado, Castile, and Bell Canyon Formations. After drilling and testing the well, a production-injection packer (PIP) was set at 1234.7 m BGS to isolate the Bell Canyon Formation and to prevent hydraulic communication between the Bell Canyon and the overlying strata. In addition, the PIP provided water-level access to the Bell Canyon Formation through the tubing attached to the packer. On April 1, 1986, the PIP was released and removed from the well. During removal, the 6-5/8-inch packer element was stripped off of the packer mandrel (probably in the Salado Formation interval between 426.7 to 518.2 m BTC). The well was re-entered on April 2, 1986. A 7-1/8-inch bridge plug was set at 266.5 m BGS and the 9-5/8-inch casing was perforated across the Culebra interval from 250.3 to 258.3 m BGS. The borehole was then configured for well development and hydrologic testing.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

04/02/86: Casing perforation at the Culebra interval.

04/08/86: Well development. An air-lift pumping system was used to surge and develop the well. Approximately 3790 L of fluid were removed from the borehole. (No water-quality data.)

04/16/86 - 04/24/86: Well development. A four-stage step-drawdown pumping exercise was performed at pumping rates of 0.11 to 0.39 L/s followed by five surge and development exercises at average pumping rates of 0.25 to 0.40 L/s. The pump intake was located 0.7 m above the top of the perforated interval. A packer was not utilized. The specific gravity of the pumped fluid decreased from 1.158 at 21.9°C (ρ = 1.155 g/cm^3) on 04/18/86 to 1.070 at 24.0°C (ρ = 1.067 g/cm^3) on 04/24/86.

05/27/86: A packer was set 1.3 m below the base of the perforated interval and 1.00 x 10^4 L of a 2-percent potassium-chloride solution were circulated in the borehole. The packer was reset to 18.9 m above the top of the perforated interval. Approximately 7630 L of 20-percent hydrochloric acid was injected into the formation. The borehole was flushed with 950 L of a 2-percent potassium-chloride solution. After allowing the acid to remain in the borehole for about 1-1/2 hours, the tubing was swabbed removing 4770 L of fluid from the borehole.

06/03/86 - 06/13/86: Well development consisting of (1) a step-drawdown exercise at 0.15 to 0.92 L/s, (2) a 23-hour pumping exercise at an average rate of 0.79 L/s, and (3) three surge-and-development actions. The pump intake was located 1.7 m above the top of the perforated interval. A packer was not utilized. The initial fluid sample, collected on 06/04/86, had a specific gravity of 1.015 at 22.0°C (ρ = 1.013 g/cm^3). The specific gravity of the pumped fluid increased to 1.048 at 22.5°C (ρ = 1.046 g/cm^3) on 06/05/86 and then showed an overall decrease to 1.043 at 24.0°C (ρ = 1.040 g/cm^3) on 06/13/86.

06/30/86 - 07/04/86: Conducted a 100-hour pumping test at an average pumping rate of 2.18 L/s. A pump and packer assembly was used to isolate the Culebra interval. The pump intake and the bottom of the packer were located 29.5 and 31.5 m, respectively, above the top of the perforated interval. The specific gravity of the pumped fluid remained relatively constant at 1.040 at 25.0°C (ρ = 1.037 g/cm^3) throughout the pumping period. The maximum specific gravity was 1.042 at 25.0°C (ρ = 1.039 g/cm^3) measured on 06/30/86 and the minimum was 1.039 at 25.0°C (ρ = 1.036 g/cm^3) measured on 07/03/86.

08/12/86 - 08/27/86: Water-quality sampling. The Culebra interval was isolated from the stagnant water in the borehole with a pump and packer assembly. The pump intake was located 2.7 m above the top of the perforated interval. Approximately 5.56 x 10^4 L of fluid were pumped from the borehole prior to sampling. The average pumping rate was 0.35 L/s. The specific gravity of the pumped fluid was constant at 1.043 at 22.3°C (ρ = 1.041 g/cm^3) during the sampling period.

09/09/86: Pressure-density survey; calculated ρ = 1.031 g/cm^3.

05/13/87: Pressure-density survey; calculated ρ = 1.025 g/cm^3.

09/08/87: Pressure-density survey; calculated ρ = 1.022 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

04/27/88 - 05/19/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 0.5 m above the top of the Culebra interval. Prior to sampling, approximately 2.16 x 10^5 L of fluid were pumped from the borehole at a flow rate of 0.25 L/s. The specific gravity of the pumped fluid was 1.042 at 22.1°C (ρ = 1.040 g/cm^3) on 05/01/88 and 1.044 at 23.3°C (ρ = 1.041 g/cm^3) on 05/19/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in DOE-2 is estimated as follows. Based on the fluid density measured on 04/24/86 (the end of the first well-development period), a density estimate of 1.067 g/cm^3 is used for the time period of 04/02/86 to 05/27/86. April 24, 1986 is the date the Culebra interval was perforated, and May 27, 1986 is the date the Culebra interval was acidized. The results of the pressure-density surveys conducted on 09/09/86 and 05/13/87 (1.031 and 1.025 g/cm^3, respectively) were averaged to obtain a density estimate of 1.028 g/cm^3 for the time period of 05/27/86 to 06/16/89. This value is lower than the estimate for the first time period because the acid solution injected into the formation on 05/27/86 was made with freshwater. The 100-hour pumping test and the water-quality sampling which occurred during the second time period are considered to have had a minor impact on the borehole-fluid density because the Culebra interval was isolated with a packer during these activities.

The borehole-fluid density uncertainty is ±0.03 g/cm^3 for the first time period. This uncertainty value translates to a freshwater-head uncertainty of ±4.3 m. For the second time period, the uncertainty in borehole-fluid density is ±0.01 g/cm^3 which indicates a freshwater-head uncertainty of ±1.4 m. The freshwater-head uncertainties were calculated assuming an average of 142.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for DOE-2

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/02/86 - 05/27/86	1.067	±0.03	±4.3
05/27/86 - 06/16/89	1.028	±0.01	±1.4

P-14

P-14 was drilled as part of a 21-well exploratory-drilling program to evaluate the potash mineral resources of the WIPP site. Because of its location near the outer boundary of the site, P-14 was selected for hydrologic testing in the transmissive zones above the salt repository horizon (Mercer and Orr, 1977). After setting 8-5/8-inch surface casing to a depth of 6.1 m BGS, P-14 was drilled to a depth of 236.5 m BGS with a diameter of 7-7/8 inches, and the well was cased with 4-1/2-inch casing cemented from the surface to a depth of 236.2 m BGS. The borehole was then deepened from 236.5 to 362.1 m BGS with a 4-inch diameter, and cored from 362.1 m to a total depth of 470.9 m BGS. On October 3, 1976, the borehole was plugged with cement from total depth to 231.3 m BGS. The casing was perforated across two intervals in January and March 1977: the Rustler-Salado contact from 206.0 to 213.4 m BGS; and the interval from 174.7 to 183.2 m BGS, which includes the Culebra dolomite. A production-injection packer (PIP) was set between the Rustler-Salado contact and the Culebra dolomite perforated intervals to allow water-level monitoring of these two zones.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

03/07/77: Casing perforation at the Culebra interval.

03/08/77: Bailed approximately 2730 L of fluid from the borehole. (No water-quality data.)

03/14/77: Bailed fluid from the borehole. The density of the bailed fluid was 1.018 g/cm^3.

03/21/77: The PIP separating the Rustler-Salado contact and the Culebra interval was pulled and reset due to possible communication between the two zones.

03/22/77 - 03/23/77: Conducted a radioactive-tracer survey and a temperature survey on the Culebra interval. A total of approximately 6190 L of fluid were injected into the borehole during the survey. Once the survey was completed, 5450 L of fluid were bailed from the borehole. (No water-quality data.)

03/24/77: The borehole was placed into a long-term dual-completion phase for monitoring Rustler-Salado contact and Culebra dolomite water levels.

03/06/80: Slug test. (No information available.)

03/29/80: Pumping exercise. (No information available.)

10/03/83 - 10/04/83: Conducted a series of slug tests using a displacement tool. No fluid was added or withdrawn from the borehole.

02/18/86 - 02/27/86: Water-quality sampling. About 2650 L of fluid were pumped from the borehole prior to sampling. The Culebra interval was not isolated with a packer for sampling. The average pumping rate was not reported. The specific gravity of the pumped fluid remained relatively constant throughout the pumping period; 1.018 at 22.9°C (ρ = 1.016 g/cm^3) on 02/19/86 and 1.019 at 21.3°C (ρ = 1.017 g/cm^3) on 02/27/86.

08/15/86: Pressure-density survey; calculated ρ = 1.015 g/cm^3.

12/08/86: Bailed approximately 80 L of fluid from the borehole. (No water-quality data.)

12/17/86: Bailed approximately 600 L of fluid from the borehole. (No water-quality data.)

12/19/86 - 12/20/86: Conducted two slug-injection tests. A packer was set 9.1 m above the perforated Culebra interval. For the first test, the slug consisted of approximately 570 L of formation fluid added to the annulus. About 170 L of formation fluid were added to the annulus for the second test. Both tests were initiated by deflating the packer.

04/23/87: Pressure-density survey; calculated ρ = 1.009 g/cm^3.

06/10/87 - 06/18/87: Water-quality sampling. A pump and packer assembly was installed to isolate the Culebra interval for sampling. The pump intake was located 0.1 m above the top of the perforated interval. Approximately 1510 L of fluid were pumped from the borehole prior to sampling. The average pumping rate was 0.02 L/s. The specific gravity of the pumped fluid was 1.020 at 22.0°C (ρ = 1.018 g/cm^3) throughout the pumping period.

08/19/87: Pressure-density survey; calculated ρ = 1.003 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

03/08/88 - 03/16/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.5 m below the top of the Culebra interval. Prior to sampling, approximately 7950 L of fluid were pumped from the borehole at a pumping rate of 0.03 L/s. The specific gravity of the pumped fluid was 1.020 at 22.0°C (ρ = 1.018 g/cm^3) on 03/11/88 and 1.020 at 21.0°C (ρ = 1.018 g/cm^3) on 03/16/88.

01/27/89 - 01/30/89: Well Development. Conducted seven phases of air-lift pumping. Each phase lasted about 1.5 hours. The specific gravity of the pumped fluid was 1.020 at 21.0°C (ρ = 1.018 g/cm^3) on 01/27/89 and 1.019 at 24.0°C (ρ = 1.016 g/cm^3) on 01/30/89.

02/02/89: Reperforated the casing across the Culebra interval from 174.7 to 183.2 m BGS.

02/03/89: Acidized the borehole. Added about 320 L of 15-percent hydrochloric acid followed by about 160 L of freshwater to the borehole. Injected approximately 3580 L of 15-percent hydrochloric acid into the Culebra interval followed by 320 L of freshwater. Added an additional 480 L of freshwater to the borehole. Evacuated the borehole with compressed air.

02/04/89 - 02/08/89: Well development. Conducted a series of air-lift pumping exercises. The specific gravity of the pumped fluid was 1.021 at 18.5°C (ρ = 1.019 g/cm^3) at the start of pumping on 02/04/89 and 1.018 at 24.0°C (ρ = 1.015 g/cm^3) at the end of pumping on 02/08/89.

02/14/89 - 02/17/89: Conducted a 72-hour pumping test on the Culebra interval using an air-lift-pump system. The specific gravity of the pumped fluid was 1.018 at 25.0°C (ρ = 1.015 g/cm^3) after 5.5 hours of pumping and 1.018 at 22.0°C (ρ = 1.016 g/cm^3) on 02/17/89 near the end of pumping. The pumping rate varied from a high of

4.00 L/s after 5.8 hours of pumping to a low of 3.05 L/s at the end of pumping

06/16/89: Pressure-density survey; calculated ρ = 1.015 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in P-14 is estimated to be 1.012 g/cm^3 for the time period of 03/07/77 to 01/27/89. This value is an average of the densities determined from the pressure-density surveys conducted on 08/15/89 and 04/23/87. For the time period of 01/27/89 to 06/16/89, the density of 1.015 g/cm^3 calculated from the results of the pressure-density survey conducted in June 1989 is assumed.

The uncertainty in the estimate of borehole-fluid density for both time periods is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.8 m. The freshwater-head uncertainty was calculated assuming an average of 78.9 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for P-14

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/07/77 - 01/27/89	1.012	±0.01	±0.8
01/27/89 - 06/16/89	1.015	±0.01	±0.8

P-15

P-15 was drilled in October 1976 as part of a 21-well resource-evaluation program to investigate the potash resources in the Salado Formation (Jones, 1978). The borehole was initially drilled with a 7-7/8-inch diameter to a depth of 194.2 m BGS and cased with 4-1/2-inch casing to 193.5 m BGS and fully cemented. A 4-inch diameter borehole was then drilled from 194.2 to 316.4 m BGS. P-15 was then cored from 316.4 to 446.5 m BGS using a 3-15/16-inch diameter core bit. The open hole and lower portion of the casing were subsequently plugged with cement from 189.0 to 446.5 m BGS. In January 1977, the borehole was re-entered and the casing was perforated across the Rustler-Salado contact from 162.2 to 169.5 m BGS. In April 1977, the casing was perforated across the Culebra dolomite interval from 125.0 to 133.5 m BGS. After hydrologic testing of both perforated intervals was completed, a production-injection packer (PIP) was set at a depth of 156.1 m BGS. In June 1985, the PIP was removed and a retrievable bridge plug was set at 134.5 m BGS to provide access to only the Culebra dolomite interval for water-level monitoring and formation testing.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

04/06/77: Casing perforation at the Culebra interval.
04/07/77: Bailed approximately 210 L of fluid from the borehole. (No water-quality data.)
05/10/77: Bailed fluid from the borehole. The density of the bailed fluid was 1.080 g/cm^3.
05/29/85: Slug-injection test. Approximately 40 L of distilled water were added to the annulus. Once the slug was in place, the packer set above the Culebra interval was deflated to initiate the test.
06/06/85 - 06/07/85: Replaced the PIP separating the Culebra and Rustler-Salado contact intervals.
09/16/86: Pressure-density survey; calculated ρ = 1.002 g/cm^3.
02/26/87: Pressure-density survey; calculated ρ = 1.034 g/cm^3.
03/27/87: Bailed approximately 380 L of fluid from the borehole. (No water-quality data.)

04/07/87: Bailed approximately 380 L of fluid from the borehole. The specific gravity of the fluid collected with the first bail was 1.005 and with the last bail was 1.007.

04/16/87: Bailed approximately 380 L of fluid from the borehole. The specific gravity of the bailed fluid was 1.006.

04/21/87: Bailed approximately 340 L of fluid from the borehole. The specific gravity of the bailed fluid was 1.007.

04/24/87: Slug-injection test attempted. Approximately 210 L of formation fluid were added to the annulus. The packer, set 3.8 m above the top of the perforated Culebra interval, was deflated to initiate the test.

05/01/87: Bailed approximately 270 L of fluid from the borehole. (No water-quality data.)

05/12/87 - 05/13/87: Slug-injection test attempted. A packer was set 4.9 m above the top of the perforated Culebra interval. A minipacker was installed and inflated in the tubing, 19.0 m above the top of the Culebra interval. Approximately 60 L of formation fluid were added to the tubing above the minipacker. Once the slug was in place, the minipacker was deflated to initiate the test.

05/16/87: Slug-injection test. A packer was set 4.9 m above the top of the perforated Culebra interval. A minipacker was installed and inflated in the tubing, 19.0 m above the top of the Culebra interval. Approximately 60 L of formation fluid were added to the tubing above the minipacker. Once the slug was in place, the minipacker was deflated to initiate the test.

05/19/87: Slug-injection test. A packer was set 4.9 m above the top of the perforated Culebra interval. A minipacker was installed and inflated in the tubing, 19.0 m above the top of the Culebra interval. Approximately 60 L of formation fluid were added to the tubing above the minipacker. Once the slug was in place, the minipacker was deflated to initiate the test.

08/28/87: Pressure-density survey; calculated ρ = 0.985 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

06/13/89: Pressure-density survey; calculated ρ = 1.006 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in P-15 is estimated as follows. Based on the fluid density measured on 05/10/77, a value of 1.080 g/cm^3 is estimated for the time period of 04/06/77 to 05/29/85. The beginning of this time period corresponds to the date the Culebra interval was perforated and the end corresponds to the date a slug-injection test, which added about 40 L of distilled water to the annulus, was conducted. The densities of 1.002 and 1.034 g/cm^3 determined from the pressure-density surveys conducted on 09/16/86 and 02/26/87, respectively, were averaged to obtain an estimated density of 1.018 g/cm^3 for the time period of 05/29/85 to 03/27/87. The decrease in density from the first time period to the second time period appears to be the result of the addition of distilled water to the annulus during the slug test on 05/29/85. From March to May 1987 the borehole was bailed five times. This bailed fluid, which consistently had a specific gravity of 1.006, was then used in four slug-injection tests conducted in April and May 1987. Based on this combination of activities and the results of the pressure-density survey conducted in June 1989, the borehole-fluid density is estimated to be 1.006 g/cm^3 for the time period of 03/27/87 to 06/16/89.

For the first time period, the borehole-fluid density uncertainty is ±0.05 g/cm^3. This value translates to a freshwater-head uncertainty of ±1.8 m. The uncertainty in borehole-fluid density for the second time period is ±0.02 g/cm^3 which is a freshwater-head uncertainty of ±0.7 m. The borehole-fluid density and freshwater-head uncertainties are +0.01 g/cm^3 and +0.4 m, respectively, for the third time period. The freshwater-head uncertainties were calculated assuming an average of 36.3 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for P-15

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/06/77 - 05/29/85	1.080	±0.05	±1.8
05/29/85 - 03/27/87	1.018	±0.02	±0.7
03/27/87 - 06/16/89	1.006	+0.01	+0.4

P-17

P-17 was originally drilled in October 1976 as part of the potash resource-evaluation program for the proposed WIPP site (Jones, 1978) and then was completed as a hydrologic monitoring well (Mercer and Orr, 1979). P-17 was drilled at a diameter of 7-7/8 inches to a depth of 230.1 m BGS, approximately 12.2 m into the Salado Formation. The borehole was cased with 4-1/2-inch casing to a depth of 225.9 m BGS and cemented to the surface. A 4-inch hole was then drilled to the coring depth of 371.9 m BGS. The borehole was subsequently deepened by coring from 371.9 m BGS to a total depth of 506.0 m BGS to obtain samples for reserve estimation and then plugged with cement from 506.0 m to a depth of 222.8 m BGS. In January 1977, P-17 was bailed dry and perforated across the Rustler-Salado contact from 214.0 to 221.3 m BGS. In April 1977, a production-injection packer (PIP) was installed 208.0 m BGS. The casing was then perforated across the Culebra dolomite interval from 170.1 to 178.6 m BGS. In March 1983, the PIP was removed from the borehole and a bridge plug was installed at 205.4 m BGS for water-level monitoring and future hydrologic testing of the Culebra.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

04/05/77: Casing perforation at the Culebra interval.

04/07/77: Bailed borehole dry. Removed approximately 1230 L of fluid from the borehole. (No water-quality data.)

05/10/77: Bailed approximately 1100 L of fluid from the borehole. The bailed fluid had a density of 1.082 g/cm^3.

07/01/83 - 07/02/83: Conducted slug-displacement tests using a displacement pipe. No fluid was added or withdrawn from the borehole.

07/13/83 - 07/15/83: Conducted slug-displacement tests using a displacement pipe. No fluid was added or withdrawn from the borehole.

07/27/83 - 07/29/83: Conducted slug-displacement tests using a displacement pipe. No fluid was added or withdrawn from the borehole.

06/11/85 - 07/12/85: Pumped well at a rate of 0.03 L/s. The pump intake was located 2.9 m above the top of the perforated Culebra interval. A packer was not utilized. (No water-quality data.)

03/04/86 - 03/17/86: Water-quality sampling. Pumped approximately 3.29×10^4 L of fluid from the borehole prior to sampling. The Culebra interval was not isolated with a packer. The average pumping rate was 0.03 L/s. The specific gravity of the pumped fluid decreased from 1.067 at 21.3°C (ρ = 1.065 g/cm^3) on 03/05/86 to 1.065 at 21.2°C (ρ = 1.063 g/cm^3) on 03/17/86.

09/29/86: Pressure-density survey; calculated ρ = 1.065 g/cm^3.

11/20/86: Slug-injection test. The slug consisted of approximately 150 L of freshwater added to the annulus. The bottom of the packer seal was set 6.5 m above the top of the perforated Culebra interval. The test was initiated by deflating the packer.

11/24/86: Slug-injection test. The slug consisted of approximately 170 L of freshwater added to the annulus. The bottom of the packer seal was set 6.5 m above the top of the perforated Culebra interval. The test was initiated by deflating the packer.

12/01/86: Bailed approximately 320 L of fluid from the borehole. (No water-quality data.)

12/03/86 - 12/18/86: Water-quality sampling. The Culebra interval was isolated for sampling with a pump and packer assembly. The pump intake was located 0.4 m above the top of the perforated Culebra interval. Approximately 3600 L of fluid were pumped from the borehole prior to sampling. The average pumping rate during the sampling period was 0.02 L/s. The specific gravity of the pumped fluid decreased from 1.066 at 20.7°C (ρ = 1.064 g/cm^3) on 12/05/86 to 1.063 at 20.9°C (ρ = 1.061 g/cm^3) on 12/18/86.

02/25/87: Pressure-density survey; calculated ρ = 1.065 g/cm^3.

08/12/87: Pressure-density survey; calculated ρ = 1.046 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

10/09/87 - 10/21/87: Water-quality sampling. A pump and packer assembly was used to isolate the Culebra interval for sampling. The pump intake was located 2.9 m above the top of the perforated Culebra interval. Approximately 5870 L of fluid were pumped from the borehole prior to sampling. The average pumping rate was approximately 0.02 L/s. The specific gravity of the pumped fluid varied from 1.062 at 21.0°C (ρ = 1.060 g/cm^3) on 10/12/87 to 1.062 at 17.6°C (ρ = 1.061 g/cm^3) on 10/21/87.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in P-17 is estimated to be 1.065 g/cm^3 from the time the Culebra interval was perforated (04/05/77) to 06/16/89. This value was taken from the results of the pressure-density surveys conducted on 09/29/86 and 02/25/87. In both cases, the calculated density was 1.065 g/cm^3. Because the Culebra interval was isolated with a packer, the water-quality sampling conducted in December 1986 and October 1987 is considered to have had a minor impact on borehole-fluid density.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.6 m. The freshwater-head uncertainty was calculated assuming an average of 64.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for P-17

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/05/77 - 06/16/89	1.065	±0.01	±0.6

P-18

P-18 was drilled as part of a 21-well exploratory-drilling program to evaluate the potash-mineral resources of the WIPP site. P-18 was drilled to a diameter of 7-7/8 inches to a depth of 347.2 m BGS, and the well was cased with 4-1/2-inch casing cemented from the surface to a depth of 346.9 m BGS. The borehole was then deepened from 347.2 to 496.8 m BGS with a 4-inch diameter bit, and cored from 496.8 m to a total depth of 609.0 m BGS. On November 6, 1976, the borehole was plugged with cement from total depth to 342.9 m BGS. The casing was perforated across the Rustler-Salado contact from 328.0 to 335.3 m BGS on January 21, 1977. The Rustler-Salado contact perforated zone was isolated using a retrievable bridge plug at 323.4 m BGS on April 4, 1977. The interval from 278.0 to 286.5 m BGS, which includes the Culebra dolomite from 277.1 to 285.9 m BGS, was perforated on April 6, 1977. On May 14, 1977, tubing was reattached to the retrievable bridge plug set between the Rustler-Salado contact and the Culebra dolomite perforated intervals to allow water-level monitoring of these two zones.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

04/04/77 - 04/07/77: Set retrievable bridge plug at 323.4 m BGS. Perforated Culebra interval. Bailed borehole dry. (No water-quality data.)

05/10/77: Bailed approximately 50 L of fluid from the borehole. The density of the bailed fluid was 1.110 g/cm^3.

05/14/77: Attached tubing to retrievable bridge plug to allow monitoring of water level in Rustler-Salado contact and Culebra.

03/83: Attempted to remove retrievable bridge plug. Packer broke up and was pushed to the bottom of the hole. Another retrievable bridge plug was set between the Culebra and Rustler-Salado contact at 304 m BGS. Bailed fluid from borehole. (No water-quality data.)

07/30/83: Conducted a slug-injection-displacement test using a displacement pipe. No fluid was added or withdrawn from the borehole.

08/23/83 - 08/25/83: Conducted piston-pulse-injection tests using an inflatable packer set at 198.1 m BGS. No fluid was added or withdrawn from the borehole.

10/17/86: Pressure-density survey; calculated ρ = 1.115 g/cm^3.

03/10/87: Pressure-density survey; calculated ρ = 1.119 g/cm^3.

04/01/87: Added approximately 15 L of fresh water to borehole.
04/09/87: Pumped approximately 132 L of fluid from borehole.
06/12/87: Reperforated the casing at the Culebra interval.
06/16/87: Installed a PIP in the borehole 274.3 m BGS. Swabbed the tubing.
07/29/87 - 08/19/87: Slug-withdrawal test. The bottom of the packer element was located 3.0 m above the top of the perforated Culebra interval. A minipacker was installed inside the tubing, 25.6 m above the top of the perforated Culebra interval. After the test, the minipacker was removed.
08/26/87: Bailed approximately 200 L of fluid from the tubing. The specific gravity of the swabbed fluid increased from 1.004 to 1.048.
11/06/87 - 05/04/88: Slug-withdrawal test. The bottom of the packer seat was located 3.0 m above the top of the perforated Culebra interval. A minipacker was installed inside the tubing, 38.6 m above the top of the perforated Culebra interval. After the test, the minipacker was removed.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in P-18 is estimated to be 1.117 g/cm^3 from the time the Culebra interval was first perforated (04/06/77) to 06/16/89. This value is an average of the densities determined from the pressure-density surveys conducted on 10/17/86 and 03/10/87.

The borehole-fluid density uncertainty is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainty was calculated assuming an average of 92.4 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for P-18

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/06/77 - 06/16/89	1.117	±0.01	±0.9

WIPP-12

WIPP-12 was drilled in late 1978 to investigate the Salado and Castile Formations (Sandia National Laboratories and D'Appolonia Consulting Engineers, 1982). The well was drilled to a 12-1/4-inch diameter through the Rustler Formation and then cased with 9-5/8-inch casing cemented to 305.3 m BGS. The well was then drilled and cored through the Salado and Castile Formations to a depth of 845.3 m BGS. In 1981 and 1982, WIPP-12 was deepened through the Castile Formation to a total depth of 1197.1 m BGS. During the deepening, a pressurized brine reservoir was encountered in the Castile Formation at a depth of 919.3 m BGS. In 1983, the brine reservoir was sealed from the upper part of the borehole by installing a borehole plug from 848.6 to 914.4 m BGS. The borehole plug consisted of a bridge plug covered with 8.2 m of sand and 57.6 m of cement (D'Appolonia, 1983). The well was capped until August 1985, when drill-stem testing of the Castile and Salado Formations was performed by Sandia National Laboratories from August to September 1985 (Beauheim, 1987). Following testing, a retrievable bridge plug was set in the casing below the Culebra dolomite interval. The Culebra was then shot perforated on October 14, 1985 from 248.4 to 256.0 m BGS and left open for testing and water-level monitoring.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/14/85: Casing perforation at the Culebra interval.

05/01/86: Step-drawdown exercise. Consisted of pumping at a rate of 0.19 to 0.38 L/s for a total of 5 hours. The pump intake was located 3.2 m above the top of the perforated interval. The specific gravity of the pumped fluid decreased from 1.212 at 24.5°C (ρ = 1.209 g/cm^3) to 1.201 at 25.0°C (ρ = 1.198 g/cm^3).

05/21/86 - 05/24/86: Set a PIP with a catcher-plug assembly in the borehole. The catcher plug was installed 0.2 m below the base of the Culebra interval. Circulated a 2-percent potassium-chloride solution in the borehole. Reset the PIP 15.6 m above the top of the perforated interval. Injected approximately 190 L of hydrochloric acid into the borehole. Released the PIP and moved it back to its original location 0.2 m below the base of the perforated interval. Injected an additional 1890 L of hydrochloric acid into the borehole. Removed the PIP and let the acid remain in the borehole for two days. Flushed the borehole with approximately 2.38 x 10^4 L of freshwater.

09/05/86: Pressure-density survey; calculated ρ = 1.000 g/cm^3.

10/13/86: Collected a 500 mL sample at the Culebra interval (250.7 m BTC) with an automatic sampler. Analysis of the sample on 10/17/86 indicated a density of 1.017 g/cm^3.

05/08/87: Pressure-density survey; calculated ρ = 0.992 g/cm^3.

08/27/87 - 08/28/87: Bailed approximately 4350 L of fluid from the borehole. The specific gravity of the bailed fluid increased from 1.000 at 22.0°C (ρ = 0.997 g/cm^3) to 1.010 at 24.0°C (ρ = 1.007 g/cm^3).

09/04/87: Pressure-density survey; calculated ρ = 1.046 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

10/07/87 - 11/03/87: Pumped approximately 1.29 x 10^4 L of fluid from the borehole. The specific gravity of the pumped fluid initially decreased from 1.080 to 1.045 at 24.0°C (ρ = 1.042 g/cm^3) and then increased to 1.100 at 24.0°C (ρ = 1.097 g/cm^3). During pumping, the pump intake was located 0.6 m above the top of the perforated interval.

12/08/87: Bailed approximately 300 L of fluid from the borehole. The specific gravity of the bailed fluid was 1.095 at 19.0°C (ρ = 1.093 g/cm^3).

12/16/87: Bailed approximately 190 L of fluid from the borehole. (No water-quality data.)

12/22/87: Slug-injection test. The bottom of the packer was located 5.8 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 65.0 m above the top of the perforated interval. The slug consisted of approximately 60 L of formation fluid added to the tubing above the minipacker. Once the slug was in place, the minipacker was deflated to initiate the test.

01/05/88: Bailed approximately 110 L of fluid from the borehole. (No water-quality data.)

01/08/88: Slug-injection test. The bottom of the packer was located 5.8 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 65.0 m above the top of the perforated interval. The slug consisted of approximately 60 L of formation fluid added to the tubing above the minipacker. Once the slug was in place, the minipacker was deflated to initiate the test.

06/09/89: Pressure-density survey; calculated ρ = 1.097 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-12 is estimated as follows. Based on the fluid density measured on 05/01/86, a value of 1.200 g/cm^3 is estimated for the time period of 10/14/85 (date Culebra was perforated) to 05/21/86 (date the borehole was acidized). For the period of 05/21/86 to 08/27/87, the densities of 1.000 and 0.992 g/cm^3 determined from the pressure-density surveys conducted on 09/05/86 and 05/08/87, respectively, were averaged to obtain an estimated value of 0.996 g/cm^3. The decrease in density from the first time period appears to be the result of acidizing and freshwater flushing of the borehole in May 1986. A density of 1.096 g/cm^3 is assumed for the time period of 08/27/87 to 06/16/89. The results of the water-quality analyses conducted on the fluid pumped from the borehole in October and November 1987 and bailed from the borehole in December 1987 and the results of the pressure-density survey conducted in June 1989 were averaged to obtain this value. The increase in density from the second to the third time period appears to be the result of pumping the well in October and November 1987. Since the Culebra interval was isolated and formation fluid was added to the tubing, not the annulus, the slug-injection tests conducted in December 1987 and January 1988 were considered to have had a minor effect on the borehole-fluid density.

The borehole-fluid density uncertainty for the first time period is large due to the lack of water-quality data during this time. It is assumed that this uncertainty is on the order of -0.05 g/cm^3 and translates to a freshwater-head uncertainty of -6.2 m. For the second time period, the uncertainty in borehole-fluid density is +0.01 g/cm^3 which is +1.2 m when expressed as freshwater-head uncertainty. For the third time period, the borehole-fluid density and freshwater-head uncertainties are -0.02 g/cm^3 and -2.5 m, respectively. The freshwater-head uncertainties were calculated assuming an average of 124.1 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for WIPP-12

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/14/85 - 05/21/86	1.200	-0.05	-6.2
05/21/86 - 08/27/87	0.996	+0.01	+1.2
08/27/87 - 06/16/89	1.096	-0.02	-2.5

WIPP-13

WIPP-13 was drilled to a 7-7/8-inch open-hole diameter to the upper part of the Salado Formation in 1978 and left filled with salt-based drilling mud. In 1979, the well was reamed to a 12-1/4-inch open-hole diameter, cased and cemented through the Rustler Formation with 9-5/8-inch casing, and then deepened to 1173.5 m BGS in the Castile Formation (Sandia Laboratories and U.S. Geological Survey, 1979a; Sandia National Laboratories and D'Appolonia Consulting Engineers, 1982). WIPP-13 was left filled with a brine-gel drilling fluid, capped, and left open hole through the Salado Formation until 1985, when a retrievable bridge plug was set in the casing below the Culebra dolomite interval. The Culebra was shot perforated on October 26, 1985 from 214.0 to 221.6 m BGS and left open for testing and water-level monitoring.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/26/85: Casing perforation at the Culebra interval.

04/04/86 - 04/14/86: Step-drawdown exercise which consisted of pumping 0.13 to 0.38 L/s for a total of six days. Surge and development pumping at rates ranging from 0.19 to 0.38 L/s. The specific gravity of the pumped fluid ranged from 1.195 at 22.8°C (ρ = 1.192 g/cm^3) after 18 minutes of pumping to 1.048 at 24.8°C (ρ = 1.045 g/cm^3) at the end of the well development pumping. For well development, the Culebra interval was not isolated with a packer. The pump intake was set 0.7 m below the top of the perforated interval.

06/12/86 - 06/13/86: Exchanged the borehole fluid for a 2-percent potassium-chloride solution (S.G. = 1.04). Set a PIP with the bottom of the seal 11.6 m above the top of the perforated interval. Acidized the Culebra interval with approximately 8600 L of 20-percent hydrochloric acid (S.G. = 1.07). Swabbed approximately 7380 L of fluid from the borehole. Removed the packer and tubing.

08/04/86 - 08/09/86: Installed a packer with the bottom located 9.8 m above the top of the perforated interval. With the packer deflated, conducted a 2-hour pumping exercise at a rate of 1.89 L/s. Inflated the packer and conducted a second 2-hour pumping exercise at a rate of 1.89 L/s. Conducted a 50-hour pumping test at a rate of 2.02 L/s from 08/07/86 to 08/09/86. The specific gravity of the fluid pumped during the 50-hour pumping test ranged from 1.049 at 24.7°C (ρ = 1.046 g/cm^3) after one hour of pumping to 1.045 at 24.8°C (ρ = 1.042 g/cm^3) at the end of pumping. For all three pumping periods, the pump intake was located 9.0 m above the top of the perforated interval.

08/15/86: Pumped one hour at a rate of 1.58 L/s to clean out debris in the well. After three minutes of pumping, a specific gravity of 1.190 at 24.8°C (ρ = 1.187 g/cm^3) was measured; 55 minutes later, a specific gravity of 1.047 at 24.8°C (ρ = 1.044 g/cm^3) was measured. During pumping, the pump intake was located 51.5 m below the base of the perforated interval and the bottom of the packer element was located 9.8 m above the top of the perforated interval.

09/04/86: Pressure-density survey; calculated ρ = 1.026 g/cm^3.

01/12/87 - 02/17/87: WIPP-13 multipad pumping test conducted at an average rate of 1.89 L/s. The bottom of the packer element and the pump intake were located 9.8 and 5.2 m, respectively, above the top of the perforated interval. Pumped about 5.93 x 10^6 L of fluid from the borehole. The specific gravity of the pumped fluid decreased from 1.048 at 23.5°C (ρ = 1.045 g/cm^3) after 20 minutes of pumping to 1.047 at 25.0°C (ρ = 1.044 g/cm^3) at the end of pumping.

05/06/87: Pressure-density survey; calculated ρ = 1.032 g/cm^3.

09/10/87: Pressure-density survey; calculated ρ = 1.017 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-13 is estimated as follows. Based on the fluid density measured on 04/04/86, a value of 1.192 g/cm^3 is estimated for the time period of 10/26/85, the date the Culebra was perforated, to 04/04/86, the beginning of developmental pumping. For the period of 04/04/86 to 06/12/86 (date of acidization), the borehole was assumed to contain the fluid pumped during the final stages of well development which had a density of

1.045 g/cm^3. Since the Culebra interval was isolated with a packer during most of the pumping activities which occurred in WIPP-13 after 06/12/86, it was estimated that these pumping periods had a minor effect on the borehole-fluid density during that time. For the time period of 06/12/86 to 06/16/89, an average of the densities from the pressure-density surveys conducted on 09/04/86 and 05/06/87 was assumed to be representative of the borehole-fluid density. This average is 1.029 g/cm^3.

The borehole-fluid density uncertainty for the first time period is large due to the lack of water-quality data from the time the Culebra was perforated until 04/04/86. It is assumed that this uncertainty is on the order of -0.05 g/cm^3 and translates to a freshwater-head uncertainty of -5.5 m. For the second time period, the borehole-fluid density and freshwater-head uncertainties are ±0.02 g/cm^3 and ±2.2 m, respectively. The borehole-fluid density uncertainty for the third time period is ±0.01 g/cm^3 which is ±1.1 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainties were calculated assuming an average of 109.1 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-13

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/26/85 - 04/04/86	1.192	-0.05	-5.5
04/04/86 - 06/12/86	1.045	±0.02	±2.2
06/12/86 - 06/16/89	1.029	±0.01	±1.1

WIPP-18

WIPP-18 was drilled in 1978 and left open, uncased, and filled with brine mud until October 1985 (Sandia Laboratories and U.S. Geological Survey, 1980a). The well was recompleted as a Culebra dolomite observation well in October 1985. The recompletion activities consisted of cleaning and reaming the well to a diameter of 7-7/8 inches using 10-lb/gal salt brine as the drilling fluid; fully cementing 5-1/2-inch casing to the top of the Salado Formation leaving a cement plug in the bottom of the casing; filling the casing with 10-lb/gal sodium-chloride brine (ρ = 1.2 g/cm^3); and shot perforating the Culebra dolomite interval from 239.0 to 245.7 m BGS on October 11, 1985.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/11/85: Casing perforation at the Culebra interval.

05/10/86 - 05/14/86: Well development. The pump intake was located 1.8 m above the top of the perforated interval. A packer was not utilized. Conducted single-stage and multiple-stage surging at pumping rates of 0.09 to 0.32 L/s. The specific gravity of the pumped fluid increased from 1.078 at 23.9°C (ρ = 1.075 g/cm^3) after 15 minutes of pumping to 1.150 at 24.8°C (ρ = 1.147 g/cm^3) during the last pumping period.

05/17/86: Conducted two slug-withdrawal tests. The pump intake was located 0.4 m below the top of the perforated interval and the bottom of the packer was located 3.1 m above the top of the perforated interval.

05/20/86 - 05/21/86: Conducted two slug-injection tests. Approximately 1000 L of freshwater were added to the annulus above the packer in both tests. The packer, located 3.1 m above the top of perforated interval, was deflated to initiate the slug tests.

08/06/86: Pressure-density survey; calculated ρ = 1.030 g/cm^3.

08/27/86: Bailed approximately 1890 L of fluid from the borehole. (No water-quality data.)

10/13/86: Collected a 500 mL sample at the Culebra interval (242.3 m BTC) with an automatic sampler. Analysis of this sample on 10/17/86 indicated a density of 1.109 g/cm^3.

05/12/87: Pressure-density survey; calculated ρ = 1.100 g/cm^3.

09/11/87: Pressure-density survey; calculated ρ = 1.100 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-18 is estimated as follows. Based on the fluid density measured on 05/10/86, a value of 1.075 g/cm^3 is estimated for the time period of 10/11/85 (date Culebra was perforated) to 05/10/86. For the time period of 05/10/86 to 08/27/86 (date borehole was bailed), the density from the pressure-density survey conducted on 08/06/86 (1.030 g/cm^3) is assumed. The density estimate for this time period is lower than the estimate for the first time period. The decrease appears to be due to the addition of freshwater to the borehole during the slug-injection tests conducted in May 1986. The density of 1.100 g/cm^3 determined by the pressure-density survey conducted on 05/12/87 is assumed for the time period of 08/27/86 to 06/16/89. The increase in density from the second time period to the third time period appears to have been the result of the bailing on 08/27/86.

The borehole-fluid density uncertainty for the first time period is large due to the lack of water-quality data from the time the Culebra was perforated until 05/10/86. It is assumed that this uncertainty is on the order of +0.05 g/cm^3 and translates to a freshwater-head uncertainty of +5.5 m. The borehole-fluid density uncertainty for the latter two time periods is ±0.01 g/cm^3 which indicates a freshwater-head uncertainty of ±1.1 m. The freshwater-head uncertainties were calculated assuming an average of 110.9 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for WIPP-18

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/11/85 - 05/10/86	1.075	+0.05	+5.5
05/10/86 - 08/27/86	1.030	±0.01	±1.1
08/27/86 - 06/16/89	1.100	±0.01	±1.1

WIPP-19

WIPP-19 was drilled in 1978 and left open, uncased, and filled with brine mud (Sandia Laboratories and U.S. Geological Survey, 1980b). The well was recompleted as a Culebra dolomite observation well in September and October 1985. The recompletion activities consisted of cleaning and reaming the well to a diameter of 7-7/8 inches using 10-lb/gal salt brine (ρ = 1.2 g/cm^3) as the drilling fluid; fully cementing 5-1/2-inch casing to the top of the Salado Formation leaving a cement plug in the bottom of the casing; filling the casing with 10-lb/gal sodium-chloride brine (ρ = 1.2 g/cm^3); and shot perforating the Culebra dolomite interval from 229.8 to 237.7 m BGS on October 9, 1985.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

10/09/85: Casing perforation at the Culebra interval.

05/28/86 - 05/29/86: Well development. The pump intake was located 2.1 m above the top of the perforated interval. A packer was not utilized. Conducted step-rate and single-stage surging at pumping rates of 0.09 to 0.19 L/s. The specific gravity of the pumped fluid was measured to be 1.180 at 23.5°C (ρ = 1.177 g/cm^3).

05/31/86: Slug-injection test. The bottom of the packer element was located 5.7 m above the top of the perforated interval. Added approximately 340 L of freshwater to the annulus, then deflated the packer to initiate the test.

06/04/86: Slug-injection test. The bottom of the packer element was located 5.7 m above the top of the perforated interval. Added approximately 300 L of freshwater to the annulus, then deflated the packer to initiate the test.

08/05/86: Pressure-density survey; calculated ρ = 1.098 g/cm^3.

08/22/86: Bailed approximately 1890 L of fluid from the borehole. (No water-quality data.)

10/13/86: Collected a 500 mL sample at the Culebra interval (233.8 m BTC) with an automatic sampler. Analysis of the sample on 10/17/86 indicated a density of 1.141 g/cm^3.

05/14/87: Pressure-density survey; calculated ρ = 1.126 g/cm^3.

06/19/87 - 07/14/87: Water-quality sampling. A pump and packer assembly, with the pump intake located 3.4 m above the top of the perforated interval, was installed for sampling. Approximately 4540 L of fluid were pumped prior to sampling. The average flow rate was 0.008 L/s. The specific gravity of the pumped fluid was 1.087 at 23.1°C (ρ = 1.084 g/cm^3) on 07/07/87 and 1.072 at 22.1°C (ρ = 1.070 g/cm^3) on 07/14/87.

09/25/87: Pressure-density survey; calculated ρ = 1.101 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.]

01/26/88 - 02/12/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.0 m above the top of the Culebra interval. Prior to sampling, approximately 5870 L of fluid were pumped from the borehole at a flow rate of 0.017 L/s. The specific gravity of the pumped fluid was 1.062 at 20.6°C (ρ = 1.060 g/cm^3) on 02/08/88 and 1.061 at 21.1°C (ρ = 1.059 g/cm^3) on 02/12/88.

08/17/88 - 08/29/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located about 1.3 m above the top of the Culebra interval. Prior to sampling, approximately 1.17 x 10^4 L of fluid were pumped from the borehole at a flow rate of about 0.02 L/s. The specific gravity of the pumped fluid was 1.062 at 22.2°C (ρ = 1.060 g/cm^3) on 08/24/88 and 1.061 at 22.1°C (ρ = 1.059 g/cm^3) on 08/29/88.

The borehole-fluid density in WIPP-19 is estimated as follows. Based on the fluid density measured on 05/28/86, a value of 1.177 g/cm^3 is estimated for the time period of 10/09/85 (date Culebra was perforated) to 05/28/86. For the period of 06/04/86 to

08/22/86, the density from the pressure-density survey conducted on 08/05/86 (1.098 g/cm^3) is assumed. The decrease in density from the first time period appears to be due to the addition of freshwater to the borehole during the slug testing in May and June 1986. The brief period between 05/28/86 and 06/04/86 affected by the slug tests is also assigned a fluid density of 1.098 g/cm^3. The density of 1.126 g/cm^3 determined by the pressure-density survey conducted on 05/14/87 is assumed for the time period of 08/22/86 to 06/19/87. The increase in this fluid density compared to the second time period appears to have been the result of the bailing on 08/22/86. For the time period of 06/19/87 to 06/16/89, a borehole-fluid density of 1.101 g/cm^3 is assumed. This density is based on the results of the pressure-density survey conducted in September 1987.

The borehole-fluid density uncertainty for the first time period is +0.02 to -0.05 g/cm^3. This uncertainty translates to a freshwater-head uncertainty of +2.0 to -5.0 m. The large uncertainty during the first time period is due to the lack of water-quality data from the time the Culebra was perforated until 05/28/86. For the second and third time periods, the uncertainty in borehole-fluid density is ±0.01 g/cm^3 which indicates a freshwater-head uncertainty of ±1.0 m. The borehole-fluid and freshwater-head uncertainties for the fourth time period are ±0.03 g/cm^3 and ±3.0 m, respectively. The freshwater-head uncertainties were calculated assuming an average of 100.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-19

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/09/85 - 05/28/86	1.177	+0.02/-0.05	+2.0/-5.0
05/28/86 - 08/22/86	1.098	±0.01	±1.0
08/22/86 - 06/19/87	1.126	±0.01	±1.0
06/19/87 - 06/16/89	1.101	±0.03	±3.0

WIPP-21

WIPP-21 was drilled in 1978 and left open, uncased, and filled with brine mud (Sandia Laboratories and U.S. Geological Survey, 1980c). The well was recompleted as a Culebra dolomite observation well in September and October 1985. The recompletion activities consisted of cleaning and reaming the well to a diameter of 7-7/8 inches using 10-lb/gal salt brine (ρ = 1.2 g/cm^3) as the drilling fluid; fully cementing 5-1/2-inch casing to the top of the Salado Formation leaving a cement plug in the bottom of the casing; filling the casing with freshwater; and shot perforating the Culebra dolomite interval from 221.6 to 228.9 m BGS on October 6, 1985.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

10/06/85: Casing perforation at the Culebra interval.

06/28/86 - 07/01/86: Well development. The pump intake was located 3.4 m above the top of the perforated interval. A packer was not utilized. Conducted step-rate and single-stage surging at pumping rates of 0.11 to 0.21 L/s. On 06/28/86, the specific gravity of the pumped fluid decreased from 1.010 at 24.0°C (ρ = 1.007 g/cm^3) at 6 minutes into pumping to 1.000 at 24.5°C (ρ = 0.997 g/cm^3) at the end of 1.2 hours of pumping.

07/11/86: Slug-injection test. Added approximately 570 L of fluid (source unknown) to the annulus. The packer, located 4.8 m above the top of the perforated interval, was deflated to initiate the test.

07/30/86: Pressure-density survey; calculated ρ = 1.014 g/cm^3.

08/24/86: Bailed approximately 1140 L of fluid from the borehole. (No water-quality data.)

08/27/86: Bailed approximately 1890 L of fluid from the borehole. (No water-quality data.)

10/13/87: Pressure-density survey; calculated ρ = 1.048 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.] A water sample taken at the Culebra depth had a specific gravity of 1.064.

06/12/89: Pressure-density survey; calculated ρ = 1.071 g/cm^3.

The borehole-fluid density for WIPP-21 is estimated as follows. Based on the fluid density measured on 06/28/86, a value of 1.007 g/cm^3 is estimated for the time period of 10/06/85 (date Culebra was perforated) to 06/28/86. For the period of 06/28/86 to 08/24/86 (date borehole was first bailed), the density from the pressure-density survey conducted on 07/30/86 (1.014 g/cm^3) is assumed. The increase in this fluid density compared to the first time period estimate appears to be the result of the slug testing conducted in July 1986. After bailing on 08/24/86 and 08/27/86, the borehole probably filled with fluid from the Culebra. Based on the results of the pressure-density conducted in June 1989, a borehole-fluid density of 1.071 g/cm^3 is estimated for the time period of 08/24/86 to 06/16/89.

The borehole-fluid density uncertainty for the first time period is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +1.9 to -0.9 m. The borehole-fluid density and freshwater-head uncertainties are ±0.01 g/cm^3 and ±0.9 m, respectively, for the second and third time periods. The freshwater-head uncertainties were calculated assuming an average of 94.8 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-21

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/06/85 - 06/28/86	1.007	+0.02/-0.01	+1.9/-0.9
06/28/86 - 08/24/86	1.014	±0.01	±0.9
08/24/86 - 06/16/89	1.071	±0.01	±0.9

WIPP-22

WIPP-22 was drilled in 1978 and left open, uncased, and filled with brine mud (Sandia Laboratories and U.S. Geological Survey, 1980d). The well was recompleted as a Culebra dolomite observation well in September and October 1985. The recompletion activities consisted of cleaning and reaming the well to a diameter of 7-7/8 inches using 10-lb/gal sodium-chloride brine as the drilling fluid; fully cementing 5-1/2-inch casing to the top of the Salado Formation leaving a cement plug in the bottom of the casing; filling the casing with 10-lb/gal sodium-chloride brine (ρ = 1.2 g/cm^3); and shot perforating the Culebra dolomite interval from 228.0 to 234.7 m BGS on October 8, 1985.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

10/08/85: Casing perforation at the Culebra interval.

06/12/86 - 06/17/86: Well development. The pump intake was located 1.8 m above the top of the perforated interval. A packer was not utilized. Conducted single-stage and multiple-stage surging at pumping rates of 0.09 to 0.13 L/s. The specific gravity of the pumped fluid decreased from 1.152 at 24.0°C (ρ = 1.149 g/cm^3) on 06/12/86 to 1.142 at 24.0°C (ρ = 1.139 g/cm^3) on 06/17/86.

06/19/86: Slug-injection test. Added approximately 240 L of freshwater to the annulus. The bottom of the packer was located 1.7 m above the top of the perforated interval. The packer was deflated to initiate the test.

08/04/86: Pressure-density survey; calculated ρ = 1.117 g/cm^3.

08/25/86 - 08/26/86: Bailed approximately 1890 L of fluid from the borehole. This bailing lowered the fluid level in the borehole to well below the perforated interval. (No water-quality data.)

10/14/86: Collected a 500 mL sample at the Culebra interval (231.3 m BTC) with an automatic sampler. Analysis of the sample on 10/17/86 indicated a density of 1.114 g/cm^3.

09/29/87: Pressure-density survey; calculated ρ = 1.087 g/cm^3. [NOTE: These data were reported as uncertain because of equipment problems.] A water sample taken at the Culebra depth had a specific gravity of 1.098.

06/08/89: Pressure-density survey; calculated ρ = 1.087 g/cm^3.

The borehole-fluid density for WIPP-22 is estimated as follows. Based on the fluid density measured on 06/12/86, a value of 1.149 g/cm^3 is estimated for the time period of 10/08/85 (date Culebra was perforated) to 06/12/86. The fluid pumped during well development from 06/12/86 to 06/17/86 is thought to be more saline than the formation fluid because of the brine used in completing and recompleting the borehole. For the period of 06/12/86 to 08/25/86 (date borehole was bailed), the density of 1.117 g/cm^3 determined by the pressure-density survey conducted on 08/04/86 is assumed. The decrease in density from the first time period to the second time period appears to be the result of the addition of freshwater to the borehole during the slug test conducted in June 1986. Based on the results of the pressure-density survey conducted in June 1989, a fluid density of 1.087 g/cm^3 is chosen for the time period of 08/25/86 to 06/16/89.

The borehole-fluid density uncertainty for the first time period is large due to the lack of water-quality data from the time the Culebra was perforated until 06/12/86. It is assumed that this uncertainty is on the order of ±0.05 g/cm^3 and translates to a freshwater-head uncertainty of ±4.7 m. The uncertainty in borehole-fluid density for the second and third time periods is ±0.01 g/cm^3 which indicates a freshwater-head uncertainty of ±0.9 m. The freshwater-head uncertainties were calculated assuming an average of 94.5 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-22

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/08/85 - 06/12/86	1.149	±0.05	±4.7
06/12/86 - 08/25/86	1.117	±0.01	±0.9
08/25/86 - 06/16/89	1.087	±0.01	±0.9

WIPP-25

WIPP-25 was drilled in August and September 1978 as part of a dissolution investigation of the near-surface rocks in the Nash Draw area west of the WIPP site (Sandia Laboratories and U.S. Geological Survey, 1979b). After coring, the hole was reamed to a diameter of 7-7/8 inches to the upper part of the Salado Formation and cased with 5-1/2-inch casing from 197.5 m BGS to surface and then left filled with freshwater. In March 1980, the Rustler-Salado contact from 176.5 to 185.3 m BGS was perforated. Bailing, slug, and pumping tests were conducted on the Rustler-Salado contact in March and July 1980. In July and August 1980, a bridge plug was set below the Culebra dolomite and the Culebra was perforated from 135.6 to 144.8 m BGS. After perforation, the Culebra dolomite interval was tested for about one month. In August and September 1980, a bridge plug was set below the Magenta dolomite and the Magenta was perforated from 91.4 to 100.6 m BGS. Two bailing tests and one pumping test were conducted on the Magenta dolomite in September 1980. The upper retrievable bridge plug was removed on August 4, 1983 and replaced with a production-injection packer (PIP) to separate the Culebra dolomite from the Magenta dolomite and enable long-term water-level monitoring of both intervals.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/06/80: Casing perforation at the Culebra interval. Bailed about 1060 L of fluid from the Culebra interval.

08/14/80: Bailed 2990 L of fluid from the borehole. The density of the bailed fluid was 1.014 g/cm^3.

08/19/80 - 08/20/80: Well pumped at an average flow rate of 2.1 L/s. The specific gravity of the pumped fluid was 1.010 at 23.0°C (ρ = 1.008 g/cm^3) on 08/20/80.

08/26/80: Set a bridge plug between the Magenta and Culebra intervals.

08/04/83 - 08/05/83: Replaced the retrievable bridge plug separating the Culebra and Magenta intervals with a PIP.

01/29/86 - 02/13/86: Water-quality sampling. The bottom of the packer and the pump intake were located 5.8 and 3.1 m, respectively, above the perforated Culebra interval. Approximately 3.55 x 10^5 L of fluid were pumped prior to sampling. The average pumping rate was 0.45 L/s. The specific gravity of the pumped fluid was 1.015 at 21.2°C (ρ = 1.013 g/cm^3) on 02/05/86 and 1.010 at 21.9°C (ρ = 1.008 g/cm^3) on 02/13/86.

11/05/86: Pressure-density survey; calculated ρ = 0.980 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 56.8 m or 62.9 percent of the total fluid column.

04/09/87 - 04/15/87: Water-quality sampling. A pump and packer assembly was installed to isolate the Culebra interval for sampling. The pump intake was located 3.9 m above the top of the perforated Culebra interval. Approximately 3.60 x 10^4 L of fluid were pumped prior to sampling. The average pumping rate was 0.34 L/s. The specific gravity of the pumped fluid was 1.009 at 22.6°C (ρ = 1.007 g/cm^3) on 04/10/87 and 1.011 at 21.6°C (ρ = 1.009 g/cm^3) on 04/15/87.

05/05/87: Pressure-density survey; calculated ρ = 1.000 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 56.0 m or 62.6 percent of the total fluid column.

10/14/87: Pressure-density survey; calculated ρ = 0.998 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 56.1 m or 62.6 percent of the total fluid column. [NOTE: These data were reported as uncertain because of equipment problems.]

03/17/88 - 03/28/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.2 m above the top of the Culebra interval. Prior to sampling, approximately 9.46 x 10^4 L of fluid were pumped from the borehole at a flow rate of 0.26 L/s. The specific gravity of the pumped fluid was 1.010 at 22.1°C (ρ = 1.008 g/cm^3) on 03/22/88 and 1.010 at 22.0°C (ρ = 1.008 g/cm^3) on 03/28/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-25 is estimated to be 0.990 g/cm^3 for the time period of 08/04/83 (date of PIP installation) to 06/16/89. The results of the pressure-density surveys conducted on

11/05/86 and 05/05/87 were averaged to obtain this value. Because the Culebra interval was isolated during the two periods of water-quality sampling, this sampling was considered to have had a minor impact on the borehole-fluid density.

The borehole-fluid density uncertainty is +0.01 g/cm^3 which is +0.9 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 89.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-25

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/04/83 - 06/16/89	0.990	+0.01	+0.9

WIPP-26

WIPP-26, drilled during August and September 1978, was one of a series of wells drilled to investigate the dissolution of near-surface rocks in the Nash Draw area west of the WIPP site (Sandia Laboratories and U.S. Geological Survey, 1979c). The well was cored and reamed to a diameter of 8-3/4 inches from the surface to a depth of 81.7 m BGS and to a diameter of 7-7/8 inches from a depth of 81.7 to 153.3 m BGS. The borehole was later cased with 5-1/2-inch casing to a depth of 153.0 m BGS, fully cemented, and left filled with freshwater. The Rustler-Salado contact was perforated from 69.5 to 100.3 m BGS in March 1980 and tested in March and July 1980. A retrievable bridge plug was set below the Culebra dolomite in August 1980. The Culebra was then perforated from 56.4 to 64.0 m BGS and tested for about one month. In September 1980, a retrievable bridge plug was set below the Magenta dolomite and the Magenta was perforated from 15.2 to 30.5 m BGS. The Magenta interval was dry. This retrievable bridge plug was removed on August 3, 1983.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/07/80: Casing perforation at the Culebra interval. Bailed about 1510 L of fluid from the Culebra interval.

08/18/80: Bailed about 3820 L of fluid from the borehole. The density of the bailed fluid was 1.013 g/cm^3.

08/23/80 - 08/24/80: Well pumped at an average flow rate of 2.1 L/s. The specific gravity of the pumped fluid was 1.005 at 22.0°C (ρ = 1.003 g/cm^3) on 08/24/80.

08/26/80: Set a bridge plug between the Magenta and Culebra intervals.

08/03/83: Removed the retrievable bridge plug separating the Magenta and Culebra intervals.

11/15/85 - 11/25/85: Water-quality sampling. A pump and packer assembly was installed to isolate the Culebra interval for sampling. The pump intake was located 0.7 m above the top of the perforated Culebra interval. Approximately 2.06 x 10^5 L of fluid were pumped prior to sampling. The average pumping rate was 0.06 L/s. The specific gravity of the pumped fluid was 1.012 at 20.1°C (ρ = 1.010 g/cm^3) on 11/20/85 and 1.012 at 21.8°C (ρ = 1.010 g/cm^3) on 11/25/85.

10/07/86: Pressure-density survey; calculated ρ = 1.002 g/cm^3. The well was blocked off 56.2 m BGS; therefore, only 12.9 m (68.5 percent) of the total fluid column could be accessed.

03/24/87 - 04/01/87: Water-quality sampling. A pump and packer assembly was installed to isolate the Culebra interval for sampling. The pump intake was located 2.3 m above the top of the perforated Culebra interval. Approximately 3400 L of fluid were pumped prior to sampling. The average pumping rate was 0.05 L/s. The specific gravity of the pumped fluid remained constant at 1.010 at 20.0°C (ρ = 1.008 g/cm^3) from 03/25/87 to 04/01/87.

04/05/88 - 04/14/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 4.1 m above the top of the perforated Culebra interval. Prior to sampling, approximately 2.04 x 10^4 L of fluid were pumped from the borehole at an average flow rate of 0.06 L/s. The specific gravity of the pumped fluid was 1.010 at 18.6°C (ρ = 1.008 g/cm^3) on 04/10/88 and 1.009 at 21.3°C (ρ = 1.007 g/cm^3) on 04/14/88.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-26 is estimated to be 1.002 g/cm^3 for the time period of 08/03/83 (date the retrievable bridge plug above the Culebra interval was removed) to 06/16/89. This density was taken from the results of the pressure-density survey conducted on 10/07/86. Because the Culebra interval was isolated during the three periods of water-quality sampling, this sampling was considered to have had a minor impact on the borehole-fluid density.

The borehole-fluid density uncertainty is +0.01 g/cm^3 which is +0.2 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 18.3 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for WIPP-26

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/03/83 - 06/16/89	1.002	+0.01	+0.2

WIPP-27

WIPP-27 was drilled in the Nash Draw area west of the WIPP site to study the dissolution of near-surface rocks (Sandia Laboratories and U.S. Geological Survey, 1979d). The well was drilled to a total depth of 180.4 m BGS. The upper 61.0 m of the borehole was cored and reamed to a diameter of 8-3/4 inches. From a depth of 61.0 to 180.4 m BGS, the well was cored and reamed to a diameter of 7-7/8 inches. After logging the hole, 179.2 m of 5-1/2-inch casing was set and fully cemented to the surface, and the borehole was left filled with freshwater. In March 1980, the Rustler-Salado contact was perforated from 146.3 to 155.4 m BGS and from 129.8 to 140.2 m BGS. After testing of the Rustler-Salado contact was completed in August 1980, a retrievable bridge plug was set below the Culebra dolomite and the Culebra was perforated from 88.4 to 97.5 m BGS. The Culebra dolomite was then tested for approximately one month. A retrievable bridge plug was set below the Magenta dolomite in September 1980. The Magenta was then perforated from 53.3 to 59.4 m BGS and tested. This retrievable bridge plug was removed on July 20, 1983 and replaced with a production-injection packer (PIP) to enable long-term water-level monitoring of both the Culebra and Magenta intervals.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/12/80: Casing perforation at the Culebra interval. Bailed about 1700 L of fluid from the Culebra interval.

08/22/80: Bailed about 1780 L of fluid from the Culebra interval. The density of the bailed fluid was 1.094 g/cm^3.

08/23/80: Conducted six slug tests on the Culebra dolomite.

09/03/80 - 09/05/80: Well pumped at an average flow rate of 1.6 L/s. The specific gravity of the pumped fluid was 1.090 at 22.0°C (ρ = 1.088 g/cm^3) on 09/05/80.

09/18/80: Set a bridge plug between the Magenta and Culebra intervals.

07/20/83: Removed the retrievable bridge plug separating the Magenta and Culebra intervals and replaced it with a PIP.

11/10/86: Pressure-density survey; calculated ρ = 1.022 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 43.5 m or 72.2 percent of the total fluid column.

04/27/87: Pressure-density survey; calculated ρ = 1.036 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 43.6 m or 72.2 percent of the total fluid column.

10/21/87: Pressure-density survey; calculated ρ = 1.026 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 43.7 m or 72.2 percent of the total fluid column. [NOTE: These data were reported as uncertain because of equipment problems.]

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-27 is estimated to be 1.029 g/cm^3 for the time period of 07/20/83 (date the PIP was installed) to 06/16/89. The results of the pressure-density surveys conducted on 11/10/86 and 04/27/87 were averaged to obtain this value.

The borehole-fluid density uncertainty is ±0.01 g/cm^3, which is ±0.6 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 60.4 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-27

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
07/20/83 - 06/16/89	1.029	±0.01	±0.6

WIPP-28

WIPP-28 was drilled and completed in August 1978 to study the dissolution of near-surface rocks in the Nash Draw area west of the WIPP site (Sandia Laboratories and U.S. Geological Survey, 1979e). The well was initially cored and reamed to a diameter of 8-3/4 inches to a depth of 68.0 m BGS, followed by coring and reaming to a diameter of 7-7/8 inches from a depth of 68.0 to 244.1 m BGS. The borehole was then cased with 243.8 m of 5-1/2-inch casing, cemented to the surface, and then left filled with freshwater. In March 1980, the Rustler-Salado contact from 167.3 to 179.5 m BGS was perforated. Tests were conducted on the Rustler-Salado contact in March and July 1980. In August 1980, a retrievable bridge plug was set below the Culebra dolomite and the Culebra was perforated from 128.0 to 135.9 m BGS. After perforation, the Culebra was tested for about one month. A second retrievable bridge plug was set below the Magenta dolomite in September 1980 and the Magenta was perforated from 86.9 to 94.5 m BGS. At the time it was perforated, the Magenta interval was dry. Both retrievable bridge plugs were removed in July 1983. A production-injection packer (PIP) was set between the Culebra dolomite and the Rustler-Salado contact on July 20, 1983 to enable long-term monitoring of both intervals.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/11/80: Casing perforation at the Culebra interval. Bailed about 1290 L of fluid from the borehole.

08/21/80 - 08/22/80: Bailed about 530 L of fluid from the borehole. The density of the bailed fluid was 1.044 g/cm^3. Set a feed-through packer 38.8 m above the Culebra interval. Conducted a shut-in and a slug test on the Culebra. Removed the packer.

08/25/80: Conducted four slug tests on the Culebra interval.

09/09/80 - 09/12/80: Well pumped at an average flow rate of 1.1 L/s. The specific gravity of the pumped fluid was 1.030 at 22.5°C (ρ = 1.028 g/cm^3) on 09/11/80.

09/16/80: Set a bridge plug between the Magenta and Culebra intervals.

07/20/83: Removed the retrievable bridge plugs and installed a PIP between the Culebra and the Rustler-Salado contact.

10/22/87: Pressure-density survey; calculated ρ = 1.002 g/cm^3. Only 20.5 m (48.0 percent) of the total fluid column was surveyed. [NOTE: These data were reported as uncertain because of equipment problems and this survey was conducted in the tubing connected to the Rustler-Salado contact.]

For the purpose of equivalent freshwater-head calculations, the borehole-fluid density in WIPP-28 is estimated to be between freshwater and the formation-fluid density of 1.032 g/cm^3 (see Table E.1). A value of 1.016 g/cm^3 is selected for calculation purposes.

The borehole-fluid density uncertainty is ±0.02 g/cm^3 which is ±0.8 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 42.4 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-28

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
07/20/83 - 06/16/89	1.016	±0.02	±0.8

WIPP-29

WIPP-29 was drilled during October 1978 as part of a program to study the dissolution of near-surface rocks in the Nash Draw area west of the WIPP site (Sandia Laboratories and U.S. Geological Survey, 1979c). The well was initially cored and reamed to a diameter of 8-3/4 inches from the surface to a depth of 41.1 m BGS, then drilled to a diameter of 7-7/8 inches from depths of 41.1 to 114.9 m BGS. The hole was cased with 5-1/2-inch casing to 114.6 m BGS, cemented to the surface, and left filled with freshwater. In March 1980, the Rustler-Salado contact from 65.8 to 76.2 m BGS was perforated. Bailing and slug tests were conducted on the Rustler-Salado contact in March and July 1980. In August 1980, a retrievable bridge plug was set below the Culebra dolomite. The Culebra was then perforated from 3.0 to 13.7 m BGS on August 8, 1980 and tested for about one month. The retrievable bridge plug deflated between August 1980 and July 1983. After pushing the deflated packer to the bottom of the well, a production-injection packer (PIP) was set between the Culebra dolomite and the Rustler-Salado contact on July 18, 1983.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/08/80: Casing perforation at the Culebra interval. Bailing test. Removed approximately 1290 L of fluid from the borehole. (No water-quality data.)

08/20/80: Bailing test. Removed approximately 4350 L of fluid from the borehole. The density of the bailed fluid was 1.178 g/cm^3.

08/26/80 - 08/28/80: Pumping test on the Culebra dolomite interval at an average pumping rate of 2.33 L/s. A packer was not used. The specific gravity of the pumped fluid was 1.160 at 20.0°C (ρ = 1.158 g/cm^3) throughout the pumping period.

07/18/83: Pushed the deflated retrievable bridge plug to the bottom of the borehole and installed a PIP between the Culebra interval and the Rustler-Salado contact.

11/26/85 - 12/15/85: Water-quality sampling. A packer and pump assembly was installed to isolate the Culebra interval for sampling. The pump intake was located 3.1 m above the base of the perforated Culebra interval. Approximately 4.80 x 10^5 L of fluid were pumped prior to sampling. The average pumping rate was 2.08 L/s. The specific gravity of the pumped fluid increased from 1.209 at 20.9°C (ρ = 1.207 g/cm^3) on 12/06/85 to 1.216 at 20.8°C (ρ = 1.214 g/cm^3) on 12/15/85.

03/02/87 - 03/11/87: Water-quality sampling. The Culebra interval was not isolated with a packer. The pump intake was located 5.6 m above the base of the perforated Culebra interval. Approximately 7.19 x 10^4 L of fluid were pumped prior to sampling. The average pumping rate was 0.40 L/s. The specific gravity of the pumped fluid decreased from 1.193 at 21.8°C (ρ = 1.190 g/cm^3) on 03/04/87 to 1.187 at 21.4°C (ρ = 1.185 g/cm^3) on 03/11/87.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-29 is estimated as follows. For the time period of 08/08/80 (date Culebra was perforated) to 03/02/87, the borehole-fluid density is estimated to be equal to the density of the fluid pumped from the borehole on 08/26/80 (1.158 g/cm^3). The Culebra interval was isolated during the water-quality sampling conducted in November and December 1985, therefore, this sampling was considered to have had a minor impact on borehole-fluid density. The Culebra was not packer isolated during the water-quality sampling conducted in March 1987. Assuming the fluid pumped during the final days of this period remained in the borehole, a fluid density of 1.185 g/cm^3 is estimated for the period of 03/11/87 to 06/16/89. The brief period between 03/02/87 and 03/11/87 affected by the water-quality sampling is also assigned a fluid density of 1.185 g/cm^3.

The borehole-fluid density uncertainty for the first time period is +0.04 to -0.01 g/cm^3 which is +0.2 to -0.1 m when expressed as freshwater-head uncertainty. For the second time period, the uncertainty in borehole-fluid density is +0.01 to -0.04 g/cm^3 and the freshwater-head uncertainty is +0.1 to -0.2 m. The freshwater-head uncertainties were calculated assuming an average of 4.9 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for WIPP-29

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/08/80 - 03/02/87	1.158	+0.04/-0.01	+0.2/-0.1
03/02/87 - 06/16/89	1.185	+0.01/-0.04	+0.1/-0.2

WIPP-30

WIPP-30 was originally drilled in September 1978 as part of a dissolution study on the near-surface rocks in the Nash Draw area west of the WIPP site (Sandia Laboratories and U.S. Geological Survey, 1980e). WIPP-30 was initially cored and reamed to a diameter of 8-3/4 inches to a depth of 75.0 m BGS, followed by coring and reaming to a diameter of 7-7/8 inches from a depth of 75.0 to 278.3 m BGS and fully cemented. In March 1980, the casing was perforated across the Rustler-Salado contact from 222.8 to 229.5 m BGS. After the Rustler-Salado contact was tested, a retrievable bridge plug was installed below the Culebra dolomite. The casing was perforated across the Culebra dolomite from 192.3 to 199.0 m BGS in July 1980. The Culebra dolomite was then tested for about one month. In August 1980, a retrievable bridge plug was set below the Magenta dolomite. The casing was perforated across the Magenta dolomite from 155.4 to 164.6 m BGS in September 1980. On August 2, 1983, the upper bridge plug was replaced with a production-injection packer (PIP) to enable long-term monitoring of both the Magenta and Culebra intervals.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

07/30/80: Casing perforation at the Culebra interval.

08/05/80: Bailed approximately 870 L of fluid from the borehole. (No water quality data.)

08/13/80 - 08/16/80: Bailed about 600 L of fluid from the borehole. The density of the bailed fluid was 1.072 g/cm^3. Set a feed-through packer 33.0 m above the perforated Culebra interval. Conducted one shut in and one slug test. Removed the packer.

08/27/80: Set a bridge plug 13.0 m below the Culebra interval.

09/02/80 - 09/06/80: Well pumped at an average flow rate of 0.01 L/s. The specific gravity of the pumped fluid was 1.020 at 22.0°C (ρ = 1.018 g/cm^3) on 09/05/80.

09/12/80: Removed the two bridge plugs located between the Culebra and the Rustler-Salado contact zone. Set one bridge plug below the Culebra dolomite and a second bridge plug below the Magenta dolomite.

08/02/83: Removed the retrievable bridge plug separating the Magenta and Culebra intervals and replaced it with a PIP.

11/19/86: Pressure-density survey; calculated ρ = 1.069 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 57.7 m or 72.3 percent of the total fluid column.

05/06/87: Pressure-density survey; calculated ρ = 1.062 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 57.7 m or 72.3 percent of the total fluid column.

10/20/87: Pressure-density survey; calculated ρ = 1.047 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 58.4 m or 72.5 percent of the total fluid column. [NOTE: These data were reported as uncertain because of equipment problems.]

10/28/87: Removed the PIP from the borehole.

10/29/87: Bailed about 600 L of fluid from the borehole. The specific gravity of the bailed fluid increased from 1.130 at 23.0°C (ρ = 1.127 g/cm^3) to 1.150 at 23.0°C (ρ = 1.147 g/cm^3). Reperforated the Culebra dolomite interval.

11/04/87: Bailed fluid from the borehole. The specific gravity of the bailed fluid decreased from 1.078 at 22.0°C (ρ = 1.076 g/cm^3) to 1.055 at 22.0°C (ρ = 1.053 g/cm^3).

11/10/87 - 12/08/87: Well development. The bottom of the packer element and the pump intake were located 11.4 and 9.7 m, respectively, above the top of the perforated Culebra interval. The packer remained deflated throughout well development. Conducted a series of five short-term pumping periods. The specific gravity of the pumped fluid decreased from 1.041 at 20.0°C (ρ = 1.039 g/cm^3) on 11/12/87 to 1.016 at 21.0°C (ρ = 1.013 g/cm^3) on 12/08/87.

12/10/87: Slug-injection test. The bottom of the packer element was located 4.2 m above the top of the perforated Culebra interval. A minipacker was installed and inflated inside the tubing, 9.2 m above the top of the perforated Culebra interval. Added approximately 60 L of formation water to the tubing, then deflated the minipacker to initiate the test.

12/15/87: Slug-injection test. The bottom of the packer element was located 4.2 m above the top of the perforated Culebra interval. A minipacker was installed and inflated inside the tubing, 9.2 m above the top of the perforated Culebra interval. Added approximately 60 L of formation water to the tubing, then deflated the minipacker to initiate the test.

01/21/88: Bailed about 190 L of fluid from the borehole. (No water-quality data.)

02/02/88 - 03/05/88: Water-quality sampling. A pump and packer assembly was installed in the borehole to isolate the Culebra interval for sampling. The pump intake was located 5.9 m above the top of the Culebra interval. Prior to sampling, approximately 1700 L of fluid were pumped from the borehole at a flow rate of 0.008 to 0.002 L/s. The specific gravity of the pumped fluid was 1.032 at 13.8°C (ρ = 1.031 g/cm^3) on 02/05/88 and 1.020 at 19.1°C (ρ = 1.018 g/cm^3) on 03/04/88.

03/15/88: Set a PIP in the borehole between the Magenta and Culebra intervals. During installation approximately 480 L of freshwater were added to the borehole.

03/16/88: Bailed approximately 420 L of fluid from the tubing to remove the freshwater added during installation of the PIP. (No water-quality data.)

05/12/89: Pressure-density survey; calculated ρ = 1.025 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 64.1 m or 76.2 percent of the total fluid column.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in WIPP-30 is estimated as follows. The results of the pressure-density surveys conducted on 11/19/86 and 05/06/87 were averaged to obtain a borehole-fluid density of 1.066 g/cm^3 for the time period of 08/02/83 to 10/29/87. The beginning of this time period corresponds to the date the retrievable bridge plug above the Culebra interval was replaced with a PIP and the end corresponds to the date the borehole was bailed in preparation for recompletion of the Culebra interval. The density of the fluid pumped during the final stages of well development (1.013 g/cm^3) is assumed for the period of

12/08/87 to 01/21/88. The brief period between 10/29/87 and 12/08/87 affected by reperforation of the Culebra interval and well development is also assigned a fluid density of 1.013 g/cm^3. Because the Culebra interval was isolated with a packer during the slug tests conducted in December 1987, it was estimated that these tests had a minor effect on the borehole-fluid density. Based on the results of the pressure-density survey conducted in May 1989, a fluid density of 1.025 g/cm^3 is assumed to be representative of the borehole fluid for the time period of 01/21/88 to 06/16/89.

For the first time period, the uncertainty in borehole-fluid density is ±0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±0.8 m. The borehole-fluid density and freshwater-head uncertainties are +0.03 to -0.01 g/cm^3 and +2.4 to -0.8 m, respectively, for the second time period. The borehole-fluid density uncertainty for the third time period is ±0.01 g/cm^3 which is ±0.8 m when expressed as freshwater-head uncertainty. The head uncertainties were calculated assuming an average of 79.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for WIPP-30

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/02/83 - 10/29/87	1.066	±0.01	±0.8
10/29/87 - 01/21/88	1.013	+0.03/-0.01	+2.4/-0.8
01/21/88 - 06/16/89	1.025	±0.01	±0.8

ERDA-9

ERDA-9 was drilled in two phases between April and June 1976 to provide stratigraphic and structural information on the Permian evaporites. During the first phase, a 15-inch diameter hole was drilled with a salt-based drilling mud from ground surface to the top of the Salado Formation at a depth of 328.6 m BGS. The borehole was then cased to 341.9 m BGS with 10-3/4-inch casing and cemented to the surface. During the second phase, the borehole was deepened to a depth of 876.9 m BGS at a diameter of 9-7/8 inches using an oil-emulsion drilling mud. The borehole was completed by setting a length of 7-inch casing from the surface to a depth of 875.1 m BGS, cementing the lower 104.5 m of the casing in place, and leaving the drilling fluid in the borehole (Sandia National Laboratories and U.S. Geological Survey, 1983). ERDA-9 was recompleted as a Culebra observation well beginning on October 1, 1986. The 7-inch casing from 298.7 m BGS to the surface was cut and removed from the borehole and a retrievable bridge plug was set inside the 10-3/4-inch casing below the Culebra dolomite interval from 231.7 to 232.2 m below the top of the wellhead. To remove remnant oil-emulsion drilling fluid that was left in the well after the original well completion, the well was flushed with approximately 4.77×10^4 L of freshwater, washed twice with about 2.38×10^4 L of freshwater mixed with 6.6 L of MilChem-MD (a degreaser), and rinsed with approximately 4.77×10^4 L of freshwater on October 4, 1986. On October 22, 1986, the 10-3/4-inch casing was perforated across the Culebra dolomite interval between the depths of 215.0 and 222.0 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

10/22/86: Casing perforation at the Culebra interval.

10/27/86 - 11/14/86: Well development. The pump intake was located 3.7 m above the top of the perforated interval. A packer was not utilized. Conducted step-rate and single-stage surging at pumping rates of 0.06 to 0.57 L/s. The first fluid sample, collected on 10/27/86, had a specific gravity of 1.040 at 24.0°C (ρ = 1.037 g/cm^3). The final fluid sample, collected on 11/14/86, had a specific gravity of 1.059 at 23.8°C (ρ = 1.056 g/cm^3).

11/20/86: Slug-injection test. The bottom of the packer was located 9.5 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 19.3 m above the top of the perforated interval. The slug consisted of approximately 60 L of freshwater added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

11/24/86: Slug-injection test. The bottom of the packer was located 9.5 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 19.3 m above the top of the perforated interval. The slug consisted of approximately 60 L of freshwater added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

12/01/86: Bailed approximately 190 L of fluid from the borehole. (No water-quality data.)

08/24/88: Pressure-density survey; calculated $\rho = 1.049\ g/cm^3$.

The borehole-fluid density in ERDA-9 is estimated as follows. The density of the fluid pumped during the final stages of well development (1.056 g/cm^3) is assumed for the period of 11/14/86 to 12/01/86. The end of this period corresponds to the date about 190 L of fluid were bailed from the borehole. The brief period between 10/22/86 and 11/14/86 affected by perforation of the Culebra interval and well development is also assigned a fluid density of 1.056 g/cm^3. The pressure-density survey conducted on 08/24/88 yielded a borehole-fluid density of 1.049 g/cm^3. This value is assumed for the time period of 12/01/86 to 06/16/89. The decrease in density from the first time period to the second time period appears to be the result of the slug-injection tests conducted in November 1986.

The borehole-fluid density uncertainty for the first time period is ±0.02 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of ±1.6 m. For the second time period, the uncertainty in borehole-fluid density is ±0.01 g/cm^3 which is ±0.8 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainties were calculated assuming an average of 78.9 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for ERDA-9

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
10/22/86 - 12/01/86	1.056	±0.02	±1.6
12/01/86 - 06/16/89	1.049	±0.01	±0.8

CABIN BABY-1

A private developer drilled Cabin Baby-1 as an exploratory oil well in two phases between May 1974 and March 1975. A 15-inch diameter hole was drilled to 198.1 m BGS, then cased with 13-3/8-inch casing cemented to the surface. The borehole was then deepened to a depth of 1267.7 m BGS. Custody of the well was assumed by Department of Energy after it was found to be unproductive as an oil well. To hydrologically test the sandstone units in the upper Bell Canyon Formation, the well was re-entered and deepened between August and November 1983 to a depth of 1307.9 m BGS at a diameter of 9-7/8 inches (Beauheim et al., 1983). After completion of testing, a 7-3/8-inch production-injection packer (PIP) was installed at the base of the Castile Formation. The 2-3/8-inch tubing attached to the PIP provided access for Bell Canyon fluid-level measurements and the annulus was open to the Castile and Salado Formations. The PIP was removed on September 12, 1986 so that the well could be recompleted as a Culebra dolomite observation well. Two retrievable bridge plugs were installed in the well on September 15, 1986, one at the base of the Castile Formation, 1229.0 m BGS, and the other from depths of 178.8 to 179.7 m below the top of the wellhead. The casing above the upper bridge plug was flushed with freshwater. On September 19, 1986, the Culebra interval was shot perforated from depths of 153.3 to 161.2 m BGS.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

09/19/86 - 10/03/86: Casing perforation at the Culebra interval. Well development. For the first single-stage surge on 09/19/86, the pump intake was located 13.9 m above the top of the perforated interval. For the remainder of well development, the pump intake was located 7.9 m below the base of the perforated interval. A packer was not utilized. Conducted single-stage and step-rate surging at pumping rates of 0.26 to 0.66 L/s. The first fluid sample, collected on 09/23/86, had a specific gravity of 1.090 at 23.0°C (ρ = 1.087 g/cm^3). The final fluid sample, collected on 10/03/86, had a specific gravity of 1.031 at 23.0°C (ρ = 1.029 g/cm^3).

11/12/86: Slug-injection test. The bottom of the packer was located 3.1 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 8.0 m above the top of the perforated interval. The slug consisted of approximately 60 L of freshwater added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

11/16/86 - 11/17/86: Removed the minipacker, tubing, and packer from the borehole.

03/03/87: Bailed fluid from the borehole. (No water-quality data.)

03/10/87: Slug-injection test. The bottom of the packer was located 2.5 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 12.6 m above the top of the perforated interval. The slug consisted of approximately 60 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

03/12/87: Slug-injection test. The bottom of the packer was located 2.5 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 12.6 m above the top of the perforated interval. The slug consisted of approximately 60 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

07/27/88: Pressure-density survey; calculated ρ = 1.031 g/cm^3.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in Cabin Baby-1 is estimated to be 1.031 g/cm^3 for the time period of 09/19/86 (date Culebra interval was perforated) to 06/16/89. This value was determined from the results of the pressure-density survey conducted on 07/27/88. The slug test conducted in November 1986 and the bailing and the slug tests conducted in March 1987 appear to have had a negligible effect on the borehole-fluid density.

The borehole-fluid density uncertainty is ±0.01 g/cm^3 which is ±0.5 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming are average of 52.4 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for Cabin Baby-1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
09/19/86 - 06/16/89	1.031	±0.01	±0.5

ENGLE WELL

Engle Well is a livestock-watering well located 11.3 km south of the WIPP-site boundary. The well is pumped by a windmill at a maximum pumping rate of 0.063 to 0.126 L/s. Little is known about the history of this well. The following information was obtained from unpublished geophysical logs of the Engle Well by the U.S. Geological Survey completed in November 1983. The well has a total depth of about 208.2 m and is cased with 7-inch casing from a depth of about 197.5 m BGS to the surface. The depth of the Culebra dolomite is 200.9 to 207.6 m BGS. The open borehole through the Culebra appears to have been drilled to a 7-inch diameter, although a caliper log indicates that it has either washed out or caved, resulting in an average diameter of about 7.4 inches.

The significant borehole activities affecting interpretation of borehole-fluid densities are:

11/03/83 - 11/07/83: Step-drawdown exercise at pumping rates of 0.63 to 0.91 L/s. A packer was not utilized. The pump intake was located 1.2 m above the top of the Culebra interval. (No water-quality data.)

07/25/84: Pumped fluid from the borehole. (No water-quality data.)

02/25/85 - 03/05/85: Water-quality sampling. A pump and packer assembly was used to isolate the Culebra interval for sampling. The pump intake was located 1.9 m below the top of the Culebra interval. Approximately 1100 L of fluid were pumped prior to sampling. The samples were not analyzed for specific gravity, however, based on the specific conductance measurements, an estimated specific gravity of 1.015 was determined.

The borehole-fluid density in Engle Well is estimated to be 1.015 g/cm^3 for the time period of 11/07/83 to 06/16/89. The borehole probably filled with formation fluid after the pumping episodes in November 1983 and July 1984. The density of the formation fluid is unknown. However, an estimate of 1.015 g/cm^3 was determined based on the results of the water-quality sampling conducted in February and March 1985.

The borehole-fluid density uncertainty is +0.02 to -0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +4.3 to -2.2 m. The freshwater-head uncertainty was calculated assuming an average of 216.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for Engle Well

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
11/07/83 - 06/16/89	1.015	+0.02/-0.01	+4.3/-2.2

USGS-1

USGS-1 is a test hole drilled to determine the ground-water conditions in the Project Gnome area (Cooper, 1961). The borehole was drilled and completed in August 1960 to a total depth of 220.4 m BGS. A 24-inch hole was drilled from the surface to a depth of 35.3 m BGS and cased with 20-inch casing. An additional 57.4 m were drilled to a diameter of 19 inches and cased with 18-inch casing. From 92.8 to 175.9 m BGS, the borehole was drilled to a 17-1/2-inch diameter. The hole was cased from the surface to 175.9 m BGS with 12-3/4-inch casing. A 12-inch hole was drilled from 175.9 m BGS to a total depth of 220.4 m BGS. The borehole was plugged with cement from total depth to 172.8 m BGS. The 12-3/4-inch casing was perforated from 158.5 to 162.5 m BGS across the Culebra dolomite. The upper 3.0 m of annular space between the 12-3/4-inch, 18-inch, and 20-inch casing were then filled with cement. Currently, a windmill pumps water from this well for use by local ranchers.

The significant-borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

08/15/60: Casing perforation at the Culebra interval.

08/17/60 - 08/18/60: 24-hour pumping and recovery test. The borehole was pumped at a rate of 6.3 L/s. (No water-quality data.)

03/16/63 - 03/17/63: 24-hour pumping and recovery test. The borehole was pumped at a rate of 3.4 L/s. (No water-quality data.)

04/12/88: Water-quality sampling. Water samples were collected from a port on the discharge pipe which empties into a storage tank. The specific gravity of the water collected was 1.003 at 20.8°C (ρ = 1.001 g/cm^3).

07/07/88: Water-quality sampling. Water samples were collected from a siphon set near the bottom of the storage tank. The specific gravity of the water collected was 1.006 at 22.8°C (ρ = 1.004 g/cm^3).

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in USGS-1 is estimated to be 1.000 g/cm^3 from the time the Culebra interval was perforated to 06/16/89. This density value was determined based on total dissolved solid and specific conductance measurements made on fluid collected from the borehole as part of the Long-Term Hydrologic Monitoring Program for the Gnome site which was initiated on February 3, 1972.

The borehole-fluid density uncertainty is +0.01 g/cm^3. This uncertainty value translates to a freshwater-head uncertainty of +0.3 m. The freshwater-head uncertainty was calculated assuming an average of 28.0 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for USGS-1

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
08/15/60 - 06/16/89	1.000	+0.01	+0.3

USGS-4

USGS-4 was drilled in November and December 1961 downgradient from the detonation point of the Gnome Project experiment (Cooper and Glanzman, 1971). The well was drilled to observe water levels and other hydrologic conditions in the Culebra dolomite before, during, and after the explosion. The borehole was drilled to a total depth of 157.9 m BGS and cased with 8-5/8-inch casing from the surface to the top of the Culebra dolomite (145.7 m BGS). From 145.7 to 157.9 m BGS, the borehole was left open hole with a diameter of 8 inches. In January 1963, the borehole was cleaned and developed in preparation for a tracer test conducted to study physical and chemical adsorption reactions of radionuclides introduced into the Culebra dolomite in relationship to the ground-water velocities in the Culebra. During the tracer test, which was conducted from February 9, 1963 to March 9, 1963, USGS-4 was used as the discharge well in a discharge-recharge system (USGS-8 was the recharge well). The tracer test consisted of injecting a mixture of tritiated water, iodine-131, strontium-90, and cesium-137 into the Culebra dolomite. This tracer study resulted in the contamination of USGS-4.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in USGS-4 is estimated to be 1.000 g/cm^3 for the time period of 03/09/63 to 06/16/89. This density value was determined based on total dissolved solid and specific conductance measurements made on fluid collected from the borehole as part of the Long-Term Hydrologic Monitoring Program for the Gnome site which was initiated on February 3, 1972.

An estimate of the borehole-fluid density uncertainty was not made.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for USGS-4

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/09/63 - 06/16/89	1.000	unknown	N/A

USGS-6

USGS-6 is a Gnome Project test hole drilled to monitor water levels and provide a sampling point for the water in the Culebra dolomite (Cooper and Glanzman, 1971). The borehole was drilled from January to March 1962 to a total depth of 453.8 m BGS. The hole was plugged with cement from total depth to 173.0 m BGS and the casing was perforated at the Culebra dolomite from 151.8 to 162.2 m BGS.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in USGS-6 is estimated to be 1.000 g/cm^3 for the time period over which water-level data are available (04/01/62 to 08/01/63).

An estimate of the borehole-fluid density uncertainty was not made.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for USGS-6

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/01/62 - 08/01/63	1.000	unknown	N/A

USGS-7

USGS-7 is a Gnome Project test hole drilled to monitor water levels and provide a sampling point for the water in the Culebra dolomite (Cooper and Glanzman, 1971). The borehole was drilled from January to March 1962 to a total depth of 459.3 m BGS. The hole was plugged with cement from total depth to 171.6 m BGS and the casing was perforated at the Culebra dolomite from 156.7 to 166.1 m BGS.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in USGS-7 is estimated to be 1.000 g/cm^3 for the time period over which water-level data are available (04/01/62 to 08/01/63).

An estimate of the borehole-fluid density uncertainty was not made.

Summary of Estimated Borehole-Fluid Densities
and Related Density and Head Uncertainties for USGS-7

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/01/62 - 08/01/63	1.000	unknown	N/A

USGS-8

USGS-8 was drilled from October 1962 to January 1963 downgradient from the detonation point of the Gnome Project experiment (Cooper and Glanzman, 1971). The well was drilled to obtain undisturbed core at the Gnome site and to act as the recharge well for a tracer study. The borehole was drilled to a total depth of 220.0 m BGS and cased with 8-5/8-inch casing from the surface to 141.1 m BGS. From 141.1 to 220.0 m BGS, the borehole was left open hole with a diameter of 7-7/8 inches. The borehole was plugged with cement from total depth to 151.0 m BGS and left uncased over the Culebra dolomite located 140.2 to 150.6 m BGS. After drilling, USGS-8 was cleaned and developed in preparation for a tracer test conducted to study physical and chemical adsorption reactions of radionuclides introduced into the Culebra dolomite in relationship to the ground-water velocities in the Culebra. During the tracer test, which was conducted from February 9, 1963 to March 9, 1963, USGS-8 was used as the recharge well in a discharge-recharge system (USGS-4 was the discharge well). The tracer test consisted of injecting a mixture of tritiated water, iodine-131, strontium-90, and cesium-137 into the Culebra dolomite. This tracer study resulted in the contamination of USGS-8.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in USGS-8 is estimated to be 1.000 g/cm^3 for the time period of 03/09/63 to 06/16/89. This density value was determined based on total dissolved solid and specific conductance measurements made on fluid collected from the borehole as part of the Long-Term Hydrologic Monitoring Program for the Gnome site which was initiated on February 3, 1972.

An estimate of the borehole-fluid density uncertainty was not made.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for USGS-8

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
03/09/63 - 06/16/89	1.000	unknown	N/A

D-268

Well D-268 was drilled in 1984 by the Duval Mining Company as a potash- exploration well. The borehole was drilled with a rock bit to the base of the Rustler Formation and 4-1/2-inch casing was installed to 160.9 m BGS, about 10.7 m below the top of the Salado Formation. An attempt was made to cement this casing to the surface, but after mixing and injecting almost 100 bags of standard cement, there were no returns at the surface. The drilling contractor estimated that the cement was lost to a water-bearing horizon, possibly the Culebra dolomite (Dallas Horton, Pennsylvania Drilling Co., telephone conversation, April 8, 1988). The well was then drilled and cored through the potash-ore zone to a total depth of 430.1 m BGS, through Marker Bed 126, and cemented from total depth to the bottom of the casing located 160.9 m BGS. As part of a cooperative agreement with Sandia National Laboratories, D-268 was intended to be converted to a Culebra observation well. However, because of problems with the partially cemented casing, the operation was abandoned. In the process of trying to retrieve the uncemented casing in preparation for plugging and abandonment, the casing was cut at 67.1 m BGS but the casing did not separate at this depth. The casing was cut again at 44.2 m BGS and removed. The well was then retained for future use and protected from cave-in by reinstalling the cut 4-1/2-inch casing with a 5-1/2-inch wedge joint on its base to provide an overshot device for seating the casing. The well was re-entered on April 12, 1988 and compressed air was used to evacuate the borehole and remove all borehole fluid. On April 13, 1988, the Culebra interval was shot perforated from 112.5 to 119.5 m BGS to provide a Culebra monitoring well. Because water was entering the borehole from the vicinity of 44.2 m BGS, and possibly at 67.1 m BGS, a production-injection packer (PIP) was installed with tubing at 106.7 m BGS to provide monitoring access to the Culebra in the tubing and to monitor fluid levels in the annular space above the packer.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

04/13/88 - 04/18/88: Casing perforation at the Culebra interval.
04/19/88 - 04/20/88: Installed a PIP above the Culebra interval.

07/12/88: Pressure-density survey; calculated ρ = 0.991 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 23.1 m or 73.1 percent of the total fluid column.

11/02/88 - 11/17/88: Well development pumping. The bottom of the packer element and the pump intake were located about 6.0 and 4.8 m, respectively, above the top of the Culebra interval. Pulled pump and packer assembly from well. Reinstalled the packer and tubing. The bottom of the packer element was located 6.9 m above the top of the Culebra interval. Bailed approximately 190 L of fluid from the tubing.

11/18/88: Slug-withdrawal test. The test was initiated by deflating the minipacker located 12.9 m above the top of the Culebra interval.

12/08/88: Slug-injection test. The slug consisted of approximately 60 L of formation fluid added to the tubing. Once the slug was in place, the minipacker located 12.9 m above the top of the Culebra interval was deflated to initiate the test.

12/09/88: Slug-injection test. The slug consisted of about 90 L of formation fluid added to the tubing. The test was initiated by deflating the minipacker located 12.9 m above the top of the Culebra interval.

03/16/89: Added approximately 640 L of fluid to the annulus. The source of the added fluid was not reported.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in D-268 is estimated to be 0.991 g/cm^3 for the time period of 04/13/88 to 06/16/89. This value is equal to the density determined from the results of the pressure-density survey.

The borehole-fluid density uncertainty is +0.01 g/cm^3 which is +0.3 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 31.6 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for D-268

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
04/13/88 - 06/16/89	0.991	+0.01	+0.3

AEC-7

AEC-7 was drilled in 1974 under the direction of the Oak Ridge National Laboratory (ORNL) to a total depth of 1190.5 m BGS in the Anhydrite II unit of the Castile Formation to provide stratigraphic and lithologic data. The well was cased through the Rustler Formation with 8-5/8-inch casing to a depth of 306.0 m BGS in the upper Salado Formation, drilled to a 7-13/16-inch diameter to 1190.5 m BGS, and left filled with brine after the ORNL testing. To investigate the regional formation-pressure distribution in the Bell Canyon Formation and to conduct a test of borehole-plugging concepts, SNL deepened the well to 1438.7 m BGS in 1979 (Christensen and Peterson, 1981; Sandia National Laboratories and D'Appolonia, 1983). The well is completed open hole to 1357.9 m BGS and is plugged with grout from 1357.9 to 1366.4 m BGS. The well was then capped and abandoned. In July 1988, the borehole was re-entered and the Culebra interval was perforated.

The significant borehole activities affecting interpretation of Culebra equivalent-freshwater heads are:

06/29/88: Installed a bridge plug 20.6 m below the base of the Culebra interval.

06/30/88: Perforated the Culebra interval from 262.1 to 270.7 m BGS. Set a PIP in the borehole. The bottom of the packer was located 2.4 m above the top of the perforated interval.

07/08/88 - 09/26/88: Well development consisting of bailing and pumping. The final sample collected during well development had a specific gravity of 1.086 at 25.0°C (ρ = 1.082 g/cm^3).

07/25/88: Pressure-density survey; calculated ρ = 1.121 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 62.5 m or 85.8 percent of the total fluid column.

10/03/88: Slug-withdrawal test. The bottom of the packer element was located 5.0 m above the top of the perforated interval. A minipacker was installed inside the tubing, 17.3 m above the top of the perforated interval.

10/07/88: Slug-injection test. The bottom of the packer element was located 5.0 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 17.3 m above the top of the perforated interval. The slug consisted of approximately 80 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

10/12/88: Slug-injection test. The bottom of the packer element was located 5.0 m above the top of the perforated interval. A minipacker was installed and inflated inside the tubing, 17.3 m above the top of the perforated interval. The slug consisted of approximately 80 L of formation fluid added to the tubing. Once the slug was in place, the minipacker was deflated to initiate the test.

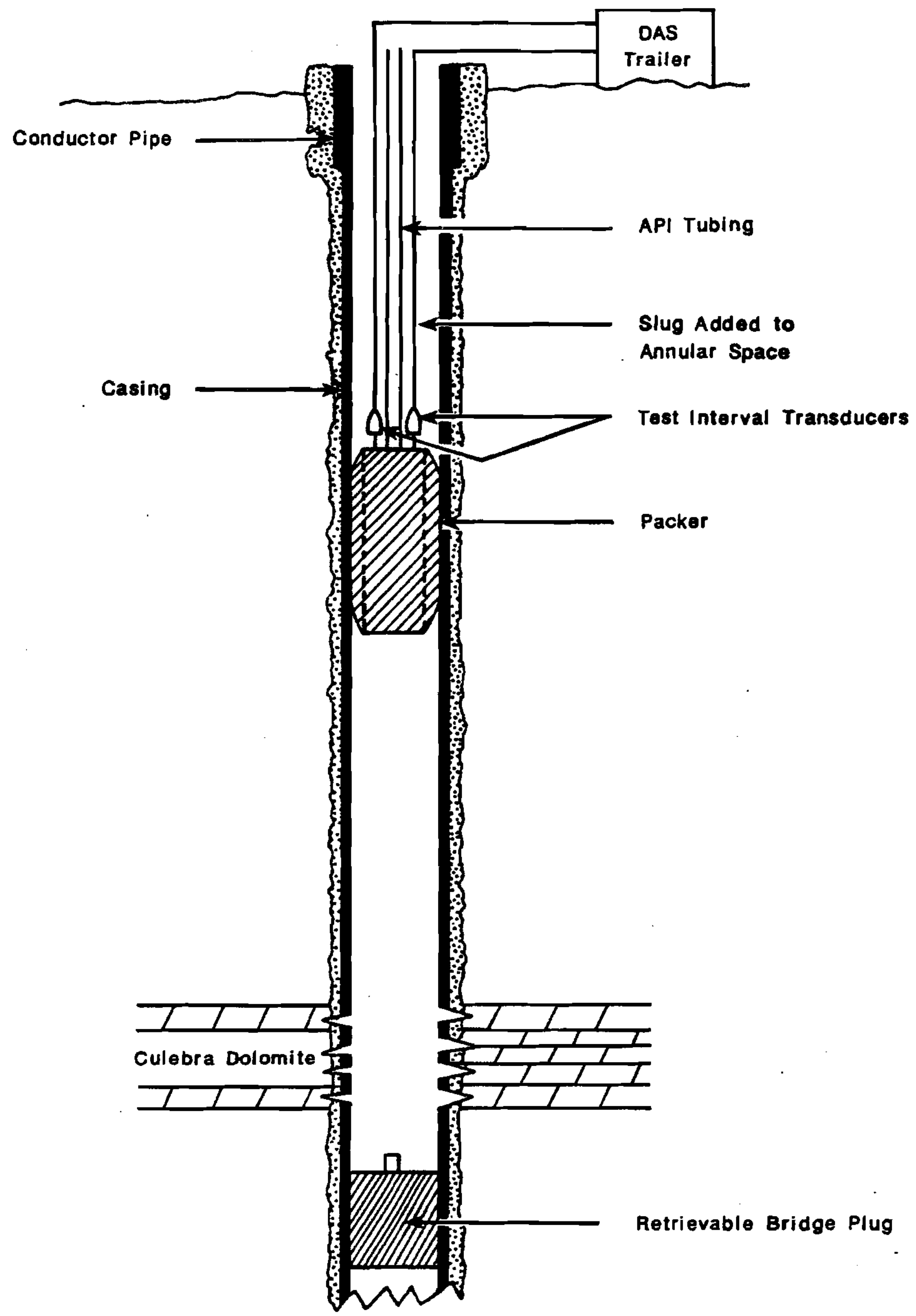
05/09/89: Pressure-density survey; calculated ρ = 1.090 g/cm^3. The presence of a PIP in the well limited the accessible fluid column to 67.4 m or 88.5 percent of the total fluid column.

For the purpose of equivalent-freshwater-head calculations, the borehole-fluid density in AEC-7 is estimated to be 1.090 g/cm^3 for the time period of 06/30/88 to 06/16/89. This value is based on the results of the pressure-density survey conducted in May 1989. Since the July 1988 pressure-density survey was conducted during well development, the results of this survey are not considered representative of the typical borehole-fluid density.

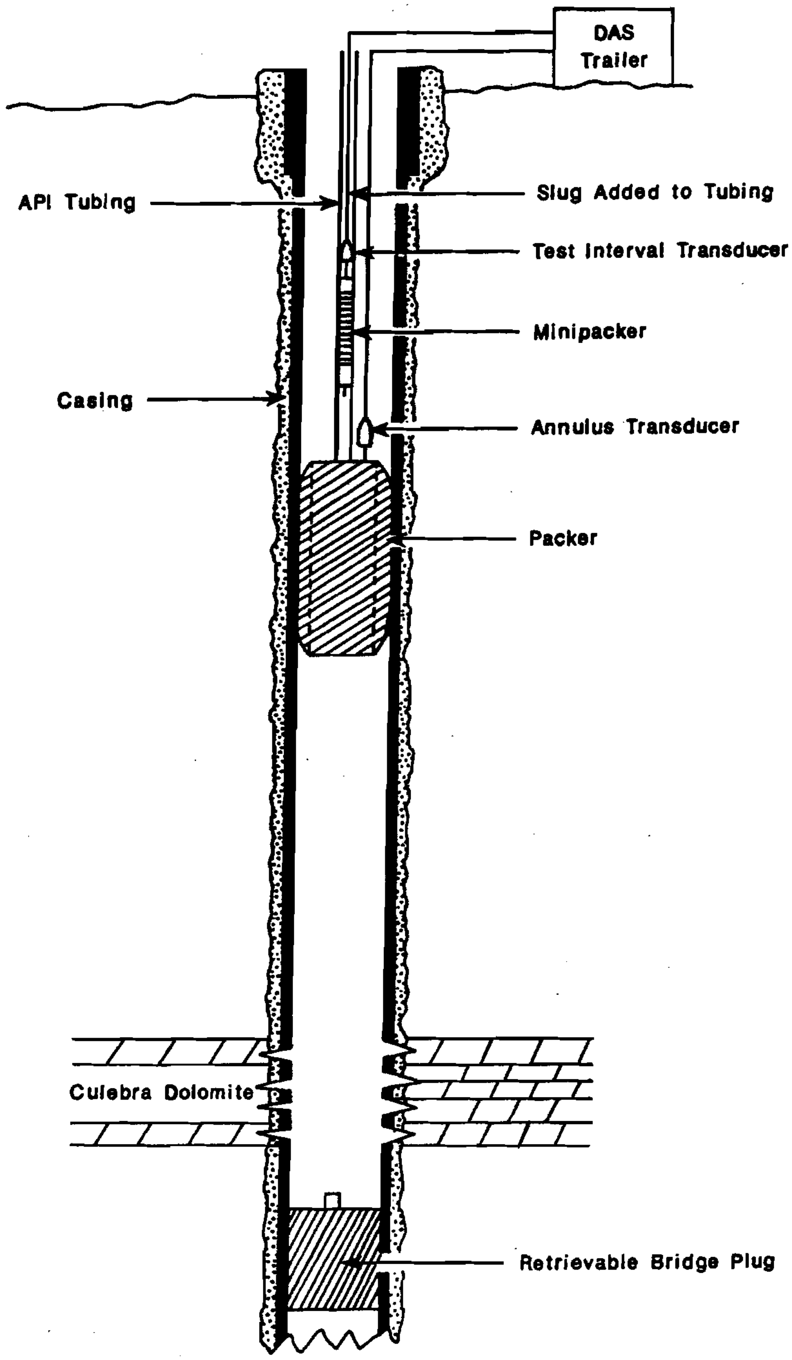
The borehole-fluid density uncertainty is ±0.01 g/cm^3 which is ±0.7 m when expressed as freshwater-head uncertainty. The freshwater-head uncertainty was calculated assuming an average of 72.9 m of fluid in the borehole above the center of the Culebra interval.

Summary of Estimated Borehole-Fluid Densities and Related Density and Head Uncertainties for AEC-7

Time Period	Borehole-Fluid Density (g/cm^3)	Density Uncertainty (g/cm^3)	Related Head Uncertainty (m)
06/30/88 - 06/16/89	1.090	±0.01	±0.7



Drawn by ABW	Date 2/2/90	Generalized Well Configuration for Slug-Injection Test Utilizing a Single Packer
Checked by T.C.	Date 2/2/90	
Revisions	Date	
#1050-000	2/2/90	
INTERA Technologies		Figure F.1



Drawn by ABW	Date 2/2/90	Generalized Well Configuration for Slug-Injection Test Utilizing a Minipacker		
Checked by T.C.	Date 2/2/90			
Revisions	Date			
#1050-000	2/2/90			
INTERA Technologies				Figure F.2

SUMMARY OF PRESSURE-DENSITY SURVEYS Updated 02/01/90

Well	Round #1 Crawley, 1988a Survey Date	Round #1 Crawley, 1988a Calculated Density (g/cm3)	Round #2 Crawley, 1988a Survey Date	Round #2 Crawley, 1988a Calculated Density (g/cm3)	Round #3 Crawley, 1988a Survey Date	Round #3 Crawley, 1988a Calculated Density (g/cm3)	Other Surveys Crawley, 1988b and Kehrman, 1989 Survey Date	Other Surveys Crawley, 1988b and Kehrman, 1989 Calculated Density (g/cm3)
H-1	10/22/86	1.066					05/11/89	1.002
H-2a								
H-2b1								
H-2b2							05/17/89	1.008
H-2c	07/29/86	1.055	04/13/87	1.042	09/30/87	1.035	05/16/89	1.035
H-3b1								
H-3b2	08/07/86	1.037	02/24/87	1.039	09/21/87	1.021		
H-3b3								
H-4a								
H-4b	08/13/86	1.021	02/17/87	1.020	08/05/87	0.997		
H-4c								
H-5a								
H-5b	08/11/86	1.108	04/15/87	1.099	09/28/87	1.090		
H-5c								
H-6a								
H-6b	09/03/86	1.040	05/11/87	1.031	09/16/87	1.029		
H-6c								
H-7b1	10/13/86	1.004	03/23/87	1.009	10/01/87	0.986		
H-7b2								
H-7c								
H-8b	10/15/86	1.000	03/30/87	1.001	10/07/87	0.976		
H-9a								
H-9b	10/14/86	1.002	03/24/87	0.999	10/05/87	0.987	06/05/89	1.003
H-9c								
H-10b			04/01/87	1.048				
H-11b1								
H-11b2								
H-11b3	09/12/86	1.082	03/05/87	1.076	09/23/87	1.063		
H-11b4								

Drawn by T.C.	Date 10/12/89
Checked by T.C.	Date 10/12/89
Revisions	Date
#1050-000	10/12/89

Summary of Pressure-Density Surveys Performed in WIPP-Area Boreholes

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Table F.1a

Well	Round #1 Crawley, 1988a Survey Date	Round #1 Crawley, 1988a Calculated Density (g/cm3)	Round #2 Crawley, 1988a Survey Date	Round #2 Crawley, 1988a Calculated Density (g/cm3)	Round #3 Crawley, 1988a Survey Date	Round #3 Crawley, 1988a Calculated Density (g/cm3)	Other Surveys Crawley, 1988b and Kehrman, 1989 Survey Date	Other Surveys Crawley, 1988b and Kehrman, 1989 Calculated Density (g/cm3)
H-12	09/30/86	1.098	03/06/87	1.097	09/24/87	1.083		
H-14					09/22/87	1.002	06/07/89	1.018
H-15					08/31/87	1.136	08/24/88	1.145
H-15							05/18/89	1.156
H-16								
H-17					12/07/87	1.179	08/03/88	1.166
H-18					12/10/87	1.181	08/02/88	1.044
DOE-1	09/10/86	1.076	02/19/87	1.108	09/02/87	1.066	08/23/88	1.069
DOE-1							05/10/89	1.077
DOE-2	09/09/86	1.031	05/13/87	1.025	09/08/87	1.022		
P-14	08/15/86	1.015	04/23/87	1.009	08/19/87	1.003	06/16/89	1.015
P-15	09/16/86	1.002	02/26/87	1.034	08/28/87	0.985	06/13/89	1.006
P-17	09/29/86	1.065	02/25/87	1.065	08/12/87	1.046		
P-18	10/17/86	1.115	03/10/87	1.119				
WIPP-12	09/05/86	1.000	05/08/87	0.992	09/04/87	1.046	06/09/89	1.097
WIPP-13	09/04/86	1.026	05/06/87	1.032	09/10/87	1.017		
WIPP-18	08/06/86	1.030	05/12/87	1.100	09/11/87	1.100		
WIPP-19	08/05/86	1.098	05/14/87	1.126	09/25/87	1.101		
WIPP-21	07/30/86	1.014			10/13/87	1.048	06/12/89	1.071
WIPP-22	08/04/86	1.117			09/29/87	1.087	06/08/89	1.087
WIPP-25	11/05/86	0.980	05/05/87	1.000	10/14/87	0.998		
WIPP-26	10/07/86	1.002						
WIPP-27	11/10/86	1.022	04/27/87	1.036	10/21/87	1.026		

Drawn by T.C.	Date 10/12/89
Checked by T.C.	Date 10/12/89
Revisions	Date
#1050-000	10/12/89

Summary of Pressure-Density Surveys Performed in WIPP-Area Boreholes

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Table F.1b

Well	Round #1 Crawley, 1988a Survey Date	Round #1 Calculated Density (g/cm3)	Round #2 Crawley, 1988a Survey Date	Round #2 Calculated Density (g/cm3)	Round #3 Crawley, 1988a Survey Date	Round #3 Calculated Density (g/cm3)	Other Surveys Crawley, 1988b and Kehrman, 1989 Survey Date	Other Surveys Calculated Density (g/cm3)
WIPP-28					10/22/87	1.002		
WIPP-29								
WIPP-30	11/19/86	1.069	05/06/87	1.062	10/20/87	1.047	05/12/89	1.025
ERDA-9							08/24/88	1.049
C.B.-1							07/27/88	1.031
ENGLE								
USGS-1								
USGS-4								
USGS-6								
USGS-7								
USGS-8								
D-268							07/12/88	0.991
AEC-7							07/25/88	1.121
AEC-7							05/09/89	1.090

Drawn by T.C.	Date 10/12/89
Checked by T.C.	Date 10/12/89
Revisions	Date
#1050-000	10/12/89

Summary of Pressure-Density Surveys Performed in WIPP-Area Boreholes

INTERA Technologies

Table F.1c

BOREHOLE-FLUID DENSITIES Updated 11/07/89

WELL	AVERAGE BOREHOLE-FLUID DENSITY (g/cm3)	ESTIMATED FLUID-DENSITY UNCERTAINTY (g/cm3)	TIME PERIOD DENSITY APPLICABLE	DATE OF F.W. HEAD SELECTION(1)
H-1	1.036	+/-0.02	03/07/77-07/14/87	08/81
	0.998	+0.02	07/14/87-09/01/87	
	1.011	+/-0.02	09/01/87-06/16/89	
H-2a	1.064	+0.01/-0.02	07/15/83-07/09/84	
	1.012	+0.02/-0.01	07/09/84-06/16/89	
H-2b1	1.010	+0.02/-0.01	02/12/77-01/09/84	
	1.053	+/-0.04	01/09/84-07/09/84	
	1.010	+0.02/-0.01	07/09/84-06/16/89	
H-2b2	1.095	+/-0.05	08/06/83-10/13/83	
	1.051	+/-0.03	10/13/83-08/22/84	
	1.008	+0.01	08/22/84-06/16/89	
H-2c	1.023	+0.02	03/23/77-07/02/84	03/78
	1.044	+/-0.01	07/02/84-06/16/89	
H-3b1	1.036	+/-0.02	03/07/77-04/17/86	08/81
H-3b2	1.038	+/-0.01	11/11/83-06/16/89	
H-3b3	1.033	+/-0.01	02/03/84-06/16/89	
H-4a	1.015	+0.02/-0.01	02/04/81-06/16/89	
H-4b	1.024	+/-0.02	05/15/78-05/13/81	
	1.008	+/-0.01	05/13/81-03/25/85	06/82
	1.021	+/-0.01	03/25/85-06/16/89	
H-4c	1.008	+0.02/-0.01	02/81-08/20/86	
H-5a	1.092	+/-0.05	01/26/81-06/16/89	
H-5b	1.104	+/-0.01	06/13/78-06/16/89	01/81
H-5c	1.103	+/-0.02	01/81-08/20/86	

Drawn by T.C.	Date 10/12/89	Borehole-Fluid Density and Estimated Density Uncertainty for WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table F.2a

WELL	AVERAGE BOREHOLE-FLUID DENSITY (g/cm3)	ESTIMATED FLUID-DENSITY UNCERTAINTY (g/cm3)	TIME PERIOD DENSITY APPLICABLE	DATE OF F.W. HEAD SELECTION(1)
H-6a	1.038	+/-0.02	01/22/81-06/16/89	
H-6b	1.038	+/-0.01	07/05/78-06/16/89	09/80
H-6c	1.038	+/-0.01	05/81-08/20/86	
H-7b1	1.005	+0.01	09/18/79-06/16/89	07/81
H-7b2	0.999	+0.01	09/22/83-06/16/89	
H-7c	1.000	+0.02	05/15/83-06/16/89	
H-8b	1.001	+0.01	08/12/79-06/16/89	02/83
H-9a	1.001	+0.01	07/22/83-06/16/89	
H-9b	1.001	+0.01	08/28/79-06/16/89	02/83
H-9c	1.001	+0.01	01/20/83-06/16/89	
H-10b	1.047	+/-0.01	10/13/79-06/16/89	05/81
H-11b1	1.080	+/-0.01	09/02/83-02/01/88	
	1.074	+/-0.01	02/01/88-06/16/89	
H-11b2	1.085	+/-0.01	11/23/83-12/04/87	07/87
	1.076	+/-0.01	12/04/87-06/16/89	
H-11b3	1.079	+0.02/-0.01	01/84-06/16/89	
H-11b4	1.065	+/-0.01	03/20/88-06/16/89	
H-12	1.080	+/-0.03	10/04/83-07/05/84	
	1.098	+/-0.01	07/05/84-06/16/89	01/87
H-14	1.013	+0.01	10/21/86-06/16/89	05/87
H-15	1.000	+0.01	11/09/86-04/16/87	04/87
	1.151	+/-0.01	04/16/87-06/16/89	

Drawn by T.C.	Date 10/12/89	Borehole-Fluid Density and Estimated Density Uncertainty for WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table F.2b

WELL	AVERAGE BOREHOLE-FLUID DENSITY (g/cm3)	ESTIMATED FLUID-DENSITY UNCERTAINTY (g/cm3)	TIME PERIOD DENSITY APPLICABLE	DATE OF F.W. HEAD SELECTION(1)
H-16	1.200	-0.05	08/11/87-06/16/89	
H-17	1.101	+/-0.02	10/07/87-11/04/87	
	1.166	+/-0.01	11/04/87-06/16/89	01/88
H-18	1.002	+0.01	10/30/87-11/16/87	
	1.181	+/-0.02	11/16/87-03/03/88	
	1.044	+/-0.01	03/03/88-06/16/89	12/88
DOE-1	1.083	+/-0.02	03/08/83-06/16/89	07/87
DOE-2	1.067	+/-0.03	04/02/86-05/27/86	
	1.028	+/-0.01	05/27/86-06/16/89	01/87
P-14	1.012	+/-0.01	03/07/77-01/27/89	08/84
	1.015	+/-0.01	01/27/89-06/16/89	
P-15	1.080	+/-0.05	04/06/77-05/29/85	
	1.018	+/-0.02	05/29/85-03/27/87	09/85
	1.006	+0.01	03/27/87-06/16/89	
P-17	1.065	+/-0.01	04/05/77-06/16/89	03/84
P-18	1.117	+/-0.01	04/06/77-06/16/89	
WIPP-12	1.200	-0.05	10/14/85-05/21/86	
	0.996	+0.01	05/21/86-08/27/87	01/87
	1.096	-0.02	08/27/87-06/16/89	
WIPP-13	1.192	-0.05	10/26/85-04/04/86	
	1.045	+/-0.02	04/04/86-06/12/86	
	1.029	+/-0.01	06/12/86-06/16/89	09/87
WIPP-18	1.075	+0.05	10/11/85-05/10/86	
	1.030	+/-0.01	05/10/86-08/27/86	
	1.100	+/-0.01	08/27/86-06/16/89	10/87
WIPP-19	1.177	+0.02/-0.05	10/09/85-05/28/86	
	1.098	+/-0.01	05/28/86-08/22/86	
	1.126	+/-0.01	08/22/86-06/19/87	
	1.101	+/-0.03	06/19/87-06/16/89	

Drawn by T.C.	Date 10/12/89	Borehole-Fluid Density and Estimated Density Uncertainty for WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table F.2c

WELL	AVERAGE BOREHOLE-FLUID DENSITY (g/cm3)	ESTIMATED FLUID-DENSITY UNCERTAINTY (g/cm3)	TIME PERIOD DENSITY APPLICABLE	DATE OF F.W. HEAD SELECTION(1)
WIPP-21	1.007	+0.02/-0.01	10/06/85-06/28/86	
	1.014	+/-0.01	06/28/86-08/24/86	
	1.071	+/-0.01	08/24/86-06/16/89	
WIPP-22	1.149	+/-0.05	10/08/85-06/12/86	
	1.117	+/-0.01	06/12/86-08/25/86	
	1.087	+/-0.01	08/25/86-06/16/89	
WIPP-25	0.990	+0.01	08/04/83-06/16/89	07/85
WIPP-26	1.002	+0.01	08/03/83-06/16/89	11/86
WIPP-27	1.029	+/-0.01	07/20/83-06/16/89	02/86
WIPP-28	1.016	+/-0.02	07/20/83-06/16/89	09/83
WIPP-29	1.158	+0.04/-0.01	08/08/80-03/02/87	08/86
	1.185	+0.01/-0.04	03/02/87-06/16/89	
WIPP-30	1.066	+/-0.01	08/02/83-10/29/87	09/87
	1.013	+0.03/-0.01	10/29/87-01/21/88	
	1.025	+/-0.01	01/21/88-06/16/89	
ERDA-9	1.056	+/-0.02	10/22/86-12/01/86	
	1.049	+/-0.01	12/01/86-06/16/89	
C.B.-1	1.031	+/-0.01	09/19/86-06/16/89	03/88
ENGLE	1.015	+0.02/-0.01	11/07/83-06/16/89	
USGS-1	1.000	+0.01	08/15/60-06/16/89	03/79
USGS-4	1.000	unknown	03/09/63-06/16/89	03/83
USGS-6	1.000	unknown	04/01/62-08/01/63	
USGS-7	1.000	unknown	04/01/62-08/01/63	
USGS-8	1.000	unknown	03/09/63-06/16/89	03/83
D-268	0.991	+0.01	04/13/88-06/16/89	08/88
AEC-7	1.090	+/-0.01	06/30/88-06/16/89	02/89

(1) The approximate date of the water-level measurement used to calculate the undisturbed freshwater head used in the modeling.

Drawn by T.C.	Date 10/12/89	Borehole-Fluid Density and Estimated Density Uncertainty for WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table F.2d

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APPENDIX G: TRANSIENT FRESHWATER HEADS AND ESTIMATION OF UNDISTURBED FRESHWATER HEADS AND THEIR UNCERTAINTIES

Water-level monitoring and well testing of the Culebra dolomite using pressure transducers has been performed in boreholes in and around the WIPP site. Where sufficient data were available from these wells, hydrographs have been constructed which plot freshwater head in meters above mean sea level (m amsl) versus time in years. The term "freshwater head", which is equivalent to the term "freshwater elevation above mean sea level" because the head values are always related to mean sea level, is used in this report. The freshwater head refers to the elevation of a column of freshwater having a density of 1.000 g/cm^3 that would exert a pressure equal to the formation pressure at the elevation of the center of the Culebra.

The hydrographs (Figures G.1 through G.47) show the transient freshwater heads resulting from the shaft and well-test activities performed at the site. For most of these hydrographs, an undisturbed freshwater head has been selected (values indicated on hydrographs) which is intended to represent conditions at the site before shaft excavations and hydrologic-characterization studies. This appendix describes the calculations and data used to create these hydrographs, and provides an estimate of the undisturbed hydraulic conditions for calibration of the steady-state model.

Water-level and pressure data for the Culebra have been collected at the WIPP site as depths to water below a reference point measured by a steel tape or an electronic sounding device and as pressure measured by downhole transducers. These data are reported in Richey (1987), Hydro Geo Chem, Inc. (1985), INTERA Technologies, Inc. and Hydro Geo Chem, Inc. (1985), INTERA Technologies, Inc. (1986), Saulnier et al. (1987), and Stensrud et al. (1987, 1988a, 1988b, 1989).

Depth-to-water data were converted to equivalent-freshwater head as follows:

$$h_f = (d_c - d_w) \frac{\rho}{\rho_f} + Z_c \qquad (G.1)$$

where h_f = equivalent freshwater head;
d_w = measured depth to water;
d_c = depth to the center of the Culebra dolomite;
Z_c = elevation of the center of the Culebra dolomite above mean sea level;
ρ = average density of the borehole fluid; and
ρf = freshwater-fluid density (assumed equal to 1.000 g/cm^3).

Transducer pressure data were converted to equivalent-freshwater head using the relationship:

$$h_f = \frac{P}{\rho f g} + (d_c - d_t)\frac{\rho}{\rho f} + Z_c \qquad \text{(G.2)}$$

where P = measured transducer pressure;
d_t = depth to transducer; and
g = gravitational constant.

Provided there is no change in the borehole-fluid density, the equivalent-freshwater head estimated from a transducer pressure should be the same as the equivalent-freshwater head estimated from a depth-to-water measurement. All depths are measured relative to a reference point of known elevation at each well. For the WIPP-site monitoring wells, depths are reported either from the top of well casing (TOC), the top of tubing (TOT) installed in the well, or the ground surface (GS). Table G.1a-d summarizes the type of reference point at each well, the elevation of the reference point, and the time period over which the reference point was used. Because water-level monitoring by the U.S. Geological Survey through early 1985 overlapped with monitoring by Sandia subcontractors, and both sets of measurements used different reference points, some wells show that more than one reference point was used over a given time period.

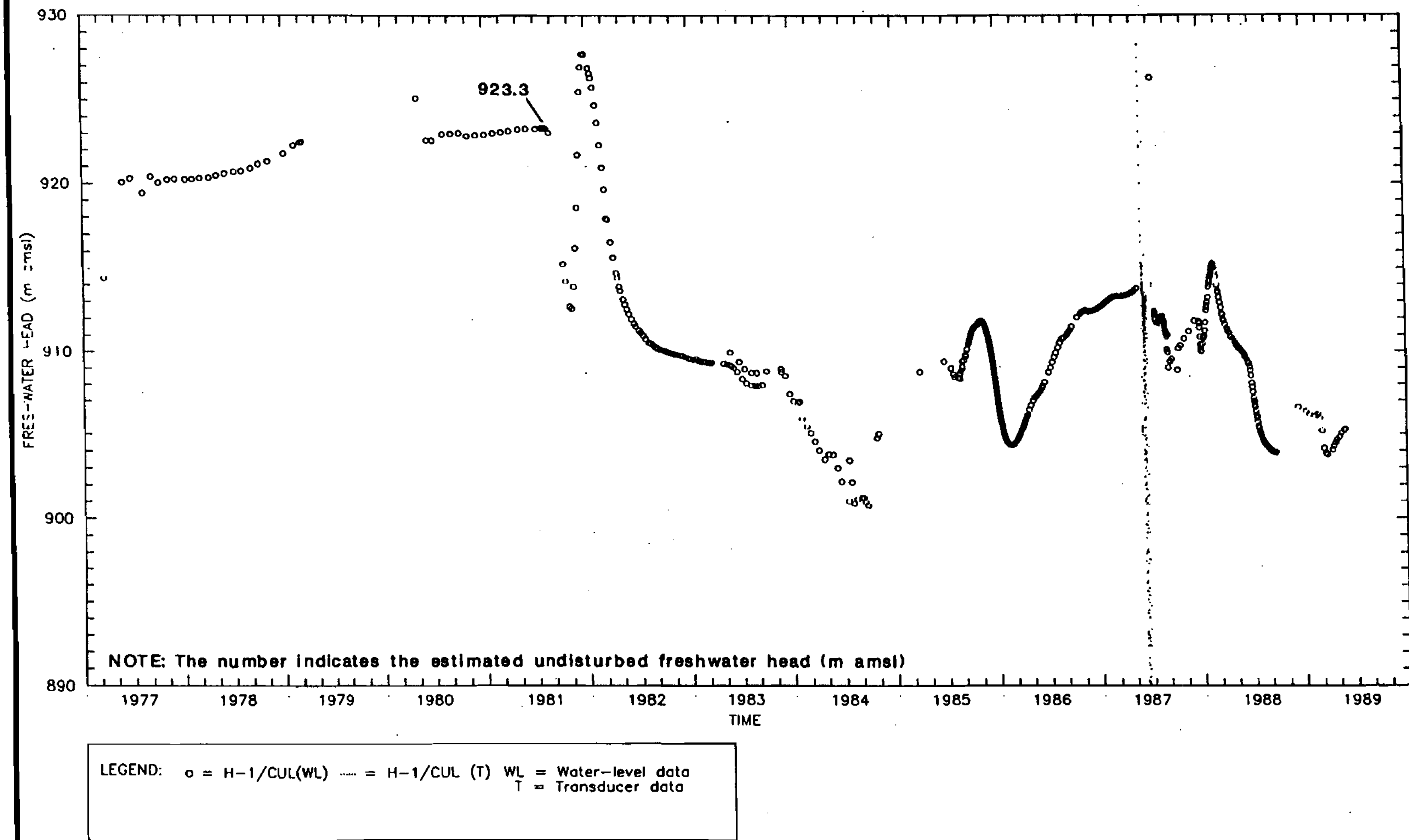
Hydrographs of equivalent-freshwater head (m amsl) versus time (years) were developed for each well using the values of Culebra elevation, measuring-point elevation, and the average borehole-fluid densities. These hydrographs are plotted in Figures G.1 through G.44. In addition, Figures G.45 through G.47 are hydrographs showing the equivalent-freshwater head versus time for pressure measurements made with the pressure transducers installed in the Culebra in the walls of the waste-handling, exhaust, and construction and salt-handling shafts at the WIPP site.

Undisturbed freshwater heads were estimated from the hydrographs in Figures G.1 through G.44. The estimation of undisturbed conditions can be complicated by well-testing, water-quality-sampling, and shaft activities. Haug et al. (1987) found that since the summer of 1981, the hydrologic state of the Culebra has been significantly influenced by the drilling and excavating of the first three shafts at the WIPP site. Most recently, the excavation of the fourth shaft (the air intake shaft) has had a significant impact on the water levels in the central WIPP-site area. Also, several large scale well interference tests since 1981 have created sub-regional transients. For these reasons, when possible, the undisturbed-freshwater heads were estimated from data collected before December 1981. For some wells, only recent (e.g., 1988) water-level data were available to estimate the undisturbed-freshwater heads. Figure G.48 shows the undisturbed-freshwater head value assigned to each borehole.

Table G.2a-b summarizes undisturbed freshwater heads for each well, the approximate date of the measurement on which it is based, and the uncertainty in the head. As in Appendix F, the term uncertainty is used here to express the lack of precision in the selected freshwater head and is not intended to have a rigorous statistical meaning. The sources of freshwater-head uncertainty include uncertainties in the borehole-fluid density, the reference elevation, and the depth-to-water measurements and observed trends or residual effects in the hydrograph data. Trends refer to poorly understood long-term regional transients and residual effects refer to shorter-term transients that are due to the stress imposed on the Culebra interval by the activities at the shafts, well testing, or water-quality sampling activities. The uncertainty in transient freshwater heads due to borehole-fluid density uncertainty is discussed in Appendix F. The reference-point elevations used in this modeling study are from Gonzales (1989). In that report, Gonzales indicates that the elevation data have a relative uncertainty of ±0.02 m. In addition, she states the uncertainty of the survey data ranges from -0.37 to +0.15 m. The uncertainty in elevation data and survey data were added to obtain a head uncertainty due to the uncertainty in the reference-point elevation. At the WIPP site depth-to-water is currently measured with Solinst meters and an Iron Horse. From 1977 to 1985, the U.S. Geological Survey measured water levels using the following methods; an air-line measurement system, a Lynes Pressure Sentry System, a M-scope device, a steel tape, and a winch (Richey, 1987). The head uncertainty due to depth-to-water measurements is estimated to be ±0.03 m for depth measurements less than 75 m, ±0.06 m for depth measurements between 75 and 120 m, and ±0.09 m for depth measurements greater than 120 m.

The head uncertainty due to trends in the water levels for the WIPP area boreholes was based on a detailed evaluation of the hydrograph of each borehole for which an undisturbed head was selected. The uncertainty value represents the maximum change possible in the undisturbed head selected for a given well based on the data currently available.

Table G.2a-b lists the head uncertainties due to the borehole-fluid density, the reference-point elevation, the depth-to-water measurements, and the short-term residuals. The final column of Table G.2a-b combines these sources of uncertainty to present an overall uncertainty for the undisturbed freshwater-head estimates. This overall uncertainty is considered to represent the upper and lower limits that bound the selected equivalent-freshwater head. When more than one value of undisturbed-freshwater head can be estimated from several wells at a hydropad, the value used is from the well with the least uncertainty in the estimated borehole-fluid density. The uncertainty values were not determined using a rigorous statistical approach. These values are meant to provide the best upper and lower bounds for the estimate of the equivalent-freshwater head. Given the limited data on borehole-fluid density, which dominates the freshwater-head uncertainty, a rigorous statistical approach was not justified.



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-1	Figure G.1

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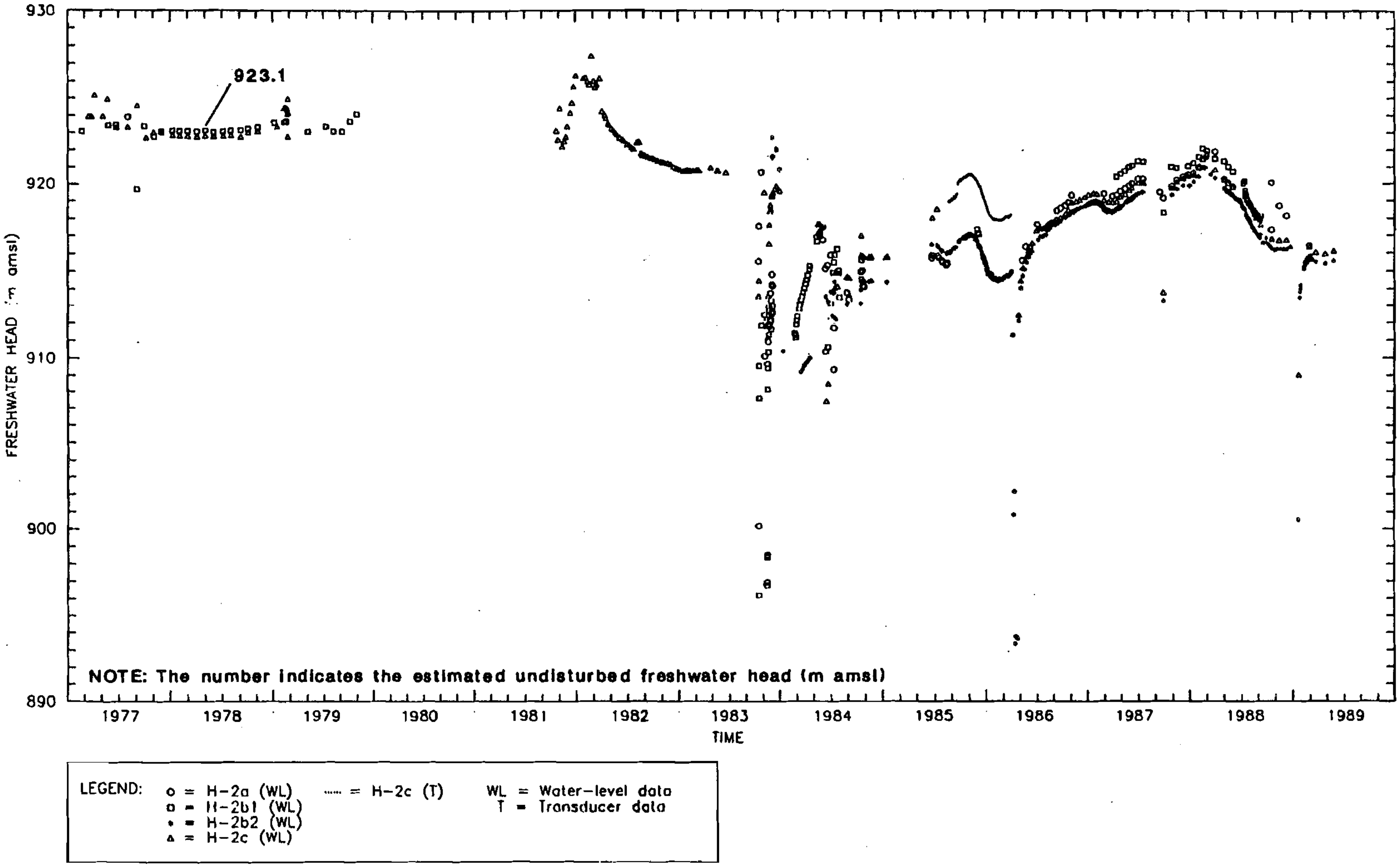

INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at the H-2 Hydropad	Figure G.2

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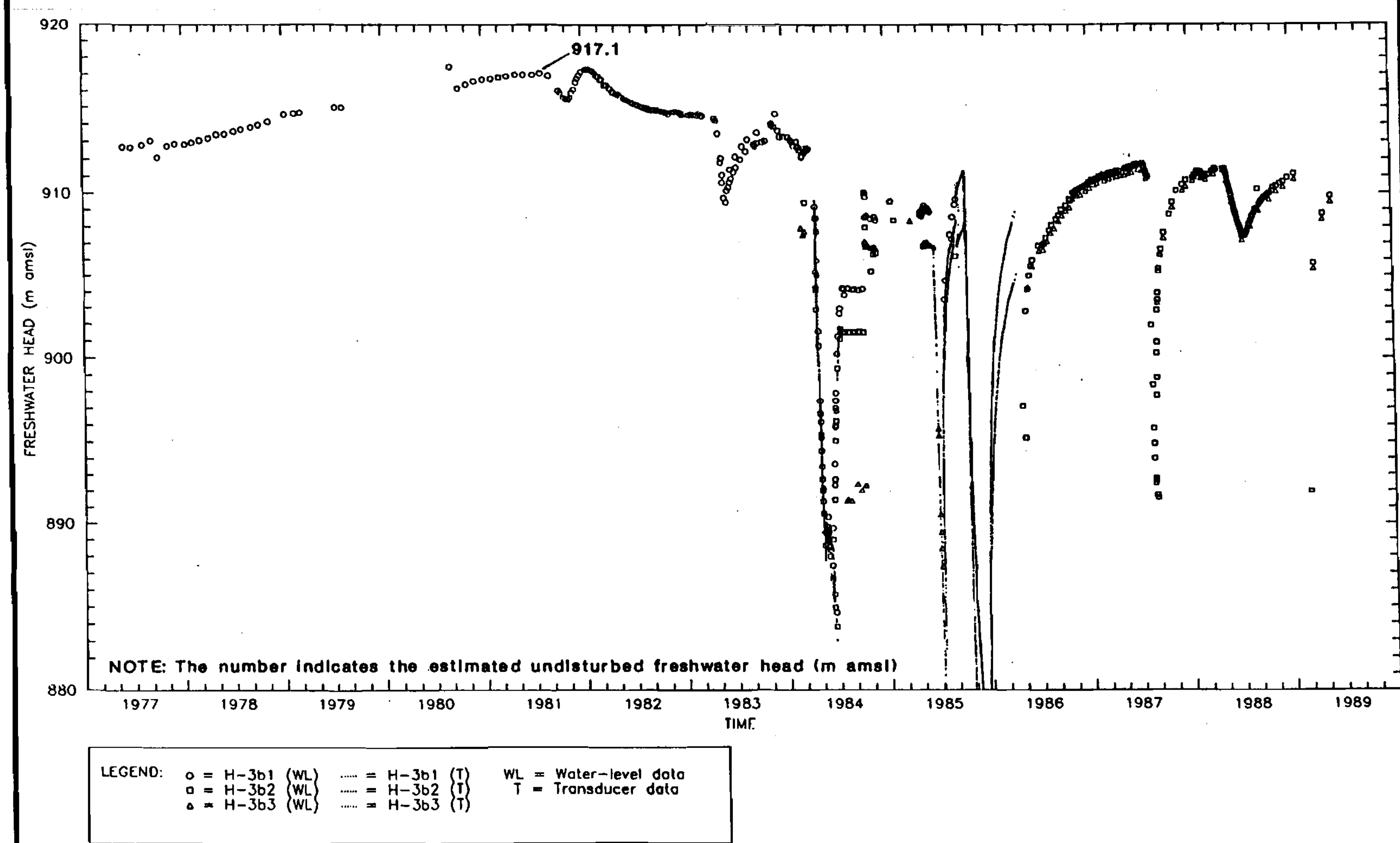
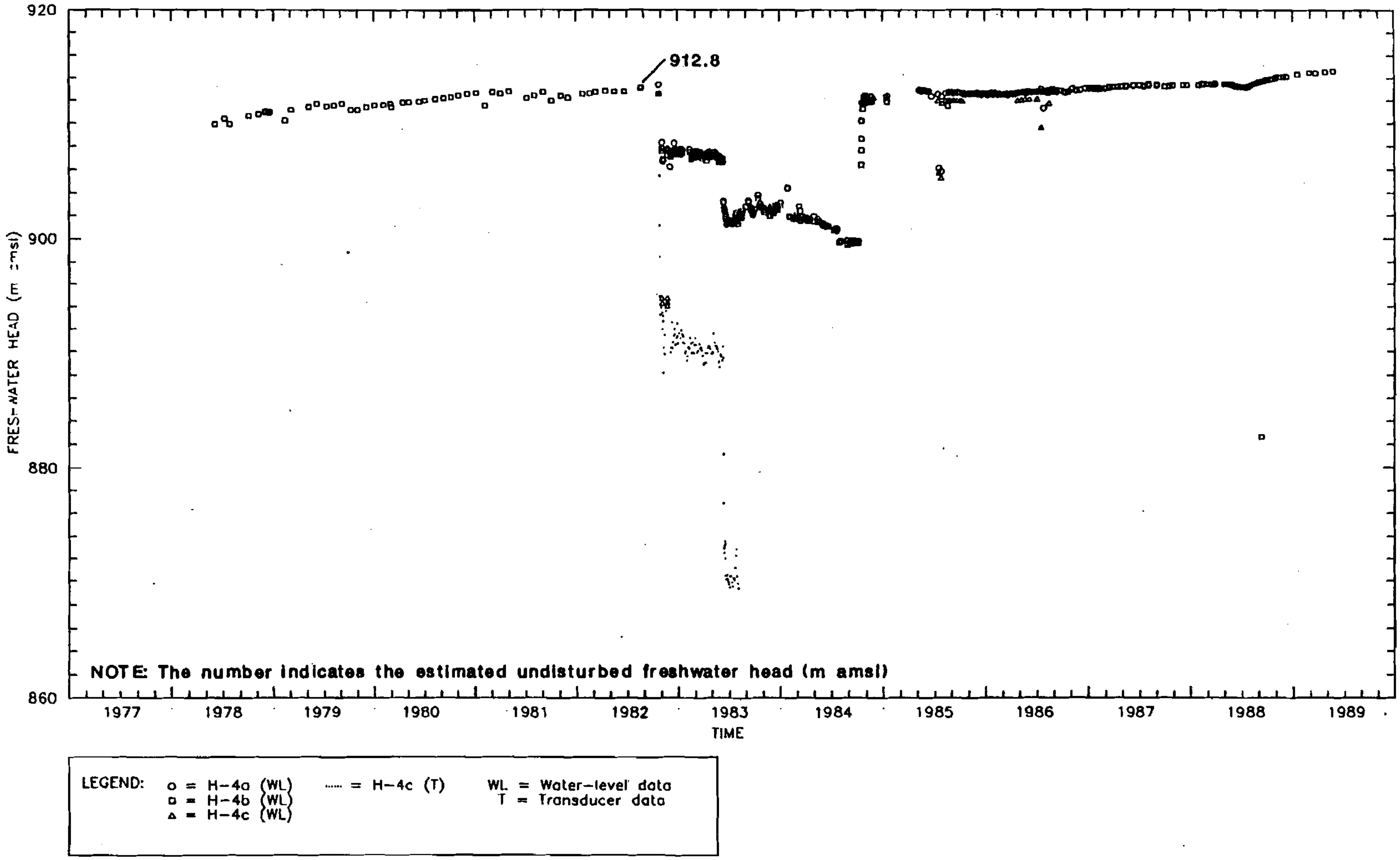


INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at the H-3 Hydropad	Figure G.3

H09700R869 ABW 10/11/89



INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the H-4 Hydropad

Figure G.4

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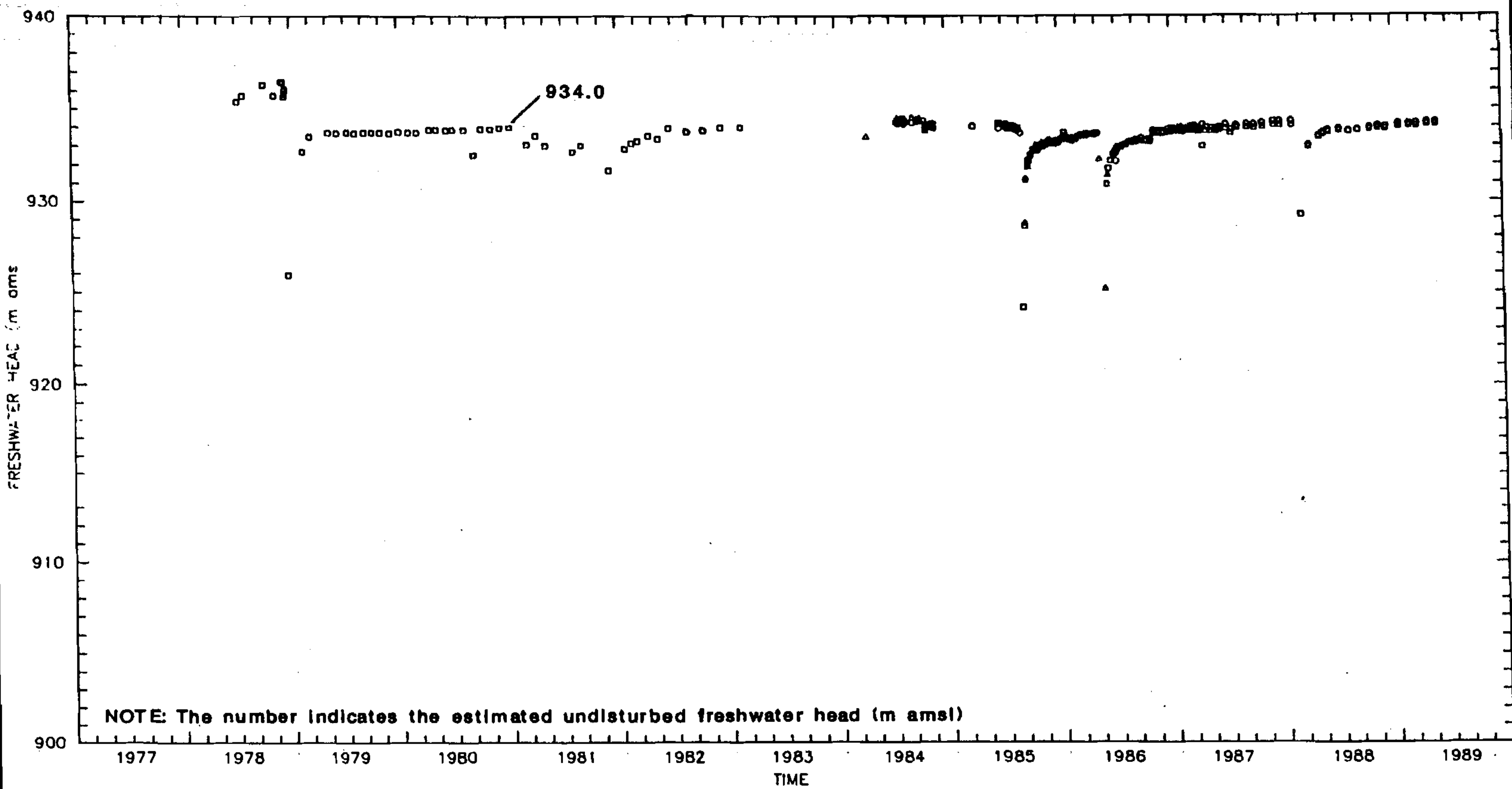
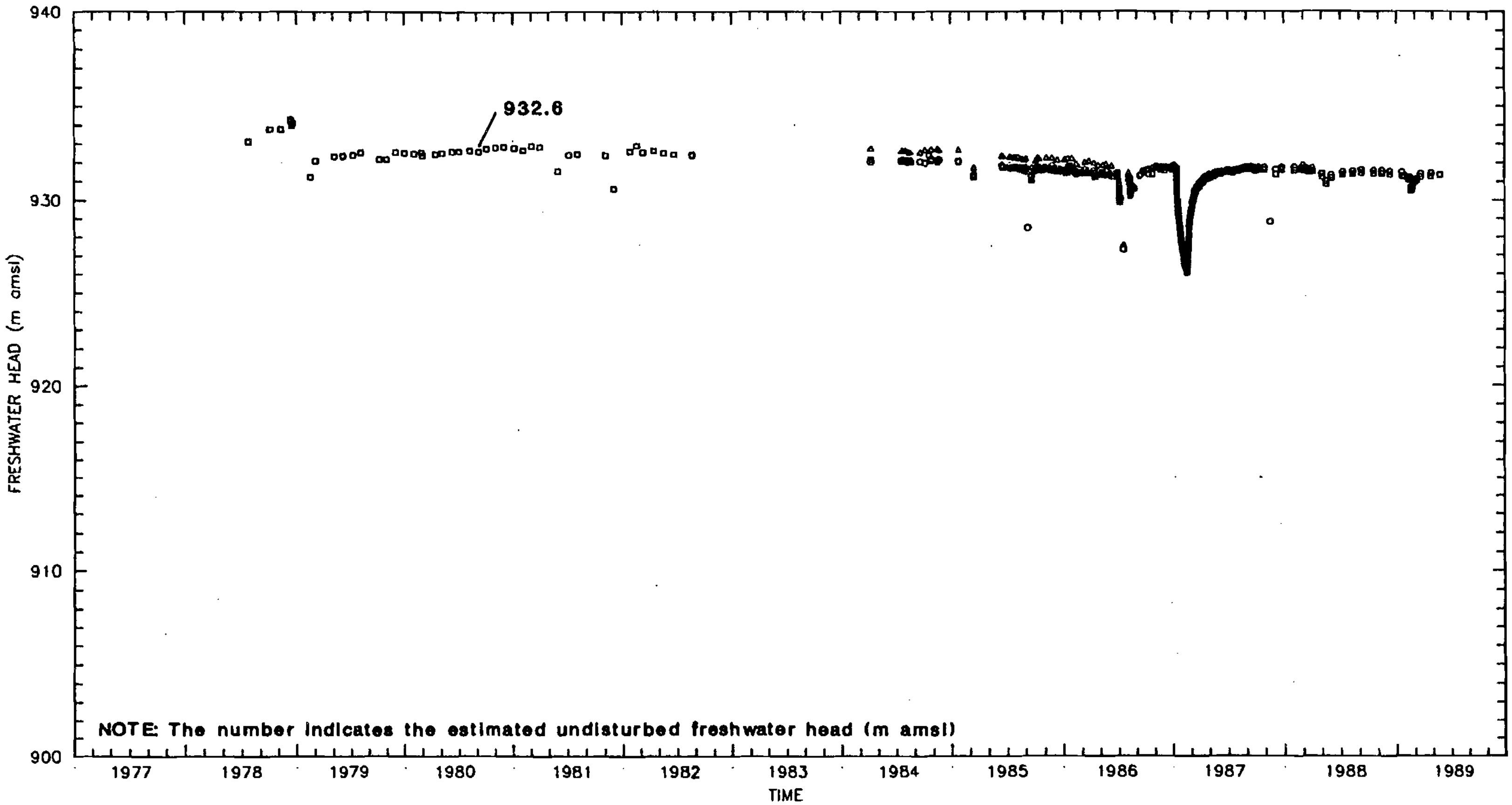


LEGEND: o = H-5a (WL)
□ = H-5b (WL)
△ = H-5c (WL)

WL = Water-level data

INTERA Technologies | Equivalent Freshwater Elevations for the Culebra Dolomite at the H-5 Hydropad | Figure G.5

H09700R869 ABW 10/11/89



LEGEND: o = H-6a (WL)
□ = H-6b (WL)
△ = H-6c (WL)

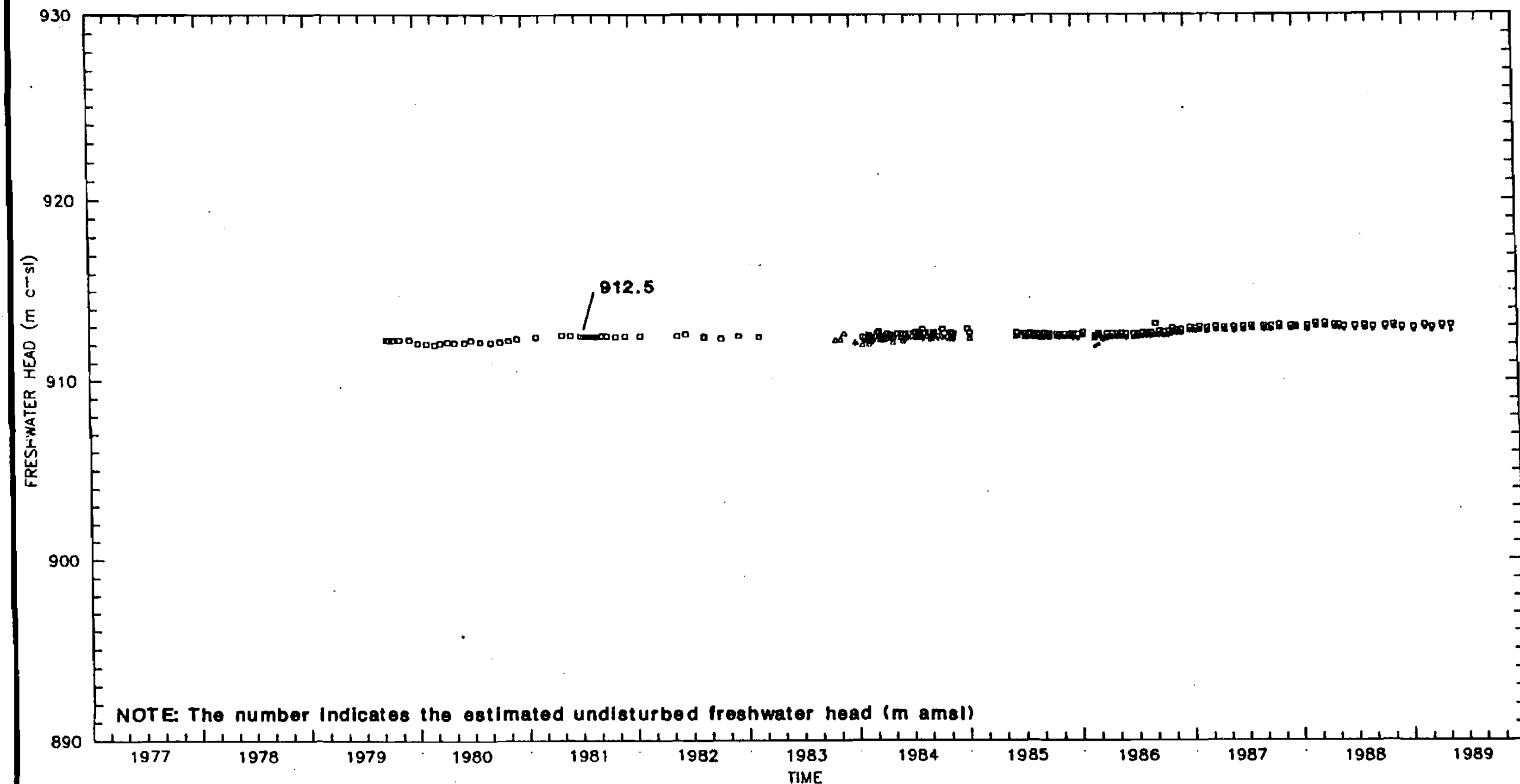
WL = Water-level data

INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the H-6 Hydropad

Figure G.6

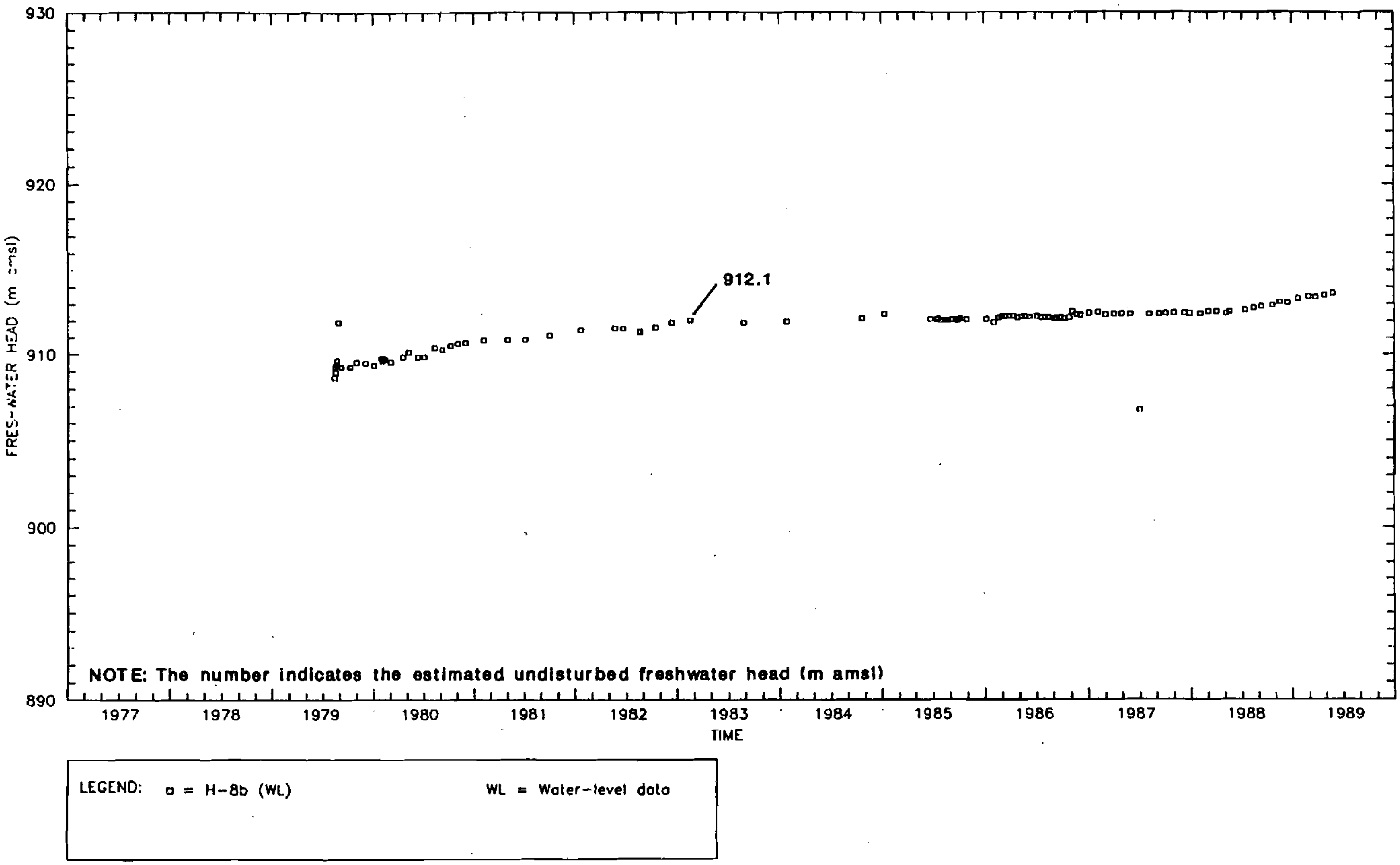
H09700R669 ABW 10/11/89



LEGEND: □ = H-7b1 (WL) • = H-7b2 (WL) △ = H-7c (WL)   WL = Water-level data

INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at the H-7 Hydropad	Figure G.7

H09700R869 ABW 10/11/89

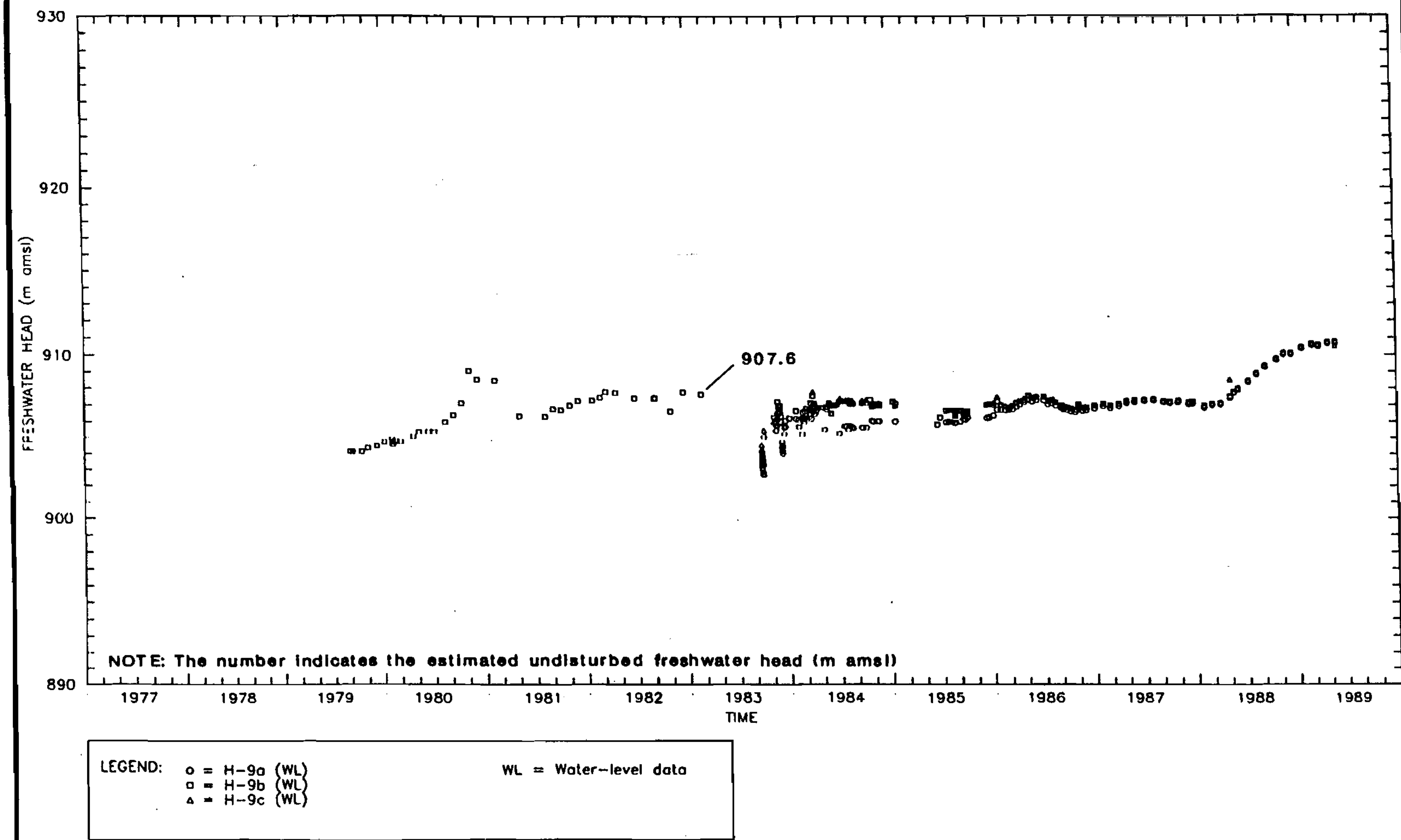


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the H-8 Hydropad

Figure G.8

H09700R869 ABW 10/11/89

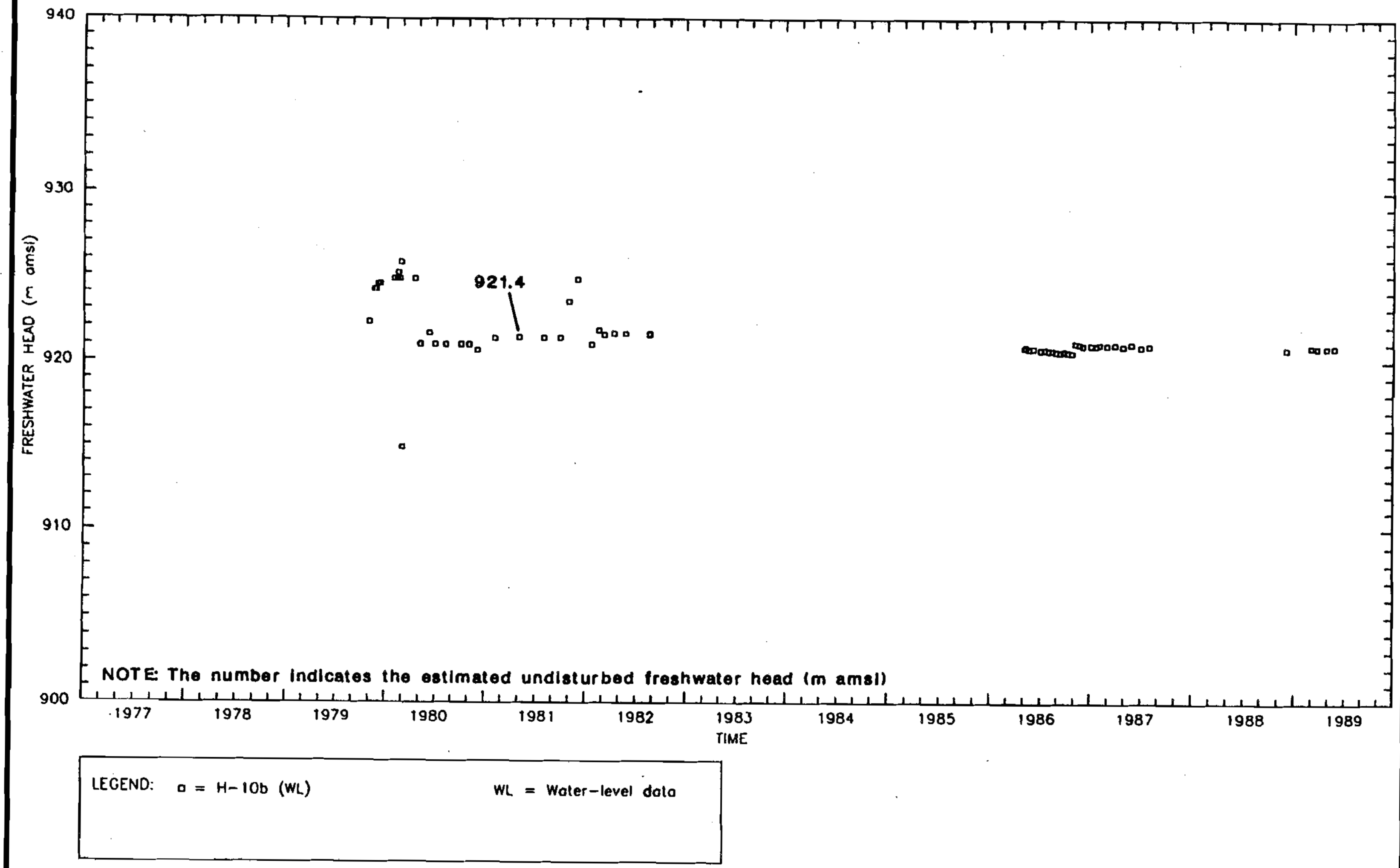


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the H-9 Hydropad

Figure G.9

H09700R869 ABW 10/11/89

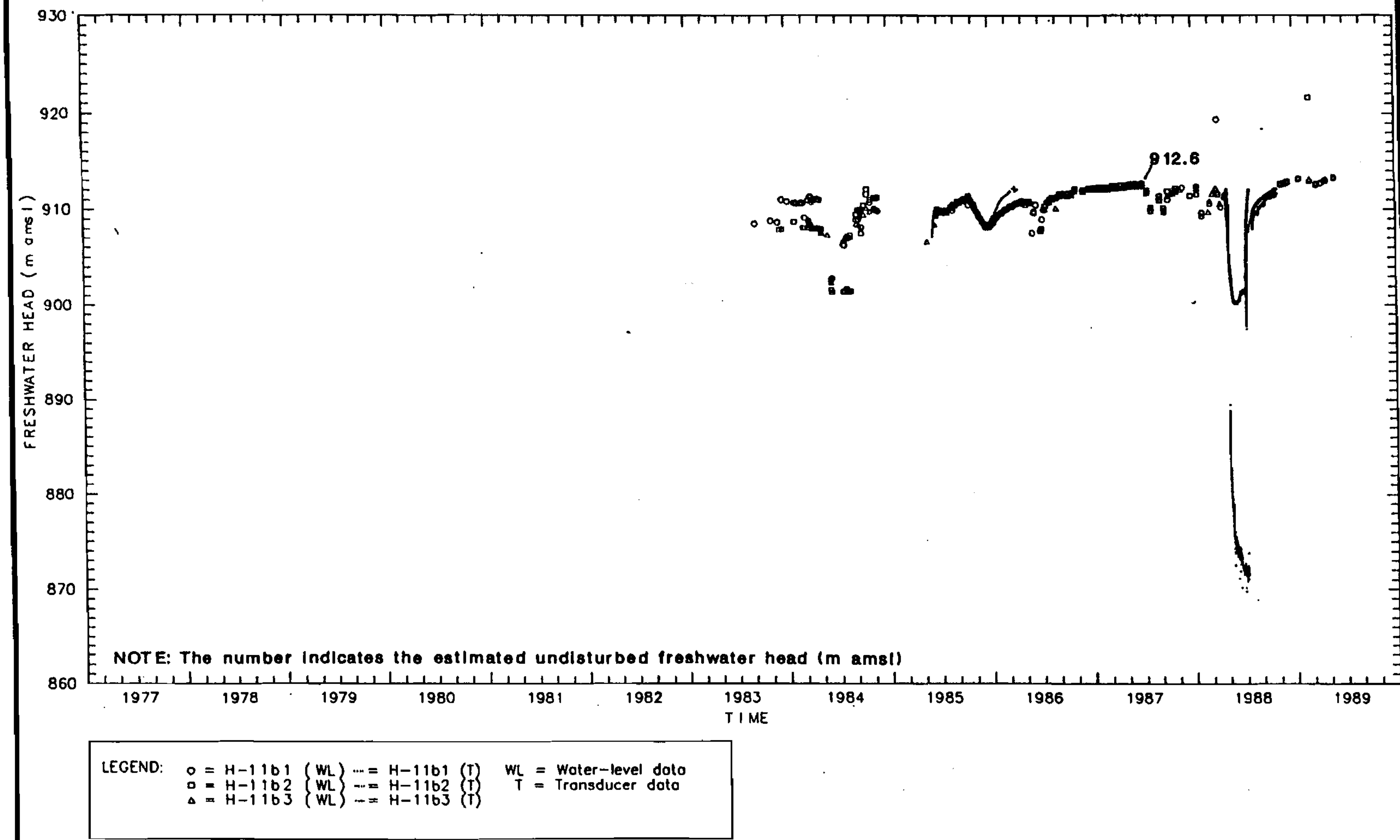


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the H-10 Hydropad

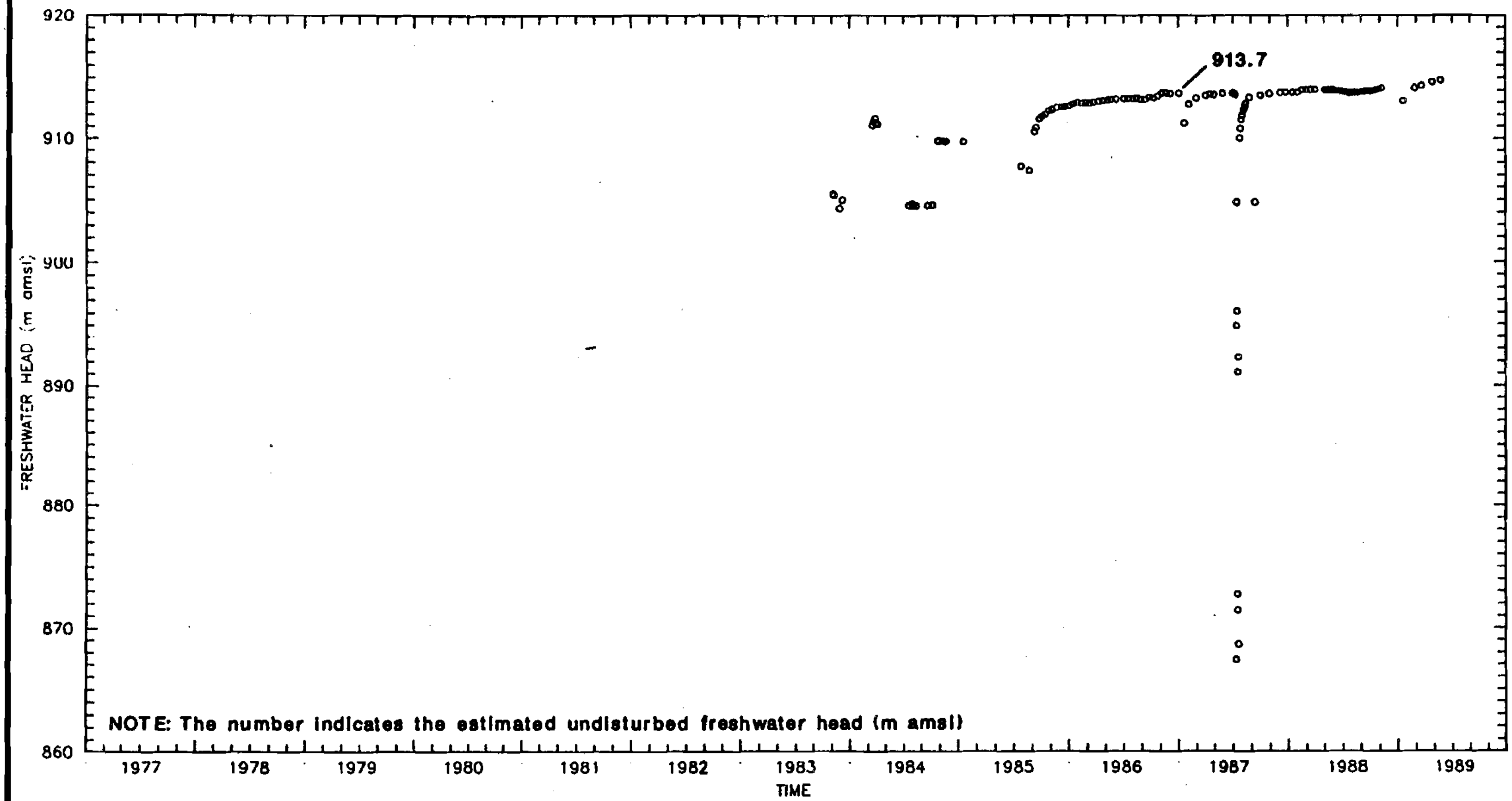
Figure G.10

H09700R869 ABW 10/11/89



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at the H-11 Hydropad	Figure G.11

H09700R869 ABW 10/11/89



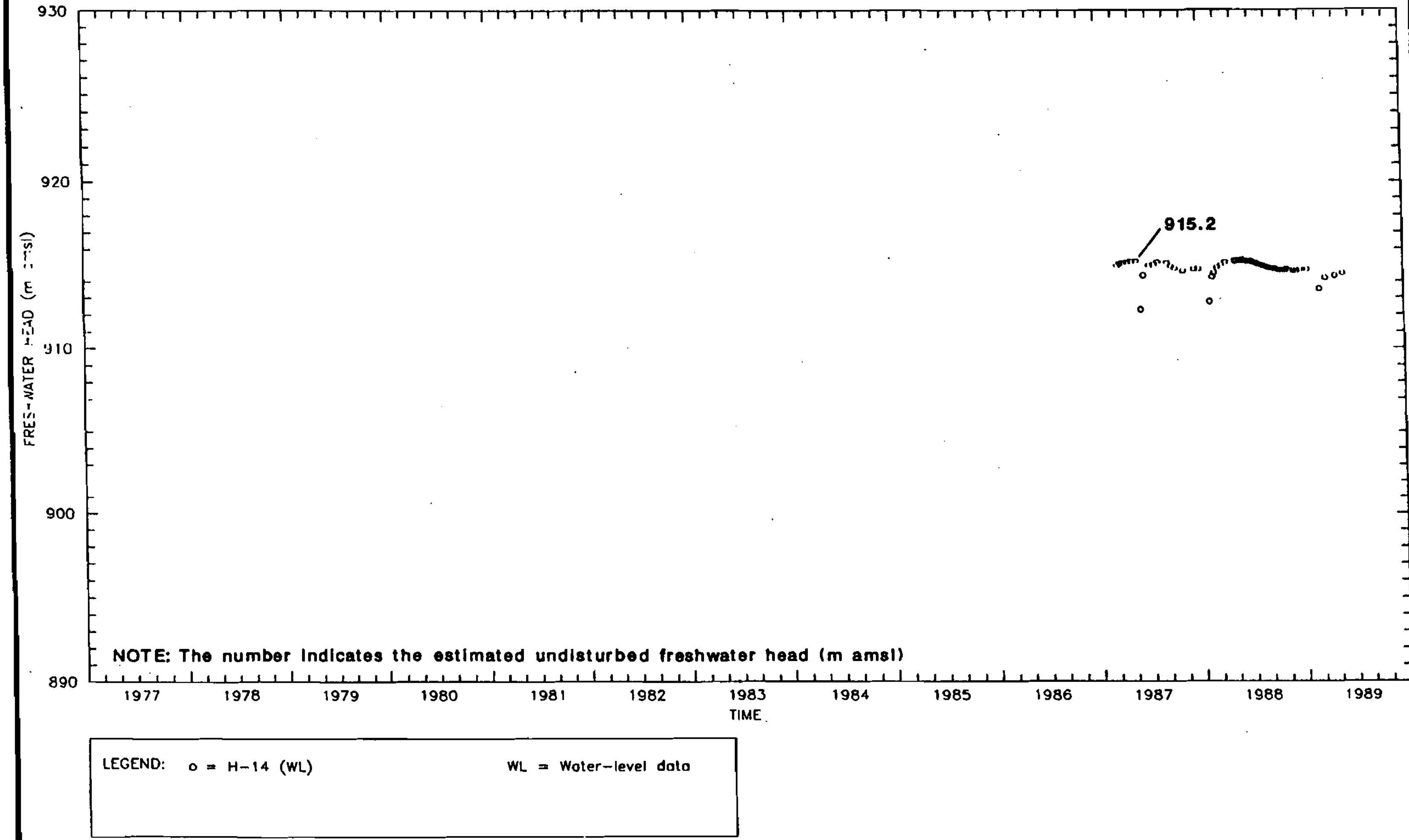
LEGEND: o = H-12 (WL)   WL = Water-level data

INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-12

Figure G.12

H09700R869 ABW 10/11/89

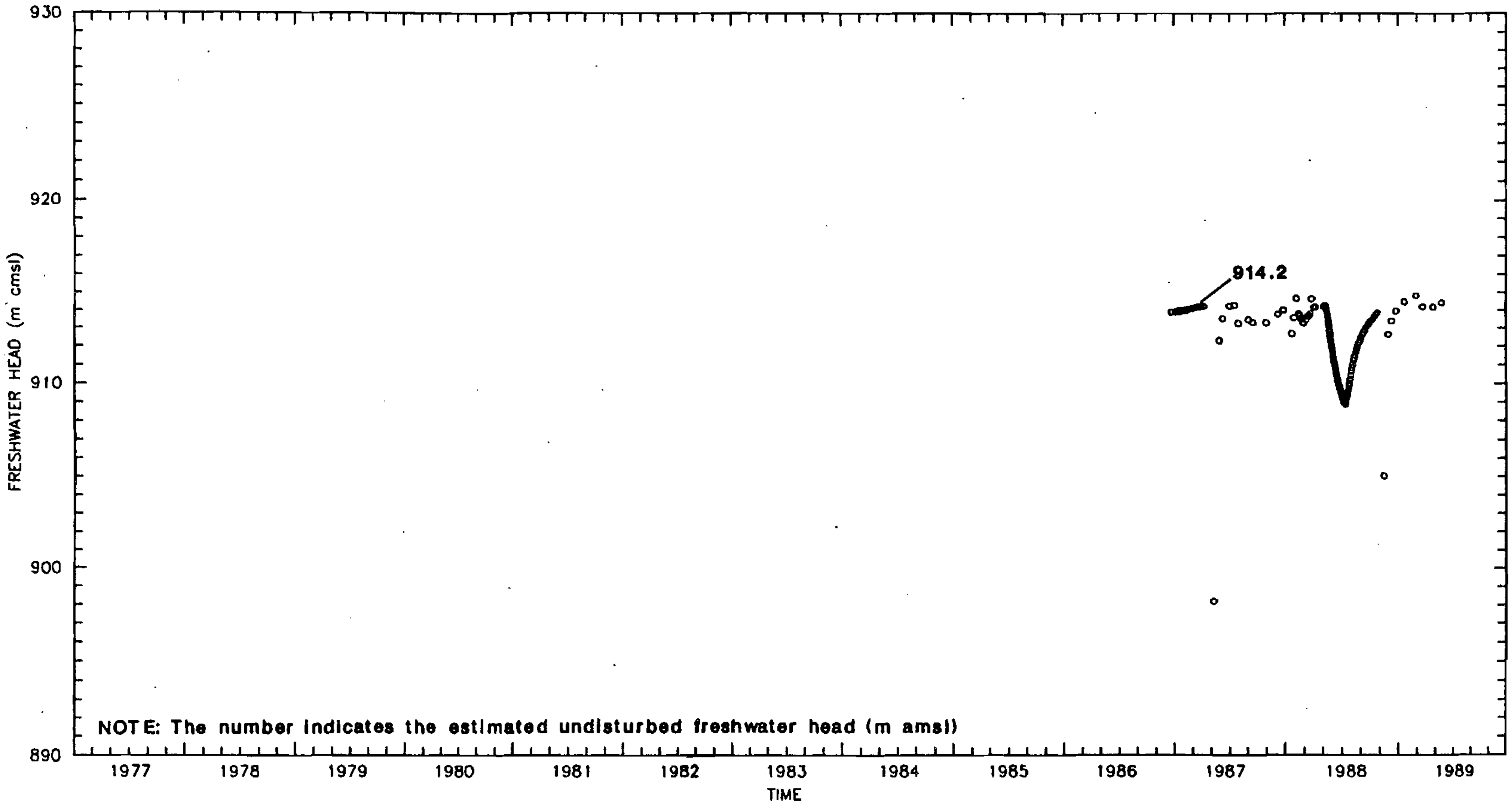


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-14

Figure G.13

H09700R869 ABW 10/11/89



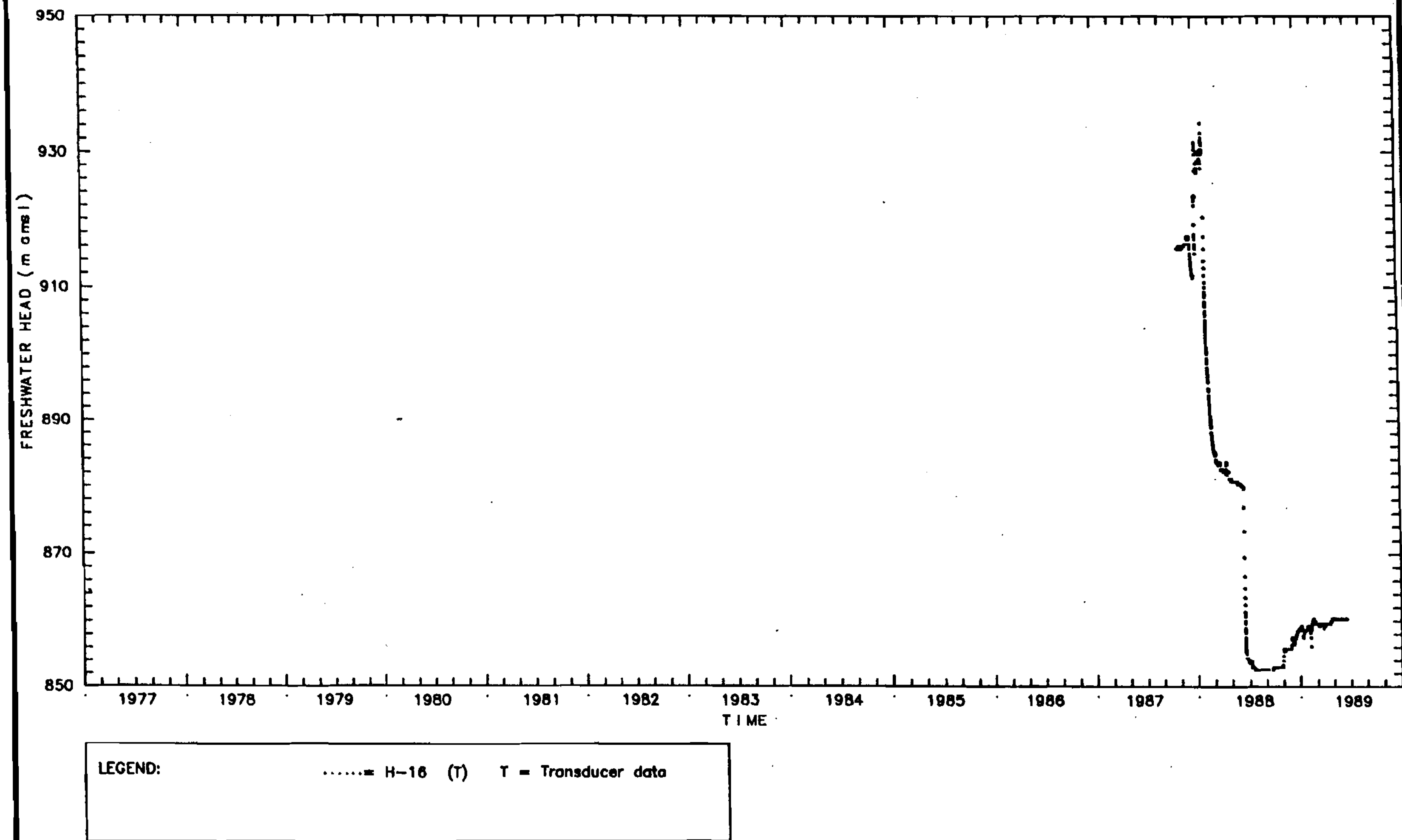
LEGEND: o = H-15 (WL) WL = Water-level data

INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-15

Figure G.14

H09700R869 ABW 10/11/89

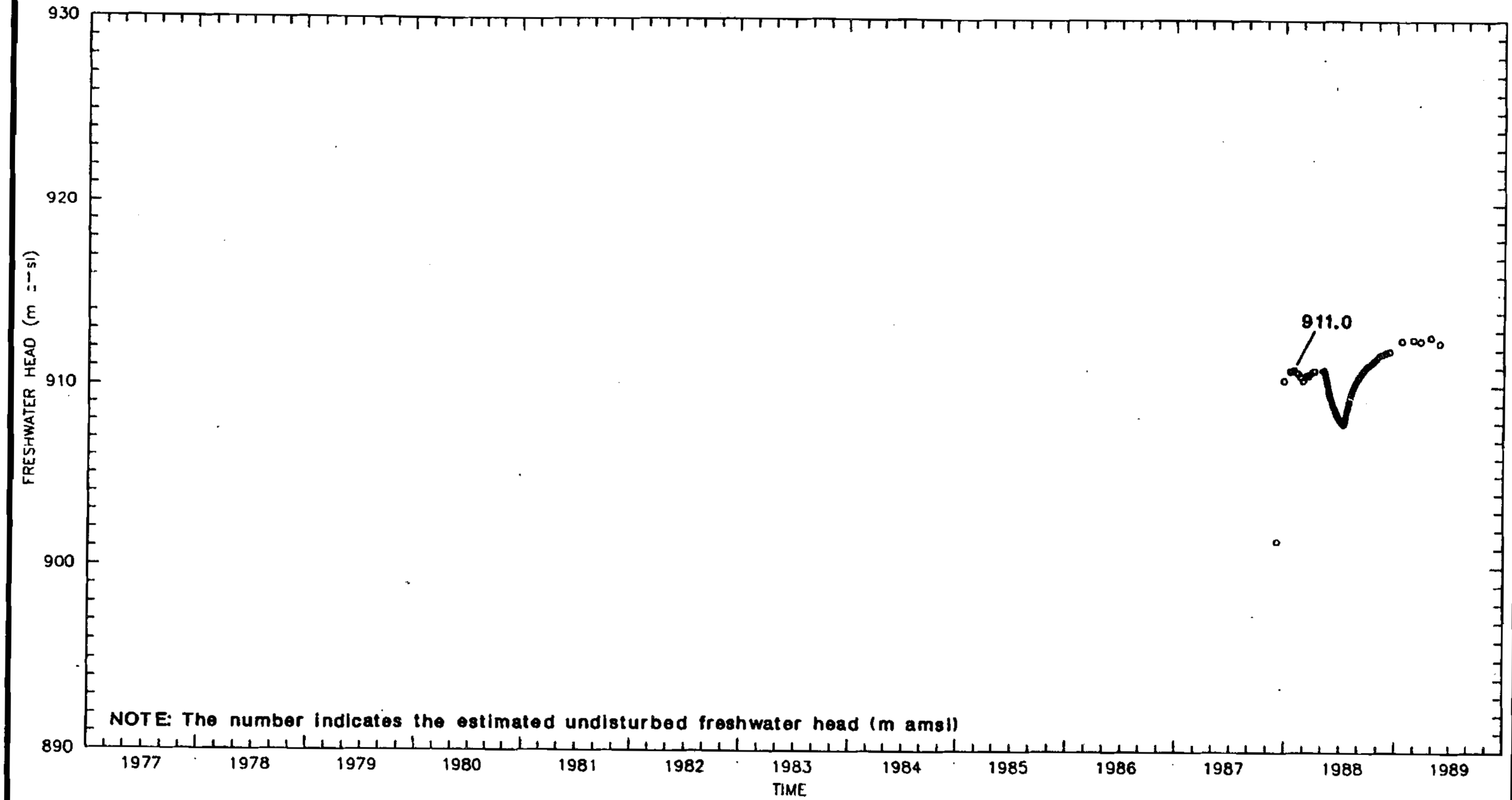


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-16

Figure G.15

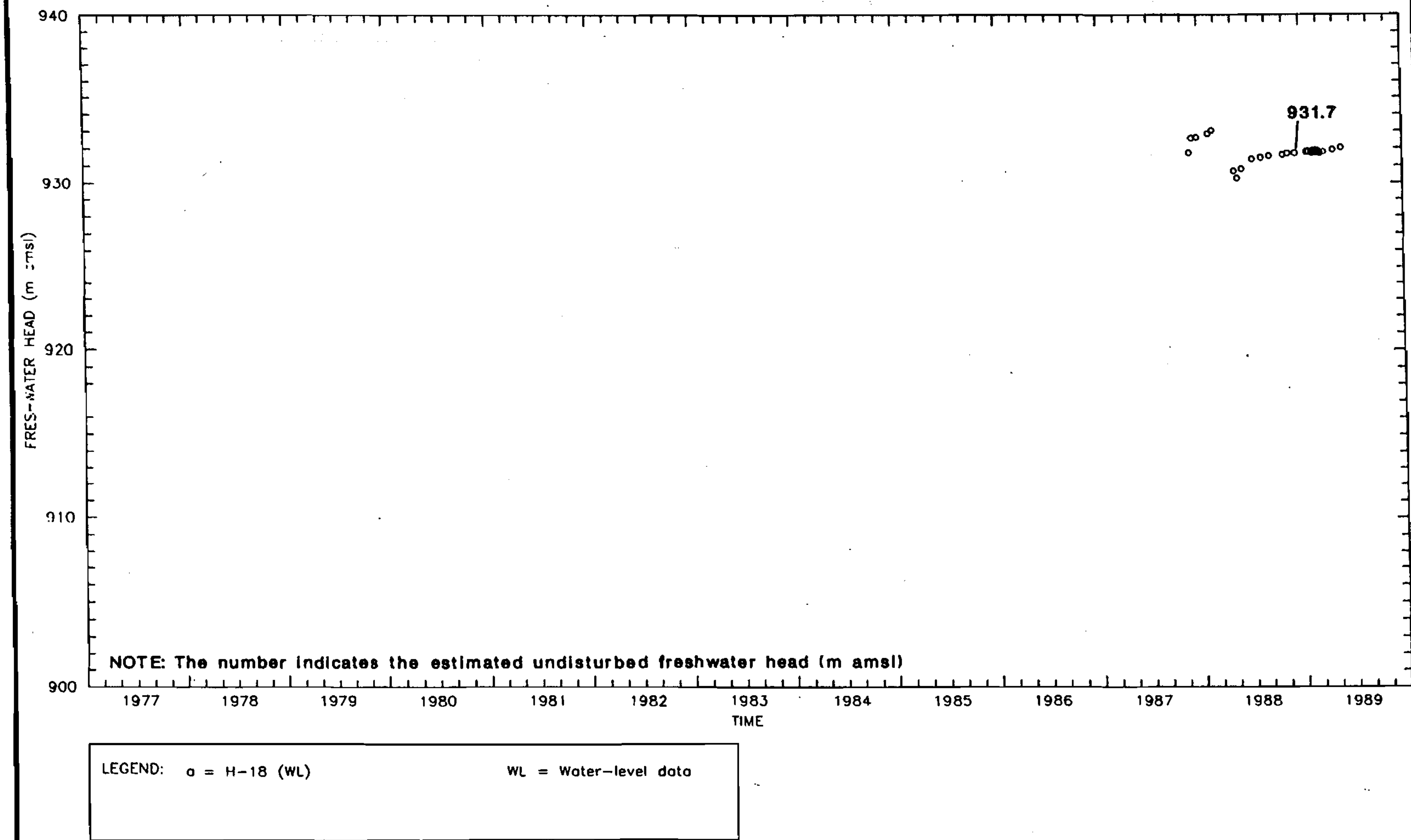
H09700R869 ABW 11/13/89



LEGEND: o = H-17 (WL) WL = Water-level data

INTERA Technologies | Equivalent Freshwater Elevations for the Culebra Dolomite at Well H-17 | Figure G.16

H09700R869 ABW 10/11/89

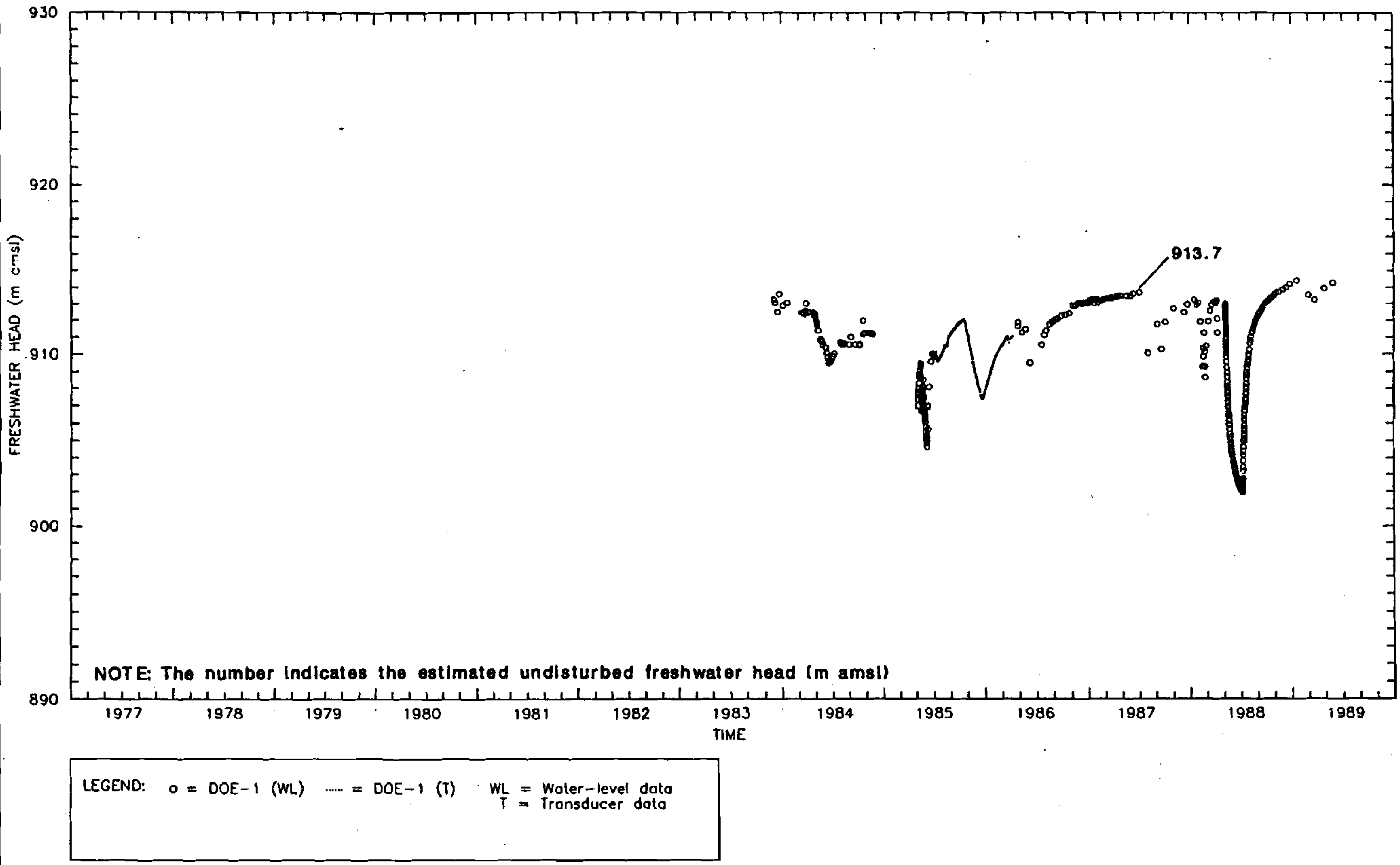


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at the Well H-18

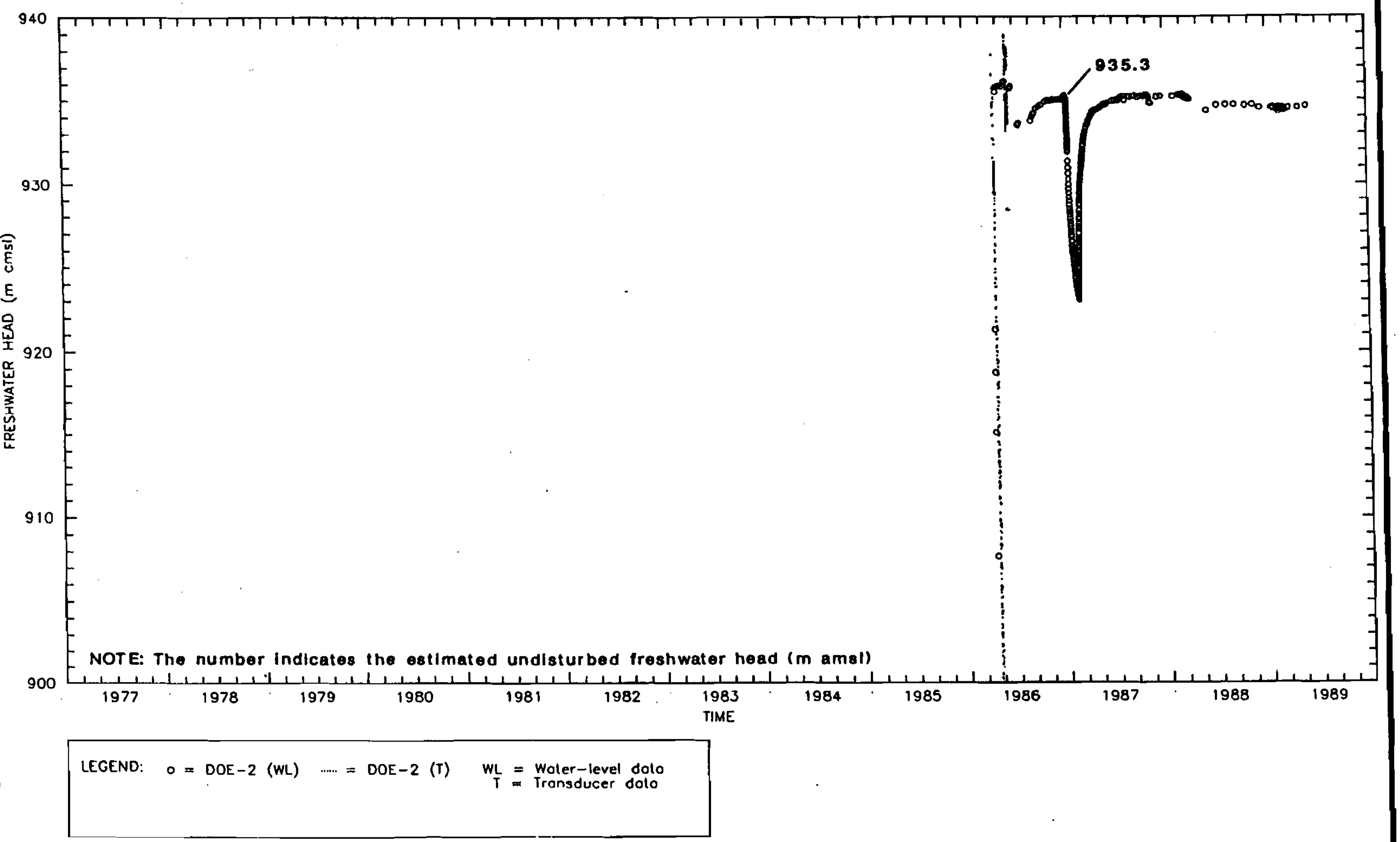
Figure G.17

H09700R869 ABW 10/11/89



INTERA Technologies | Equivalent Freshwater Elevations for the Culebra Dolomite at Well DOE-1 | Figure G.18

H09700R869 ABW 10/11/89

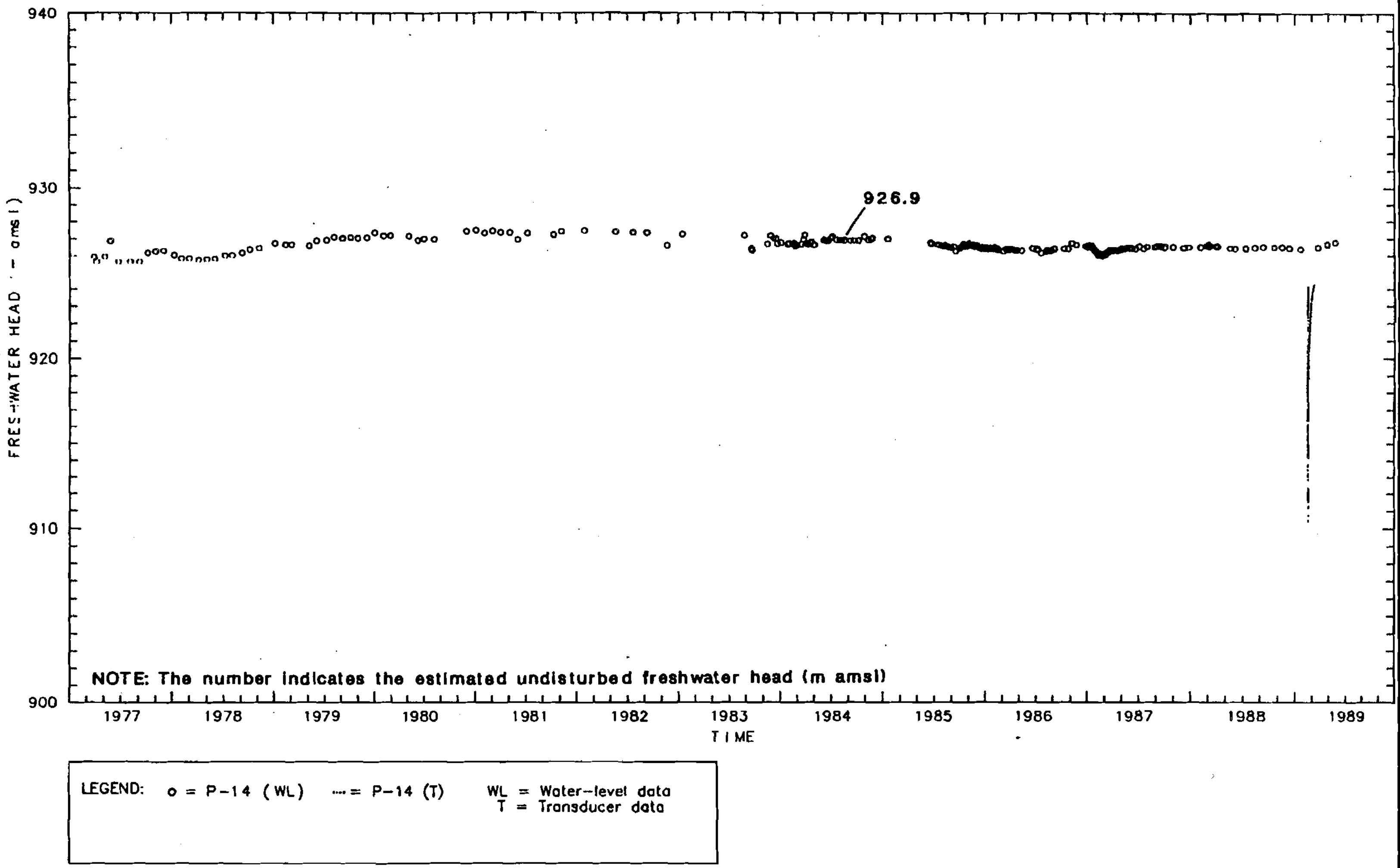


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well DOE-2

Figure G.19

H09700R869 ABW 10/11/89

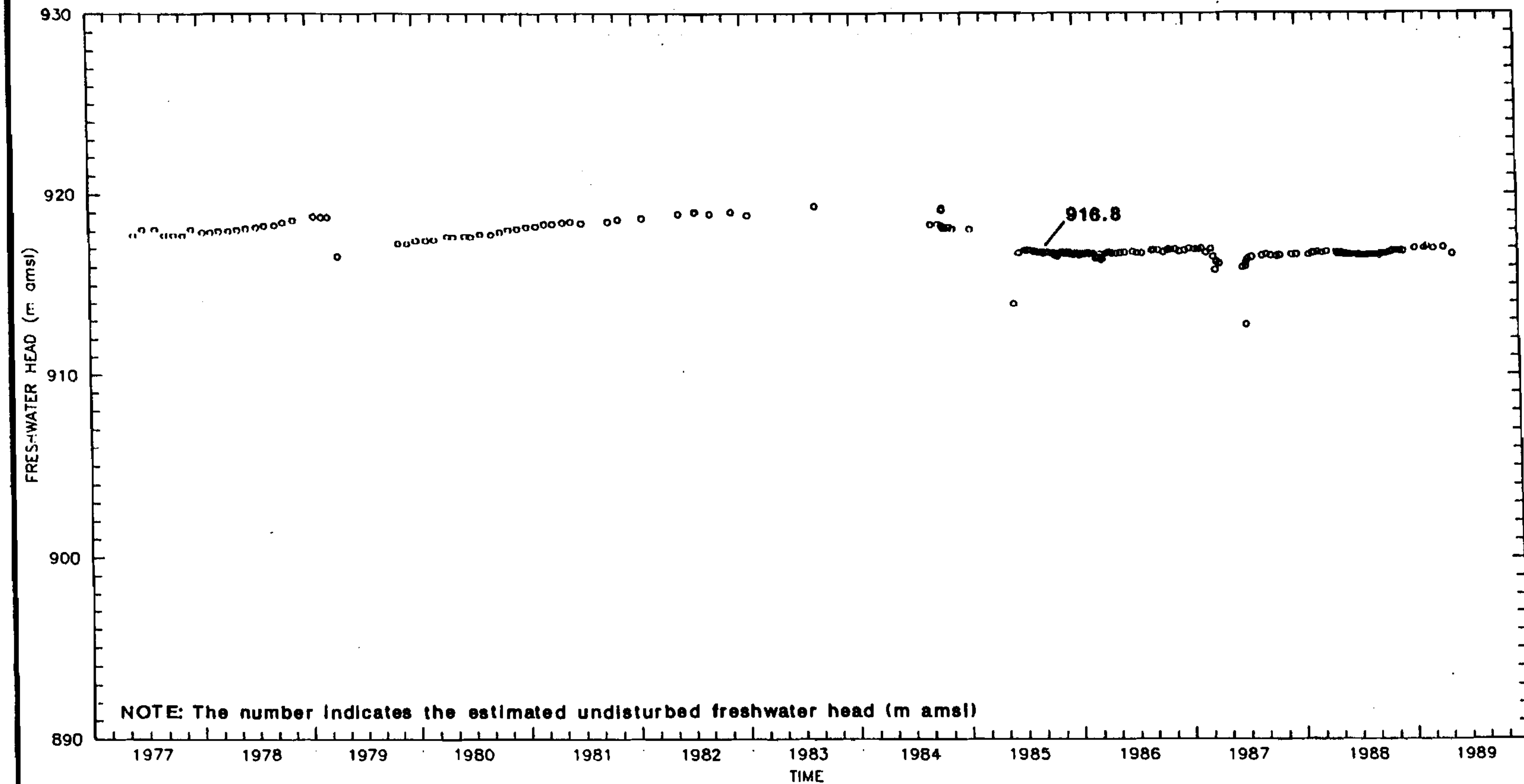


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well P-14

Figure G.20

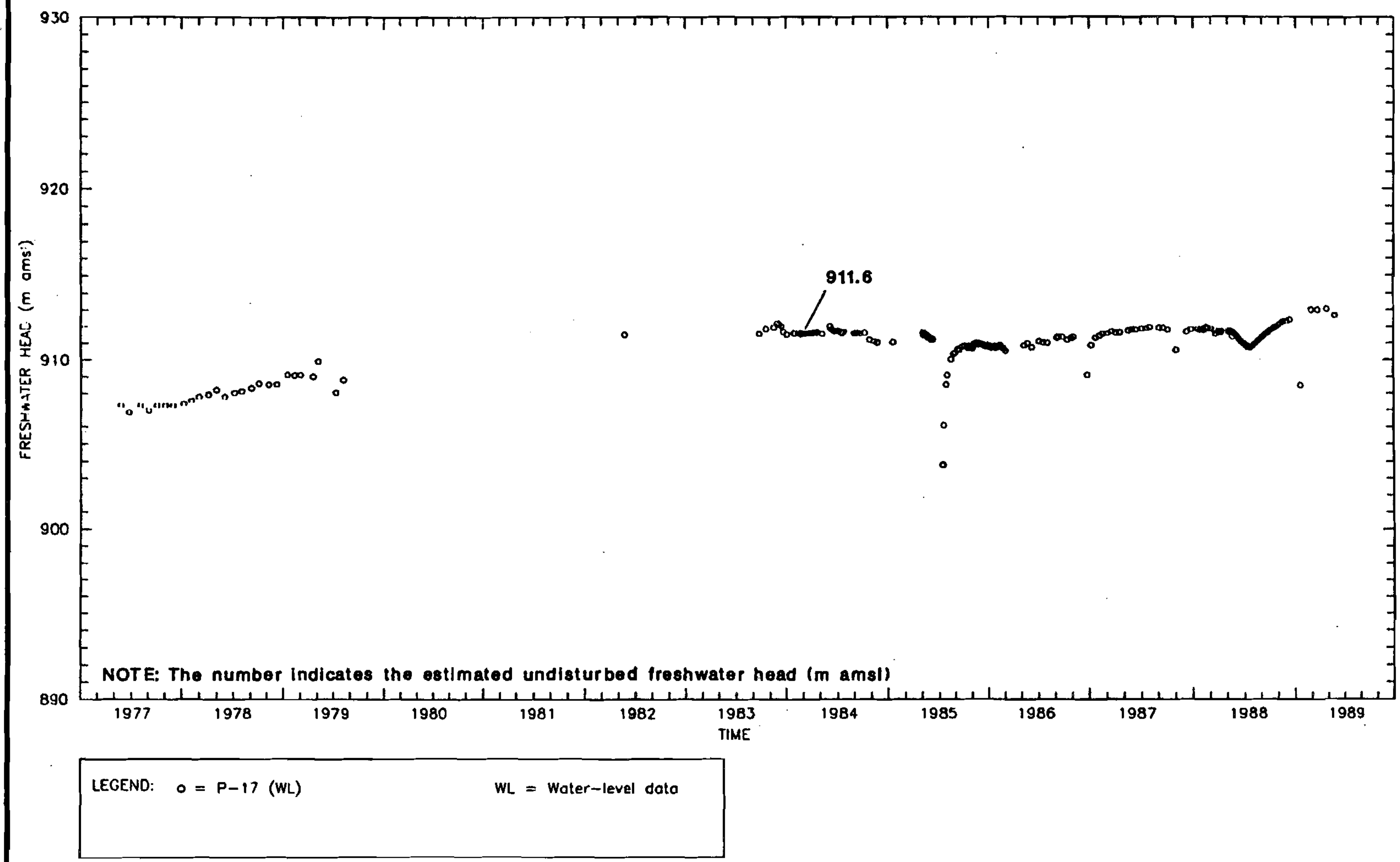
H09700R869 ABW 10/11/89



LEGEND: o = P-15 (WL) WL = Water-level data

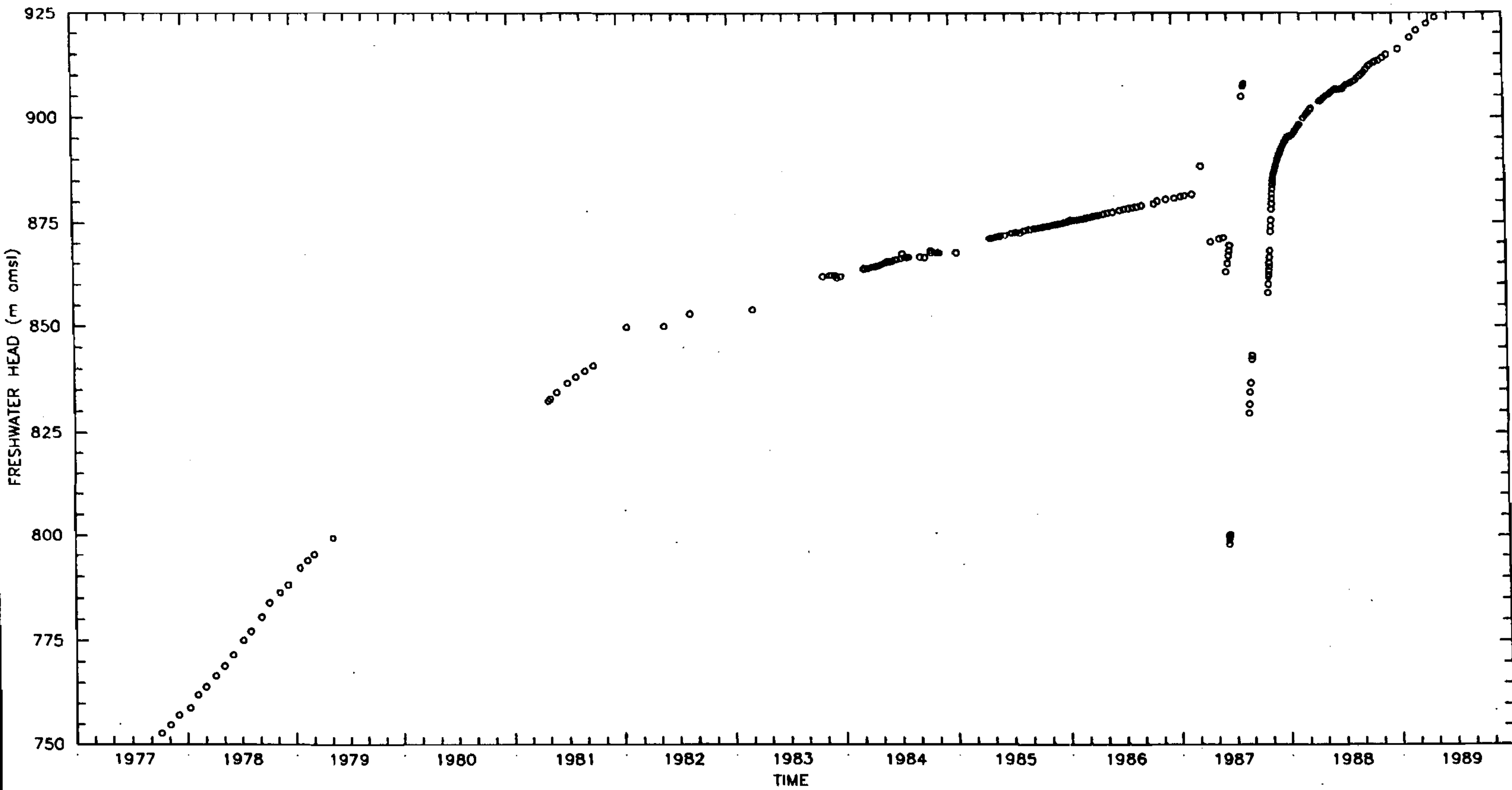
INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well P-15	Figure G.21

H09700R869 ABW 10/11/89



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well P-17	Figure G.22

H09700R869 ABW 10/11/89



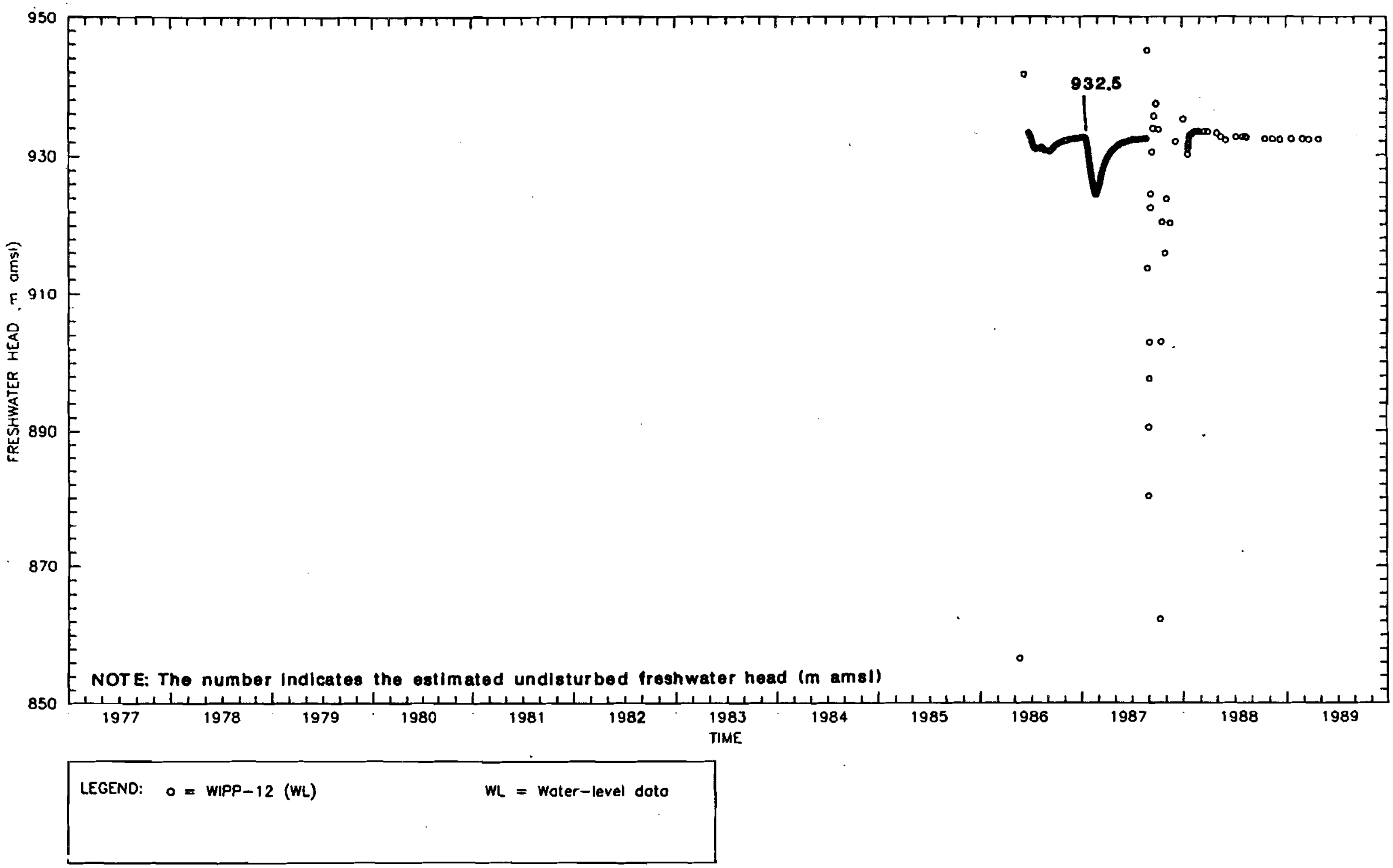
LEGEND: o = P-18 (WL) WL = Water-level data

INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well P-18

Figure G.23

H09700R869 ABW 10/11/89

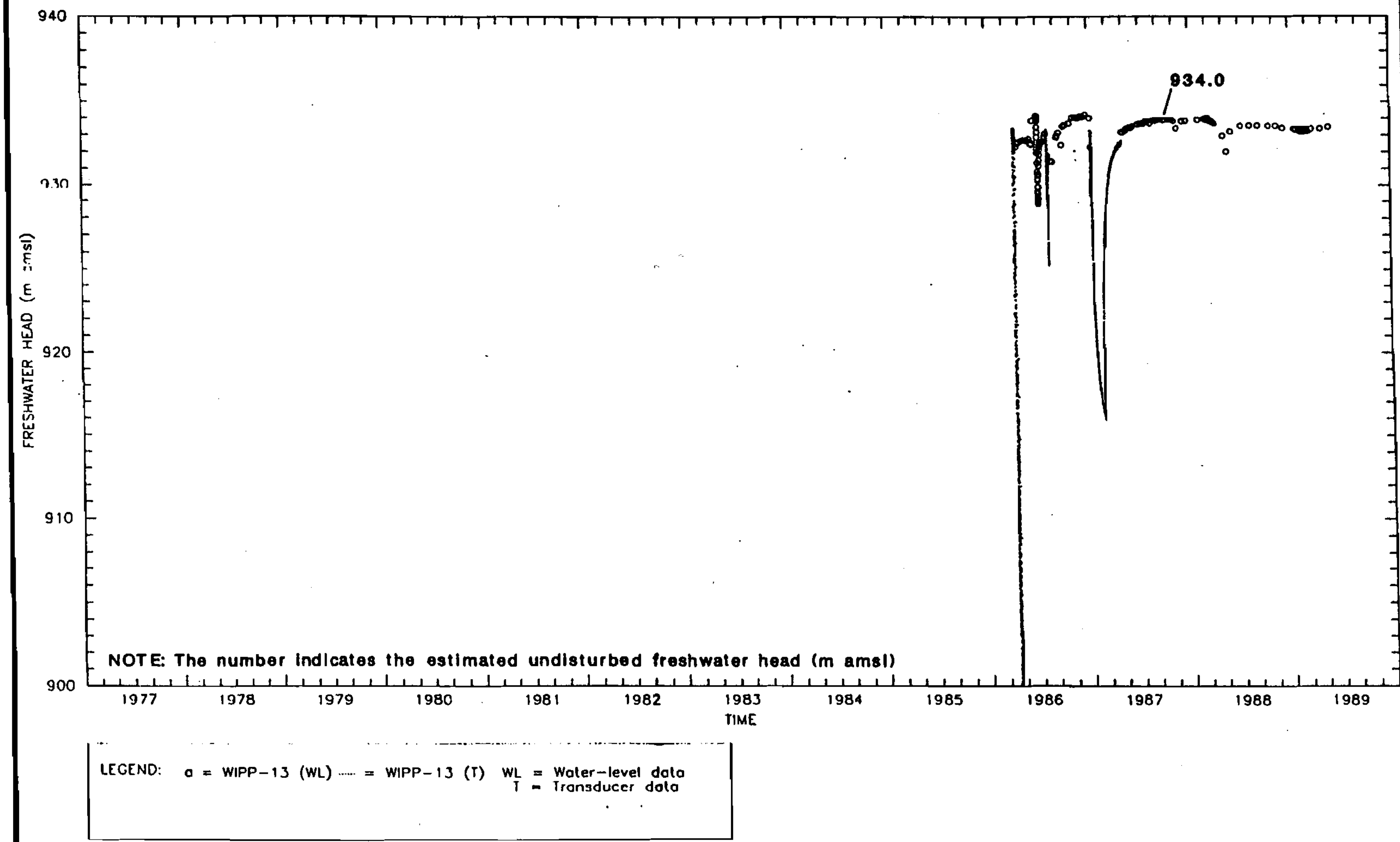


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-12

Figure G.24

H09700R869 ABW 10/11/89

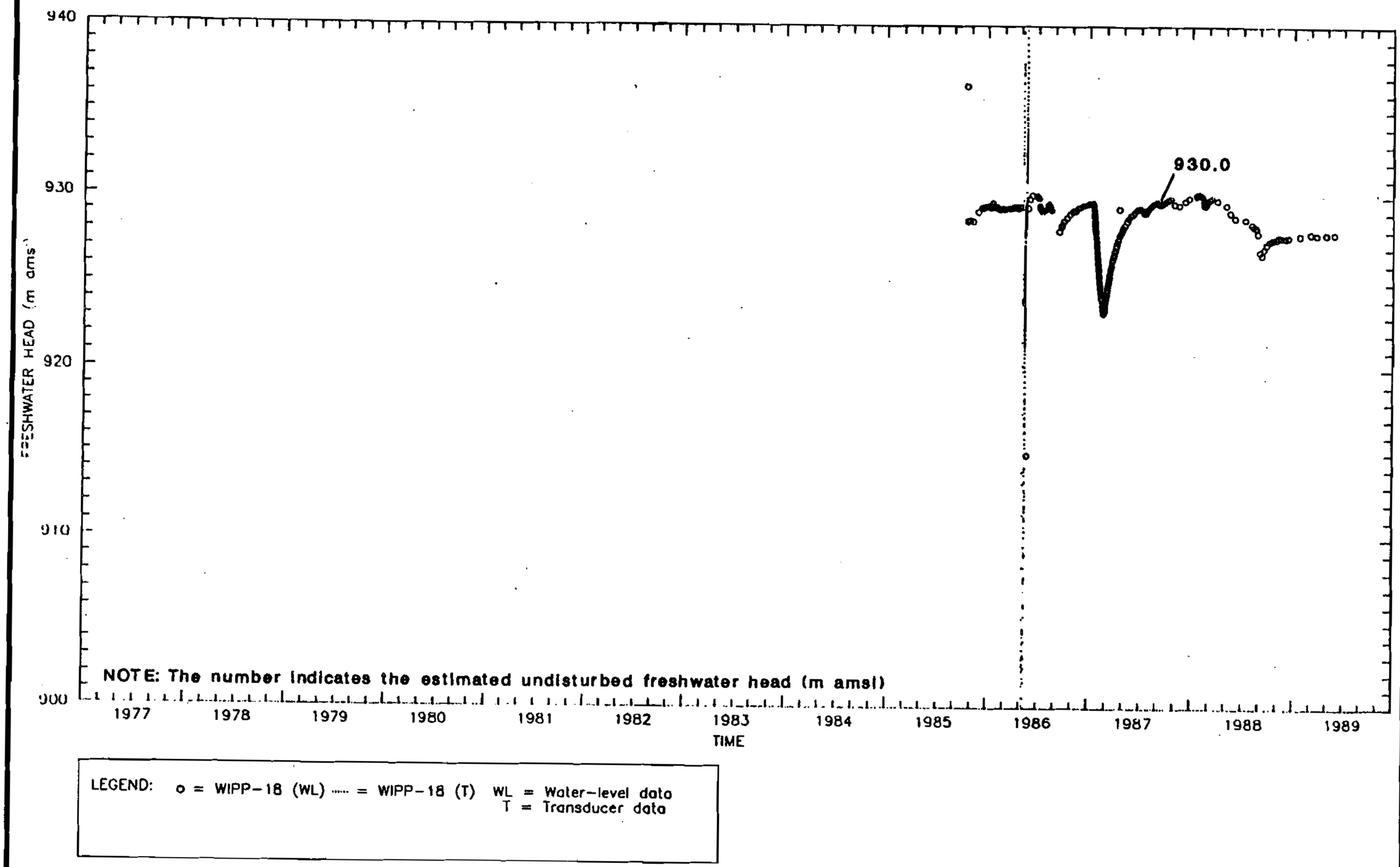


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-13

Figure G.25

H09700R669 ABW 10/11/89

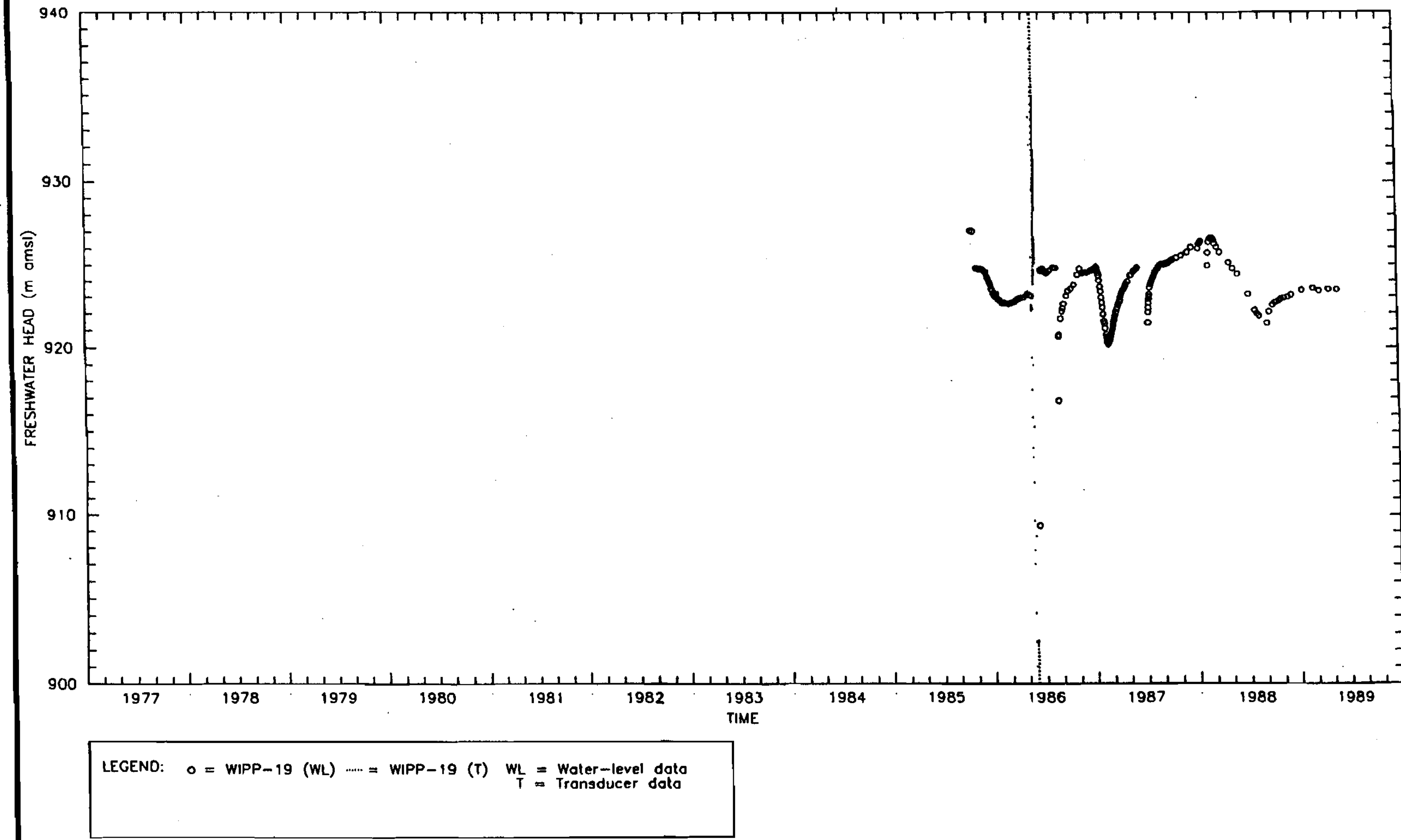


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-18

Figure G.26

H09700R869 ABW 10/11/89

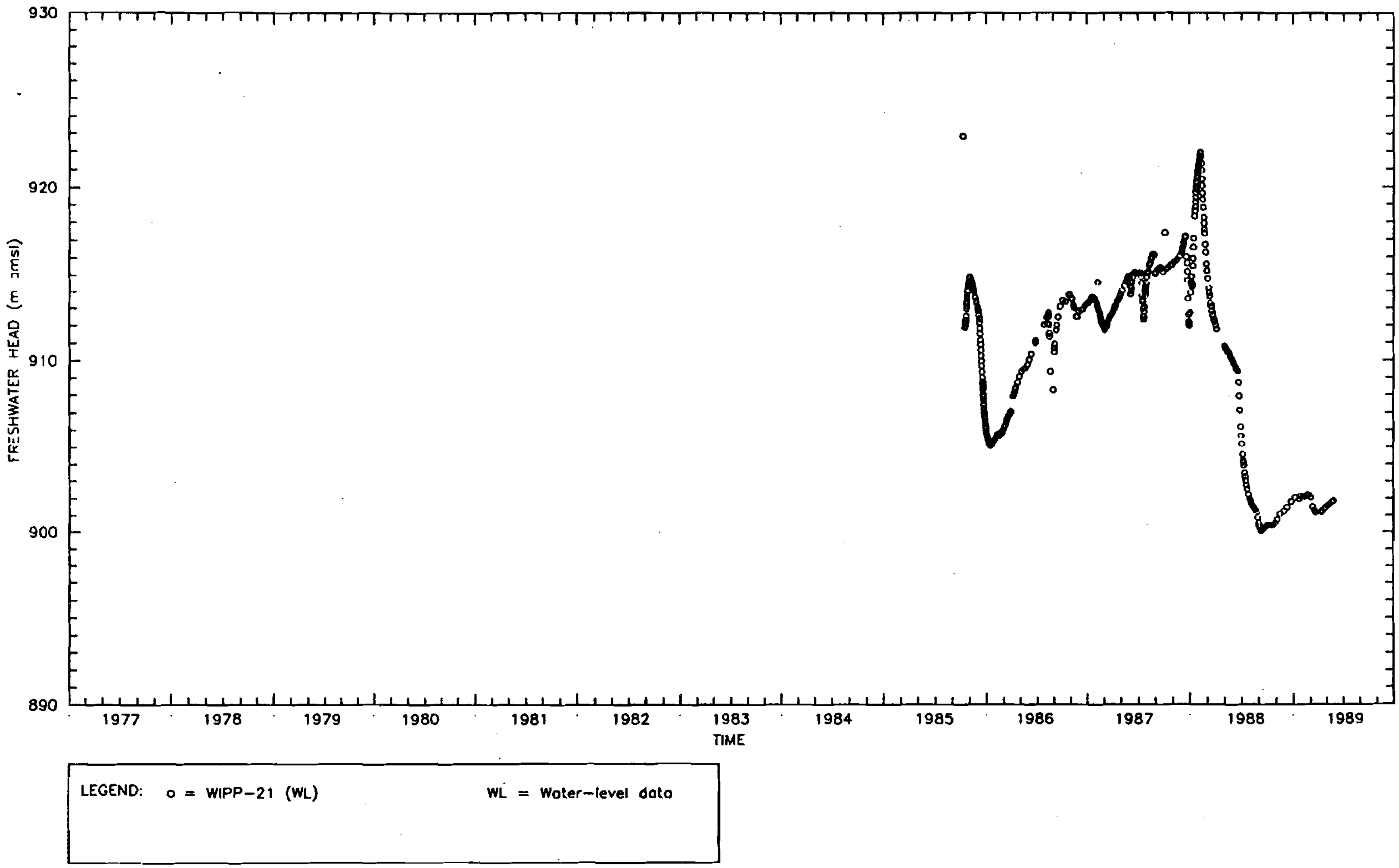


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-19

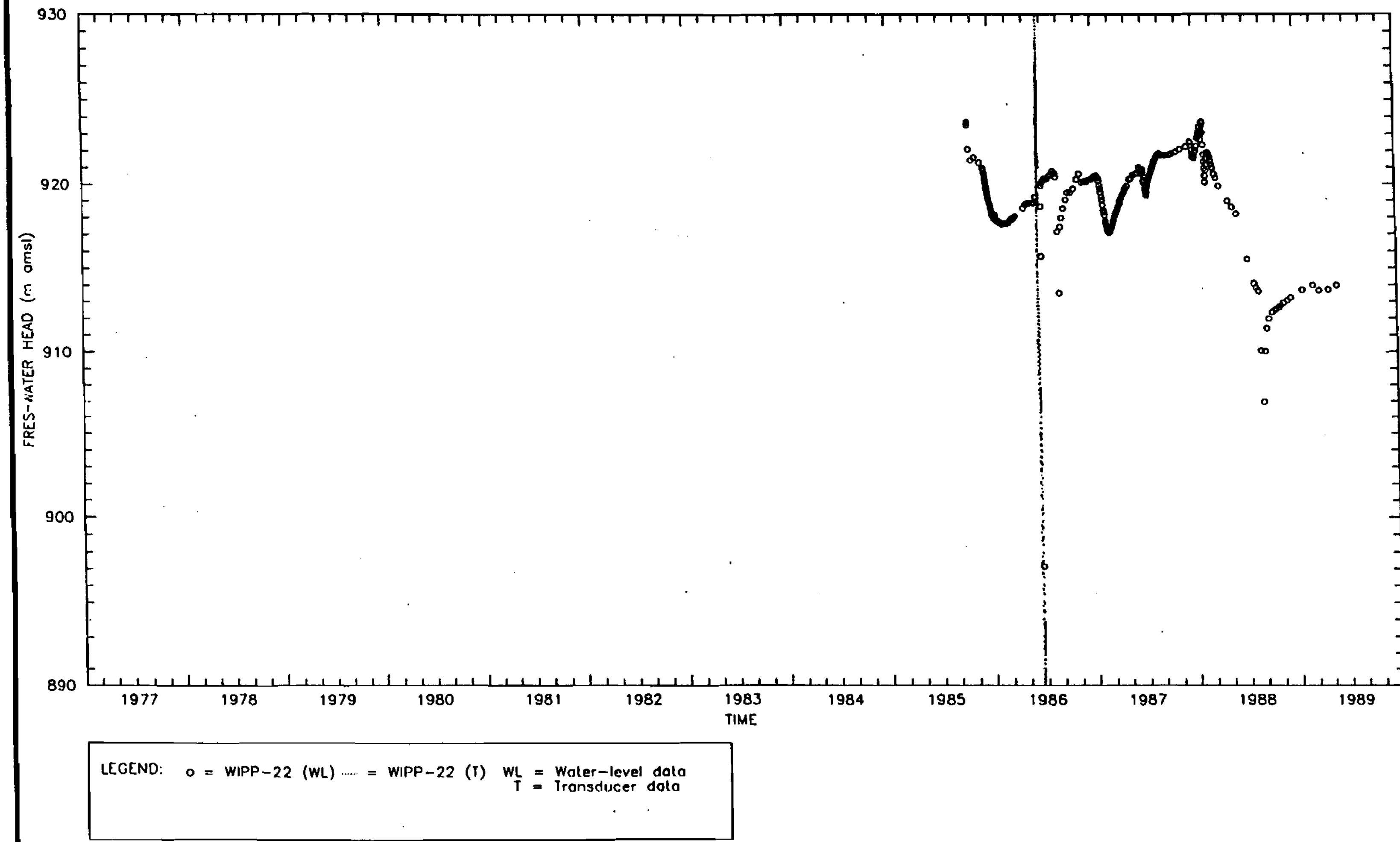
Figure G.27

H09700R869 ABW 10/11/89



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-21	Figure G.28

H09700R869 ABW 10/11/89

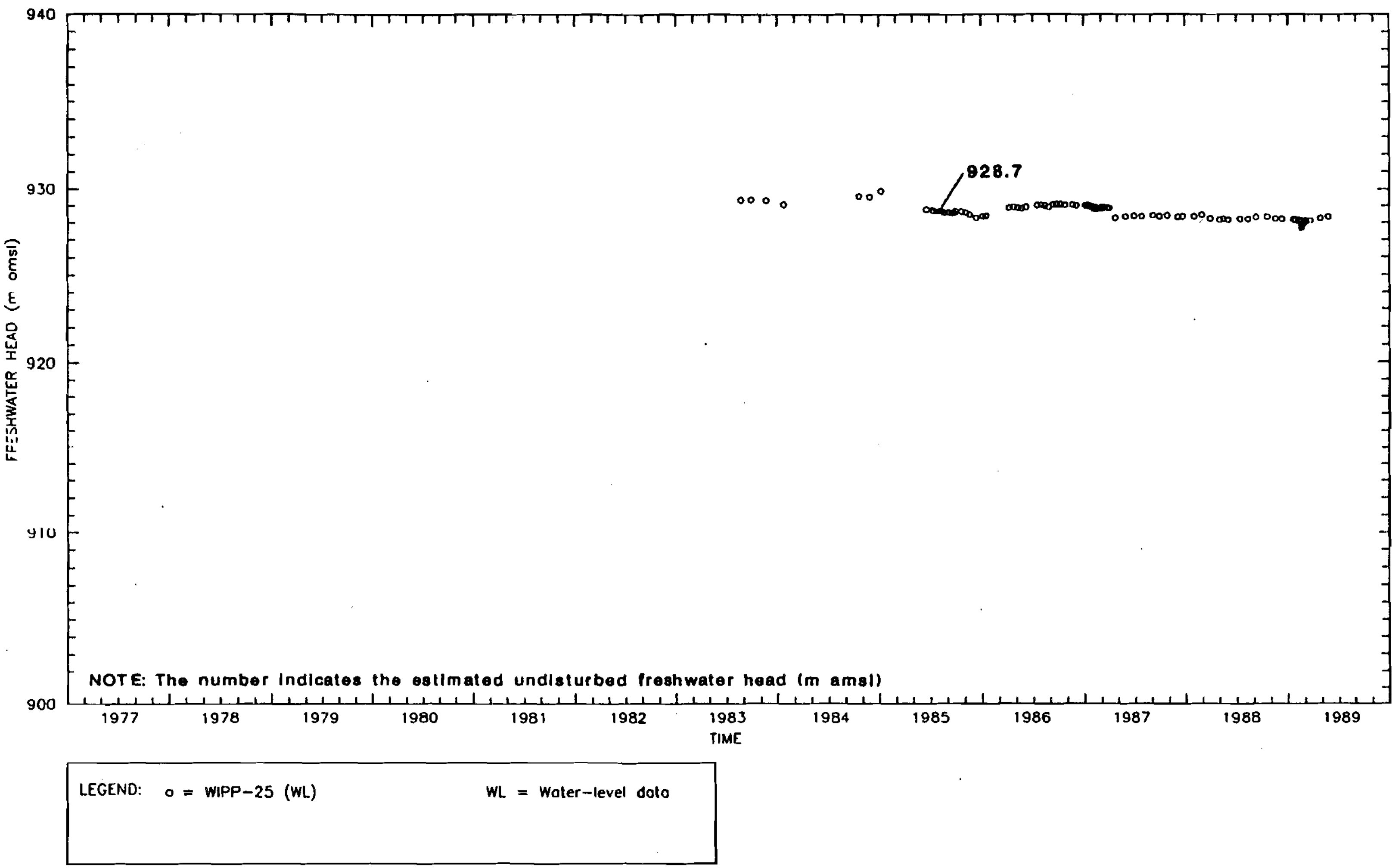


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-22

Figure G.29

H09700R669 ABW 10/11/89

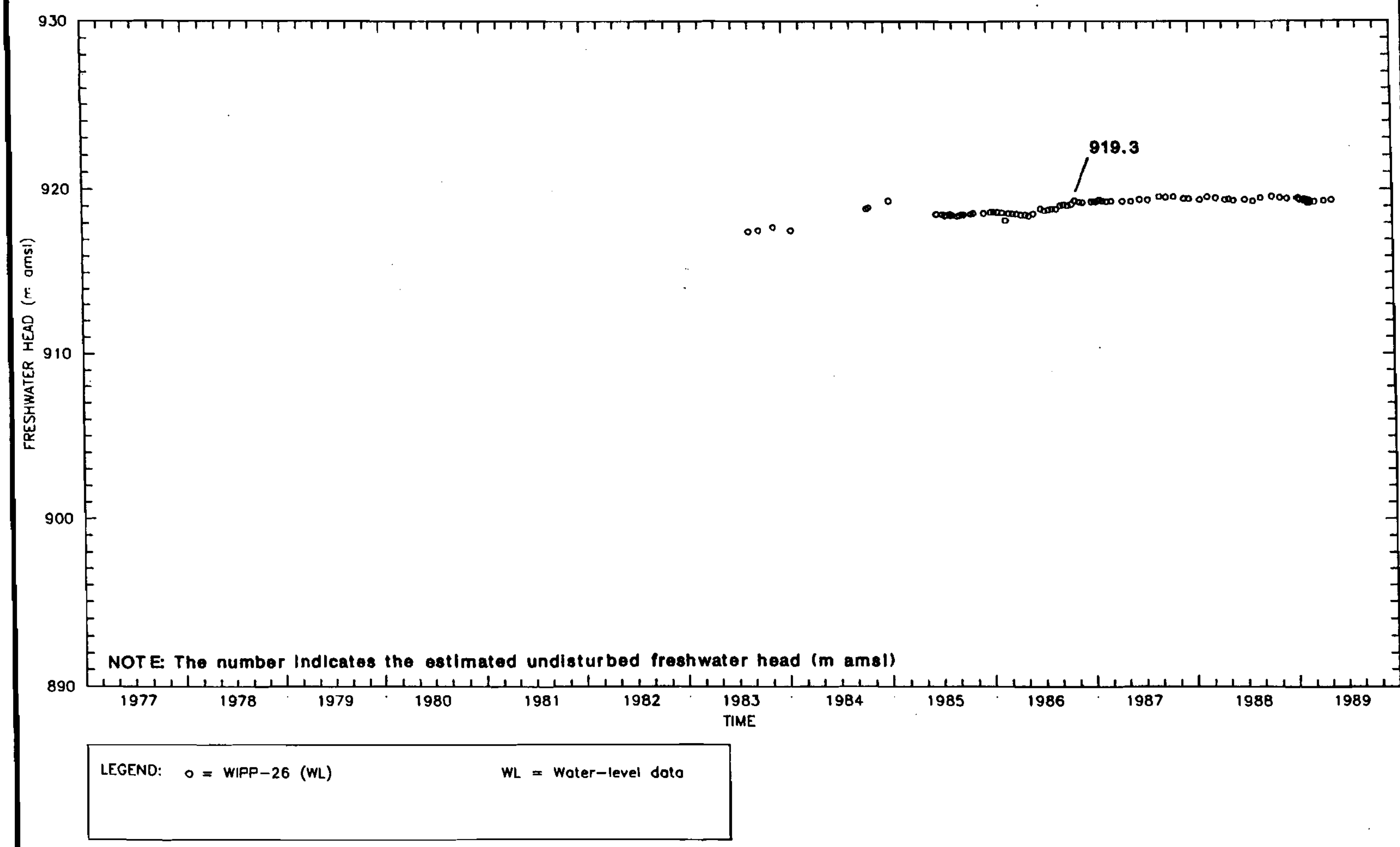


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-25

Figure G.30

H09700R869 ABW 10/11/89

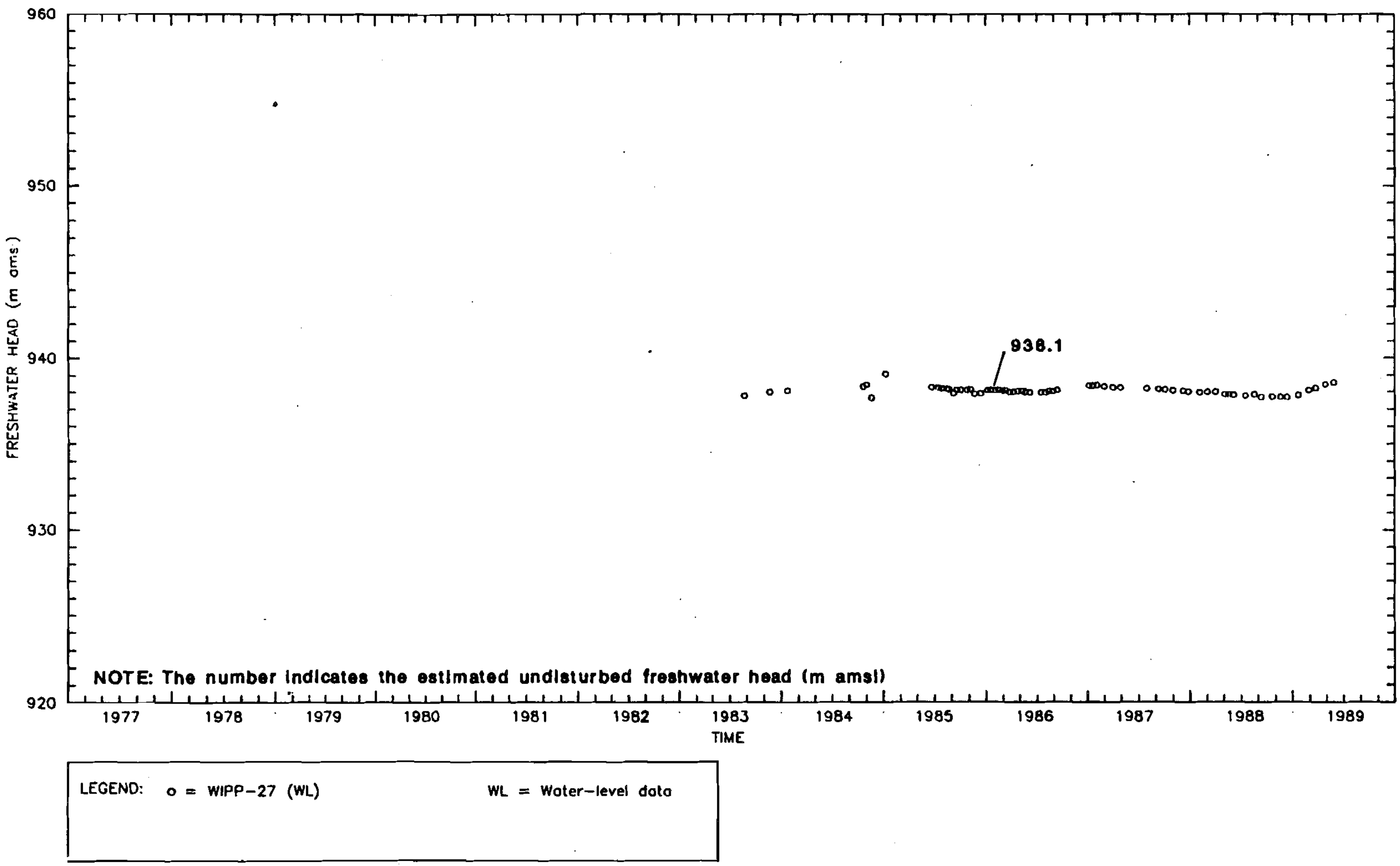


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-26

Figure G.31

H09700R869 ABW 10/11/89

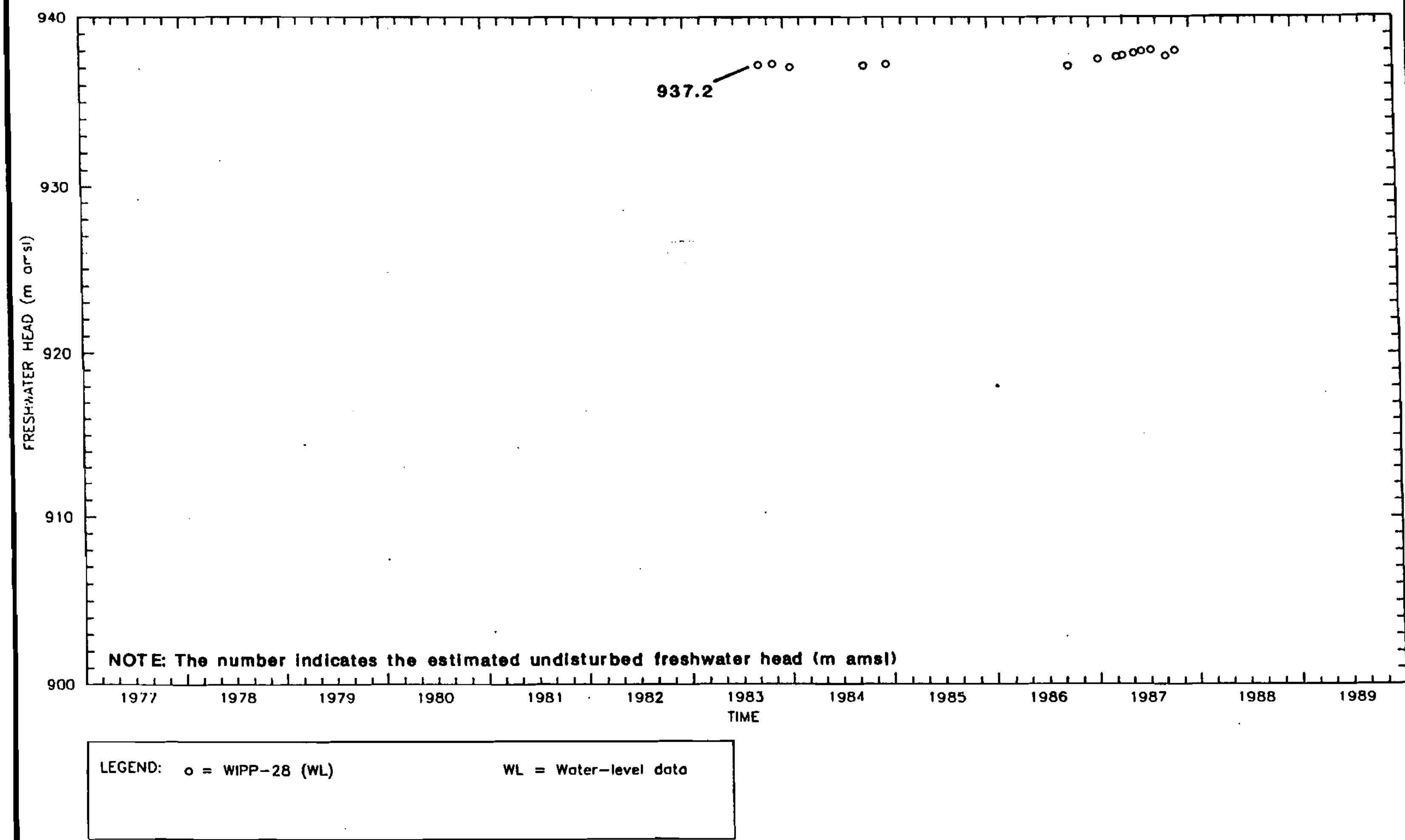


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-27

Figure G.32

H09700R869 ABW 10/11/89

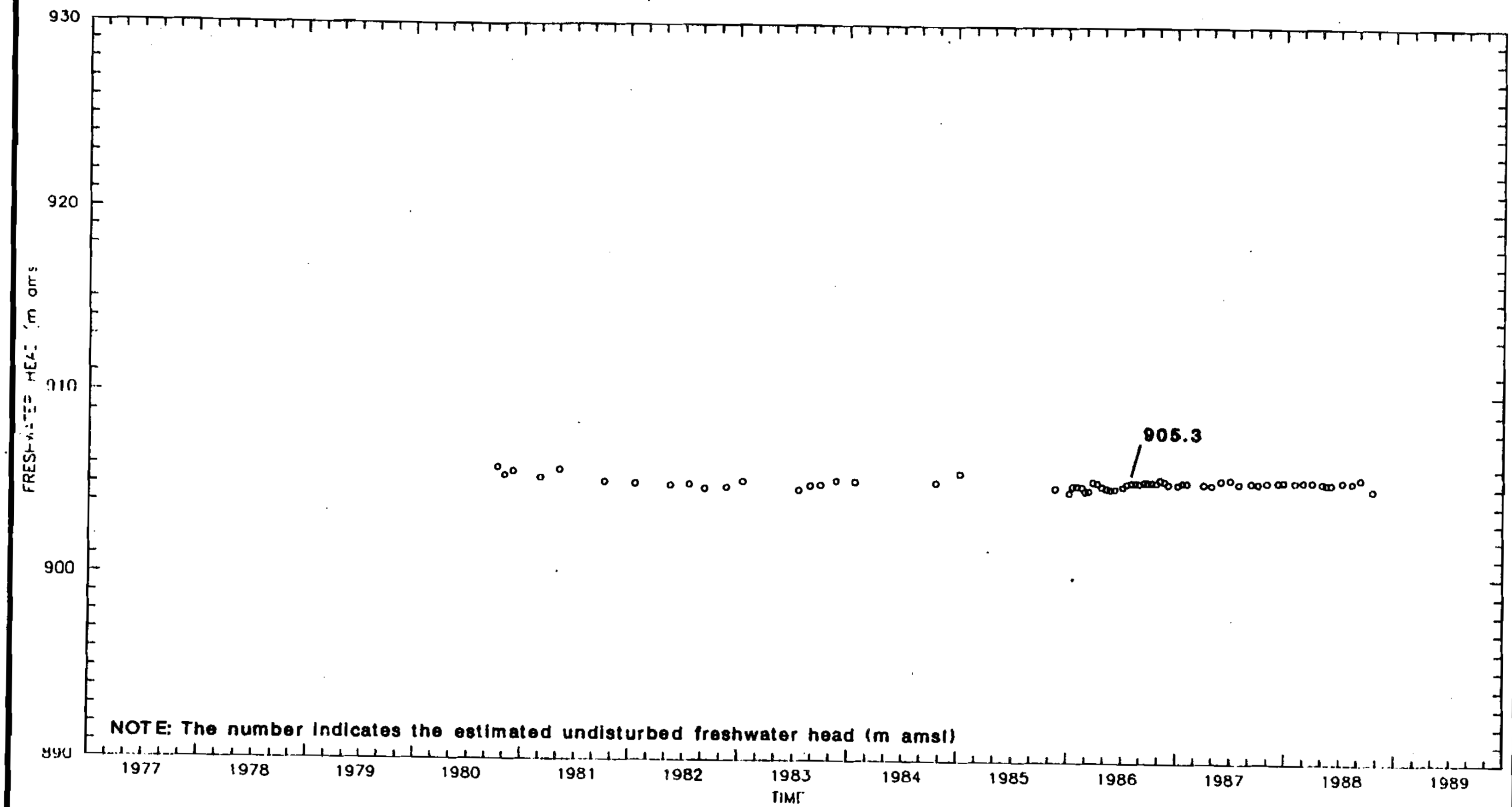


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-28

Figure G.33

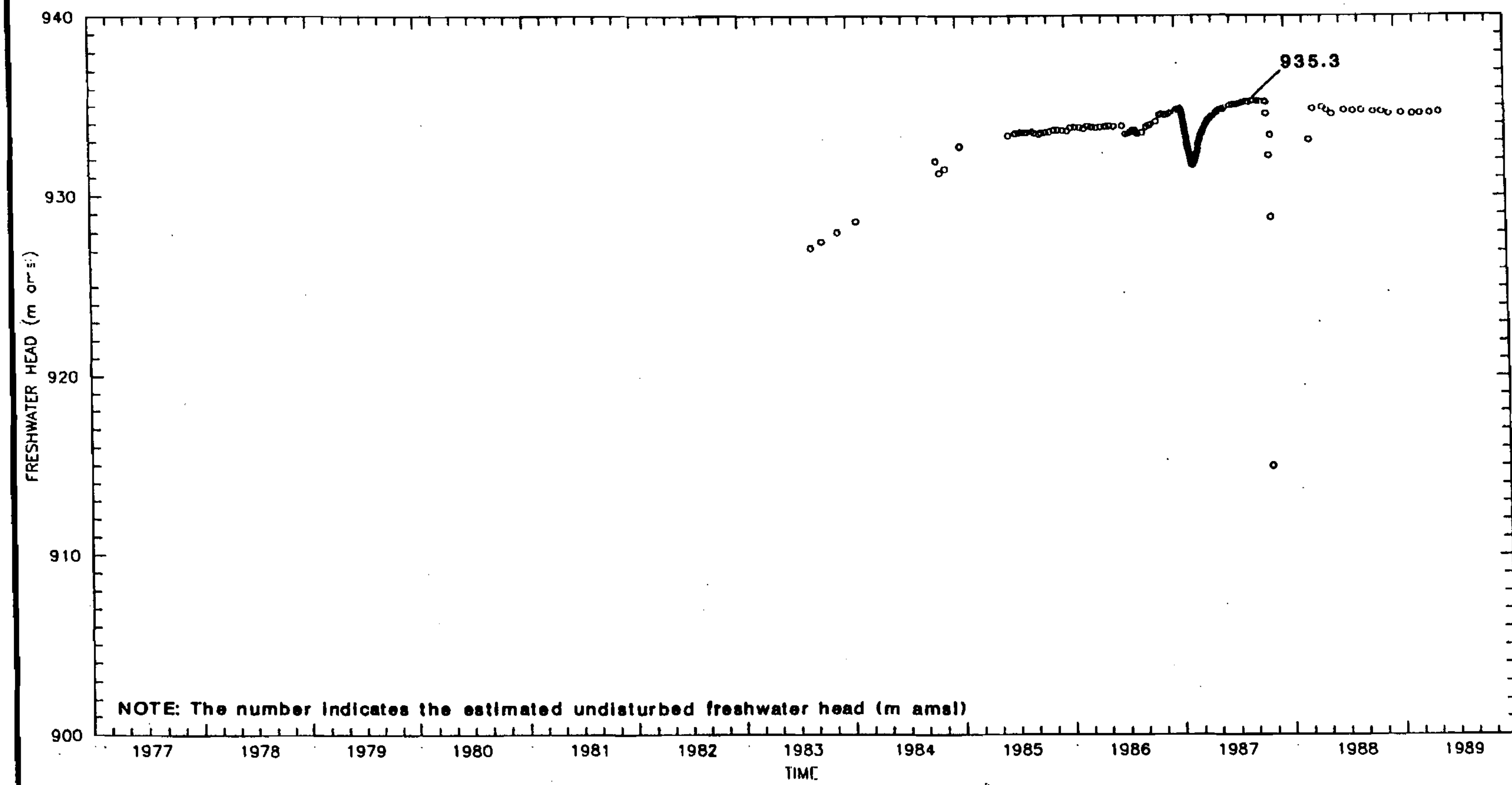
H09700R869 ABW 10/11/89



LEGEND: o = WIPP-29 (WL) WL = Water-level data

INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-29	Figure G.34

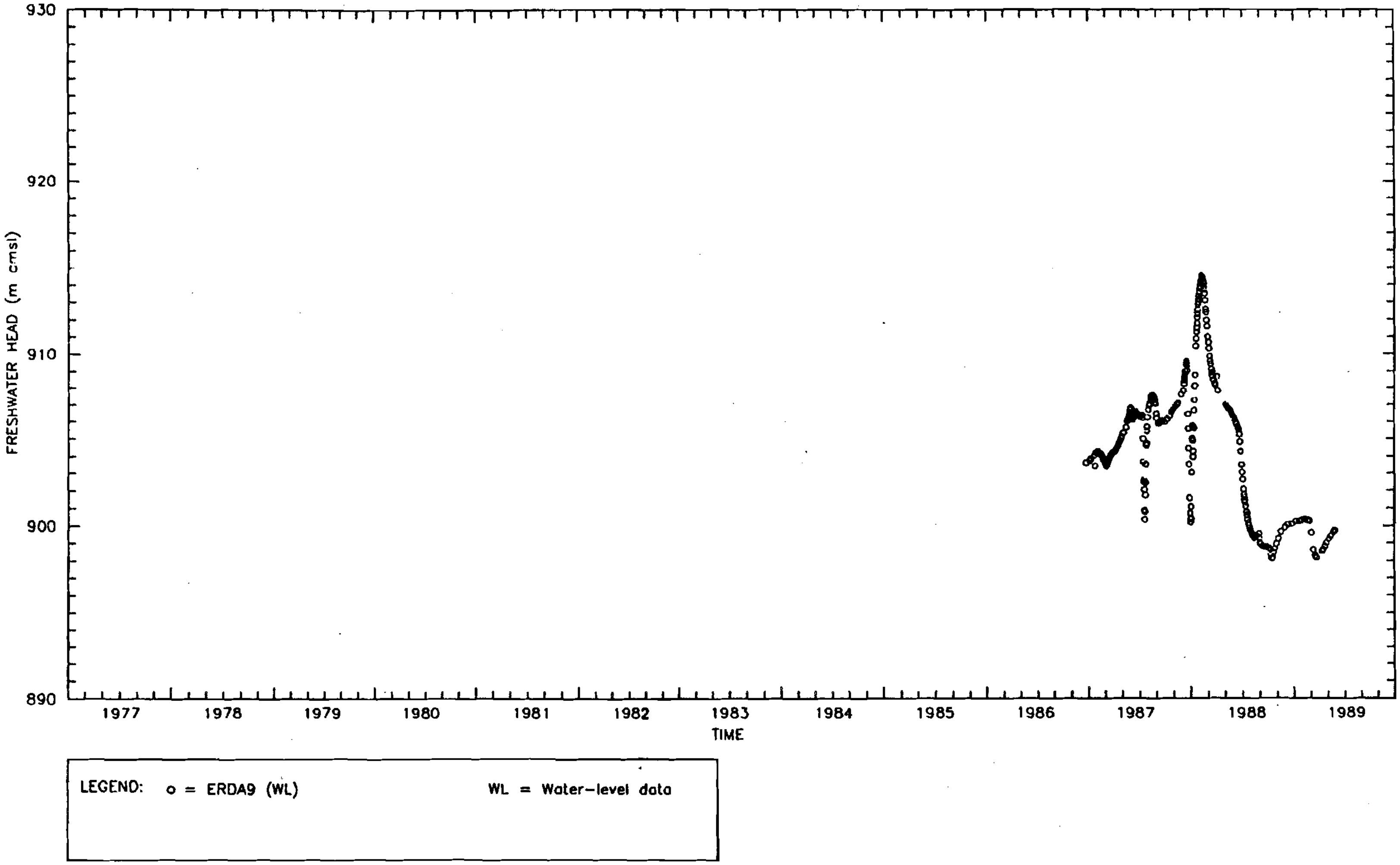
H09700R869 ABW 10/11/89



LEGEND: o = WIPP-30 (WL) WL = Water-level data

INTERA Technologies | Equivalent Freshwater Elevations for the Culebra Dolomite at Well WIPP-30 | Figure G.35

H09700R869 ABW 10/11/89

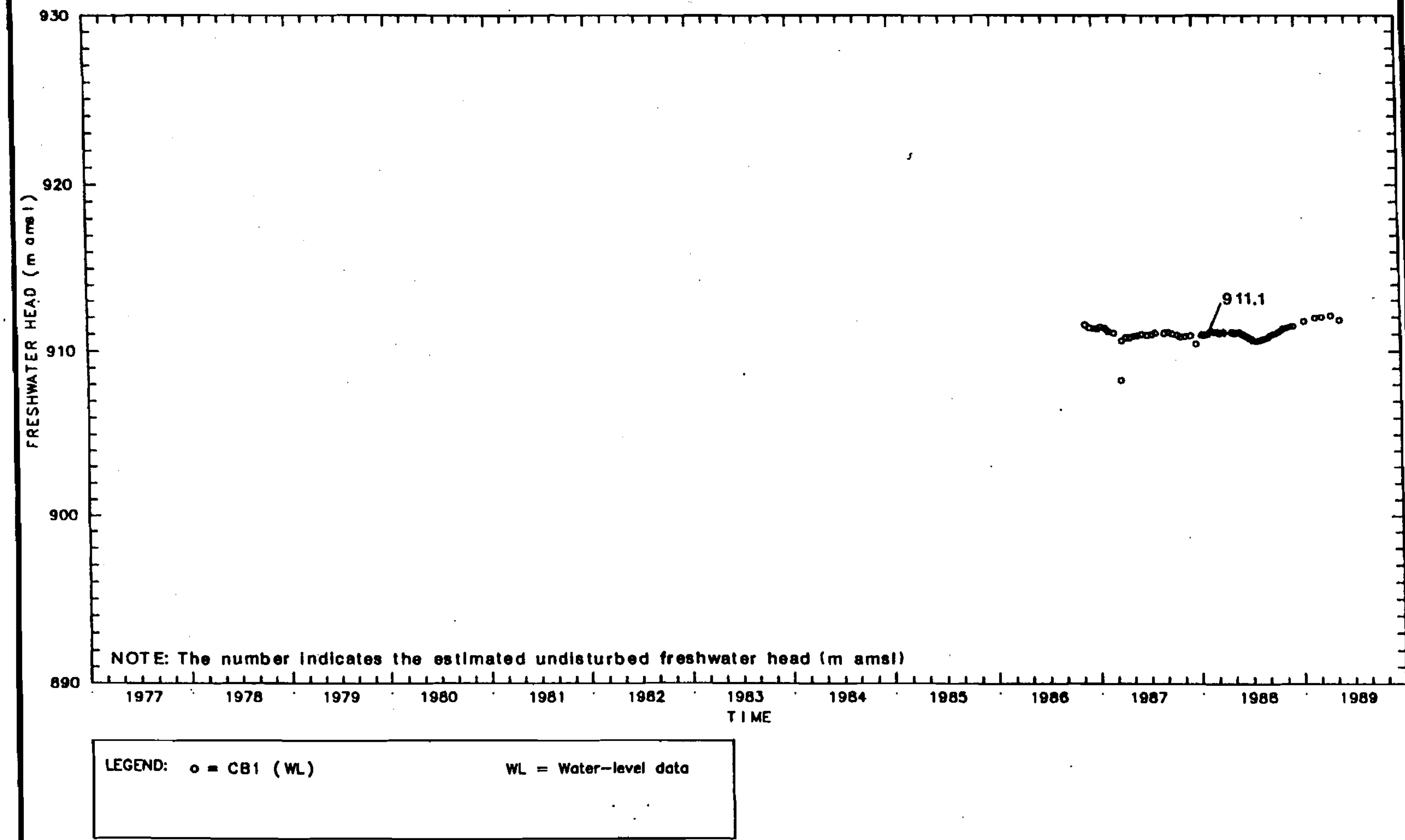


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well ERDA-9

Figure G.36

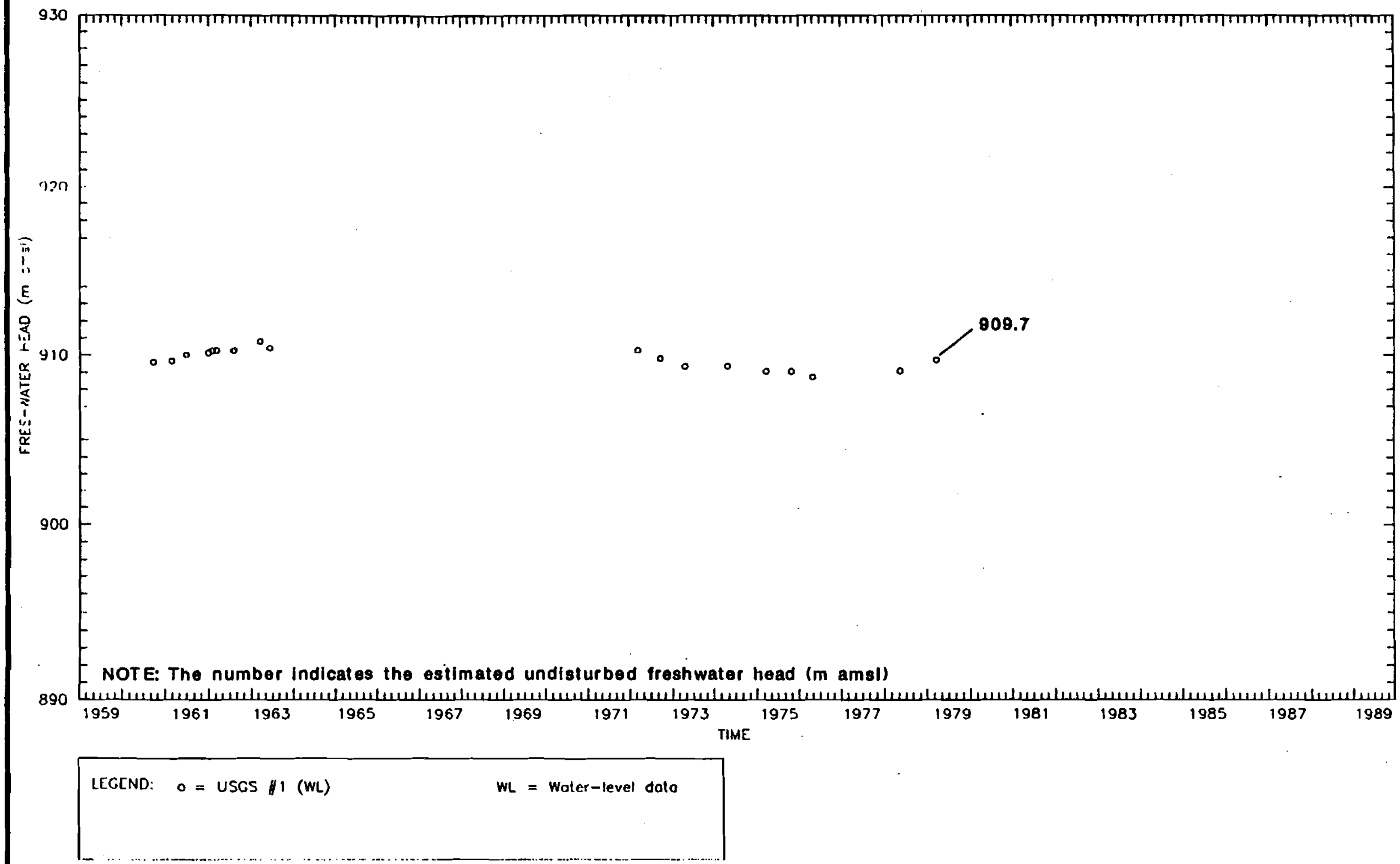
H09700R869 ABW 10/11/89



INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well Cabin Baby-1

Figure G.37



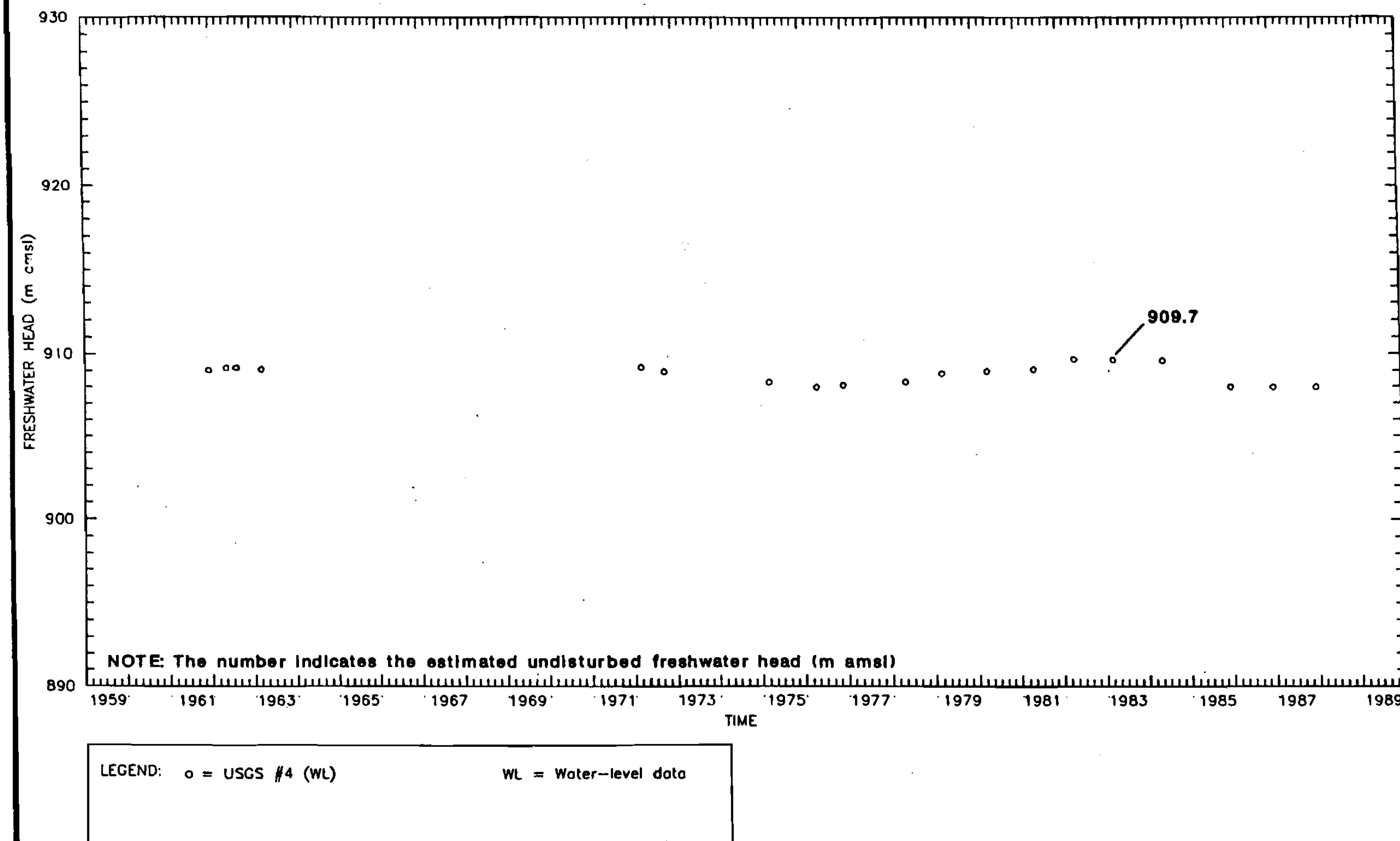
INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well USGS #1

Figure G.38

H09700R869 ABW 10/11/89

G-43

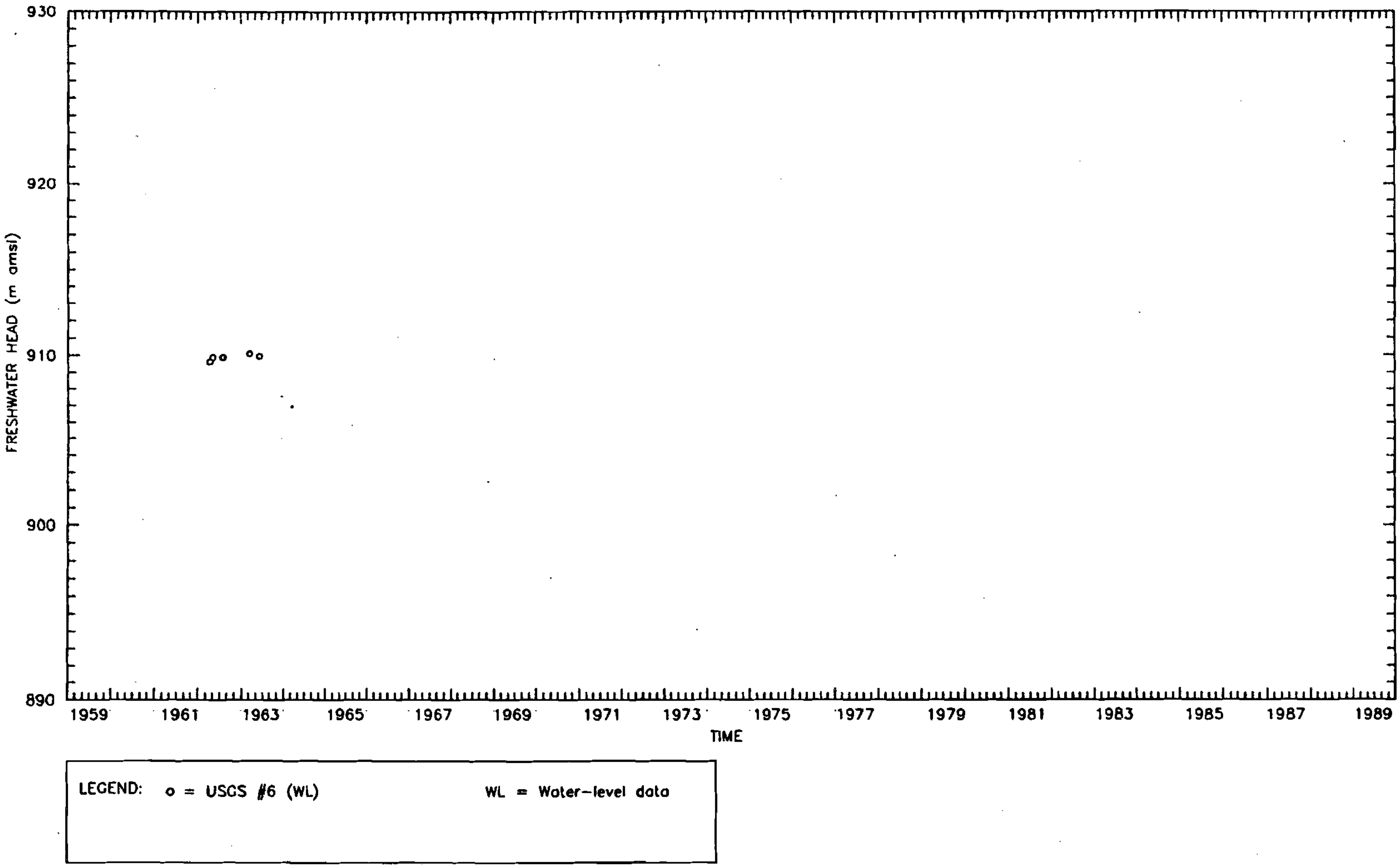


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well USGS #4

Figure G.39

H09700R869 ABW 10/11/89

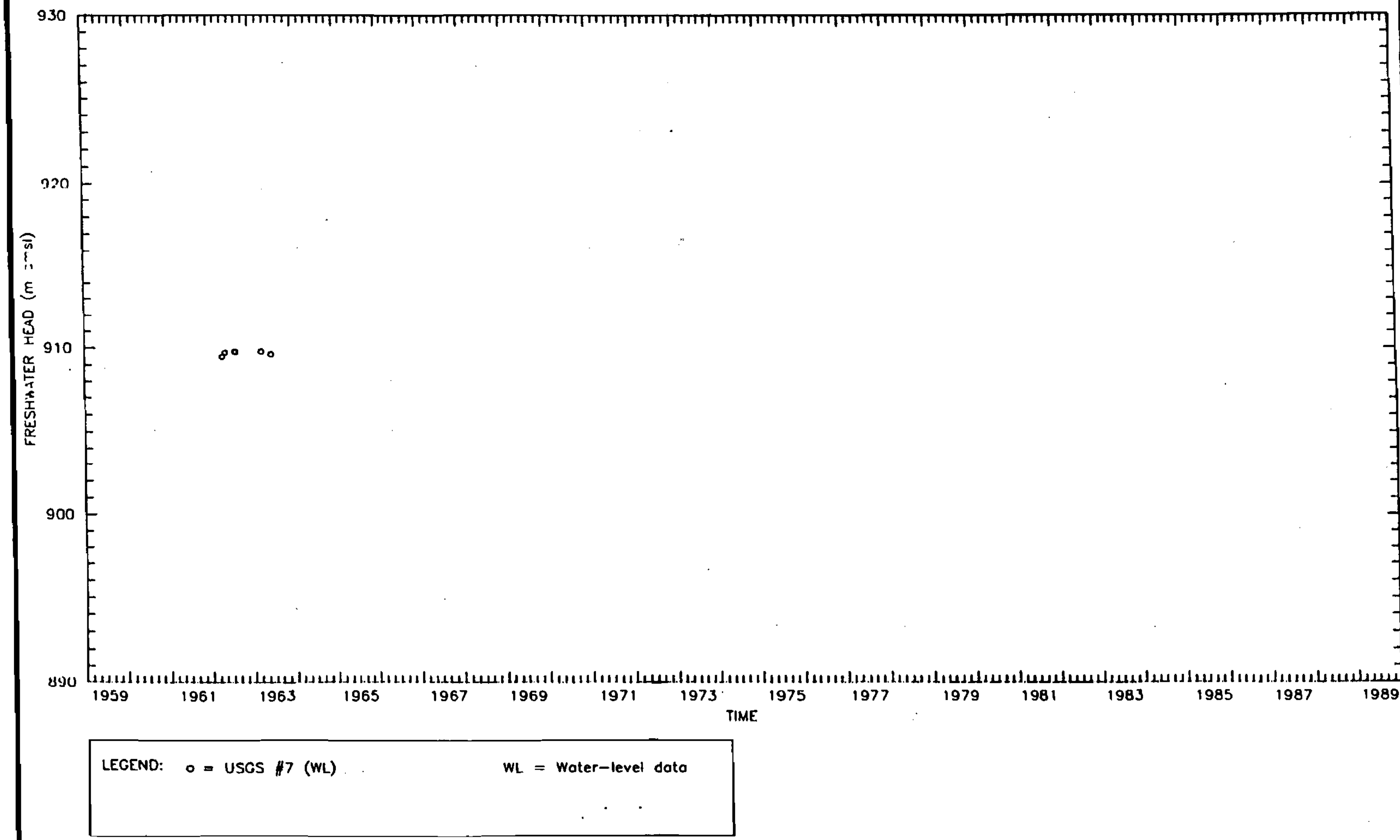


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well USGS #6

Figure G.40

H09700R869 ABW 10/11/89

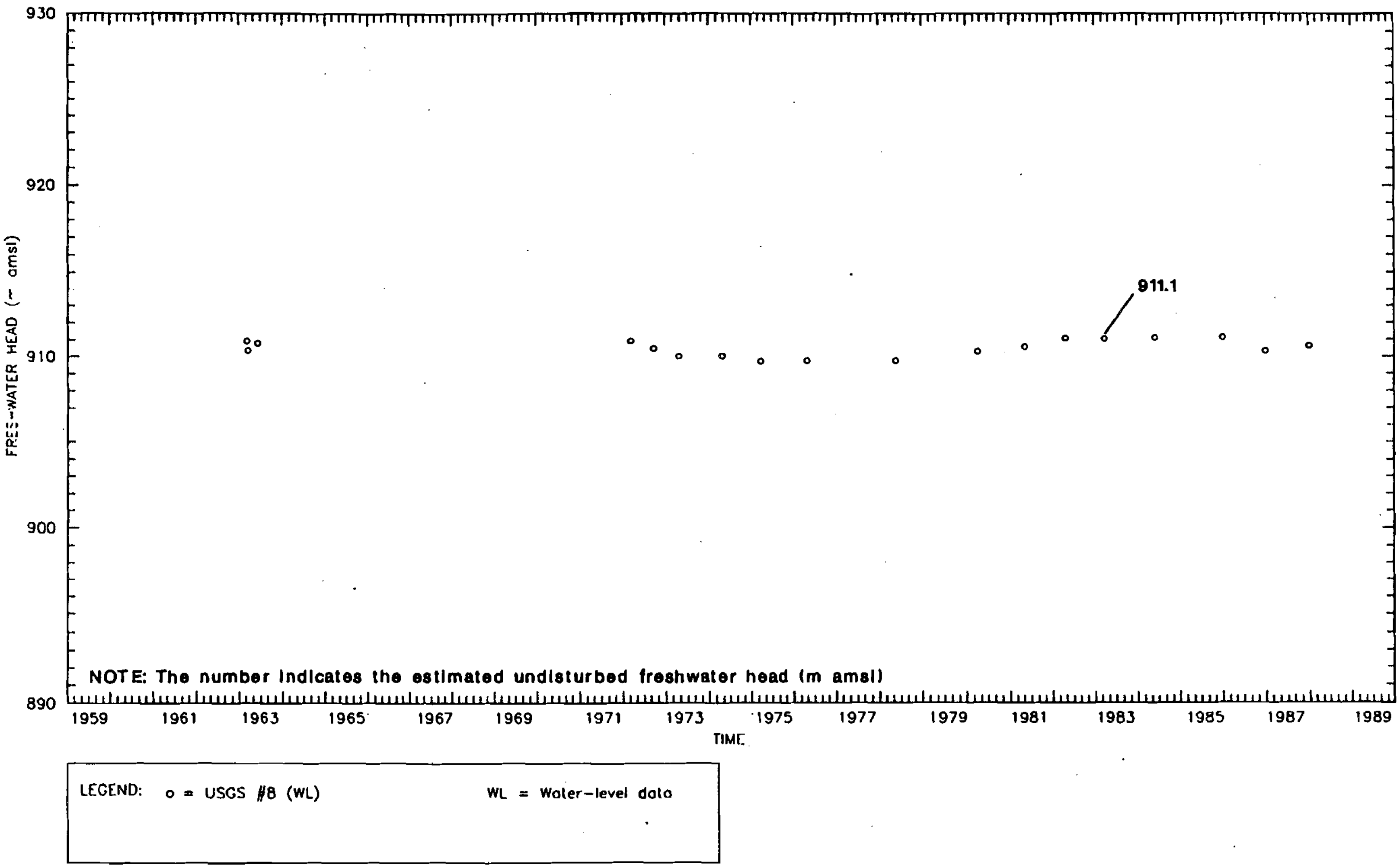


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well USGS #7

Figure G.41

H09700R869 ABW 10/11/89

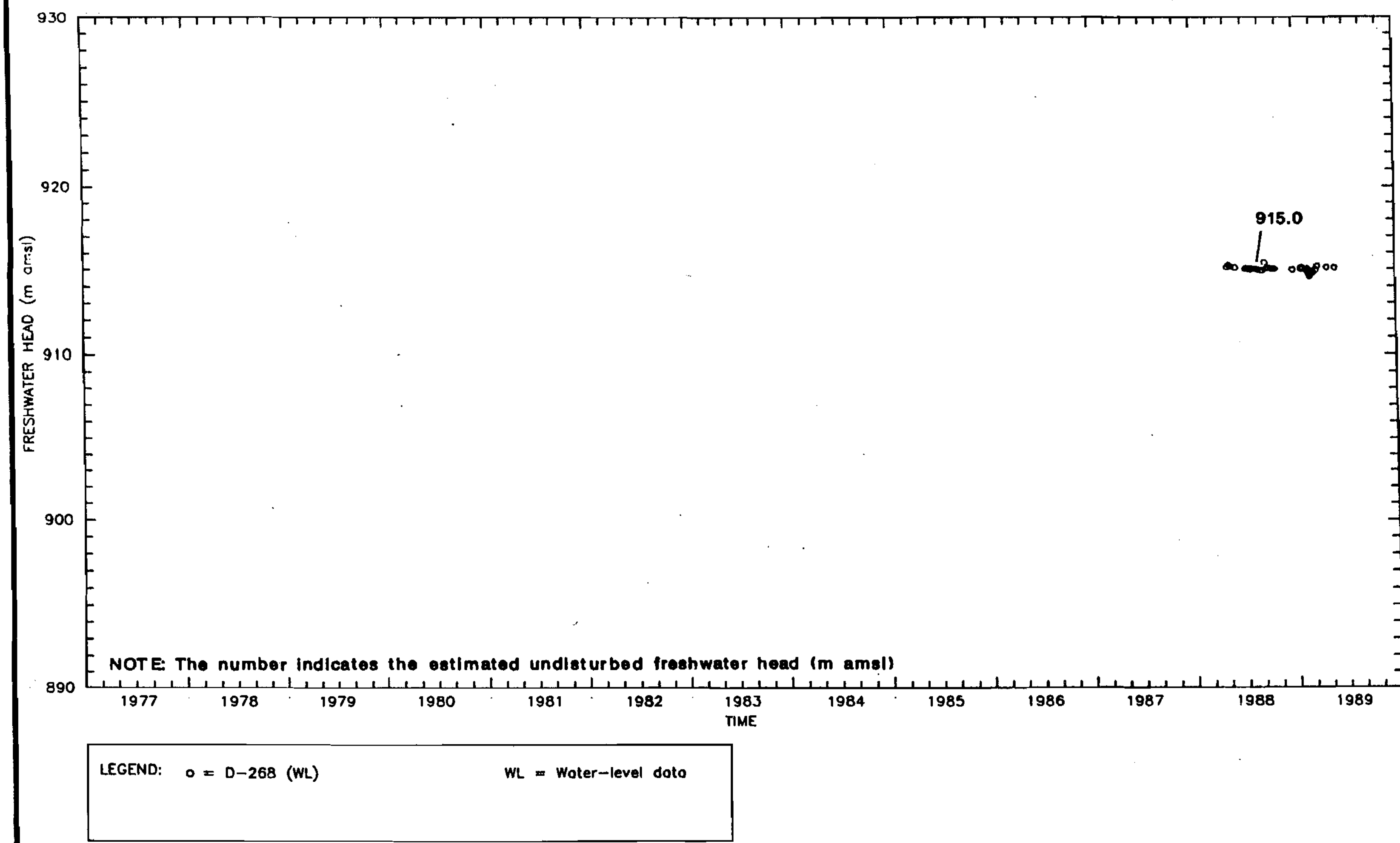


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well USGS #8

Figure G.42

H09700R869 ABW 10/11/89

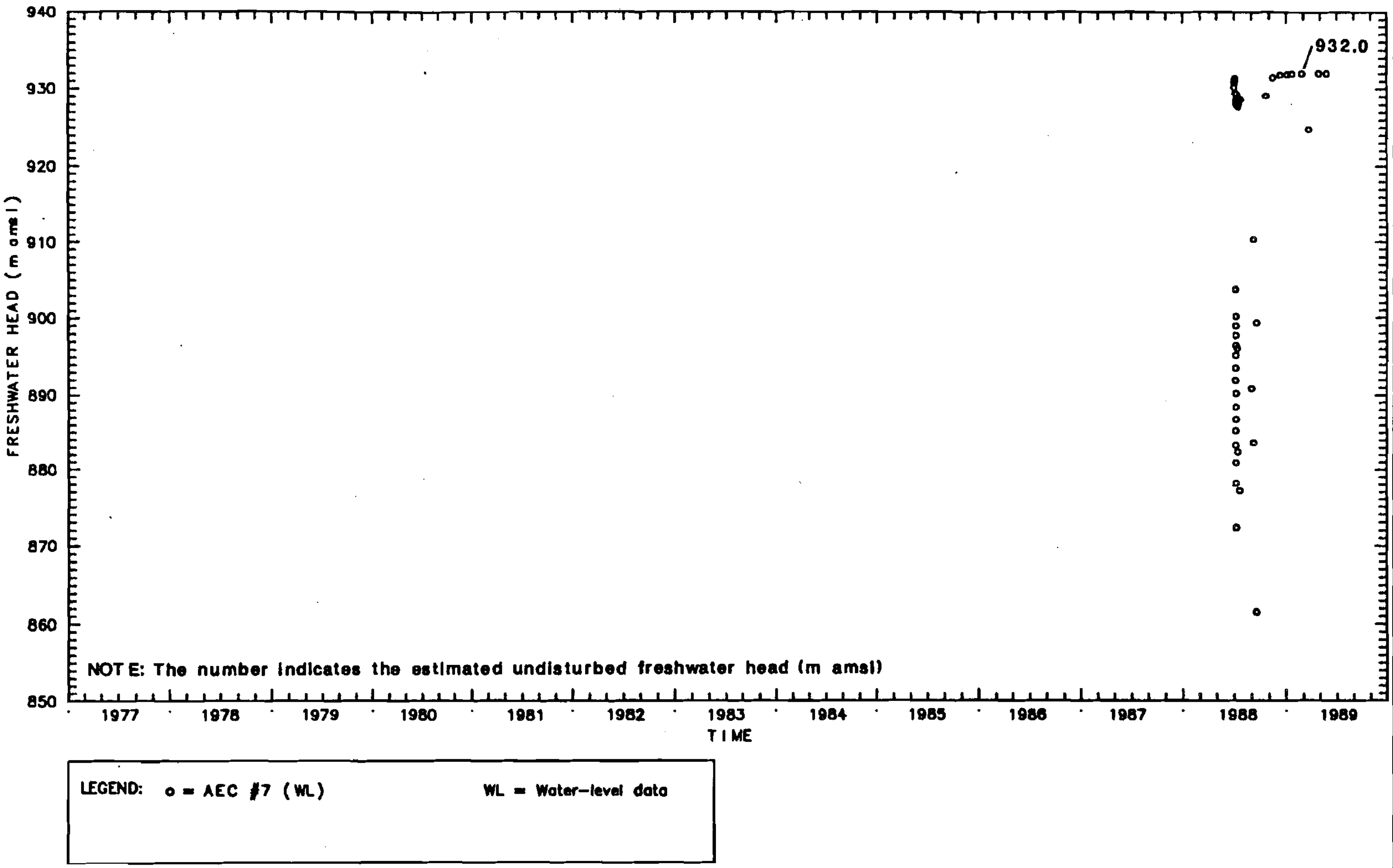


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite at Well D-268

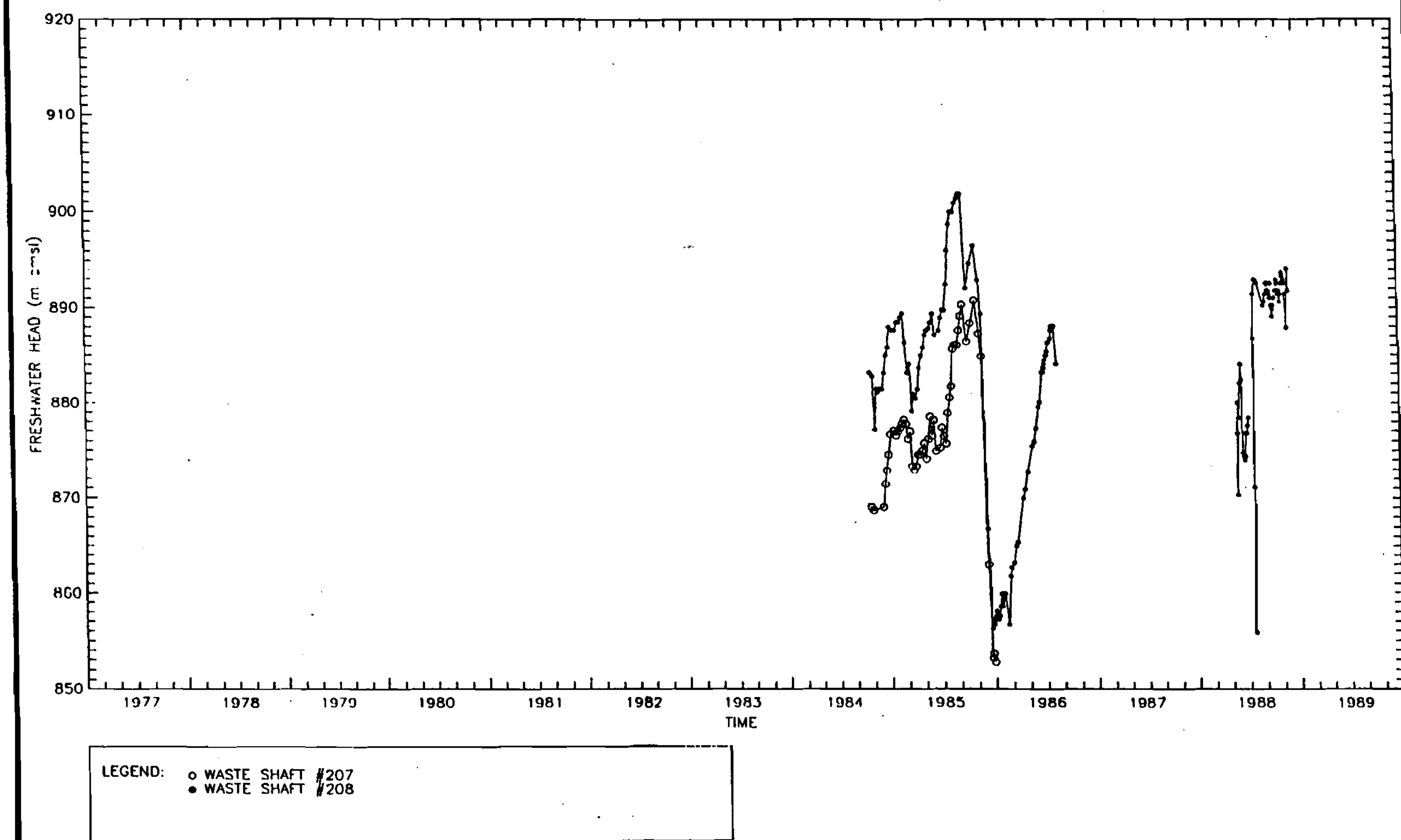
Figure G.43

H09700R669 ABW 10/11/89



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite at Well AEC-7	Figure G.44

H09700R869 T.C. 2/2/90

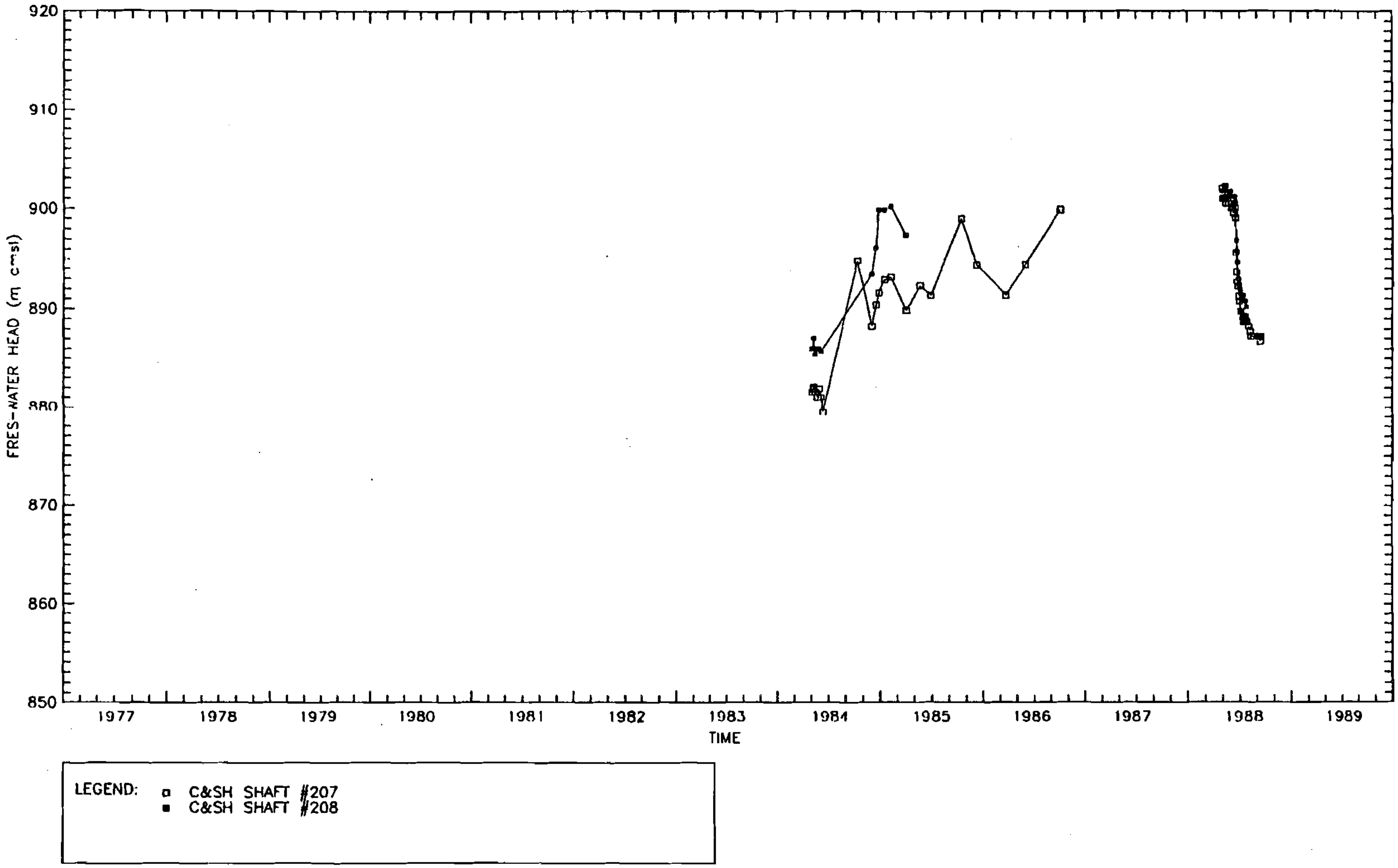


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite in the Waste-Handling Shaft

Figure G.45

H09700R869 ABW 10/11/89

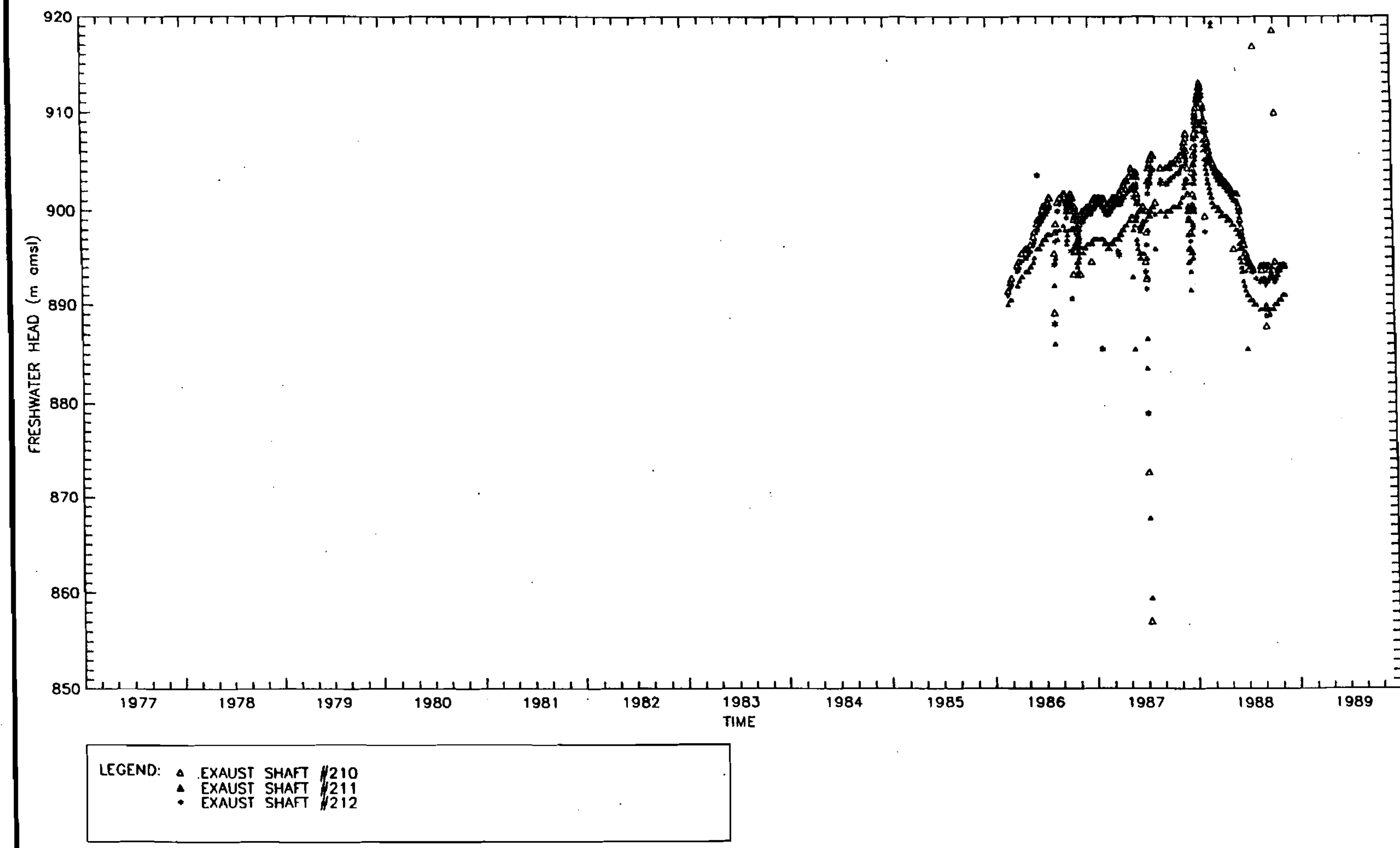


INTERA Technologies

Equivalent Freshwater Elevations for the Culebra Dolomite in the Construction and Salt-Handling Shaft

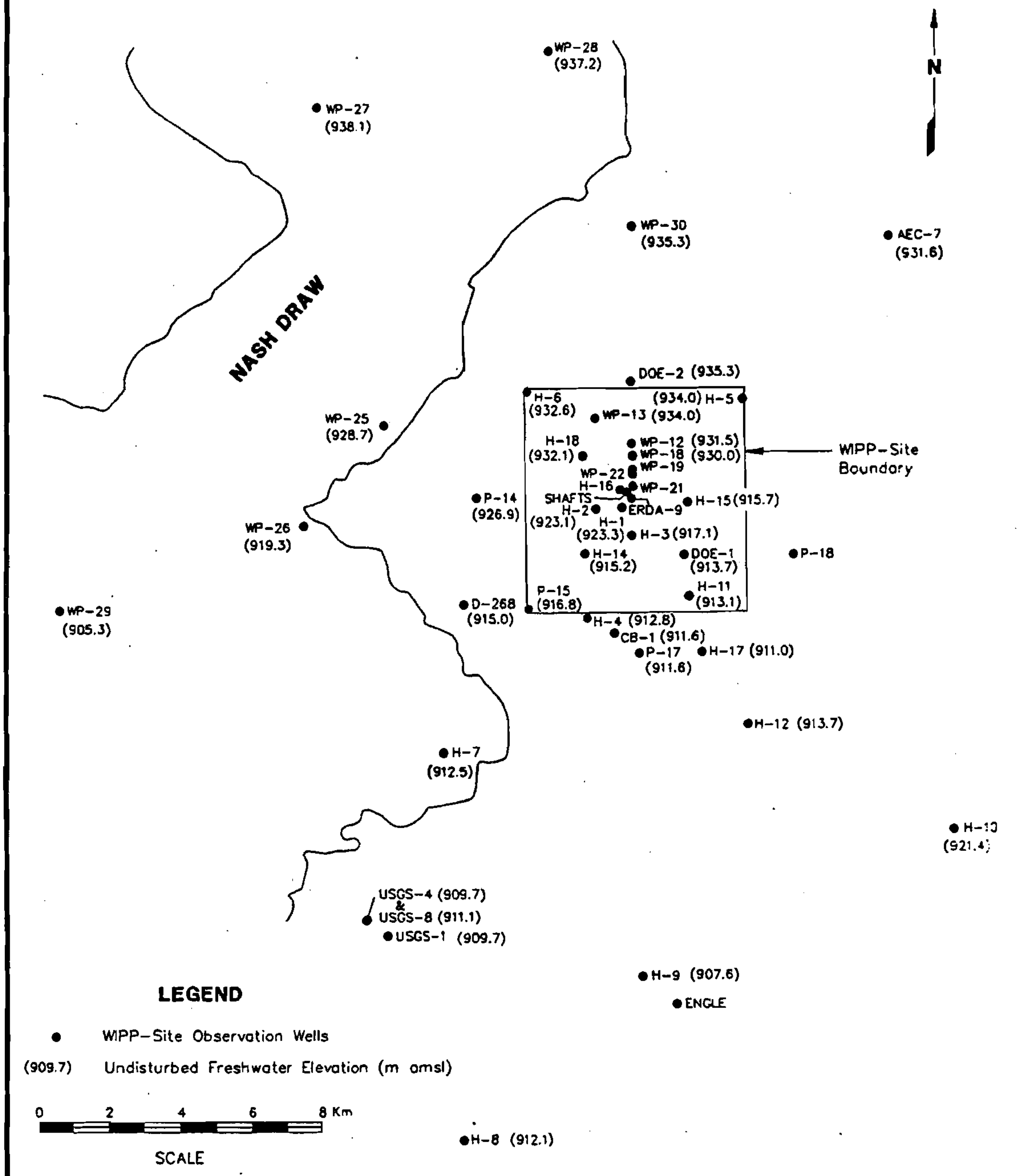
Figure G.46

H09700R869 ABW 10/11/89



INTERA Technologies	Equivalent Freshwater Elevations for the Culebra Dolomite in the Exhaust Shaft	Figure G.47

H09700R869 ABW 10/11/89



Drawn by ABW	Date 11/15/89
Checked by T.C.	Date 11/15/89
Revisions	Date
H09700R869	11/15/89

INTERA Technologies

Undisturbed Freshwater Elevations of the Culebra Dolomite

Figure G.48

MEASURING-POINT ELEVATIONS Updated 12/03/88

WELL	REFERENCE ELEVATION (m amsl)	MEASURING POINT (1) (TOC/TOT/GS)	MEASURING-POINT ELEVATION (m amsl)	PERIOD MEASURING POINT APPLICABLE
H-1	1035.68	GS	1035.68	3/17/77-1/24/84
		TOT	1036.37	5/16/83-PRESENT (2)
H-2a	1029.55	TOT	1029.87	10/16/83-4/30/84
		TOC	1029.64	4/30/84-PRESENT
H-2b1	1029.50	GS	1029.50	2/21/77-6/24/83
		TOT	1029.90	6/24/83-7/10/84
		TOT	1030.17	7/10/84-7/8/86
		TOT	1030.02	7/8/86-PRESENT
H-2b2	1029.49	TOC	1029.71	12/5/83-PRESENT
H-2c	1029.52	GS	1029.52	1/1/77-6/1/83
		TOC	1029.74	6/1/83-PRESENT
H-3b1	1033.10	GS	1033.10	5/25/77-11/21/83
		TOT	1033.68	4/30/83-1985
		TOC	1033.47	POST-1985
H-3b2	1033.10	TOC	1033.28	3/12/84-PRESENT
H-3b3	1033.10	TOC	1032.87	2/27/84-PRESENT
H-4a	1015.84	TOT	1016.12	10/23/82-PRESENT
H-4b	1015.80	GS	1015.80	6/2/78-8/20/82
		TOC	1016.01	8/20/82-PRESENT
H-4c	1016.04	TOC	1016.22	10/23/82-PRESENT
H-5a	1068.49	TOT	1068.70	7/19/84-PRESENT
H-5b	1068.44	GS	1068.44	7/7/78-10/18/84
		TOC	1068.64	10/18/84-PRESENT
H-5c	1068.56	TOC	1068.64	4/9/84-PRESENT
H-6a	1020.24	TOT	1020.50	4/9/84-PRESENT
H-6b	1020.34	GS	1020.34	7/25/78-10/18/84
		TOC	1020.55	4/9/84-PRESENT
H-6c	1020.45	TOC	1020.63	4/9/84-PRESENT

Drawn by T.C.	Date 10/12/89
Checked by T.C.	Date 10/12/89
Revisions	Date
#1050-000	10/12/89

Measuring-Point Elevations for the WIPP-Area Boreholes

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Table G.1a

WELL	REFERENCE ELEVATION (m amsl)	MEASURING POINT (1) (TOC/TOT/GS)	MEASURING-POINT ELEVATION (m amsl)	PERIOD MEASURING POINT APPLICABLE
H-7b1	964.25	GS	964.25	9/19/79-1/7/85
		TOC	964.44	1/26/84-PRESENT
H-7b2	964.35	TOC	964.51	1/2/84-PRESENT
H-7c	964.21	TOC	964.43	10/28/83-PRESENT
H-8b	1046.34	GS	1046.34	8/13/79-1/7/85
		TOC	1046.58	1/7/85-PRESENT
H-9a	1038.16	TOC	1038.36	9/21/83-PRESENT
H-9b	1038.21	GS	1038.21	8/29/79-1/7/85
		TOC	1038.41	9/21/83-PRESENT
H-9c	1038.31	TOC	1038.55	6/21/83-PRESENT
H-10b	1124.32	GS	1124.32	11/1/79-8/20/82
		TOC	1124.55	5/6/86-PRESENT
H-11b1	1040.00	TOC	1039.87	9/7/83-PRESENT
H-11b2	1040.00	TOC	1039.88	12/5/83-PRESENT
H-11b3	1040.00	TOC	1040.12	3/16/84-PRESENT
H-11b4	1039.37	TOC	1039.65	3/24/88-PRESENT
H-12	1044.24	TOC	1044.61	11/4/83-PRESENT
H-14	1019.70	TOC	1020.20	3/11/87-PRESENT
H-15	1060.77	TOC	1061.20	12/23/86-PRESENT
H-16	1039.25	TOT	1039.00	8/7/88-PRESENT
H-17	1031.45	TOC	1031.84	11/17/88-PRESENT
H-18	1040.39	TOC	1040.65	11/26/88-PRESENT
DOE-1	1056.16	TOC	1056.20	12/1/83-PRESENT
DOE-2	1041.89	TOC	1042.14	4/2/86-PRESENT
P-14	1024.05	GS	1024.05	3/27/77-8/24/83
		TOC	1024.45	8/24/83-PRESENT

Drawn by T.C.	Date 10/12/89	Measuring-Point Elevations for the WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table G.1b

WELL	REFERENCE ELEVATION (m amsl)	MEASURING POINT (1) (TOC/TOT/GS)	MEASURING-POINT ELEVATION (m amsl)	PERIOD MEASURING POINT APPLICABLE
P-15	1008.82	GS	1008.82	5/25/77-8/25/83
		TOC	1009.31	8/25/83-PRESENT
P-17	1016.74	GS	1016.74	5/25/77-5/25/82
		TOC	1017.19	5/25/82-PRESENT
P-18	1059.88	GS	1059.88	5/25/77-3/15/83
		TOC	1060.22	3/15/83-PRESENT
WIPP-12	1058.05	TOC	1058.28	10/14/85-PRESENT
WIPP-13	1037.96	TOC	1038.06	10/27/85-PRESENT
WIPP-18	1053.51	TOC	1054.23	8/5/85-PRESENT
WIPP-19	1046.40	TOC	1047.03	8/5/85-PRESENT
WIPP-21	1041.53	TOC	1042.10	8/5/85-PRESENT
WIPP-22	1044.18	TOC	1044.89	8/5/85-PRESENT
WIPP-25	979.16	GS	979.16	8/24/83-1/7/85
		TOT	979.88	11/27/84-PRESENT
WIPP-26	960.65	GS	960.65	8/24/83-1/7/85
		TOC	961.10	10/27/84-PRESENT
WIPP-27	968.40	GS	968.40	8/24/83-1/7/85
		TOT	969.08	10/30/84-PRESENT
WIPP-28	1020.05	GS	1020.05	9/29/83-1/7/85
		TOT	1020.97	1/7/85-PRESENT
WIPP-29	907.37	GS	907.37	10/8/80-1/7/85
		TOC	907.77	1/7/85-PRESENT
WIPP-30	1044.70	GS	1044.70	8/23/83-1/7/85
		TOT	1045.30	10/30/84-PRESENT
ERDA-9	1039.00	TOC	1039.40	1/5/87-PRESENT
CABIN BABY-1	1014.15	TOC	1014.49	11/20/86-PRESENT
USGS-1	1044.12	TOC	1044.39	9/22/60-PRESENT

Drawn by T.C.	Date 10/12/89	Measuring-Point Elevations for the WIPP-Area Boreholes
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INTERA Technologies		Table G.1c

WELL	REFERENCE ELEVATION (m amsl)	MEASURING POINT (1) (TOC/TOT/GS)	MEASURING-POINT ELEVATION (m amsl)	PERIOD MEASURING POINT APPLICABLE
USGS-4	1040.22	TOC	1041.17	12/01/61-PRESENT
USGS-6	1036.32	TOC	1037.27	3/30/62-PRESENT
USGS-8	1039.52	TOC	1040.48	10/01/62-PRESENT
D-268	999.30	TOC	999.96	4/12/88-PRESENT
AEC-7	1114.73	TOC	1114.74	7/2/88-PRESENT

(1) TOC = Top of Casing
TOT = Top of Tubing
GS = Ground Surface

(2) PRESENT refers to date of latest update of the data base (approximately June 1989)

Drawn by T.C.	Date 10/12/89	Measuring-Point Elevations for the WIPP-Area Boreholes
Checked by T.C.	Date 10/12/89	
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#1050-000	10/12/89	
INTERA Technologies		Table G.1d

UNDISTURBED FRESHWATER HEADS AND UNCERTAINTIES Updated 01/04/90

WELL	UNDISTURBED F.W. ELEV (m amsl)	DATE SELECTED	HEAD UNCERTAINTY (m) DUE TO: BOREHOLE-FLUID DENSITY	REFERENCE POINT ELEVATION	DEPTH TO WATER MEASUREMENTS	RESIDUAL EFFECTS IN THE DATA	TRENDS IN THE DATA*	OVERALL HEAD UNCERTAINTY (m)
H-1	923.3	08/81	+/-1.90	+0.02/-0.03	+/-0.09		(3.4)	+/-2.0
H-2c	923.1	03/78	+1.70	+0.02/-0.04	+/-0.06		(2.2)	+1.8/-0.1
H-3b1	917.1	08/81	+/-1.80	+0.06/-0.02	+/-0.06		(4.6)	+/-1.9
H-4b	912.8	06/82	+/-0.50	+0.02/-0.04	+/-0.06		(1.3)	+/-0.6
H-5b	934.0	01/81	+/-1.30	+/-0.02	+/-0.09		(0.7)	+/-1.4
H-6b	932.6	09/80	+/-0.90	+/-0.02	+/-0.06		(1.8)	+/-1.0
H-7b1	912.5	07/81	+0.30	+0.17/-0.02	+/-0.03		(1.1)	+0.5/-0.1
H-8b	912.1	02/83	+0.50	+0.04/-0.02	+/-0.09		(3.5)	+0.6/-0.1
H-9b	907.6	02/83	+1.10	+/-0.02	+/-0.09		(3.4)	+1.2/-0.1
H-10b	921.4	05/81	+/-2.10	+/-0.02	+/-0.09		(0.9)	+/-2.2
H-11b2	912.6	07/87	+/-0.90	+/-0.02	+/-0.09	+0.50	(2.6)	+1.5/-1.0
H-12	913.7	01/87	+/-1.10	+0.02/-0.06	+/-0.09		(0.7)	+1.2/-1.3
H-14	915.2	05/87	+0.60	+0.02/-0.03	+/-0.06		(1.0)	+0.7/-0.1
H-15	914.2	04/87	+1.20	+0.02/-0.05	+/-0.09	+1.50	(1.3)	+2.8/-0.1
H-17	911.0	01/88	+/-0.80	+/-0.02	+/-0.09		(0.8)	+/-0.9
H-18	931.7	12/88	+/-1.00	+0.03/-0.02	+/-0.06	+0.40	(2.1)	+1.5/-1.1
DOE-1	913.7	07/87	+/-2.00	+0.02/-0.13	+/-0.09	+0.50	(3.0)	+2.6/-2.2
DOE-2	935.3	01/87	+/-1.40	+0.04/-0.02	+/-0.06		(1.2)	+/-1.5
P-14	926.9	08/84	+/-0.80	+/-0.02	+/-0.06		(1.8)	+/-0.9
P-15	916.8	09/85	+/-0.70	+0.03/-0.02	+/-0.06		(2.4)	+/-0.8

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Undisturbed Freshwater Heads and Their Uncertainties for the WIPP-Area Culebra Boreholes

INTERA Technologies

Table G.2a

WELL	UNDISTURBED F.W. ELEV (m amsl)	DATE SELECTED	HEAD UNCERTAINTY (m) DUE TO					OVERALL HEAD UNCERTAINTY (m)
			BOREHOLE-FLUID DENSITY	REFERENCE POINT ELEVATION	DEPTH TO WATER MEASUREMENTS	RESIDUAL EFFECTS IN THE DATA	TRENDS IN THE DATA*	
P-17	911.6	03/84	+/-0.60	+0.03/-0.02	+/-0.06		(5.3)	+/-0.7
WIPP-12	932.5	01/87	+1.20	+0.02/-0.03	+/-0.09		(1.0)	+1.3/-0.1
WIPP-13	934.0	09/87	+/-1.10	+0.02/-0.12	+/-0.06		(1.2)	+1.2/-1.3
WIPP-18	930.0	10/87	+/-1.10	+0.03/-0.02	+/-0.09		(0.9)	+/-1.2
WIPP-25	928.7	07/85	+0.90	+/-0.02	+/-0.03		(2.0)	+/-1.0
WIPP-26	919.3	11/86	+0.20	+0.17/-0.02	+/-0.03		(1.9)	+0.4/-0.1
WIPP-27	938.1	02/86	+/-0.60	+0.02/-0.08	+/-0.03		(0.8)	+/-0.7
WIPP-28	937.2	09/83	+/-0.80	+0.02/-0.33	+/-0.06		(1.1)	+0.9/-1.2
WIPP-29	905.3	08/86	+0.20/-0.10	+0.02/-0.07	+/-0.03		(0.9)	+0.3/-0.2
WIPP-30	935.3	09/87	+/-0.80	+0.02/-0.39	+/-0.06		(2.0)	+0.9/-1.3
CB-1	911.1	03/88	+/-0.50	+0.11/-0.02	+/-0.06		(1.2)	+0.7/-0.6
USGS-1	909.7	03/79	+0.30	+/-0.02	+/-0.09		(2.0)	+0.4/-0.1
USGS-4	909.7	03/83	unknown	+/-0.02	+/-0.09		(2.0)	+/-0.1
USGS-8	911.1	03/83	unknown	+/-0.02	+/-0.09		(1.8)	+/-0.1
D-268	915.0	08/88	+0.30	+0.02/-0.07	+/-0.06		(0.3)	+0.4/-0.1
AEC-7	932.0	02/89	+/-0.70	+0.02/-0.03	+/-0.06		(1.0)	+/-0.8

* Not included in the overall head uncertainty because the longterm trends are not clearly understood.

Drawn by T.C.	Date 10/12/89	Undisturbed Freshwater Heads and Their Uncertainties for the WIPP-Area Culebra Boreholes
Checked by T.C.	Date 10/12/89	
Revisions	Date	
#1050-000	10/12/89	
INTERA Technologies		Table G.2b

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APPENDIX H: SHAFT HISTORIES

The hydrogeology of the Culebra dolomite has been influenced by drilling and excavating four shafts (the waste-handling shaft, the exhaust shaft, the construction and salt-handling shaft, and the air-intake shaft) at the center of the WIPP site. The shaft activities have caused the principle hydrologic disturbances at the WIPP site since 1981, resulting in large changes in the potentiometric surface in the central part of the WIPP site. This appendix describes the shaft events which have affected the hydrologic condition within the Culebra since 1981.

Several potash mine shafts penetrate the Culebra dolomite in the vicinity of the WIPP site. The potential influence of these shafts on the Culebra flow regime is also discussed in this appendix.

H.1 Description of WIPP Shaft Activities

H.1.1 Construction and Salt-Handling Shaft

The first shaft excavated was the construction and salt-handling shaft (C & SH), formerly called the exploratory shaft (Figure H.1). A detailed history of the shaft construction was reported by Fenix and Scisson (1982). This history was used by Stevens and Beyeler (1985) to model the effect of shaft drilling and completion on the hydrologic responses in both the Magenta and the Culebra Dolomite Members of the Rustler Formation at the H-1, H-2, and H-3 hydropads. As demonstrated by Stevens and Beyeler (1985), the effect of construction of the exploratory shaft on pressures in the Culebra dolomite was observable at the H-1, H-2, and H-3 hydropads.

A synopsis of drilling and construction events relevant to this study is summarized below (modified after Stevens and Beyeler, 1985):

July 4, 1981:	Start of reverse-rotary drilling with 3.68-m diameter bit. Land-surface elevation is about 1039.4 m above mean sea level (amsl).

August 4, 1981:	Drilled into the top of the Culebra dolomite.
August 9, 1981:	Drilled through the bottom of the Culebra dolomite. The drilling-fluid level in the shaft fell below the bottom of the Magenta dolomite (about 847.4 m amsl). Consequently, the fluid pressure in the Culebra dolomite (center at 822 m amsl) fell below 350 kPa.
August 15, 1981:	Drilling-fluid level in the shaft fell below the bottom of the Culebra dolomite; subsequently, ground-water flow from the Culebra dolomite into the shaft was unrestricted and the Culebra dolomite was exposed to atmospheric pressure (about 101 kPa).
October 24, 1981:	Drilling stopped 701 m below land surface; the borehole was filled with brine to about 77 m below land surface (962 m amsl). The brine density was not reported. Stevens and Beyeler (1985) estimated the ratio of the density of the brine to the density of the formation fluid to be about 1.3. The formation-fluid density at the shaft location is not exactly known but is likely to be between 1.02 g/cm^3 (e.g., at H-1) and 1.04 g/cm^3 (e.g., at H-3 or DOE-2). It was assumed that the density of the brine was rather high at about 1.3 g/cm^3. Using this density, the pressure at the center of the Culebra dolomite was calculated to be 1886 kPa. The corresponding equivalent freshwater head equals 1004 m amsl.
October 25, 1981 to November 15, 1981:	Brine was continually added to the shaft. The drilling fluid level, which was occasionally reported, rose about 35 m over the time period. It is likely

that a considerable amount of brine entered the Culebra dolomite during this time period.

November 16, 1981: The drilling fluid level in the shaft was approximately 997.2 m amsl, resulting in a pressure of about 2334 kPa at the center of the Culebra dolomite (assuming 1.3 g/cm^3 as the brine density). This corresponds to an equivalent freshwater head of 1049.7 m amsl.

November 16, 1981 to December 3, 1981: The casing was lowered into the shaft. Stevens and Beyeler (1985) assumed that the brine either over-flowed the shaft while the casing was being lowered or the brine level was at ground level. This assumption results in a calculated formation pressure in the Culebra dolomite of 2873 kPa or an equivalent freshwater head of 1104.6 m amsl.

December 4, 1981 to December 6, 1981: Beginning December 4, the annular space between the casing and the shaft wall was cemented. Stevens and Beyeler (1985) again made the assumption that the brine in the shaft was either overflowing onto the land surface or was at land surface. Thus, it can be assumed that the formation pressure in the Culebra dolomite was about the same as during installation of the casing. On December 6, the cement-sealing operation ended.

The effects of the activities at the C & SH shaft from July 1981 through December 1981 on the hydrologic conditions at the locations of H-1, H-2, and H-3 can be seen in the hydrographs presented in Appendix G (Figures G.1, G.2, and G.3). All three figures show a sudden decrease in the freshwater head in the third quarter of 1981 which was caused by the first exposure of the Culebra dolomite to atmospheric pressure. The peak elevation, caused by filling the exploratory shaft with brine in

December 1981, is also clearly shown. The subsequent decrease in the freshwater heads in 1982 reflects the end of the influence by the C & SH shaft and the exposure of the Culebra dolomite to atmospheric pressure at the waste-handling shaft (Section H.1.2).

The ground-water inflow rate from the Culebra to the C & SH shaft has never been directly measured. On September 13, 1981, a water-inflow test was conducted during shaft drilling. The shaft had been drilled to 452.3 m in depth, approximately 49 m below the Rustler-Salado contact. The brine level was at 310.3 m and had been below the contact for four to five days prior to the test (Deshler and McKinney, 1988). The inflow test lasted four hours and gave an inflow rate of 0.11 L/s (Figure H.1). Unfortunately the stratigraphic sources of the inflow were not identified.

Additional inflow tests have been performed since the C & SH shaft was grouted and lined in December 1981. These tests generally consisted of measuring the water-level rise in a sump at the base of the shaft. The water collected by this system usually is not differentiated by stratigraphic units. However, inflow values from the base of the Rustler were taken on October 2, 1982 from a 30-minute inflow test. The inflow from the Rustler during this test was 2.5×10^{-2} L/s (Figure H.1). In June 1987, the C & SH shaft underwent extensive reconditioning which was designed to end inflow to the shaft. Measurements of inflow into the C & SH shaft are summarized in Table H.1a-c.

H.1.2 Waste-Handling Shaft

Drilling of the ventilation shaft (1.83-m diameter), which was excavated to a 6.55-m diameter two years later and renamed the waste-handling shaft, was started in December 1981 and completed in February 1982 (Figure H.1). Drilling-fluid-level data from this time period are not available. It was assumed that, similar to the drilling of the C & SH shaft (Section H.1.1), the drilling-fluid level fell below the Culebra dolomite on January 15, 1982 allowing unrestricted ground-water flow from the Culebra dolomite into the shaft and the Culebra dolomite was again exposed to atmospheric pressure. During the spring of 1982, inflow measurements taken from the base of the Rustler yielded an approximate flow rate of 1.9×10^{-2} to 2.5×10^{-2} L/s (Deshler and McKinney, 1988). The ventilation shaft remained open and draining prior to excavation as the waste-handling shaft between November 1983 and August 1984 (Figure H.1).

The shaft through the Culebra was enlarged to 6.55 m in February 1984. Grouting and lining the Culebra was completed on April 5, 1984. In June 1984, inflow at a rate of 3.2×10^{-2} L/s was "visually estimated" to be entering the shaft through cracks and construction joints in the lining (Roberts, 1985). The inflow rate was reduced to 9.5×10^{-4} L/s (as measured in October 1984) after a grouting program was begun in August 1984 to seal minor water leaks in the lining.

Over the next several years, inflow into the shaft increased (Figure H.1). During this same period, inflow to the shaft averaged 1.6×10^{-2} L/s (Deshler and McKinney, 1988). An inflow estimate made at the base of the Culebra on August 6, 1987 was approximately 8.2×10^{-3} L/s. The waste-handling shaft was again grouted from October 1987 to April 1988. It should be noted that holes drilled for grouting purposes might have resulted in higher inflow rates for the period during which they were open prior to grouting. The leakage from the Culebra was essentially reduced to negligible amounts in mid-November 1987 (Figure H.1). Measurements of inflow into the waste-handling shaft are summarized in Table H.1a-c.

H.1.3 Exhaust Shaft

The third of the four shafts, the exhaust shaft, was started as a 0.20-m pilot hole in October 1983. It was reamed to a 0.28-m diameter in December 1983. The shaft was then raise bored to 1.83-m diameter from December 1983 to February 1984 (Figure H.1). The only inflow measurements made during construction of the shaft were taken from the pilot hole. On November 30, 1983, a measurement of 2.6×10^{-2} L/s was taken at the base of the 0.20-m drill hole. An inflow rate of 3.0×10^{-2} L/s was measured on December 21, 1983 at the base of the 0.28 m drill hole (Deshler and McKinney, 1988). During the geologic mapping of the shaft, inflow from bedding planes and fracture surfaces over the Culebra interval was "visually estimated" to be between 0.19 and 0.38 L/s (Deshler and McKinney, 1988). The high uncertainty of both the magnitude and range of the inflow observed during mapping does not provide reliable information concerning inflow from the Culebra and was therefore not considered quantitatively in the model.

In October 1984, the 1.83-m borehole was reamed to 4.27 m (Figure H.1). The liner plate was grouted at the elevation of the Culebra dolomite in December 1984. After this time, inflow of 2.2×10^{-2} L/s from the Rustler occurred through the lining (Deshler and McKinney, 1988). Measurements of inflow into the exhaust shaft are summarized in Table H.1a-c. Additional grouting and sealing of the Culebra dolomite was conducted in June and July 1985. After the first grouting exercise, inflow was reduced to negligible amounts (Deshler and McKinney, 1988). Two additional grouting exercises were conducted in the exhaust shaft from July through December 1986 and from June 16 through August 26, 1987. The second grouting was conducted in order to stop leaks that had developed in the upper portions of the shaft and at the construction joints. The third grouting consisted of high-pressure contact cement grouting of the Culebra and Magenta dolomite intervals, the liner, and the key. No measurable inflow has occurred since that time (Deshler and McKinney, 1988).

H.1.4 Air-Intake Shaft

Construction of the air-intake shaft (AIS) was accomplished in several phases (Figure H.1). A summary of the drilling and construction events affecting hydraulic conditions in the Culebra is presented below:

January 1, 1988:	The 0.25-m pilot hole penetrated the Culebra. Borehole was full of clay-based drilling mud with an assumed weight of 1174.4 kg/m^3 (measured on January 13, 1988). Pressure at the Culebra dolomite depth was estimated to be about 2.50 MPa for a relatively short time (3 hours) until the buildup of a significant filter-cake skin occurred (Avis and Saulnier, 1990). After the skin had formed, the

pressure within the Culebra was reduced to about 1.31 MPa (Avis and Saulnier, 1990).

January 6, 1988:	The Culebra interval was cemented during activities designed to correct deviation in the borehole.
January 8, 1988:	The 0.25-m pilot hole repenetrated the Culebra. A pressure of 2.50 MPa was estimated at the Culebra depth for approximately 20 hours and then is reduced to 1.69 MPa (Avis and Saulnier, 1990).
February 2, 1988:	The Culebra interval was reamed to 0.37 m. Pressure exerted on the Culebra was estimated to be 2.50 MPa initially (5 hours) and then to reduce to 1.51 MPa (Avis and Saulnier, 1990).
February 7, 1988:	The drilling fluid was drained from the borehole. The Culebra was exposed to atmospheric pressure and allowed to drain unrestricted to the pilot hole.
June 17, 1988:	The Culebra was upreamed to 6.17 m and remained open and draining to the AIS.

Several inflow measurements have been made at the air-intake shaft. The first measurement, taken on February 7, 1988 at the base of the 0.37-m pilot hole, was determined to be 3.2×10^{-2} L/s (Deshler and McKinney, 1988). Eight months later, the Culebra inflow rate was measured and estimated to be 5.6×10^{-2} L/s (Avis and Saulnier, 1990). This measurement was made on October 28, 1988, four months after the pilot hole had been reamed to 6.17 m. In November 1988, a steel plate was placed over the Culebra interval to direct flow. Three measurements taken in June of 1989 determined an inflow rate of 4.7×10^{-2} L/s. Table H.1a-c summarizes measurements of inflow into the air-intake shaft.

H.2 Potash Mine Shafts in the WIPP-Site Region

Several potash mine shafts penetrate the Culebra dolomite in the WIPP-site area (Figure H.2). These shafts lie both west and east of the center of Nash Draw. The influence of the shafts located to the west of the center of Nash Draw upon the hydrologic conditions within the Culebra dolomite can be considered minimal. The potential influence of the shafts lying east of the center of Nash Draw on the Culebra flow regime is summarized below.

Duval (Western Agate) Mine Shafts No. 5 and 6

The No. 5 and No. 6 shafts of the Duval Corporation were constructed in 1963 to depths of approximately 275 m in order to develop the potash ore body within the Salado. The diameters of the shafts are approximately 4.25 and 3.66 m for No. 5 and 6, respectively. A concrete liner was installed in both shafts. The Culebra, located about 75 m BGS, and the residuum layer (110 m BGS) above the Salado comprise the water-bearing units at this location.

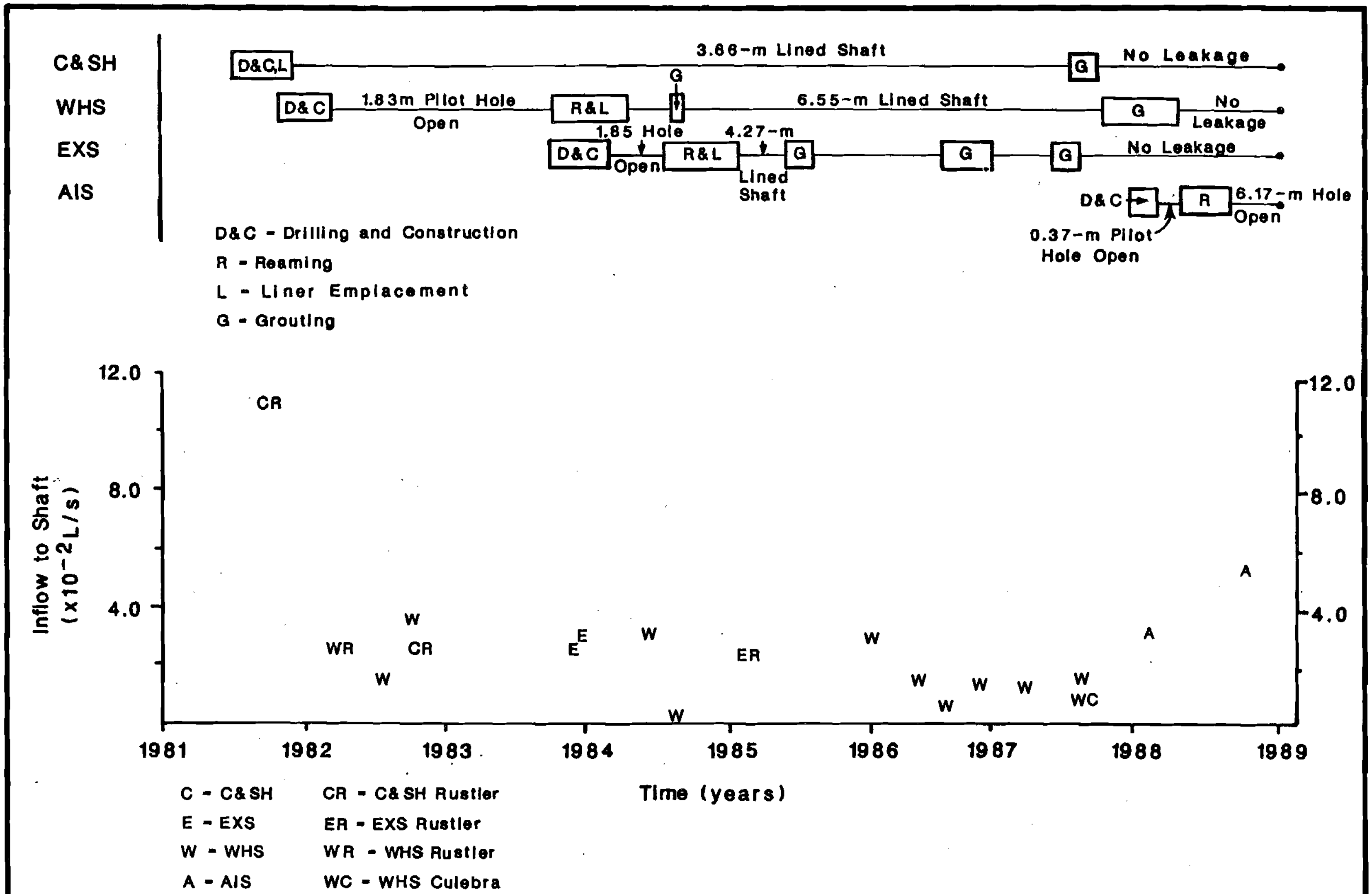
Ground-water inflow into these shafts has not been adequately documented since their construction. However, shaft operators estimate the total inflow for each shaft is less than 0.06 L/s (J.Hunt, personal communication, 1987). Since the Culebra is highly transmissive in this region, the effect of a 0.06 L/s inflow to the shafts from the Culebra can be considered negligible.

IMC. No. 5 Shaft

The International Minerals and Chemical Corporation (IMC) constructed their No. 5 shaft in 1983. The shaft is approximately 267 m deep, 5.5 m in diameter, and has a 0.61 m thick concrete liner. Ground-water inflow records have been maintained since the shaft was completed. The average rate of inflow into the shaft since 1983 is 2.5×10^{-3} L/s (Gary Williams, personal communication, 1987). The effect of this inflow upon the Culebra flow regime can be considered minimal because of the high transmissivity of the Culebra in this region.

Kerr McGee Shafts No. 1 and 2

The Kerr McGee Chemical Corporation completed construction on shafts No. 1 and No. 2 in 1960 and 1963, respectively. The No. 1 shaft is approximately 515 m deep, 4.57 m in diameter, and is lined throughout with 0.5 m of concrete. The No. 2 shaft is 508 m deep, 2.4 m in diameter, and is lined down through the Culebra with 0.5 m of concrete. Leakage in these shafts occurs only within the top 30 m of the shaft (Walter Case, personal communication, 1987), therefore, flow conditions within the Culebra dolomite are not affected.

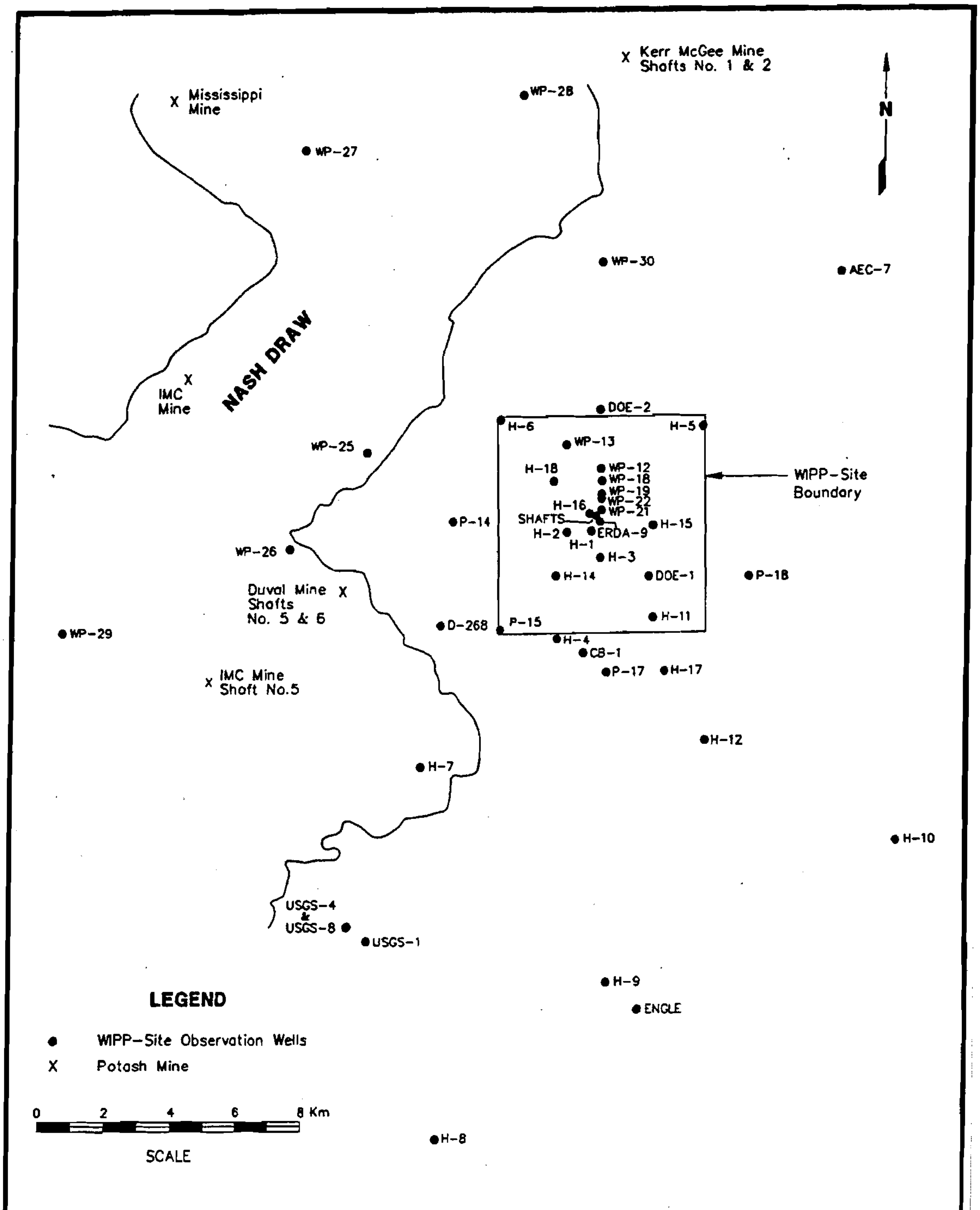


INTERA Technologies

Summary of WIPP-Site Shaft Histories and Leakage

Figure H.1

H09700R869 ABW 4/12/89



Drawn by ABW	Date 11/15/89	WIPP-Area Culebra Boreholes and Potash Mine Shafts
Checked by T.C.	Date 11/15/89	
Revisions	Date	
H09700R869	11/15/89	
INTERA Technologies		Figure H.2

RUSTLER INFLOW INTO WIPP SHAFTS Updated 11/07/89

Date	Inflow Rate (1) (L/s)	Reference
Construction & Salt-Handling Shaft		
09/13/81	0.110	Deshler & McKinney
07/03/82	0.019	Gonzales
09/28/82	0.036	Gonzales
10/02/82	0.025	Gonzales
10/02/82	0.025	Gonzales
10/02/82	0.025	Gonzales
10/02/82	0.019	Gonzales
10/02/82	0.025	Gonzales
10/08/82	0.043	Gonzales
Waste-Handling Shaft		
03/10/82	0.022	Gonzales
07/03/82	0.019	Deshler & McKinney
09/28/82	0.032	Deshler & McKinney
10/02/82	0.025	Deshler & McKinney
10/08/82	0.038	Deshler & McKinney
06/84	0.032	Roberts
10/84	0.001	DOE
01/02/86	0.025	Deshler & McKinney
01/15/86	0.027	Deshler & McKinney
01/15/86	0.030	Deshler & McKinney
01/23/86	0.030	Deshler & McKinney
01/30/86	0.023	Deshler & McKinney
02/03/86	0.027	Deshler & McKinney
02/03/86	0.028	Deshler & McKinney
02/05/86	0.021	Deshler & McKinney
02/12/86	0.028	Deshler & McKinney
02/13/86	0.028	Deshler & McKinney
02/17/86	0.028	Deshler & McKinney
02/19/86	0.028	Deshler & McKinney
02/20/86	0.019	Deshler & McKinney
02/28/86	0.021	Deshler & McKinney
03/07/86	0.021	Deshler & McKinney
03/13/86	0.019	Deshler & McKinney
03/17/86	0.027	Deshler & McKinney
03/18/86	0.019	Deshler & McKinney
03/21/86	0.028	Deshler & McKinney
03/26/86	0.019	Deshler & McKinney
04/02/86	0.018	Deshler & McKinney
04/03/86	0.025	Deshler & McKinney

Drawn by T.C.	Date 10/25/89	Measurements of Inflow into the WIPP Shafts
Checked by T.C.	Date 10/25/89	
Revisions	Date	
#1050-000	10/25/89	
INTERA Technologies		Table H.1a

Date	Inflow Rate (1) (L/s)	Reference
Waste-Handling Shaft (cont.)		
04/07/86	0.014	Deshler & McKinney
04/08/86	0.017	Deshler & McKinney
04/10/86	0.017	Deshler & McKinney
04/15/86	0.016	Deshler & McKinney
04/16/86	0.020	Deshler & McKinney
04/18/86	0.019	Deshler & McKinney
04/24/86	0.018	Deshler & McKinney
04/25/86	0.020	Deshler & McKinney
04/25/86	0.017	Deshler & McKinney
05/15/86	0.014	Deshler & McKinney
05/19/86	0.014	Deshler & McKinney
05/22/86	0.014	Deshler & McKinney
05/28/86	0.015	Deshler & McKinney
06/02/86	0.013	Deshler & McKinney
06/06/86	0.008	Deshler & McKinney
06/06/86	0.008	Deshler & McKinney
06/12/86	0.010	Deshler & McKinney
06/19/86	0.009	Deshler & McKinney
06/24/86	0.014	Deshler & McKinney
07/01/86	0.008	Deshler & McKinney
10/13/86	0.008	Deshler & McKinney
10/28/86	0.011	Deshler & McKinney
11/06/86	0.013	Deshler & McKinney
11/11/86	0.012	Deshler & McKinney
11/20/86	0.016	Deshler & McKinney
11/26/86	0.015	Deshler & McKinney
12/04/86	0.015	Deshler & McKinney
12/29/86	0.016	Deshler & McKinney
01/29/87	0.011	Deshler & McKinney
03/13/87	0.010	Deshler & McKinney
03/20/87	0.006	Deshler & McKinney
04/03/87	0.013	Deshler & McKinney
04/08/87	0.013	Deshler & McKinney
04/22/87	0.012	Deshler & McKinney
04/19/87	0.010	Deshler & McKinney
05/07/87	0.020	Deshler & McKinney
05/08/87	0.004	Deshler & McKinney
05/15/87	0.011	Deshler & McKinney
05/22/87	0.012	Deshler & McKinney
06/11/87	0.011	Deshler & McKinney
06/18/87	0.011	Deshler & McKinney
06/30/87	0.010	Deshler & McKinney
07/07/87	0.009	Deshler & McKinney

Drawn by T.C.	Date 10/25/89	Measurements of Inflow into the WIPP Shafts
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INTERA Technologies		Table H.1b

Date	Inflow Rate (1) (L/s)	Reference
Waste-Handling Shaft (cont.)		
07/16/87	0.010	Deshler & McKinney
07/23/87	0.010	Deshler & McKinney
07/29/87	0.009	Deshler & McKinney
08/05/87	0.010	Deshler & McKinney
08/06/87	0.008	Gonzales
08/20/87	0.009	Deshler & McKinney
08/26/87	0.010	Deshler & McKinney
09/11/87	0.010	Deshler & McKinney
09/16/87	0.015	Deshler & McKinney
10/01/87	0.010	Deshler & McKinney
10/07/87	0.010	Deshler & McKinney
10/08/87	0.010	Deshler & McKinney
10/16/87	0.012	Deshler & McKinney
10/30/87	0.011	Deshler & McKinney
11/04/87	0.012	Deshler & McKinney
Exhaust Shaft		
11/30/83	0.026	Deshler & McKinney
12/21/83	0.030	Deshler & McKinney
01/85	0.022	Deshler & McKinney
Air-Intake Shaft		
02/07/88	0.030	Deshler & McKinney
10/28/88	0.056	Avis & Saulnier
06/01/89	0.047	INTERA
06/07/89	0.047	INTERA
06/12/89	0.047	INTERA

(1) The majority of the inflow rates reflect combined flow from the Magenta and Culebra dolomites. For a complete description of the inflow measurements see the appropriate references.

Drawn by T.C.	Date 10/25/89	Measurements of Inflow into the WIPP Shafts
Checked by T.C.	Date 10/25/89	
Revisions	Date	
#1050-000	10/25/89	
INTERA Technologies		Table H.1c

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