WILLIAMS & ASSOCIATES, INC.

P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

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Mr. Jeff Pohle
Division of Waste Management
Mail Stop SS-623
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: SALT

Dear Jeff:

I am enclosing a review of each of the following documents:

1. Dutton, A.R., Fisher, R.S., Richter, B.C., and Smith, D.A., 1985, Hydrologic Testing in the Salt-Dissolution Zone of the Palo Duro Basin, Texas Panhandle: Preliminary Report of Field Data at Sawyer #2 and Mansfield #2 Wells: Texas Bureau of Economic Geology, Austin, TX, OF-WTWI-1985-3.

2. Parizek, R., Mink, L., Domenico, P., and Robertson, J., July 1985, Report of the Panel on Evaluation of Ground-Water Flow in Fractures at the Palo Duro Basin: transmittal letter from J. Tracy to T. Naymik.

If you have any questions concerning these reviews, please call.

Sincerely,

Gerry V Winter/sl

Gerry V. Winter

GVW:sl

WM-RES
WM Record File
D-1020
W+A

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

Distribution:
Pohle

(Return to WM, 623-SS)

2779

WMGT DOCUMENT REVIEW SHEET

FILE #:

TEXAS BUREAU OF ECONOMIC GEOLOGY REPORT #: OF-WTWI-1985-3

DOCUMENT: Dutton, A.R., Fisher, R.S., Richter, B.C., and Smith, D.A., 1985, Hydrologic Testing in the Salt-Dissolution Zone of the Palo Duro Basin, Texas Panhandle: Preliminary Report of Field Data at Sawyer #2 and Mansfield #2 Wells: Texas Bureau of Economic Geology, Austin, TX.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: February 11, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

This report summarizes data collected at the Sawyer #2 and Mansfield #2 wells. These wells were constructed to conduct hydrogeologic testing in the salt-dissolution zone of the Palo Duro Basin. The report contains hydrogeologic parameter values of transmissivity and hydraulic conductivity and chemical analyses data. Isotopic data are included also. We have no major concerns regarding the report under review. We have several minor concerns regarding testing procedures.

BRIEF SUMMARY OF DOCUMENT:

The report describes the construction and testing of two wells placed in the salt-dissolution zone in the Palo Duro Basin. These wells, Sawyer #2 and Mansfield #2, were used to measure hydrogeologic properties on a single well basis and to obtain water samples. Test intervals were selected based on the interpretation of electric logs and core. Bases of the test zones were within 7 to 49 feet of the upper surface of bedded salt. The Sawyer #2 and Mansfield #2 wells were offset by 100 to 200 feet from deeper wells that were drilled previously. The wells were drilled to the top of the test zone whereupon geophysical logs were run and the borehole cased. The test zone was then drilled or cored with an air-mist foam. Thiocyanate

(SCN^-) was used as a tracer in the drilling fluid. The Sawyer and Mansfield wells were developed by air-lift pumping using the drill pipe. These wells yielded about 50 to 80 gallons per minute via air-lift pumping.

The report presents some details of the drilling and construction of the Detten #2 well and the Harmon #1 well. The Detten #2 well was drilled similarly to the Sawyer and Mansfield wells. The Detten #2 well did not yield water by air-lift pumping. The Harmon #1 well was drilled using a salt base mud. The salt-dissolution zone test interval was created by placing a cement plug in the borehole below the zone of interest. A 148-foot interval between the base of the casing and the top of the plug was used as the test zone. The report states that the test zone at the Harmon well was more contaminated with drilling fluid than the test zones at the other three wells. Additional details on the Detten and Harmon wells are not presented in the report.

A 5 horsepower submersible electric turbine pump was used to test the Sawyer #2 and the Mansfield #2 wells. Water level recorders were used to measure nontest water level fluctuations created by atmospheric pressure changes and other factors. Test data were obtained from the pumping wells using silicon stain gauge transducers. The transducers were not placed at the test interval depth; the transducers were placed at an intermediate depth.

The wells were tested to measure the concentration of tracer concentration in the groundwater samples. Samples were obtained after clean-up was complete. Water sample analyses are tabulated in the attached table. The groundwater from the Sawyer #2 well is a saline, sodium-chloride type water with a total dissolved solids content of 94,924 mg/L. The groundwater from the Mansfield #2 well is a saline, sodium-chloride type water with a total dissolved solids content of 67,537 mg/L.

The report describes interpretations of geology at the Sawyer #2 well based on geophysical log interpretation and correlation to information obtained from the Sawyer #1 well. The report states that marker beds at the Sawyer #2 well are displaced upward by up to 20 feet relative to the beds at the Sawyer #1 well. The collapse breccia overlying the Unit 4 carbonate are 25 feet thicker than at the Sawyer #1 well. The gypsum bed immediately above the carbonate does not appear to be influenced by salt dissolution. The report states that "the dip and thickness variations in the collapsed breccia overlying the carbonate probably reflect subsidence of overburden and infilling of large subterranean cavities created by solution of the Unit-4 salt" (p. 4). The testing was conducted at the Sawyer #2 well in cycles. The first recovery period occurred after pumping the well constantly for 7 days at 12 to 13 gpm. The first drawdown test

was approximately 14 hours; a second recovery period occurred for approximately 7 hours. Data were obtained via the transducer. The report states that equipment difficulties rendered recovery #1 data unanalyzable. The report states further that the first 100 minutes of drawdown and recovery were influenced strongly by wellbore storage effects. Results of the various analyses applied to the test data are appended to this report. Recovery data from the well are affected adversely because the pump was not equipped with a check valve. This omission allows water in the pump column to drain back into the well which creates an abnormal recovery rate. This adnormal recovery rate greatly affects the recovery data.

The Mansfield #2 well was pumped using the same 5 horsepower submersible pump. No observation well was available for this test. Several problems occurred during the testing of the Mansfield #2 well. The initial drawdown and recovery period were approximately 11 hours in length. Test #2 was of no value due to a recorder malfunction. Drawdown period #3 was aborted due to recorder malfunction. The drawdown and recovery periods for the fourth cycle were usable for analysis. The second drawdown period was approximately 9 hours in length; the recovery period was 4 hours. The results of analyses of the data are appended to our review. It should be noted that recovery data from this test are affected as was recovery data from the test of the Sawyer #2 well. A check valve was not in place during testing. Consequently water in the discharge tubing drained back into the well which affects recovery data adversely.

The report states that diurnal fluctuations occurred in the water level data obtained from the water level recorders. It is not clear from the report whether these data were collected prior to or after the testing, but we believe it was collected after testing in Sawyer #2 and possibly prior to testing in Mansfield #2 wells. The hydrographs attached to the report under review are not labeled; we are not certain about this interpretation. The report states that the fluctuations in hydraulic head in the salt-dissolution zone are in response to fluctuations of atmospheric pressure. The report states "This means the salt-dissolution zone is confined." The report further states that water level changes at the Sawyer #2 well were approximately twice the change recorded at the Mansfield #2 well. The report states that this is an indication that the coefficient of storage at the Sawyer #2 well is smaller than the coefficient of storage at the Mansfield #2 well.

The report states that the isotopic data indicate that the origin of dissolved sulfate in the test zones is the "dissolution of Permian Age evaporites or of vein-filling gypsum" (p. 11). The report states further that the age of the water may be at least several thousand years. The report states that the origin of the

water found at the Mansfield #2 well was meteoric with an origin probably farther to the west than the origin of the water at the Sawyer #2 well.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

This report is important to the Waste Management Program because the topic of salt-dissolution is a primary issue with respect to repository stability and performance. This report investigates the hydrogeologic and hydrochemical properties of the dissolution zone in the Palo Duro Basin. These are the first tests that we have seen reported in the literature regarding the dissolution zone. Hydraulic conductivity values and chemical data are included in the report which provide evidence as to the origin and age of the groundwater.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

We have no major problems with the report under review. We do have several minor comments which follow. The testing of the Sawyer #2 and Mansfield #2 wells was conducted using a submersible pump. The submersible pump will facilitate excellent drawdown data measurements in the pumping well; however, the lack of a check valve in the discharge tubing renders the recovery data virtually unanalyzable. The drainage of water back through the pump seriously affects the recovery data. The investigators have done a credible job of analyzing the drawdown and recovery data subject to the limitations noted. Observations wells are not available for these tests on the dissolution zone. Coefficient of storage was not investigated from these tests because of the lack of observation wells.

The report states that fluctuations in the water level are due to atmospheric pressure fluctuations. The report states that "This means the salt-dissolution zone is confined." We find this statement to be unsupported. It is noted in the literature (Freeze and Cherry, 1979, p. 234) that changes in atmospheric pressure can create changes in the water table in unconfined aquifers. Fluctuations of up to 6 cm in fine-grained aquifers have been noted in shallow water table aquifers. Additional information should be included in the report under review to substantiate the claim that these diurnal fluctuations are due to atmospheric pressure fluctuations and that the salt-dissolution zone is confined. We believe that these zones are confined but the statement is not supported in the report under review.

The report states that the natural movement of water in the dissolution zone was sufficient to flush the small amount of drilling contamination away from the test wells. The rate of groundwater movement at the site in these zones is not stated in the report under review. An estimation of the groundwater flow rate is worth including to substantiate the claim that the contamination had been moved from the site.

REFERENCES:

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 p.

Table 2

Summary of Hydrologic Tests

Test Period	Q (m^3/day)	b (m)	P_D	ΔP (psi)	s/cycle (m)	T m^2/day	K m/day	Method
				Sawyer #2 Well				
drawdown #1	58.875	6.71	1.0	5.25 & 3.36	-	2.4 to 3.6	0.4 to 0.5	type-curve match
recovery #2	58.875	6.71	1.0	5.43 & 3.42	-	2.3 to 3.7	0.3 to 0.6	type-curve match
				Mansfield #2 Well				
drawdown #1	49.55	16.76	1.0	3.3	-	3.2	0.19	type-curve match
	"	"	-	-	2.83	3.2	0.19	Jacob approximation
recovery #1	49.55	16.76	1.0	3.7	-	2.8	0.17	type-curve match
	"	"	-	-	3.32	2.7	0.16	Theis approximation
drawdown #3	53.73	16.76	1.0	4.15	-	2.7	0.16	type-curve approximation
	"	"	-	-	3.25	3.0	0.181	Jacob approximation
drawdown #4	58.57	16.76	1.0	4.95	-	1.5	0.09	type-curve approximation
	"	"	-	-	3.38	3.2	0.189	Jacob approximation
recovery #4	58.57	16.76	1.0	2.47	-	5.0	0.3	type-curve approximation
	"	"	-	-	3.102	3.5	0.19	Theis approximation

Q - flow rate; b - test-zone thickness; P_D - type-curve pressure match-point; ΔP - data match point; s/cycle - straight-line slope on semi-log plot; T - transmissivity; K - hydraulic conductivity

Table 3

Results of Chemical Analyses
(concentrations in mg/L)

Constituent	Sawyer #2 Well	Mansfield #2 Well
Ca^{2+}	1,860.0	1,460.0
Mg^{2+}	480.0	388.0
Na^{+}	33,000.0	23,850.0
K^{+}	30.3	31.9
Sr^{2+}	27.8	23.1
SiO_2	5.69	4.23
Fe	0.773	0.091
SO_4^{2-}	4,725.0	5,610.0
Cl^{-}	54,700.0	36,120.0
HCO_3^{-}	72.6	41.53
Br^{-}	21.4	6.2
I^{-}	bdl	bdl
H_2S	bdl	bdl
pH	6.3	7.2 to 7.55
Eh(v)	-0.185	-0.325
T°C	23.5	22.9
t.d.s.	94,924.	67,537.
c/a^1	0.96	1.01
$\delta D^{2,6}$	-47.7‰	-60.5‰
$\delta D^{3,6}$	-52.0‰	-72.0‰

Table 3 (Concluded)

Constituent	Sawyer #2 Well	Mansfield #2 Well
$\delta^{18}O$ [2,6]	-7.3 °/oo	-9.2 °/oo
$\delta^{18}O$ [3,6]	-7.18 °/oo	-9.40 °/oo
$\delta^{34}S$ [3,7]	+11.92 °/oo	+9.07 °/oo
$\delta^{13}C$ [4,8]	-1.9 °/oo	-3.1 °/oo
^{14}C [4,9]	3.3 $\pm$0.4	1.7 $\pm$0.13
^{36}Cl [5]	not reported	not reported

1 - ratio of cations (meq/L) to anions (meq/L)
2 - reported by Knauth, L. P., Arizona State University
3 - reported by Mankiewicz, P. J., Global Geochemistry Corp.
4 - reported by Long, A., University of Arizona
5 - reported by Bentley, H., Hydro Geo Chem, Inc.
6 - SMOW standard
7 - Canyon Diablo meteorite standard
8 - PDB standard
9 - % Modern
bdl - below detection limit

WMGT DOCUMENT REVIEW SHEET

FILE #:

ONWI #:

DOCUMENT: Parizek, R., Mink, L., Domenico, P., and Robertson, J., July 1985, Report of the Panel on Evaluation of Ground-Water Flow in Fractures at the Palo Duro Basin: (transmittal letter from J. Tracy to T. Naymik)

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: February 10, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The document under review presents the basic information generated by the panel regarding groundwater flow in the Palo Duro Basin. The panel believes that the most probable flow path should be considered as a porous medium flow mechanism through the sedimentary strata. The panel believes further that the porous flow paths and resultant travel time should be evaluated stochastically.

We have no major concern regarding the report under review. We have some minor comments about the text of this document.

BRIEF SUMMARY OF DOCUMENT:

The report discusses the possible correlation of linear features present at the land surface with deeper structural features that may carry down to the crystalline basement. The report notes that one well (Detten #1) was drilled in an area associated with a surface linear. The report states that "no-out-of-the-ordinary structures, open joints, fluids occurrences or higher permeability values were noted in this deep test well when compared to other Stone and Webster deep test wells" (p. 5). It is noted that it is difficult to intercept a near vertical feature with a vertical drillhole.

The report states that there is no evidence to suggest that "detectable amounts of post-Permian ground waters have moved through more brittle beds within the salt section to enhance salt dissolution and to increase rock permeability" (p. 6). The report further states that there are no apparent significant losses of salt that can be related to intrastrata bound dissolution which has been noted in the Delaware Basin.

The report states that veins are oriented parallel to the regional structural trends suggesting that the halite veins were developed under the influence of the regional stress field. Fracturing in the Wolfcamp group is nearly vertical; fracturing has a NE-SW and NW-SE orientation. The report states that the overall stress system indicates that NE trending fractures are most apt to be open. This orientation is most likely to influence groundwater flow and salt dissolution. In-situ measurements of stress at the Holtzclaw Well #1 in Randall County indicates that the regional comprehensive stresses are oriented NE-SW. The report states that fracturing may be a factor in considering groundwater flow through brittle beds but that the halite beds should help isolate open fractures or joints in the vertical direction between the brittle beds.

The report cites experimental evidence regarding the fracturing and healing characteristics of salt. The report states that salt does not fracture in the same manner as consolidated rock such as limestone or sandstone (p. 9). Salt tends to "build a fracture from an initial point" (p. 9). Experimental evidence strongly indicates that fractures will heal in pure halite under loading conditions simulating in-situ compressive stresses.

The report states that there is significant uncertainty regarding the magnitude and direction of vertical gradients within the evaporite section. The report states that gradients can range from predominantly downward to slightly upward in some locations. This uncertainty should be considered in a probability analysis of travel times. The report describes several problems associated with modeling the hydrogeologic system found in the Palo Duro Basin. The report states that "these models should not be considered reasonable representations of the real flow system for pathway and travel time analyses because of the following limitations." The reference is to east-west cross sectional models which are constructed for gross conceptual analysis of major features. The report further states "The frequency of reference to these models in many publications and figures could mislead readers into an incorrect interpretation of the real flow system" (p. 10).

The ^{18}O and the deuterium content of water samples from the salt sequence suggest that this water was formed due to the evaporation of sea water. Water samples obtained from the

eastern end of the basin have a different isotopic character that does not contain a meteoric component. A mixed meteoric-formation water is forming in the basin. The isotopic composition of the deep formation waters and the major ion content of these waters suggests that this mixing is occurring from the western end of the basin. The report states that Knauth "argues that saline meteoric water moving through the salt sequence would not produce the observed patterns of mixing within the Wolfcamp series" (p. 11).

The report states that there are uncertainties inherent in the description of the geology and hydrogeologic setting in the Palo Duro Basin. The report suggests further that the uncertainties should be reflected in the way travel time assessments are made by using an estimated probability distribution of travel time. The report suggests that a Monte Carlo technique is probably appropriate for estimating travel time. This approach is being developed by INTERA Technologies, Inc.

The report states that fluid flow probably will occur in both fractured and porous rocks but that this flow probably will be dominated by porous flow (p. 14). The panel recommends that fracture flow be modeled as equivalent porous flow with the effective porosity and permeability being adjusted appropriately. The report states that "effective porosity should fall in a range from slightly less than total porosity to a lower limit of 1×10^{-3}" (p. 14). The report states that the data are insufficient to justify using network models for simulating fracture flow.

The report presents four conceptual models of flow in the Palo Duro Basin. The conceptual model that is considered to be most probable is that of non-fractured porous flow. The other scenarios include fracturing in the brittle units which may be confined within those units; or they may extend through all units. The panel does not believe that the conceptual model which includes fracturing extending through all units is probable but it should be considered in the Monte Carlo analysis.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review outlines the procedures which will be used to consider groundwater flow through the salt sequence at the Palo Duro Basin. The concept of groundwater flow is important to considerations of travel time because the methodologies used for fracture versus porous media flow are extremely different. This report should be reviewed for determination of the thought processes which are guiding the

travel time estimates which will be made by the Department of Energy for the Palo Duro Basin site.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report states (p. 1) that the "main component of flow [in the salt section] appears to be dominantly horizontal." On the following page the net vertical gradient is stated to be downward across the salt section resulting in a "downward flow component." Horizontal flow occurs in the more permeable units below the salt horizon. These statements appear to be contradictory on page 2. These statements require clarification.

The report states on page 6 that no detectable amounts of post-Permian groundwater have moved through the more brittle beds within the salt section. We point out that further testing may reveal indications of such groundwater movement. Such groundwater movement would enhance salt dissolution and tend to increase permeability. The report states on this page that no significant losses of salt have occurred that can be attributed to intrastrata bound dissolution of the type that has been found in the Delaware Basin. We wish to point out that very little testing and drilling has been conducted for the collection of hydrogeologic data within the salt section to date. The primary emphasis of testing has been in the strata below the evaporite sequence.

The report states (p. 11) that saline meteoric water moving through the salt sequence would not produce the patterns of mixing which have been observed within the Wolfcamp series. We point out that the groundwater sampling to date in the Palo Duro Basin has been on a limited basis. Additional wells and sampling may indeed reveal areas that indicate mixing of ground waters. We do not argue that the present data suggest differently; we suggest that additional data may provide new evidence regarding this conclusion.

The report states (p. 14) that effective porosity probably will fall in a range from slightly less than total porosity to a lower limit that is 1×10^{-3}. No justification is given in the report for the lower limit of 1×10^{-3}. This value may be an order of magnitude higher than is appropriate for consideration of a lower limit of effective porosity. This value should be justified in the report under review.

The report conveys that the Case A conceptual model (non-fractured porous flow) is the most probable condition in the Palo Duro Basin. We cannot argue with this conclusion. We point out that this conceptual model may prove to be a non-conservative

approach unless certain measures are taken to insure that reasonable values of hydraulic conductivity and porosity are used in subsequent travel time estimates and model simulations.