Memorandum No. 2 Concerning Magnesium Brine Wells of the Emro Corporation Near Carlsbad, New Mexico

By C. V. Theis and W. E. Hale
In cooperation with the Defense Plant Corporation
March 15, 1942

As it now appears that the U.S. Geological Survey will be only casually connected with any further exploration of the magnesium brines in Red Bluff Draw, south of Carlsbad, New Mexico, it seems proper to record certain tentative hypotheses and tentative estimates of the reserve available arrived at as the result of the work already done. The hypotheses are based upon insufficient data and can only be said to be reasonable geologically and to fit the available data better than any others that have occurred to the writer. If the question of further exploration arises they may furnish a means of estimating the chances of success in finding a usable reserve of brine, and if further work is done they will furnish a rational background to guide the exploration.

Nature of the Aquifer

The materials penetrated by the drill in this area consist primarily of massive, selenitic, alabastine, and saccaroidal gypsum, with which is admixed some minor amount of clay and siltstone and some dolomite. Below the horizon of the brine some anhydrite is encountered. The brine has been encountered at depths between 100 and 200 feet and is always under pressure, sufficient to result in flowing wells at the lower elevations. No definite confining bed is present and there is no abrupt and definite change in material at any horizon. Gypsiferous water is found at shallow depths, between 14 and 52 feet in most of the holes and at a depth of 80 feet in Etz No. 1, also in gypsum apparently indistinguishable from the remainder of the gypsum. The material appears, therefore, to be heterogeneous in detail but rather uniform en masse and yet possesses sufficient bedding to give rise to porous zones and impervious confining beds over sufficient area to yield considerable pressure on the brine.

Two hypotheses have been proposed to explain the nature of the material in which the brine occurs. The first considers the gypsum a fill in an older valley excavated to a considerable depth below the present surface. The second, apparently originally proposed by Lang, considers the gypsum a weathering product of the anhydrite originally making up the Castile formation. The difficulties facing the acceptance of the fill hypothesis seem insurmountable. The valley must be filled with a gypsum debris to the almost entire exclusion of other material more resistant to abrasion and solution. The debris must be arranged in beds or perhaps shoe-string lenses that have continuous permeability over considerable distances and must be overlain by material, indistinguishable in drill cuttings from the porous material, that is impermeable over an area sufficient to give rise to considerable head in the underlying brine. These porous beds must be at various elevations but must also be to some degree interconnected. On the other hand, weathering commonly works down some beds at a faster rate than in adjacent more resistant beds. Given the thorough weathering of a thick mass of bedded anhydrite to gypsum it would be expected that certain beds would be opened up in a porous manner whereas others would be left impervious either because of less weathering or because of more weathering reducing the original beds to a mass of gypsum blocks embedded in a clayey residuum. Further the fact that the brine occurrences can be interpreted as being in one or two beds, as will be shown later, is contributory evidence that we are dealing here with a weathered residuum.

The origin of the brine appears obscure. The process which gave rise to it must be one capable of giving a saturated solution of magnesium, sodium, and sulphate with a high boron content, with the almost complete exclusion of calcium, although it occurs in high-calcium rocks, and of chloride, the radical commonly accompanying sodium and magnesium in the Permian basin. The origin forms a very interesting problem for a physical chemist. The brine is apparently not connate because in the first place it seems difficult to produce a mother liquor of its composition by the processes of evaporation, although considering the complex chemistry of saline deposits it might not be impossible. Probably more conclusive evidence is found in the apparent fact that the brine occurs in weathered zones. The brine itself, being saturated, must insulate the rocks that it covers from weathering, and apparently the only way the rocks could be weathered would be by first diluting the brine. Lang has proposed that the constituents have been concentrated from minute quantities of the elements brought in from long distances and that the solutions because of their density have settled in the traps. This hypothesis may hold the nucleus of the truth but needs some amplification. The ground-water circulation must have been quite abnormal and the solutions must have been concentrated before they arrived at the traps. This would point to an extremely slow ground-water circulation.

The simplest hypothesis from the geological standpoint would be to consider the brines as a product of the weathering that converted the anhydrite to gypsum. The problem lies in the realm of physical chemistry. There are sources of magnesium present in the deposits themselves in the form of thin dolomite beds. Sources of sodium and boron are problematical but it would seem possible that they might be present in traces. Zeoloitic minerals in the clay may possibly be a source of the sodium. It would seem probable that as weathering proceeded in these beds, concentrated solutions would be formed of the most soluble materials available because there would be a tendency for any increment of fresh water to be bound as water of crystallization as the anhydrite was changed to gypsum. There would be a multiple phase system of anhydrite, gypsum, and a concentrated solution of highly soluble salts. If such an hypothesis is acceptable to the physical chemist, it would probably to most acceptable to the geologist.

It may be noted that this hypothesis implies that the accumulations of brine are geologically temporary and that its quantity is limited. As the brine becomes saturated, weathering of the bed enclosing it is arrested. Fresher water added at the surface by rainfall infiltration weathers down the more resistant beds between the brine traps. As these are lowered the brine overflows its dams and joins the ground-water circulation.

Perhaps the simplest explanation of the brine from a geological standpoint would be to assume that there is or has been ground-water circulation along the strike of the beds. If the beds are assumed to have in themselves small amounts of sodium, magnesium, and boron, water seeping into the beds at a higher elevation and discharging at a lower would in one continuous process probably prepare the solution cavities and fill them with the concentrate. In the initial stages of solution the water would move from the higher level to the lower converting the anhydrite to gypsum and opening solution passages probably by a combination of physical disruption of the bed in the process of hydration and solution of gypsum. This process would begin at the surface and gradually work down the dip of the bed. Near the base of the weathered zone at any time the solutions would probably always be more concentrated because they would travel more slowly thru the incipient openings they were in process of enlarging and perhaps also because some of the water would be bound in the gypsum molecule. In the initial stages this more highly mineralized water would be swept onward with the general circulation. As the action progressed, however, down the dip, the flow lines become more and more circuitous and longer giving additional opportunity for solution and concentration. A point would be reached where the density of the brine and the height it must be lifted from the base of the weathered zone to the outlet would be sufficient to balance the longer column of fresh water behind it. The heavier solution would remain in the aquifer and fresher water moving near the surface would override it. As the heavy brine accumulated it would fill part of the openings, thus restricting and slowing the flow of the fresher water and giving it more opportunity to pick up soluble salts. The brine trapped in the bed would probably approach or attain saturation. Eventually an equilibrium would be attained in which the top level of the brine extended nearly horizontally from the point of outflow.

Fortunately, all the questions about the origin of the brine do not have to be resolved before reaching some conclusions as to the probable amount of brine in the vicinity, although because the nature and occurrence are so intangible any evidence that makes more definite our concepts related to it helps also to make our estimates more valid.

Probable Structure of the Rocks in Which the Brine Occurs

The accompanying table gives the elevations of the piezometric surface at each of the wells and the elevations at which the brine was encountered. Wells Nos. 1 and 2 were pumped and the water levels in Nos. 5 and 7 were lowered, the latter conclusively as a result of pumping No. 2 and the former almost certainly so. It will be observed that the static water levels in Nos. 2 and 7 had almost exactly the same elevation before pumping, the small differences being probably the result of slightly different densities of the brine operative over columns about 100 feet long. The level of No. 5 could not be measured before pumping began but it is probable that its static level was also at about the same elevation within the differences resulting from different densities.

If we assume that these three occurrences of the brine known to be connected lie in the same bed and at the same horizon, the dip as shown in figure 1 (not found in archives) is about 90 feet to the mile north 30° east. This is about the same dip as noted by Lang in the beds of the reef in the Barrera del Guadalupe. Although the three wells lie too nearly on a straight line to sharply define the structure yet the brine occurrences at Nos. 3 and 6 lie also within a few feet of the plane containing the occurrences at Nos. 2, 5, and 7. Neither well 3 nor well 6 was affected by the pumping; the peizometric surface of No. 3 was a little higher than that of the three wells known to be connected, and that of No. 6 was about 10 feet higher. Hence there is definite evidence that Nos. 3 and 6 are not connected with Nos. 2, 5, and 7, at least in a direct manner. However, if the brines do occur in solution passages in a weathered bed it would seem altogether possible that there might be fairly independent systems of passages in beds at or near the same geologic horizon. It would seem therefore that the location of these brine occurrences apparently in or near the same plane that contains the others supports the conception that we are dealing with one bed or a thin series of beds, notwithstanding the fact that the occurrences have no direct connection.

A lower horizon of brine, 48 feet below the upper, was struck in well No. 5. The brine occurs in wells 4 and 1 at elevations respectively 60 and 35 feet below the supposed plane of the brine in the other wells. There is a suggestion that these also may be related to one bed but if so an explanation must be found for the fact that the static level of No. 1 is over 100 feet below that of No. 4.

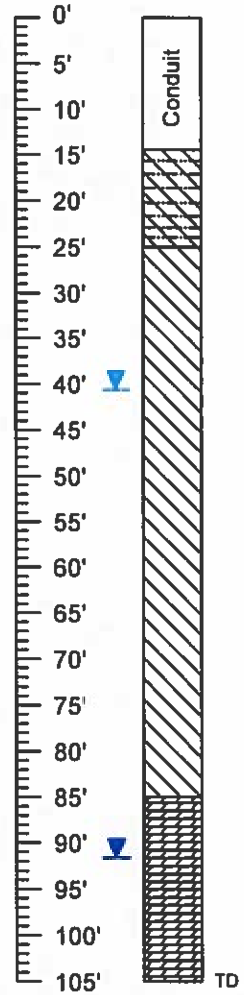
Significance of Pumping Tests

The pumping test on well No. 1 did not yield data that are of particular significance in determining the nature of the aquifer. By its low yield and high drawdown it indicated that the aquifer near it is of comparatively low transmissibility. Its very low piezometric surface and the fact that no other wells reacted to its pumping indicates that the body of brine that furnishes it is probably of quite local extent.

The data on well 2 are more complete. It was pumped at practically a constant rate and an automatic record is available for the fluctuations of water level in well 7 during the time that well 2 was pumping. The rate of fall in well 7 indicates a transmissibility of around 15,000 and a coefficient of storage of the order of 0.0001. The zone in which the brine is found is thought to average about 3 feet thick, which thickness would make the coefficient of permeability about 5,000. The coefficient of storage represents the amount of water in cubic feet withdrawn from each column of the aquifer with base 1 foot square when the head is reduced 1 foot. This low coefficient of storage indicates that the aquifer is under artesian conditions and that there is for instance no significant seepage of liquid through the confining bed.

It was found that the drawdown curve of well 7 could be made to fit the type curves for withdrawal either from a point source, as for instance a well, or from a line, as for instance a trench. There was no difference in the order of the coefficients determined by the two methods. So far as this curve indicates the wells might be drawing from an areally extensive aquifer or from a trench-like aquifer. During the first 24 hours of recovery the rate of recovery in well 2 followed the rule for recovery of a well drawing from an aquifer extensive in all directions and for the next 10 days it appeared to follow that for recovery from a trench-like aquifer. This phenomenon could be explained as the effects produced in a linear aquifer bounded by more or less parallel impermeable walls. Under such an interpretation the early part of the recovery would cover the period before the readjustment of water pressure had reached the boundaries of the aquifer and the remainder of the recovery would represent the extension of the readjustment linearly along the aquifer.

Monitor Well MW-1



Notes
No Odor / No Stain
No Odor / No Stain
No Odor / No Stain
No Odor / No Stain
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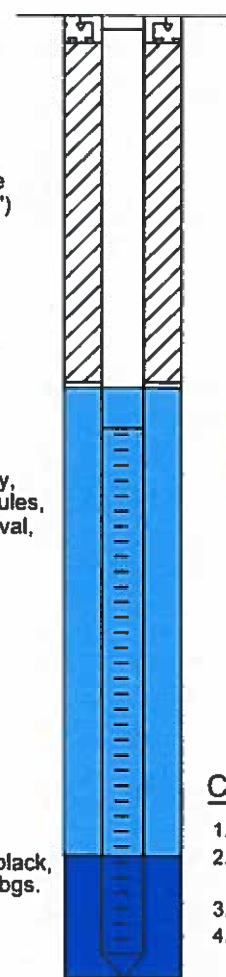
Soil Description

0 - 14.5' - Drilling conduit in former excavation

14.5' - 25' - Sand, light brown, Clay, red, Gypsum, white dry 15' - 25', (moist at 25') soft to hard.

25' - 85' - Gypsum, white to light gray, with some Sandstone nodules, white, dry throughout interval, soft to very hard.

85' - 105' - Dolomite, dark brown to black, wet at approximately 93' bgs.



Monitor Well Details

Date Drilled	September 20, 2018
Thickness of Bentonite Seal	3 ft
Length of PVC Well Screen	37 ft
Depth of PVC Well	105 ft
Depth of Exploratory Well	105 ft

Grout Surface Seal - 3' to Surface

Bentonite Pellet Seal - 40' to 3'

Sand Pack - 40' to 105'

Screen - 45' to 105"

Indicates the ground water level measured on 9/20/2018.

Indicates the ground water level measured on 9/29/2018.

Completion Notes

1. The monitor well was installed on date using Air rotary drilling techniques.
2. The well was constructed with 2" ID, 0.020 inch factory slotted, threaded joint, schedule 40 PVC pipe.
3. The well is flush mount Style.
4. The lines between material types shown on the profile log represent approximate boundaries. Actual transitions may be gradual.
5. The depths indicated are referenced from the ground surface.

Figure 3
MW-1 Boring Log And Monitor Well Details
Plains Pipeline, LP
Alpha Gathering Seg 3 LAT 6E Eddy County, NM

Scale: None
CAD By: CS
Checked By: CS
Draft: October 21, 2018
Lat. N 32.039236° Long. W 104.131222°
TRC Proj. No.: 274959

TRC
10 Desta Drive, Suite 150E
Midland, Texas 79705
432.520.7720

PERMIAN BASIN
ENVIRONMENTAL LAB, LP
1400 Rankin Hwy
Midland, TX 79701

PBELAB

Analytical Report

Prepared for:

Curt Stanley
TRC Solutions- Midland, Texas
10 Desta Dr STE 150E
Midland, TX 79705

Project: Screech Owl CTB
Project Number: SRS# 2017-053
Location:

Lab Order Number: 8J09010

NELAP/TCEQ # T104704516-17-8

Report Date: 10/18/18

TRC Solutions- Midland, Texas
10 Desta Dr STE 150E
Midland TX, 79705

Project: Screech Owl CTB
Project Number: SRS# 2017-053
Project Manager: Curt Stanley

Fax: (432) 520-7701

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
MW-1	8J09010-01	Water	10/08/18 14:50	10-09-2018 09:04

TRC Solutions- Midland, Texas
10 Desta Dr STE 150E
Midland TX, 79705

Project: Screech Owl CTB
Project Number: SRS# 2017-053
Project Manager: Curt Stanley

Fax: (432) 520-7701

MW-1

8J09010-01 (Water)

Permian Basin Environmental Lab, L.P.

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Organics by GC									
Benzene	ND	0.00100	mg/L	1	P8J1201	10/12/18	10/12/18	EPA 8021B	
Toluene	ND	0.0100	mg/L	1	P8J1201	10/12/18	10/12/18	EPA 8021B	
Ethylbenzene	ND	0.00500	mg/L	1	P8J1201	10/12/18	10/12/18	EPA 8021B	
Xylene (p/m)	ND	0.0200	mg/L	1	P8J1201	10/12/18	10/12/18	EPA 8021B	
Xylene (o)	ND	0.0100	mg/L	1	P8J1201	10/12/18	10/12/18	EPA 8021B	
Surrogate: 4-Bromofluorobenzene		*112 %*	*80-120*		*P8J1201*	*10/12/18*	*10/12/18*	*EPA 8021B*	
Surrogate: 1,4-Difluorobenzene		*86.6 %*	*80-120*		*P8J1201*	*10/12/18*	*10/12/18*	*EPA 8021B*	
General Chemistry Parameters by EPA / Standard Methods									
Total Dissolved Solids	**485000**	20.0	mg/L	1	P8J1504	10/15/18	10/16/18	EPA 160.1	

Organics by GC - Quality Control

Permian Basin Environmental Lab, L.P.

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch P8J1201 - General Preparation (GC)										
Blank (P8J1201-BLK1)				Prepared & Analyzed: 10/12/18						
Benzene	ND	0.00100	mg/L							
Toluene	ND	0.0100	"							
Ethylbenzene	ND	0.00500	"							
Xylene (p/m)	ND	0.0200	"							
Xylene (o)	ND	0.0100	"							
Surrogate: 4-Bromofluorobenzene	*0.0642*		"	*0.0600*		*107*	*80-120*			
Surrogate: 1,4-Difluorobenzene	*0.0561*		"	*0.0600*		*93.4*	*80-120*			
LCS (P8J1201-BS1)				Prepared & Analyzed: 10/12/18						
Benzene	0.102	0.00100	mg/L	0.100		102	80-120			
Toluene	0.109	0.0100	"	0.100		109	80-120			
Ethylbenzene	0.112	0.00500	"	0.100		112	80-120			
Xylene (p/m)	0.234	0.0200	"	0.200		117	80-120			
Xylene (o)	0.113	0.0100	"	0.100		113	80-120			
Surrogate: 4-Bromofluorobenzene	*0.0641*		"	*0.0600*		*107*	*80-120*			
Surrogate: 1,4-Difluorobenzene	*0.0611*		"	*0.0600*		*102*	*80-120*			
LCS Dup (P8J1201-BSD1)				Prepared & Analyzed: 10/12/18						
Benzene	0.0894	0.00100	mg/L	0.100		89.4	80-120	12.7	20	
Toluene	0.0957	0.0100	"	0.100		95.7	80-120	13.1	20	
Ethylbenzene	0.114	0.00500	"	0.100		114	80-120	1.70	20	
Xylene (p/m)	0.210	0.0200	"	0.200		105	80-120	10.7	20	
Xylene (o)	0.112	0.0100	"	0.100		112	80-120	1.31	20	
Surrogate: 4-Bromofluorobenzene	*0.0648*		"	*0.0600*		*108*	*80-120*			
Surrogate: 1,4-Difluorobenzene	*0.0607*		"	*0.0600*		*101*	*80-120*			
Matrix Spike (P8J1201-MS1)	**Source: 8J09010-01**			Prepared & Analyzed: 10/12/18						
Benzene	0.0954	0.00100	mg/L	0.100	ND	95.4	80-120			
Toluene	0.104	0.0100	"	0.100	ND	104	80-120			
Ethylbenzene	0.107	0.00500	"	0.100	ND	107	80-120			
Xylene (p/m)	0.221	0.0200	"	0.200	ND	111	80-120			
Xylene (o)	0.112	0.0100	"	0.100	ND	112	80-120			
Surrogate: 4-Bromofluorobenzene	*0.0735*		"	*0.0600*		*123*	*80-120*			*S-GC*
Surrogate: 1,4-Difluorobenzene	*0.0671*		"	*0.0600*		*112*	*80-120*			

Organics by GC - Quality Control

Permian Basin Environmental Lab, L.P.

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch P8J1201 - General Preparation (GC)										
Matrix Spike Dup (P8J1201-MSD1)		**Source: 8J09010-01**		Prepared & Analyzed: 10/12/18						
Benzene	0.0946	0.00100	mg/L	0.100	ND	94.6	80-120	0.863	20	
Toluene	0.105	0.0100	"	0.100	ND	105	80-120	0.730	20	
Ethylbenzene	0.115	0.00500	"	0.100	ND	115	80-120	6.67	20	
Xylene (p/m)	0.217	0.0200	"	0.200	ND	109	80-120	1.67	20	
Xylene (o)	0.112	0.0100	"	0.100	ND	112	80-120	0.00894	20	
Surrogate: 4-Bromofluorobenzene	*0.0730*		"	*0.0600*		*122*	*80-120*			*S-GC*
Surrogate: 1,4-Difluorobenzene	*0.0635*		"	*0.0600*		*106*	*80-120*			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Permian Basin Environmental Lab, L.P.

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch P8J1504 - * DEFAULT PREP *****										
Blank (P8J1504-BLK1)				Prepared: 10/15/18 Analyzed: 10/16/18						
Total Dissolved Solids	ND	20.0	mg/L							
Duplicate (P8J1504-DUP1)		**Source: 8J09011-02**		Prepared: 10/15/18 Analyzed: 10/16/18						
Total Dissolved Solids	250	20.0	mg/L		240			4.08	20	

Notes and Definitions

S-GC	Surrogate recovery outside of control limits. The data was accepted based on valid recovery of the remaining surrogate.
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Brent Barron Date: 10/18/2018

Brent Barron, Laboratory Director/Technical Director

PBELAB

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Permian Basin Environmental Lab, LP
10014 S. County Road 1213
Midland, Texas 79706
Phone: 432-686-7235

Project Manager: Curt Stanley
Company Name: TRC Solutions
Company Address: 10 Desta Drive
City/State/Zip: Midland Tx 79705
Telephone No: (432) 520-7720
Fax No:
Sampler Signature: [signature]
e-mail:

Project Name: Screech Owl
Project #:
Project Loc:
PO #:
Report Format: ☐ Standard ☐ TRRP ☐ NPDES

(lab use only)
ORDER #: 8509010

LAB # (lab use only)	FIELD CODE	Beginning Depth	Ending Depth	Date Sampled	Time Sampled	Field Filtered	Total #. of Containers	Ice	HNO_3	HCl	H_2SO_4	NaOH	$Na_2S_2O_3$	None	Other (Specify)	Matrix (DW=Drinking Water SL=Sludge GW=Groundwater S=Soil/Solid NP=Non-Potable Specify Other)	TPH by TX 1005 8015B 8015M	Chloride	BTEX by 8021B	TDS	RUSH TAT (Pre-Schedule) 24, 48, 72 hrs	Standard TAT
	MW1			10-8-18	1450		3	X		X						GW			X			X
	MW1			10-8-18	1450		1	X								GW				X		X

Preservation & # of Containers; Analyze For: TCLP: TOTAL:

Special Instructions:

Relinquished by:	Date	Time	Received by:	Date	Time
[signature]	10-9-18	9:00			
Relinquished by:	Date	Time	Received by:	Date	Time
Relinquished by:	Date	Time	Received by PBEL: Carolyn Benson	10/9	9:04

Laboratory Comments:
Sample Containers Intact? (Y) N
VOCs Free of Headspace? (Y) N
Labels on container(s) (Y) N
Custody seals on container(s) (Y) N
Custody seals on cooler(s) (Y) N
Sample Hand Delivered (Y) N
by Sampler/Client Rep. ? N
by Courier? UPS DHL FedEx Lone Star
Temperature Upon Receipt:
Received: 0.0 °C
Adjusted: 4.1 °C Factor