BW - 24

PERMITS, RENEWALS, & MODS

CLOSED

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

New Mexico DRUG FREE It's a State of Mind!

BRUCE KING
GOVERNOR

POST OFFICE BOX 2088
STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO 87504
(505) 827-5800

November 1, 1991

BW-024

The Permian Corporation
P. O. Box 3119
Midland, Texas 79702-3119

Attention: Larry Evans

Re: $5,000 One-Well Plugging Bond
The Permian Corporation, Principal
Utica Mutual Insurance Co., Surety
1600' FEL and 2450' FSL of Sec. 33,
T-21-S, R-27-E, Eddy County
Bond No. SU1461348

Dear Mr. Evans:

The Oil Conservation Division hereby approves cancellation of the above-captioned one-well plugging bond effective this date.

Sincerely,

WILLIAM J. LEMAY,
Director

30-015-26733

dr/

cc: Oil Conservation Division
Artesia, New Mexico

Utica Mutual Insurance Co.
P. O. Box 530
Utica, NY 13503

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

New Mexico DRUG FREE It's a State of Mind!

BRUCE KING
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POST OFFICE BOX 2088
STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO 87504
(505) 827-5800

November 1, 1991

The Permian Corporation
P. O. Box 3119
Midland, Texas 79702-3119

Attention: Larry Evans

Re: $5,000 One-Well Plugging Bond
The Permian Corporation, Principal
Utica Mutual Insurance Co., Surety
1400' FEL and 2230' FSL of Sec. 33,
T-21-S, R-27-E, Eddy County
Bond No. SU1461347

Dear Mr. Evans:

The Oil Conservation Division hereby approves cancellation of the above-referenced plugging bond effective this date.

Sincerely,

WILLIAM J. LEMAY,
Director

dr/

cc: Oil Conservation Division
Artesia, New Mexico

Utica Mutual Insurance Co.
P. O. Box 530
Utica, New York 13503

OIL CONSERV ON DIVISION
REC /ED
'91 AUG 19 AM 9 43

The Permian Corporation
P.O. Box 3119
Midland, Texas 79702-3119
FAX 915/684-0501
915/683-4711

August 13, 1991

Ms. Kathy M. Brown
State of New Mexico
Oil Conservation Division
P.O. Box 2088
Santa Fe, New Mexico 87504

Re: Two brine wells
Eddy County
Section 33, TWP So. Range 27
East NMPM

Dear Ms. Brown:

As a follow-up to our conversation, we did not find salt on either of the two wells we drilled on our Carlsbad yard. We have plugged both wells from top to bottom with cement, under the supervision of Messrs. Mike Stubbifield, Darrel Moore, and Mike Williams.

Dry hole markers have been installed and all evidence of any construction has been eradicated. New Mexico forms for plugging have been completed and filed at the district office in Artesia, New Mexico.

Please find attached copies of the New Mexico form C-103 showing the wells have been plugged. If all state requirements have been met, please return the two plugging bonds that were posted on the onset of this project.

Please allow me to extend my appreciation for the help you and your associates have given us during this project. I hope we will be able to drill in another area for salt (brine water) in the near future.

Sincerely,

Larry Evans

Attachment

cc: Keith Bracewell
Bill Talley
Steward Rogers
Richard Lentz
file

Spoke w/ Mike Williams 9-10-91 - he said when Permian gets their subsequent report in then OCD will send it to Diane and she can release their bond. - Just waiting on Permian to file followup report.

Spoke w/ Larry Evans 9-10-91 - said he would send the needed reports. Didn't know they needed to send them in.

Submit 3 Copies
to Appropriate
District Office

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
En[illegible], Minerals and Natural Resources Departm[illegible]

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-103
Revised 1-1-89

WELL API NO.

5. Indicate Type of Lease STATE ☐ FEE

6. State Oil & Gas Lease No.

SUNDRY NOTICES AND REPORTS ON WELLS

(DO NOT USE THIS FORM FOR PROPOSALS TO DRILL OR TO DEEPEN OR PLUG BACK TO A DIFFERENT RESERVOIR. USE "APPLICATION FOR PERMIT" (FORM C-101) FOR SUCH PROPOSALS.)

7. Lease Name or Unit Agreement Name Tracy Lease

1. Type of Well: OIL WELL ☐ GAS WELL ☐ OTHER Brine Well

2. Name of Operator The Permian Corp.

8. Well No. 2

3. Address of Operator P.O. Box 1183 Houston, Texas 77001

9. Pool name or Wildcat Wildcat

4. Well Location
Unit Letter 2 : 1600 Feet From The East Line and 2450 Feet From The South
Section 33 Township 21-S Range 27-E NMPM Eddy Coun

10. Elevation (Show whether DF, RKB, RT, GR, etc.) 3122 GL

11. Check Appropriate Box to Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:		
PERFORM REMEDIAL WORK	☐	PLUG AND ABANDON	☒	REMEDIAL WORK	☐	ALTERING CASING
TEMPORARILY ABANDON	☐	CHANGE PLANS	☐	COMMENCE DRILLING OPNS.	☒	PLUG AND ABANDONMEN
PULL OR ALTER CASING	☐			CASING TEST AND CEMENT JOB	☐	
OTHER:			☐	OTHER:		

12. Describe Proposed or Completed Operations *(Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work)* SEE RULE 1103.

Filled 4½" Cassing From Top To Bottom With 2.5 Yds Redy Mix Cement With 2% C.C.

I hereby certify that the information above is true and complete to the best of my knowledge and belief.

SIGNATURE Richard Lentz TITLE District Manager DATE 8-8-91

TYPE OR PRINT NAME Richard Lentz TELEPHONE NO. 392-655

(This space for State Use)

APPROVED BY TITLE DATE

May 24, 1991

VIA CERTIFIED MAIL

State of New Mexico
Oil Conservation Division
P. O. Box 2088
Santa Fe, NM 87504-2088

30-015-26734

RE: $5,000 One-Well Plugging Bond
Principal: The Permian Corporation
Surety: Utica Mutual
Well Location: Tracy II, 1,600 feet from East Line and 2,450 feet from South Line of Section 33, T-21-S, R-27-E, Eddy County

Gentlemen:

Enclosed is the One-Well Plugging Bond for the above well.

Should you have any questions, please let me know.

Sincerely,

THE PERMIAN CORPORATION

Mary E. Isbell, CPCU
Risk Manager

MEI:ltf

Enclosure

c - Larry Evans
Midland, Texas

May 24, 1991

VIA CERTIFIED MAIL

State of New Mexico
Oil Conservation Division
P. O. Box 2088
Santa Fe, NM 87504-2088

RE: $5,000 One-Well Plugging Bond
Principal: The Permian Corporation
Surety: Utica Mutual
Well Location: Tracy I, 1,400 feet from East Line and 2,230 feet from South Line of Section 33, T-21-S, R-27-E, Eddy County

30-015-26733

Gentlemen:

Enclosed is the One-Well Plugging Bond for the above well.

Should you have any questions, please let me know.

Sincerely,

THE PERMIAN CORPORATION

Mary E. Isbell, CPCU
Risk Manager

MEI:ltf

Enclosure

c - Larry Evans
Midland, Texas

STATE OF
NEW MEXICO

OIL
CONSERVATION
DIVISION

MEMORANDUM OF MEETING OR CONVERSATION

☒ Telephone ☐ Personal

Time
3:00 P.M.

Date
8-1-91

Originating Party	Other Parties
K. Brown OCD	Larry Evans 1-915-686-1777 The Permian Corp. (TPC)

ubject
TPC proposed brine wells BW-

Discussion
The wells were drilled and both dry - no salt. Hickerson was consultant - didn't do his homework. First well cost ≈ $50,000 and was dry. Second well, just drilled a rat hole and also didn't hit salt. OCD district had them plug both to their satisfaction.

TPC was bought by Ashland Oil who also bought Scurlock Oil. New name these companies go by is Scurlock/Permian Corp. (owned by Ashland).

onclusions or Agreements

Will get a letter stating cancelation of permit BW-24.
Will then request the drilling + plugging records from the district to put in the file here (Santa Fe).

stribution

Signed K. Brown

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

1912

BRUCE KING
GOVERNOR

POST OFFICE BOX 2088
STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO 87504
(505) 827-5800

July 25, 1991

Mr. Owen Mobley
The Permian Corporation
P. O. Box 1183
Houston, Texas 77001

RE: **Correction on Approval of Discharge Plan BW-24**
The Permian Corporation-Carlsbad Brine Station

Dear Mr. Mobley:

The approval letter for the discharge plan renewal BW-24 for The Permian Corporation (TPC) Carlsbad Brine Station has an error. The approval dated April 29,1991 states that TPC Carlsbad Brine Station is located in Section 33, Township 21 South, Range 30 East, NMPM, Eddy County, New Mexico. The correct location is Section 33, Township 21 South, Range 27 East, NMPM, Eddy County, New Mexico. I am sorry for any inconvenience this may have caused.

The Oil Conservation Division (OCD) has not recieved any information on the status of this proposed brine facility. Does TPC still plan to drill the two permitted wells and construct the brine facility? Please send the OCD an updated report on the current status and plans for this facility. If you have any questions, feel free to contact me at (505) 827-5824.

Sincerely,

Kathy M Brown

Kathy M. Brown
Environmental Geologist

OIL CONSERVATION DIVISION
RECEIVED
'91 MAY 13 AM 9 23

A L. Hickerson
PROFESSIONAL ENGINEER
TEXAS #1183OK

6067 W. TENTH ST.
ODESSA, TEXAS 79763

OFFICE PHONE:
(915) 381-0531
(915) 563-4730
FAX 915/381-9316
DIRECT LINE: (915) 381-8420

RESIDENCE:
3216 BAINBRIDGE DRIVE
ODESSA, TEXAS 79762
PHONE: (915) 362-4814

May 7, 1991

Mr. Mike Wiliams
New Mexico Oil Conservation Division
P.O. Drawer DD
Artesia, New Mexico 88210

RE: The Permian Corporation - Carlsbad Brine
Well Permit - Corrected Forms C-101
for wells No. 1 and No. 2 to allow
for 2" clearance for cementing.

Dear Sir:

Attached, as per our telephone conversation, are the corrected original subject forms for the subject brine well request. The hole size has been changed to 12", so that the 8.5" O.D. coupling will have more than the required clearance. The 5 ½" casing has been changed to 4 ½", so that the 4 ½" coupling O.D. of 5" will leave the required two inches of clearance between the 4 ½" and 7 5/8".

If you need any additional information, or if this is not satisfactory, please advise.

Very Truly Yours,

A. L. Hickerson

A.L. Hickerson

Attachments

cc Kathy Brown - NMOCD Santa Fe ✓
Larry Evans - TPC Midland
Owen Mobley - Houston

Submit to Appropriate
District Office
State Lease – 6 copies
Fee Lease – 5 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work:
DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

b. Type of Well:
OIL WELL ☐ GAS WELL ☐ OTHER SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name
TRACY LEASE

2. Name of Operator
THE PERMIAN CORPORATION

8. Well No.
1

3. Address of Operator
PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat
WILDCAT

4. Well Location
Unit Letter 1 : 1400 Feet From The EAST Line and 2230 Feet From The SOUTH Line

Section 33 Township 21-S Range 27-E NMPM EDDY County

10. Proposed Depth
600'

11. Formation
ROCK SALT

12. Rotary or C.T.
ROTARY

13. Elevations *(Show whether DF, RT, GR, etc.)*
3122 GL

14. Kind & Status Plug. Bond
#SU1326252/Utica Mut

15. Drilling Contractor
NOT LET

16. Approx. Date Work will start
2 WKS AFTER APPROV

17.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
12"	7 5/8"	24#	400'	200	circulate
7""	4 1/2"	11.6#	525'	105	circulate

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE ZONE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

I hereby certify that the information above is true and complete to the best of my knowledge and belief.

SIGNATURE TITLE CONSULTANT DATE 05-07-91

TYPE OR PRINT NAME A.L. HICKERSON TELEPHONE NO. 915-381-053

(This space for State Use)

APPROVED BY TITLE DATE

CONDITIONS OF APPROVAL, IF ANY:

Submit to Appropriate
District Office
State Lease -- 6 copies
Fee Lease -- 5 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
.O. Drawer DD, Artesia, NM 88210

DISTRICT III
000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1. Type of Work:
DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

. Type of Well:
OIL WELL ☐ GAS WELL ☐ OTHER SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name
TRACY LEASE

Name of Operator
THE PERMIAN CORPORATION

8. Well No.
2

Address of Operator
PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat
WILDCAT

Well Location
Unit Letter 2 : 1600 Feet From The EAST Line and 2450 Feet From The SOUTH Line

Section 33 Township 21-S Range 27-E NMPM EDDY County

10. Proposed Depth 600'

11. Formation ROCK SALT

12. Rotary or C.T. ROTARY

Elevations *(Show whether DF, RT, GR, etc.)* 3122 GL

14. Kind & Status Plug. Bond #SU1326252/Utica Mut

15. Drilling Contractor NOT LET

16. Approx. Date Work will start 2 WKS AFTER APPROV.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
12"	7 5/8"	24#	400'	200	circulate
7"	4 1/2"	11.6#	450'	90	circulate

ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE
E. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

reby certify that the information above is true and complete to the best of my knowledge and belief.

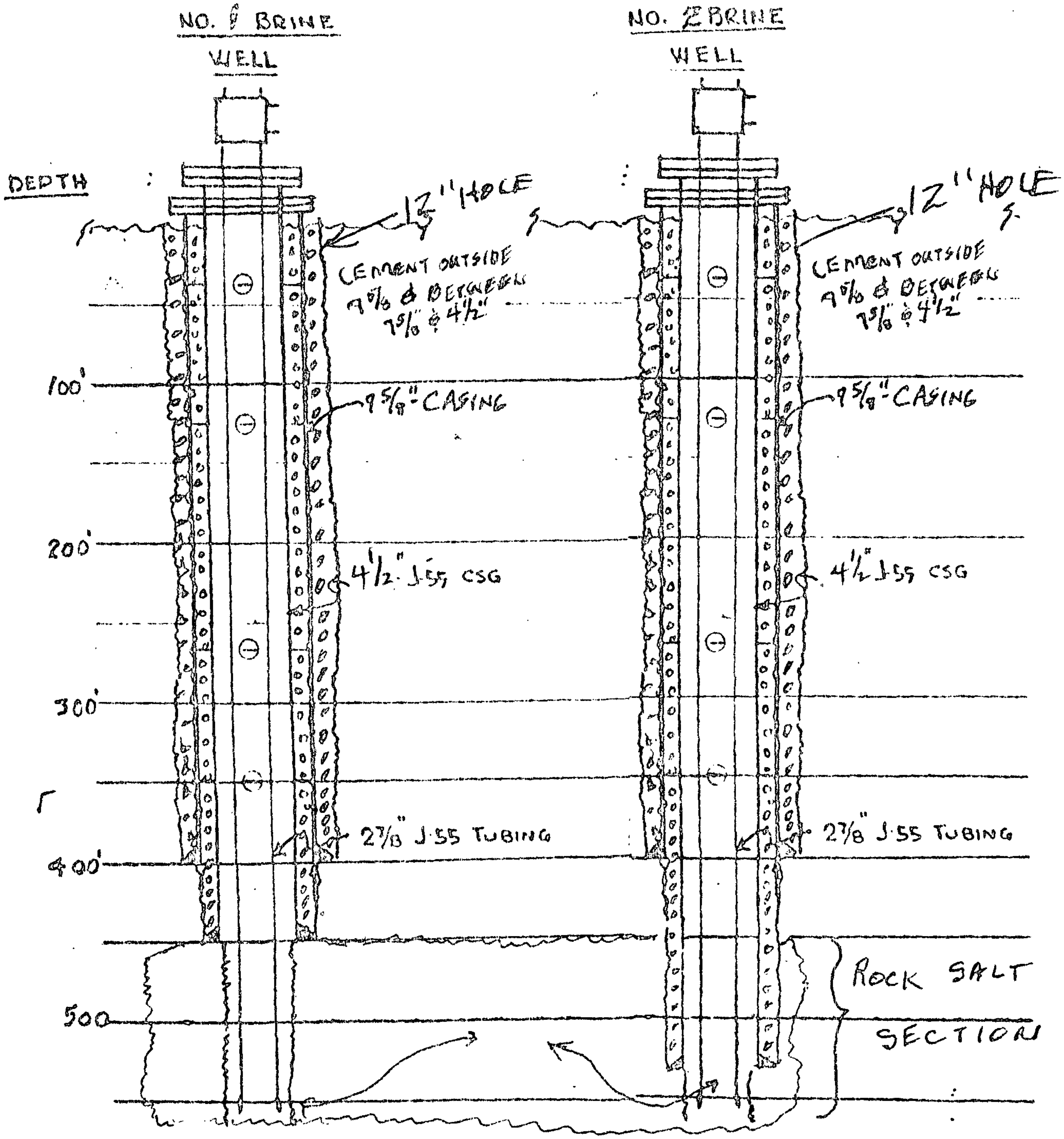
NATURE TITLE CONSULTANT DATE 5-07-91

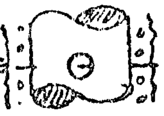
E OR PRINT NAME A.L. HICKERSON TELEPHONE NO. 915-381-053

: space for State Use)

ROVED BY TITLE DATE

DITIONS OF APPROVAL, IF ANY:





THE
PERMIAN CORPORATION
MIDLAND, TEXAS

BRINE WELL COMPLETIONS
CARLSBAD BRINE STATION

DRAWING NO. 6-K.1

DATE 1-10-91, Reg. P.E. 9844

Rev 5-7-91

To Bill Lemay

SPECIAL EDITION

Permian Perspectives

THE PERMIAN CORPORATION The Permian Tower 2500 CityWest Boulevard Houston, Texas 77042 APRIL 29, 1991

Permian To Be Acquired By Ashland Oil

On April 29, 1991, National Intergroup, Inc. (NII), parent company of The Permian Corporation, announced that the company has signed a Stock Purchase Agreement for the sale of Permian to Ashland Oil, Inc. Permian's management believes that this transaction is a positive step in the continued growth and development of Permian.

Following the signing of the Stock Purchase Agreement, we will be working closely with NII and Ashland to make final decisions on a number of issues involving details of the sale and the eventual merger process. It is anticipated that the transaction will be closed by the end of June or July. The transition of merging Permian and Scurlock (Ashland's gathering company subsidiary) will begin after the sale is closed.

We expect the transition to be a smooth and orderly process with Ashland, Scurlock and Permian people working together to assure continued high levels of service to all Permian customers.

I know that you will have many questions about this announcement. Let me answer a few of them today and let you know the process for providing more information to you.

About Ashland

First, who is Ashland? Many of us are familiar with Ashland and Scurlock. They have been worthy competitors to Permian, as well as valuable customers and trading partners. Their geographic areas and ours are quite compatible and provide a strong fit for the two companies. The intention is to combine Permian with Ashland's Scurlock Oil gathering and marketing subsidiary in a manner which will minimize any negative impact on the employees and customer base of both entities.

Ashland is engaged in the energy business through a number of operations. It operates gathering and trunk pipeline systems, as well as trucks and barges for the transportation of crude oil and products. Ashland also operates refineries in Catlettsburg, Kentucky; St. Paul, Minnesota; and Canton, Ohio. The company is engaged in the sale and trading of refined products and chemicals, as well as exploration and production activities.

Ashland's revenues in 1990 were over $9 billion with net earnings of about $182 million. Ashland is traded on the New York Stock Exchange. Stock symbol is ASH.

Service Policies

How will this affect my service? Of course, any transaction of this nature will mean some changes. However, there will be a period of transition with policies and procedures continuing as they are at the present until the most effective actions can be determined. Becoming part of the Ashland organization offers us an opportunity for challenging jobs for our employees and continued high service to our customers.

How will I get more information about the transaction? As specific details of the merger are worked out, we will communicate them to you. We have discussed the sales process with you since it began, and we will continue to keep you informed through regular communications.

How will this affect the Permian people and offices I now use? Specifics have not yet been determined. However, for the next few months, as the sales process is completed, we anticipate no changes. We will communicate any changes to you as they occur.

We are joining with a company that understands our business. It knows what we do. The strengths that Ashland will bring to the Permian organization will help our own organization grow and prosper.

I am looking forward to working with Ashland and its management team to assure a smooth transition and to make our combined operations the most successful in the country.

The ownership changes that Permian has had during the past few years have created uncertainty in the marketplace for all of us. Ashland is a major company in our business. It will stay in our business, giving us the stability that is so important to our future.

Exciting Step

I hope you share my excitement at this step. We will be sending you additional announcements during the next few weeks as events occur and more information is available.

Let me extend to you my personal appreciation for being one of Permian's valued customers. Despite the uncertainties both within our industry and within our company during the past few years, we have endeavored to set an example for the industry in providing the highest levels of service and operating performance in all sectors.

Thank you.

Gaylon H. Simmons
President and Chief Executive Officer

State of New Mexico
ENERGY, MINERALS and NATURAL RESOURCES DEPARTMENT
Santa Fe, New Mexico 87505

BRUCE KING
GOVERNOR

ANITA LOCKWOOD
CABINET SECRETARY

April 29, 1991

CERTIFIED MAIL
RETURN RECEIPT NO. P-327-278-159

Mr. Owen Mobley
The Permian Corporation
P. O. Box 1183
Houston, Texas 77001

RE: Discharge Plan BW-24 Approval
The Permian Corporation-Carlsbad Brine Station
Eddy County, New Mexico

Dear Mr. Mobley:

31

The **discharge plan BW-24 for The Permian Corporation Carlsbad Brine Station** located in Section 33, Township 21 South, Range 30 East, NMPM, Eddy County, New Mexico, **is hereby approved.** The approved discharge plan consists of the discharge plan dated February 12, 1991, and the materials dated March 6, 1991, submitted as supplements to the application.

The discharge plan was submitted pursuant to Section 5-101.B.3 of the New Mexico Water Quality Control Commission Regulations. It is approved pursuant to Sections 5-101.A and 3-109.C. Please note Sections 3-109.E and 3-109.F which provide for possible future amendments or modifications of the plan. Please be advised that the approval of this plan does not relieve you of liability should your operation result in actual pollution of surface water, ground water, or the environment which may be actionable under other laws and/or regulations.

The monitoring and reporting shall be as specified in the above referenced materials. Please note that Section 3-104 of the regulations requires that "When a plan has been approved, discharges must be consistent with the terms and conditions of the plan." Pursuant to Section 3-107.C. you are required to notify the Director of any facility expansion, production increase, or process modification that would result in any charge in the discharge of water quality or volume.

VILLAGRA BUILDING - 408 Galisteo
Forestry and Resources Conservation Division
P.O. Box 1948 87504-1948
827-5830

Park and Recreation Division
P.O. Box 1147 87504-1147
827-7465

2040 South Pacheco
Office of the Secretary
827-5950

Administrative Services
827-5925

Energy Conservation & Management
827-5900

Mining and Minerals
827-5970

LAND OFFICE BUILDING - 310 Old Santa Fe Trail
Oil Conservation Division
P.O. Box 2088 87504-2088
827-5800

Pursuant to Section 3-109.G.4., this plan is for a period of five (5) years. This approval will expire April 29, 1996 and you should submit an application for renewal in ample time before this date. Note that under Section 5-101.G. of the regulations, if a discharger submits a discharge plan renewal application at least 180 days before the discharge plan expires and is in compliance with the approved plan, then the existing discharge plan will not expire until the application for renewal has been approved or disapproved.

On behalf of the staff of the Oil Conservation Division, I wish to thank you and your staff for your cooperation during this discharge plan review,

Sincerely,

William J. LeMay
Director

WJL/KMB/sl

cc: OCD Artesia Office

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
Suite D, 3530 Pan American Highway, NE
Albuquerque, New Mexico 87107

OIL CONSERVATION DIVISION
RECEIVED
'91 APR 17 AM 8 58

April 12, 1991

Mr. William J. Lemay, Director
New Mexico Energy, Minerals and
  Natural Resources Department
Oil Conservation Division
P.O. Box 2088
Santa Fe, New Mexico 87504-2008

Dear Mr. Lemay:

This responds to your Notice of Publication on March 15, 1991, regarding the effects of granting a State of New Mexico discharge plan application. The U.S. Fish and Wildlife Service has reviewed the proposed discharge plan and has not identified any resource issues of concern to our agency.

> (GW-70) - The Permian Corporation proposed brine extraction facility to be located in the NW/4 SE/4, Section 33, Township 21 South, Range 27 East, NMPM, Eddy County, New Mexico.

If you have any questions concerning our comments, please contact Richard Roy at (505) 883-7877 or FTS 474-7877.

Sincerely,

Jennifer Fowler-Propst
Field Supervisor

cc:
Director, New Mexico Department of Game and Fish, Santa Fe, New Mexico
Director, New Mexico Energy, Minerals and Natural Resources Department,
  Forestry and Resources Conservation Division, Santa Fe, New Mexico
Regional Administrator, U.S. Environmental Protection Agency, Dallas, Texas
Regional Director, U.S. Fish and Wildlife Service, Fish and Wildlife
  Enhancement, Albuquerque, New Mexico

Affidavit of Publication

No. 13462

STATE OF NEW MEXICO,

County of Eddy:

Gary D. Scott being duly sworn, says: That he is the Publisher of The Artesia Daily Press, a daily newspaper of general circulation, published in English at Artesia, said county and state, and that the hereto attached Legal Notice was published in a regular and entire issue of the said Artesia Daily Press, a daily newspaper duly qualified for that purpose within the meaning of Chapter 167 of the 1937 Session Laws of the state of New Mexico for 1 days consecutive weeks on the same day as follows:

First Publication March 26, 1991

Second Publication

Third Publication

Fourth Publication

Gary D Scott

Subscribed and sworn to before me this 8th day of April 1991

Barbara Ann Beans

Notary Public, Eddy County, New Mexico

My Commission expires September 23, 1991

Copy of Publication

LEGAL NOTICE

NOTICE OF PUBLICATION STATE OF NEW MEXICO ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT OIL CONSERVATION DIVISION

Notice is hereby given that pursuant to New Mexico Water Quality Control Commission Regulations, the following discharge plan applications and renewal applications have been submitted to the Director of the Oil Conservation Division, State Land Office Building, P.O. Box 2088, Santa Fe, New Mexico 87504-2088, Telephone (505) 827-5800:

(GW-70) - The Permian Corporation, Owen Mobley, P.O. Box 1183, Houston, Texas 77001, has submitted a discharge plan application for their proposed brine extraction facility to be located in the NW/4 SE/4 Section 33, Township 21 South, Range 27 East, NMPM, Eddy County, New Mexico. Proposed operations call for an average injection of 20,000 bbls per month of fresh water through a dual-cased well to dissolve the rock salt at a depth of approximately 450 feet. Saturated brine will be extracted from a ssecond well simarily constructed and stored in surface tanks. Groundwater most likely to be affected by a spill, leak or other accidental discharge to the surface is at a depth of approximately 150 feet with a total dissolved solids concentration of approximately 2000 mg/l. Protectable fresh water extends to a depth of approximately 360 feet and the production casing is proposed to be set at 400 feet. The discharge plan application addresses injection well construction and operation, and how spills, leaks and other accidental discharges to the surface will be managed.

Any interested person may obtain further information from the Oil Conservation Division and may submit written comments to the Director of the Oil Conservation Divsion at the address given above. The discharge plan applicaiton may be viewed at the above address between 8:00 a.m. and 5:00 p.m., Monday through Friday. Prior to ruling on any proposed discharge plan or its modification, the Director of the Oil Conservation Division shall allow at least thrity (30) days after the date of publication of this notice during which comments may be submitted to him and public hearing may be requested by any interested person. Requests for public hearing shall set forth the reasons why a hearing should be held. A hearing will be held if the Director determines there is significant public interest.

If no public hearing is held, the Director will approve or disapprove the proposed plan based on information available. If a public hearing is held, the Director will approve or disapprove the proposed plan based on information in the plan and information submitted at the hearing.

GIVEN under the Seal of New Mexico Oil Conservation Commission at Santa Fe, New Mexico, on this 15th day of March, 1991. To be published on or before March 27, 1991.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION
s-William J. LeMay
WILLIAM J. LEMAY,
Director

SEAL

Published in the Artesia Daily Press, Artesia, N.M. March 26, 1991.

Legal 13462

RE: Al Hickerson - status of TPC proposed brine facility

April 8, 1991

AH wanted to know the status of the DP plan proposal. I informed him that

1) He needed the original C-101 + C-102 forms to be filed with the district

2) ~~That~~ Although I am still concerned about collapse/subsidence, I feel that the OCD cannot justify not approving their operations. Because TPC will be using the 2 well systems, setting casing ~~[illegible]~~ deep and mining the lower portion of the salt; and injecting oil to use as a roof cushion - ~~this is~~ this type of mining system is designed to have minimal collapse/subsidence threat. TPC has demonstrated that they have taken precautions (in design + operations) with respect to the OCD's concerns.

March 25, 1991

RE: Talk w/ A.L. Hickerson on The Permian Corp. proposed brine wells - casing corrossion, collapse, ect....

Corrossive Nature of Brine

A.L.H.:

No, brine is not corrossive (pH 7). Water has a greater affinity for the salt and not the air so the oxygen comes out of the water as the brine is formed. This oxygen collects on the roof of the cavern cavity and at the casing shoe. This forms a natural air cushion protecting the roof of the cavity and keeping it from dissolving. The older the well the larger the air cushion. This is demonstrated by the fact that it takes much longer to pressure up old wells (for MIT). Some wells may take up to 2 days to pressure up cavity (ref: old wells in Texas).

Collapse

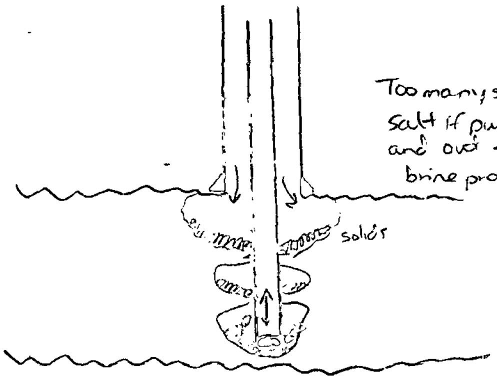
A.L.H. In early days didn't know much about how much salt you could remove ~~and~~ before collapse. First brine wells in U.S. were in 1949. First brine well for brine for drilling fluids was in 1958 - A.L.H. drilled this. Had several brine wells mining salt 200' thick with top at 1200'. Unsure how much could remove before collapse. Started with 50,000 bbl. washed out, ended with 350,000 bbl. washed out. Stored propane in cavities and displaced with ~~brine~~ fresh water. Cavity got 13% bigger as displaced propane w/ fresh water. Had shallower salt @ 600'. Drilled wells into this salt and produced large quantity of brine to help fill cavity. Did have subsidence from this mining.

Brine vs. Fresh Water Volumes

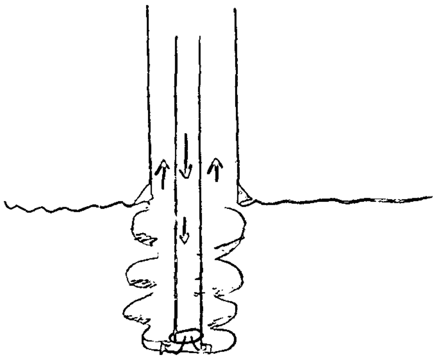
<u>ALH</u> You should always get less brine back than the water you put in. Lose water continually. Approx. pump 8 bbl and retrieve 7 bbl.
There are 111 lb. salt per 42 gal (1 bbl.)
7 bbl of brine would have 777 lb salt. removed from the cavity

Brine Production Operations

<u>A.L.H.</u> Wrote letter to NMOCD (Jerry Sexton) on June 27, 1983 asking that OCD not require pumping fresh water down annulus + produce brine out of tubing.* Explained why you can't do this + why the other method doesn't cause casing deterioration.



Too many solids on face of salt if pump down annulus and over tubing. Inhibits brine production



tubing perfed?

* A.L.H. will fax copy of letter and attachments to NMOCD

Sent March 25, 1991 +

PERMIAN BRINE SALES, INC.

24-HOUR BRINE SERVICE THROUGHOUT THE PERMIAN BASIN

ODESSA, TEXAS
79760

P. O. BOX 1591
PHONE 332-0531

June 27, 1983

Mr. Jerry Sexton
Oil Conservation Division
New Mexico Energy and Minerals Department
P.O. Box 1980
Hobbs, New Mexico 88240

Dear Jerry:

We, hereby request that we not be forced to solution mine salt in our brine wells by circulating fresh water down the casing and out the tubing for the following reasons.

The fresh water, being 20% lighter than brine, floats on top in the cavern. As salt goes into solution along the edge, the brine formed sinks to the bottom and is circulated out the tubing.
In the Permian Basin, the rock salt is about 20% solids, therefore, as salt is dissolved in the top of the cavern, the solids fall and cover up the face of the salt lying below. Thus, over a period of time, the cavern formed is in the shape of a daisy - broad at the top and rapidly tapering to the stem. See Sketch B.W. No. 1 This causes frequent "cave-ins" of the cavern roof because of the broader unsupported roof. After a "cave-in", the tubing has to be pulled out of the brine well, the crooked tubing replaced, a drill bit placed on the tubing and the tubing is drilled back into the brine well with a reverse unit and pump. As the anhydrite ledges are covered with solids, you have to drill a new hole through each ledge. Another difficulty in circulating down the casing is the frequent occurrence of plugging of the tubing. The solids falling to the bottom of the cavern form "key seats" at each anydrite ledge and also form a "block" around the tubing shoe.

Sketch B.W. No. 1 also shows the approximate shape of a cavern washed by direct circulation. This method gives you a series of "cylinders" that are more conducive to trouble free operation. Attached for your information is a sketch of the cavern at our Kermit LPG well. This well had two strings of tubing (4" inside 7") in order to allow us to make brine while storing propane in the upper cavern. The well was installed in 1961 and the cavern shape was measured in 1966. We initially washed from bottom to top to get the initial cylinders. We then washed 115,000 barrels of cavern top to bottom in order to get storage space for propane. After storing propane, we washed 220,000 barrels of cavern from the bottom to the middle tubing. This technique of "shaping" a cavern to fit your needs was first developed by Phillips Petroleum Company in Borger in 1952.

Figure 13, from an article on Silurian Rock Salt of Ohio shows various methods of brine production. The reverse circulation (in casing and out tubing) is known as the TULLY METHOD, and leads to early cavern abandonment.

Also attached is an article on "Solution Mining Studies" that points out that imperfect salt covers the underlying salt with impurities.

Brine is not corrosive in the absence of oxygen. Therefore, the casing between the flow of brine and the fresh water zones is not likely to corrode and cause communication with the fresh water zones. When fresh water is pumped into a brine well and the rock salt goes into solution, the air present in the water is displaced with salt. The air is then trapped under the ledges of anhydrite. This air is compressed when water is pumped into a cavern. Some of our brine wells take as much as 12 hours of pumping into a closed in cavern in order to pressure up to 1½ times operating pressure for integrity testing.

I apologize for the "wordiness" of this request, but the decision is of great importance to us. In a few of our wells, we have been forced to circulate down the casing because we could not get tubing far enough back into the cavern (from junk tubing from previous cave-ins) to make saturated brine using the direct method. It has been our experience that we continually have cave-ins and tubing plugging problems when we were forced to circulate down the casing.

We also feel that if we run a recorded pressure test on the cavern once a year, as we do on our Texas wells, we will further be assured that no leaking casing will allow contamination of fresh water.

Your favorable consideration of our request to circulate our brine wells down the tubing and out the casing will be appreciated.

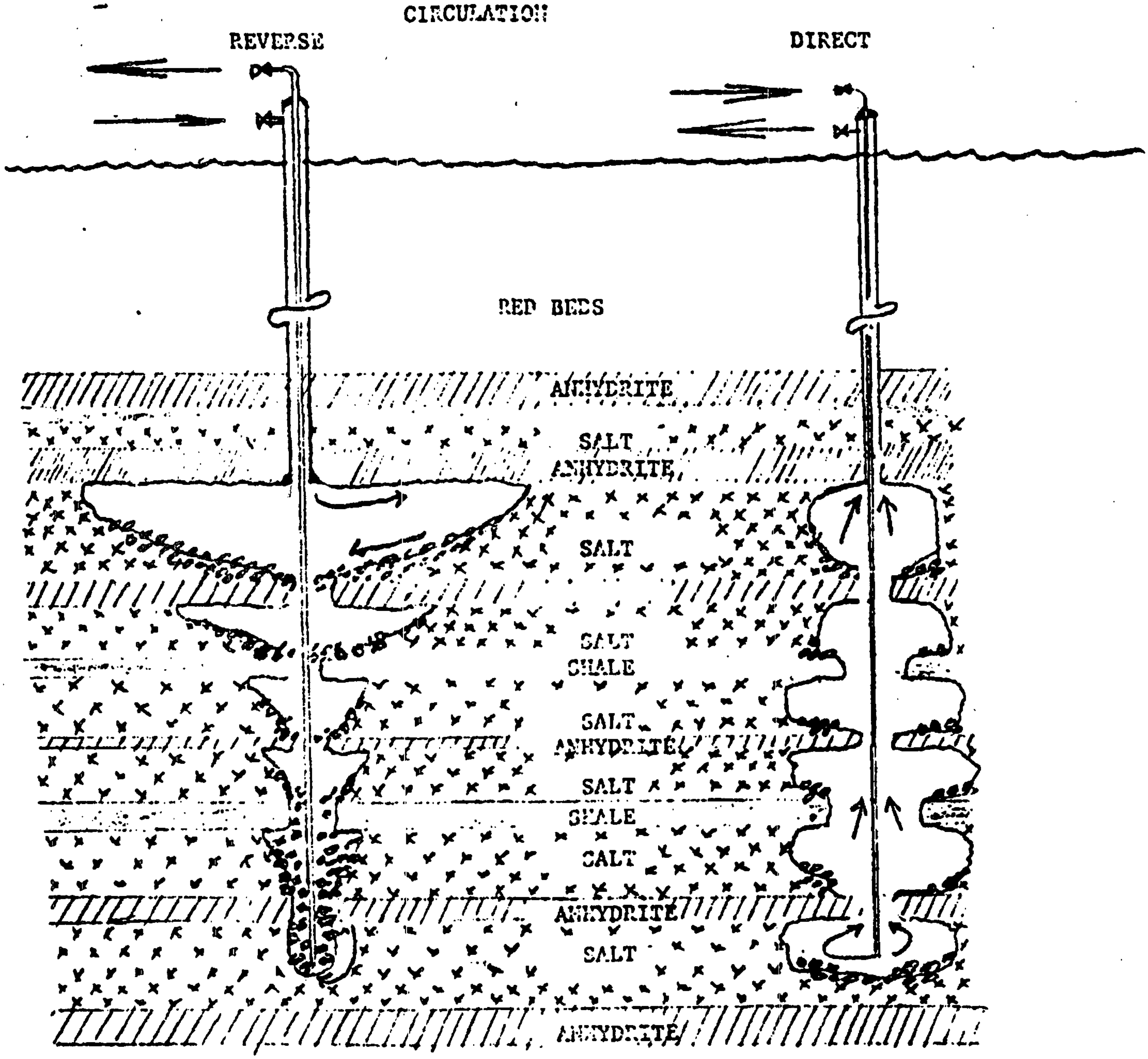
Very truly yours,
PERMAIN BRINE SALES, INC.

A.L. Hickerson

A.L. HICKERSON
PRESIDENT

ALH/lam

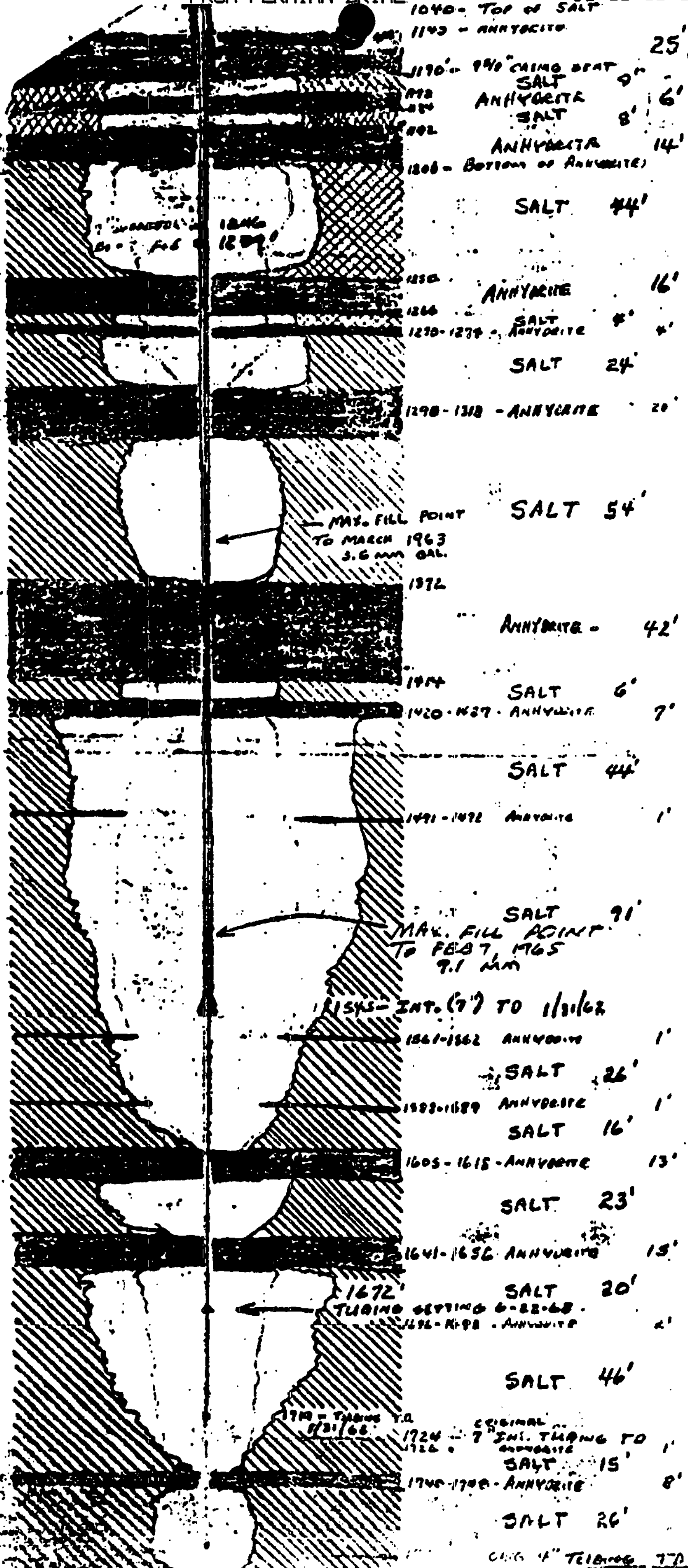
TYPICAL BRINE WELL CONFIGURATION



PERMIAN BRINE SALES, INC.
ODESSA, TEXAS

COMPARISON OF BRINE WELL SHAPES - REVERSE AS COMPARED TO DIRECT CIRCULATION

DATE:	BY	DRAWING NO.:



SCALE - 1" = 40'
CALC. SIZE 400000 bbl
CALC. RADIUS = 60 ft. MA

WASHING HISTORY

45000 BBLS IN 4" OUT 7"
115000 " IN 9 5/8" OUT 4"
20,000 " IN 7" OUT 4"
220,000 " " " "

TUBING STRINGS

7" - 23# = 35,600#
4" - 9.5# = 15,950#

ANNULAR CAPACITIES

9 5/8 - 7" - 1.245 g/ft = 1460 gal
7 - 4" - 1.0 g/ft = 1545 gal
4" ID - 0.5 g/ft = 859.5 gal

PERMIAN BRINE SALES, INC
RTE. 3, BOX 3033
ODESSA, TEXAS 79763

KEEM
WELL

IITRI—SMRI Solution Mining Studies

Richard H. Snow
Hugo J. Nielsen
IIT Research Institute
Technology Center
Chicago, Illinois 60616

ABSTRACT

A model of the solution processes in a solution mine cavity was developed based on boundary layer theory. Computer predictions of solution rates were compared with data from laboratory experiments on perfect salt crystals, and a discrepancy of a factor of 3 resulted. The discrepancy was traced to inadequacy of the Colburn j-factor correlation for predicting the mass transfer coefficient at the high Schmidt number (1000) of salt in water. Reasonable results were obtained when the j-factor was changed to depend on the Schmidt number to the 0.52 power, a value that is in agreement with the penetration theory.

The model includes different thickness parameters for the profiles of concentration and velocity in the boundary layer, and this is necessary to predict correct brine production rates. Experimental techniques to measure these profiles were developed; preliminary results indicate that the ratio of the thickness is 0.03 for salt in water.

A computer program was developed to predict the cavity growth and shape, the build-up of a concentration pattern in the bulk solution and its effect on the boundary layer, and the concentration of brine produced over a period of time when the feed water is top injected. The analysis can be extended to other cases.

PROBLEM DEFINITION

The objective of this project is to understand the processes that govern the solution of salt in a solution mine. The problem is important to the member companies of the Solution Mining Research Institute because this knowledge can determine the conditions which lead to the most efficient production of brine. This includes developing a cavity of a shape that minimizes the tendency of roof falls, which can end production of a brine well altogether. Another objective is the prediction of the dimensions of the cavity, which determine the location of potential ground subsidence. This information is important from the point of view of property losses, especially since there is still no adequate means of measuring the size and shape of an underground cavity, at least in the presence of irregular wall shapes, piles of fallen rock, and uncertain configurations near the casing seal.

A computer program was written from available boundary layer theory to predict the rate of cavity growth. However, laboratory experiments on small salt samples showed that the predictions were in error by a factor of 3. This was surprising, since boundary layer theory gives accurate results for mass transfer of other materials. On further study, it was found that the properties of salt are rather unusual, in that it has a Schmidt number of about 1000, while most materials that have been studied have a smaller Schmidt number. Consequently, some of the equations were not valid when applied to salt.

As a result, it was decided that further measurements of velocity and concentration profiles in the salt boundary layer were necessary. Techniques to make these measurements had to be developed, since such measurements have never been done for a material with the properties of salt. A digression in the original research plan was, therefore, necessary, and this phase of the work is only now coming to fruition. In the meantime an empirical modification in the mass-transfer equation has been made, and it is believed that the computer model now gives valid results.

LITERATURE STUDY

A study of the literature revealed only one direct observation of the shape of a full-scale cavity by Trump (1947). Some experiments on dissolving of cavities in blocks of salt had been done at the University of Texas, (Leont'ev, and Kidryaskin, 1966). These gave indications of the type of convective flow to be expected, but there was no assurance that different behavior would not occur when scaled up 100-fold to an actual mine cavity size.

Further experiments by Durie (1963) at the University of Texas on slabs of rock salt indicated that the convective flow of a boundary layer near the salt face is the most important phenomenon in determining the solution process. Durie also investigated the boundary layer theory. He applied the equations of Eckert and Jackson (1951) developed for forced convection heat transfer in pipes, to the free convection salt solution process. Although Durie's results did not fully agree with experiment, we concluded that this approach was worth investigating further, because the boundary layer behavior appeared to be the main process determining the solution rate and cavity growth.

Although there is an extensive literature on boundary layer theory, most of it is not directly applicable to the salt solution problem. For example, many articles present experimental results on rates of mass or heat transfer in terms of empirical dimensionless equations that are valid only for special conditions, but not for the conditions of salt dissolving. A long-range plan was prepared, beginning with further development of the boundary layer theory in the first year, and extending to other important effects in subsequent years.

BASIC PHENOMENA AFFECTING SOLUTION IN A CAVITY

At this point it is worthwhile to summarize the important effects occurring in the cavity.

The rate of solution of a material such as salt is determined primarily by the conditions in the fluid. Conditions in the solid are important too, but their effects are superimposed on the fluid behavior. If the solid is a perfect crystal, only one property of the solid is of primary importance: the solubility. Two other variables of imperfect salt may be important: the fraction of its surface that is covered by impurities and the roughness of its surface.

An important property of the fluid is the diffusivity of the salt molecules in solution. Since solution cannot take place when saturated brine is adjacent to the crystal face, diffusivity allows solution to occur by transporting salt molecules away from the face. An analysis of published salt diffusivity data showed that previous workers used an inconsistent definition of diffusivity that led to a 25% error in some cases.

A second property of the fluid that affects solution rate is the flow behavior. Flow aids the removal of dissolved salt from the crystal face.

Fluid flow may arise from two sources: forced convection, caused, for example, by pumping into the cavity; and free convection, caused by density differences. If both occur at once, the situation is difficult to analyze. However, calculations showed that the flow velocity due to pumping is important only during the first hours of cavity operation. After that, flow due to pumping can cause mixing of the bulk fluid in the cavity if there is bottom injection, but forced flow does not normally reach the salt face directly.

Free, or natural convection is the most important phenomenon in the cavity. It is caused by the increased density of concentrated brine near the salt face compared with the density of brine in the bulk of the cavity. The downward flow of dense brine, and simultaneous molecular diffusion govern the concentration profile adjacent to the salt face and determine the rate of solution. Flow, in turn, is limited by drag of the fluid against the salt face and drag against the bulk fluid. Thus a balance of forces determines the velocity profile against the salt face. If the flow increases to the point where it becomes turbulent, this causes additional mixing which in turn affects the concentration profile and the solution rate.

DEVELOPMENT OF BOUNDARY LAYER THEORY

The general differential equations for boundary layers are known (Eckert and Jackson, 1951). If these equations could be solved exactly to determine the flow pattern throughout the boundary layer at any depth in the cavity, then the solution rate would also be determined. In general, these equations can only be solved on a computer. Even then, the problem is too difficult to obtain a practical answer in a reasonable time with the largest

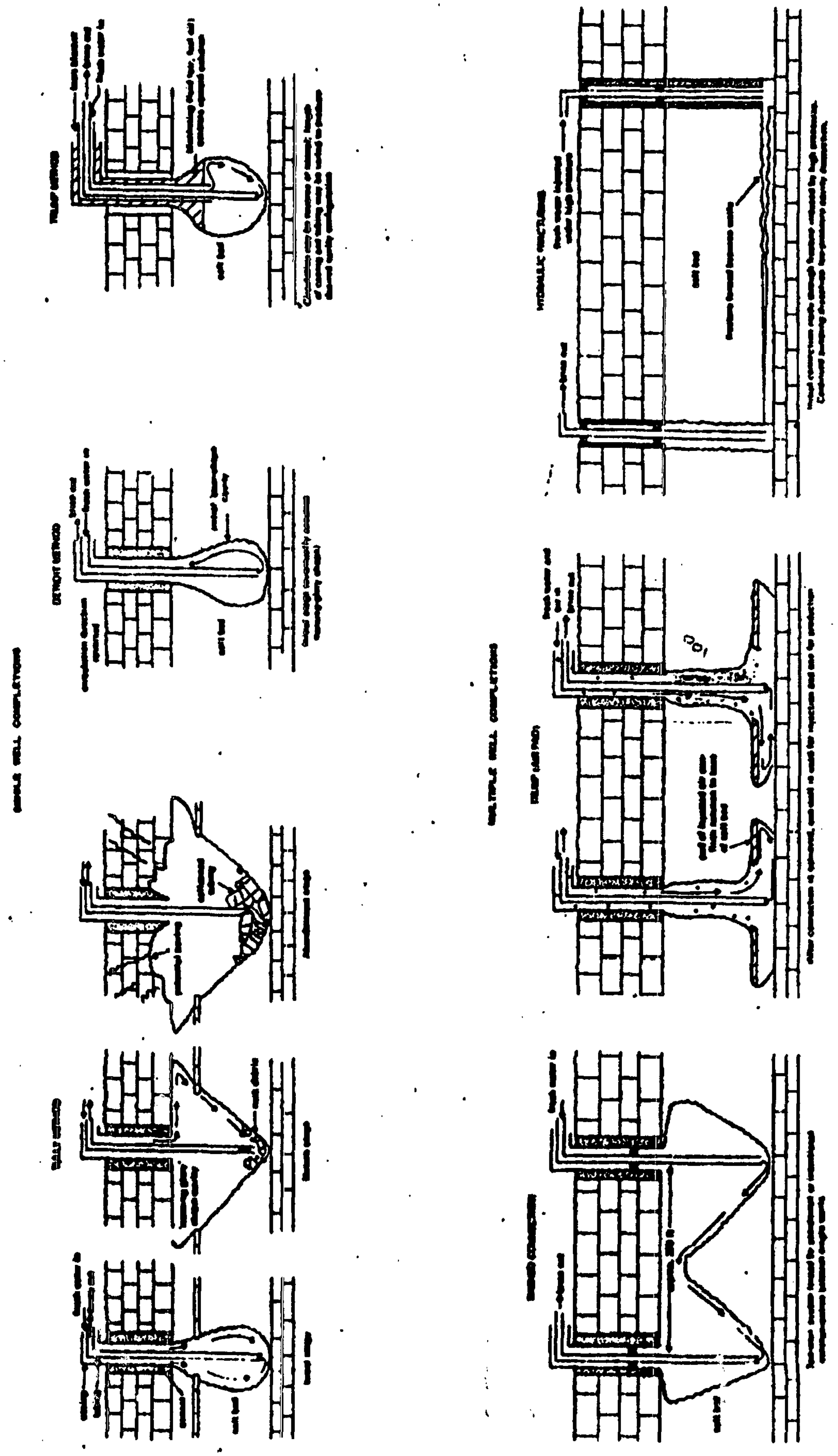


FIGURE 13.—Methods of artificial brine production (compiled from several sources).

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NOTICE OF PUBLICATION
STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

Notice is hereby given that pursuant to New Mexico Water Quality Control Commission Regulations, the following discharge plan applications and renewal applications have been submitted to the Director of the Oil Conservation Division, State Land Office Building, P.O. Box 2088, Santa Fe, New Mexico 87504-2088, Telephone (505) 872-5800:

(GW-70) - The Permian Corporation, Owen Mobley, P.O. Box 1183, Houston, Texas 77001, has submitted a discharge plan application for their proposed brine extraction facility to be located in the NW/4 SE/4, Section 33, Township 21 South, Range 27 East, NMPM, Eddy County, New Mexico. Proposed operations call for an averae injection of 20,000 bbls per month of fresh water through a dual-cased well todlssolve the rock salt at a depth of approximately 450 feet. Saturated brine will be extracted from a second well simarily constructed and stored in surface tanks. Groundwater most likely to be affected by a spill, leak or other accidental discharge to the surface is at a depth of approximately 150 feet with a total disolved solids concentration of approximately 2000 mg/l. Protectable fresh water extends to a depth of approximately 360 feet and the production casing is proposed to be set at 400 feet. The discharge plan application addresses injection well construction and operation, and how spills, leaks and other accidental discharges to the surface will be managed.

Any interested person may obtain further information from the Oil Conservation Division and may submit written comments to the Director of the Oil Conservation Division at the address given above. The discharge plan application may be viewed at the above address between 8:00 a.m. and 5:00 p.m., Monday through Friday. Prior to ruling on any proposed discharge plan or its modification, the Director of the Oil Conservation Division shall allow at least thiryty (30) days after the date of publication of this notice during which comments may be submitted to him and public hearing may be requested by any interested person. Requests for public hearing shall set forth the reasons why a hearing should be held. A hearing will be held if the Director determines there is significant public interest.

If no public hearing is held, the Director will approve or disapprove the proposed plan based on information available. If a public hearing is held, the Director will approve or disapprove the proposed plan based on information in the plan and information submitted at the hearing.

GIVEN under the Seal of New Mexico Oil Conservation Commission at Santa Fe, New Mexico, on this 15th day of March, 1991.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION
WILLIAM J. LEMAY, Director
Journal: March 26, 1991

STATE OF NEW MEXICO
County of Bernalillo ss

Thomas J. Smithson being duly sworn declares and says that he is National Advertising manager of the **Albuquerque Journal**, and that this newspaper is duly qualified to publish legal notices or advertisements within the meaning of Section 3, Chaper 167, Session Laws of 1937, and that payment therefore has been made or assessed as court costs; that the notice, a copy of which is hereto attached, was published in said paper in the regular daily edition,

for.......1.......times, the first publication being on the....26....day

of.......Mar......., 1991, and the subsequent consecutive

publications on..............................., 1991.

Thomas J. Smithson..............

Sworn and subscribed to before me, a Notary Public in and for the County of Bernalillo and State of New Mexico, this ....26..... day of.......Mar......., 1991.

Bernadette Ortiz
BERNADETTE ORTIZ
12/18/93

PRICE.........$25.13.........

Statement to come at end of month.

CLA-22-A (R-12/91) ACCOUNT NUMBER.........C 80932.........

NOTICE OF PUBLICATION

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION

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GIVEN under the Seal of New Mexico Oil Conservation Commission at Santa Fe, New Mexico, on this 15th day of March, 1991. To be published on or before March 27, 1991.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

WILLIAM J. LEMAY, Director

S E A L

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

BRUCE KING
GOVERNOR

POST OFFICE BOX 2088
STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO 87504
(505) 827-5800

March 18, 1991

CERTIFIED MAIL
RETURN RECEIPT NO. P-327-278-102

Mr. Owen Mobley
The Permian Corporation
P. O. Box 1183
Houston, Texas 77001

RE: Discharge Plan Application, TPC-Carlsbad Brine Station
Eddy County, New Mexico

Dear Mr. Mobley:

The Oil Conservation Division (OCD) has received and is in the process of reviewing the above referenced discharge plan renewal application. On March 1, 1991 the OCD requested additional hydrogeological information from The Permian Corporation (TPC) concerning the proposed brine extraction facility. This material was received by the OCD on March 7, 1991 and is being incorporated into the review process.

Pursuant to the telephone conversation between the OCD and TPC on March 15, 1991 please submit the following:

1. Evidence that TPC brine extraction operations will not cause subsidence or collapse of overlying strata in the area of the proposed facility.

2. Revised Forms C-101 and C-102 for Well No. 1 and Well No. 2.

3. An explanation of how casing deterioration from contact with brine water will be prevented if packers are not used.

Submission of the above requested information will allow review of your application to continue. Enclosed is a copy of the guidelines for discharge plans at brine extraction facilities, and a copy of the Water Quality Control Commission Regulations.

If you have any questions, please do not hesitate to call me at (505) 827-5824.

Sincerely,

Kathy M. Brown

Kathy M. Brown
Environmental Bureau Geologist

RCA/sl
Enclosures

cc: OCD Artesia Office
A. L. Hickerson - PBS

A. L. Hickerson

OFFICE PHONE:
(915) 381-0531
(915) 563-4730
FAX 915/381-9316
DIRECT LINE: (915) 381-8420

PROFESSIONAL ENGINEER
TEXAS #11830K

6067 W. TENTH ST.
ODESSA, TEXAS 79763

RESIDENCE:
3216 BAINBRIDGE DRIVE
ODESSA, TEXAS 79762
PHONE: (915) 362-4814

CONSERVATION DIVISION
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'91 MAR 20 AM 9 11

March 15, 1991

Mr. William J. Lemay
Director of Oil Conservation Division
State of New Mexico
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

RE: Forms C101 and C102 for requested brine wells No. 1 and No. 2 for The Permian Corporation. NW/4 of SE/4 of Section 33, T-21-S, R-27-E.

ATTN: Kathy Moore

Dear Sirs:

Attached as requested by phone are subject forms. Also attached are copies of articles on fracturing between wells in the rock salt section, as well as articles on well configuration.

Attached is a sketch showing three methods of solution mining of salt. The two well system is used when the rock salt section is relatively thin, as at Carlsbad.

The hole development generally has a triangular cross section. By introducing the fresh water through tubing set near the bottom of the section, and removing the brine from the tubing in the second well set near the bottom of the salt section, the hole can be developed with a minimum cross sectional diameter. This of course reduces the chance of subsidence.

I have been solution mining salt for thirty-two years, from over fifty caverns. I presently have in operation three two well caverns. I have never had a subsidence to the surface. We do have some sloughing off of the shale and anhydrite stringers as the cavern is enlarged.

I feel sure that the proposed operation on the Tracy Lease will be safe.

If additional information is desired, please call me. (915-381-0531).

Very Truly Yours,

A. L. Hickerson

A.L. Hickerson

cc Owen Mobley - TPC Houston
Larry Evans - TPC Midland
Richard Lentz - TPC Hobbs

Submit to Appropriate
District Office
State Lease – 6 copies
Fee Lease – 5 copies

State of New Mexico
Energy, Minerals and Natural Resources Department

Form C-101
Revised 1-1-89

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work: DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

b. Type of Well: OIL WELL ☐ GAS WELL ☐ OTHER Brine Well SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name: Tracy Lease

2. Name of Operator: The Permian Corporation

8. Well No.: 2

3. Address of Operator: PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat: Wildcat

Well Location
Unit Letter 2 : 1600 Feet From The East Line and 2450 Feet From The South Line

Section 33 Township 21-S Range 27-E NMPM Eddy County

10. Proposed Depth: 600'

11. Formation: Rock Salt

12. Rotary or C.T.: Rotary

3. Elevations (*Show whether DF, RT, GR, etc.*): 3120 GL

14. Kind & Status Plug. Bond: #SU1326252/Utica Mut.

15. Drilling Contractor: Not Let

16. Approx. Date Work will start: 2 wks after approv.

7.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
10 ½"	7 5/8"	24#	400'	125	circulate
6 3/4"	5 ½"	17#	525'	85	circulate

N ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE ONE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

hereby certify that the information above is true and complete to the best of my knowledge and belief.

ONATURE A. L. Hickerson TITLE Consultant DATE 2-11-91

PE OR PRINT NAME A.L. Hickerson TELEPHONE NO. 915-381-0532

his space for State Use)

PROVED BY ________ TITLE ________ DATE ________

NDITIONS OF APPROVAL, IF ANY:

ıbmit to Appropriate
istrict Office
ate Lease - 4 copies
e Lease - 3 copies

STRICT I
). Box 1980, Hobbs, NM 88240

STRICT II
). Drawer DD, Artesia, NM 88210

STRICT III
00 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
En[illegible]gy, Minerals and Natural Resources Departm[illegible]

Form C-102
Revised 1-1-89

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

perator THE PERMIAN CORPORATION		Lease TRACY		Well No. 2
nit Letter	Section 33	Township 21-S	Range 27-E NMPM	County EDDY

ctual Footage Location of Well:
1600 feet from the EAST line and 2450 feet from the SOUTH line

round level Elev. 3122	Producing Formation ROCK SALT	Pool WILDCAT	Dedicated Acreage: 40 Acres

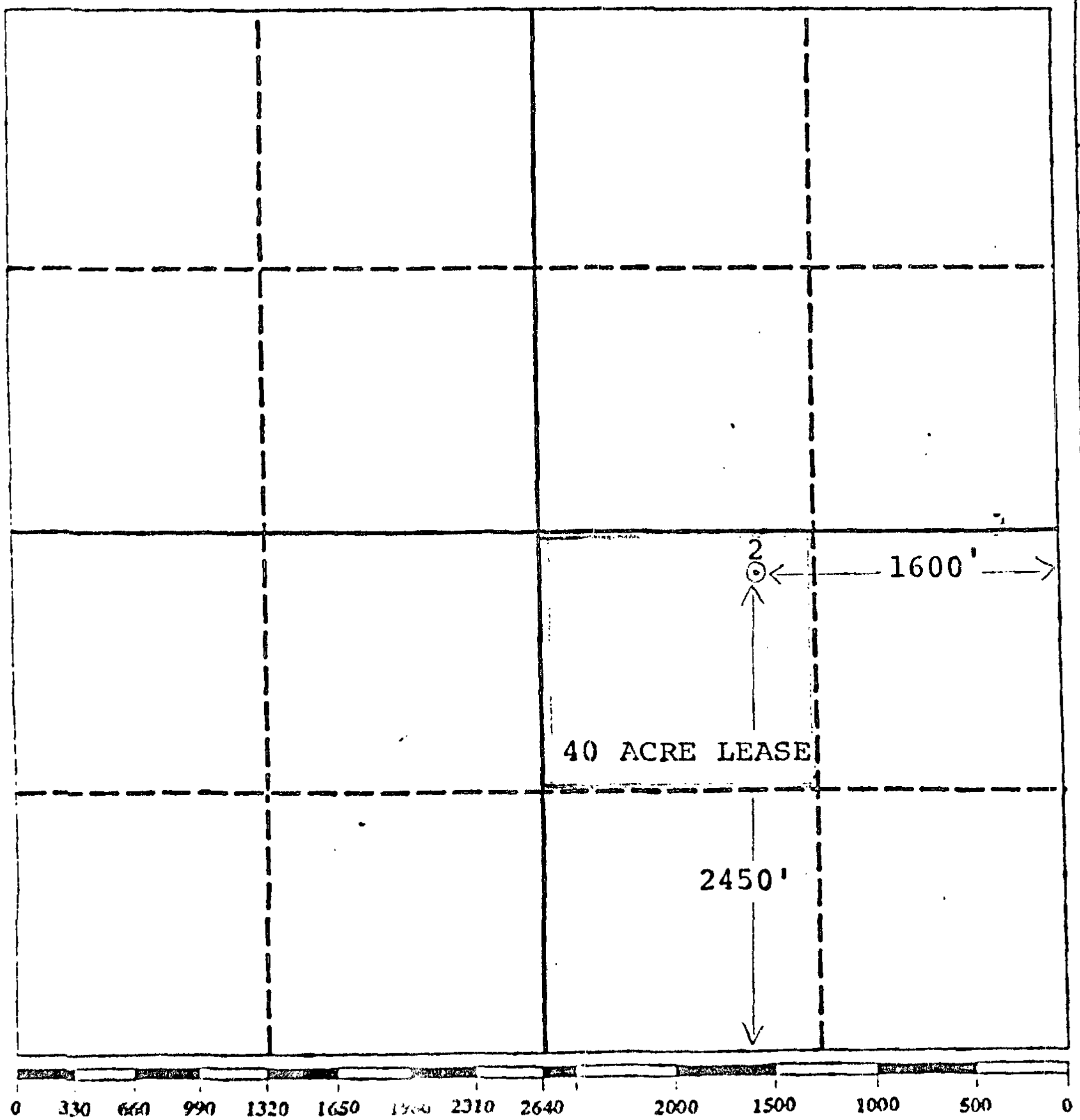
1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

3. If more than one lease of different ownership is dedicated to the well, have the interest of all owners been consolidated by communitization, unitization, force-pooling, etc.?
☐ Yes ☒ No If answer is "yes" type of consolidation

If answer is "no" list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if neccessary.

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interest, has been approved by the Division.



OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature Marvin J Reynolds

Printed Name
Marvin J. Reynolds

Position
Vice President - Operations

Company
THE PERMIAN CORPORATION

Date
February 14, 1991

SURVEYOR CERTIFICATION

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

Date Surveyed
February 18, 1991

Signature & Seal of Professional Surveyor

5412

Certificate No.
NM PE&PS NO. 5412

Submit to Appropriate
District Office
State Lease – 6 copies
Fee Lease – 5 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work:

DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

b. Type of Well:

OIL WELL ☐ GAS WELL ☐ OTHER Brine Well SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name
Tracy Lease

. Name of Operator
The Permian Corporation

8. Well No.
1

. Address of Operator
PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat
Wildcat

. Well Location
Unit Letter 1 : 1400 Feet From The EAST Line and 2230 Feet From The South Line

Section 33 Township 21-S Range 27-E NMPM EDDY County

10. Proposed Depth
600'

11. Formation
Rock Salt

12. Rotary or C.T.
Rotary

. Elevations *(Show whether DF, RT, GR, etc.)*
3122 GL

14. Kind & Status Plug. Bond
#5U1326252/Utica Mut

15. Drilling Contractor
Not Let

16. Approx. Date Work will start
2 wks after approv.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
10½"	7 5/8"	24#	400'	125	circulate
6 3/4"	5 ½"	17#	450'	75	circulate

ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE NE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

ereby certify that the information above is true and complete to the best of my knowledge and belief.

NATURE A. L. Hickerson TITLE Consultant DATE 2-11-91

PE OR PRINT NAME A.L. Hickerson TELEPHONE NO. 915-381-05

is space for State Use)

ROVED BY TITLE DATE

DITIONS OF APPROVAL, IF ANY:

bmit to Appropriate
strict Office
ate Lease - 4 copies
e Lease - 3 copies

STRICT I
). Box 1980, Hobbs, NM 88240

STRICT II
). Drawer DD, Artesia, NM 88210

STRICT III
00 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
E[illegible]gy, Minerals and Natural Resources Departm[illegible]

Form C-102
Revised 1-1-89

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

perator THE PERMIAN CORPORATION		Lease TRACY		Well No. 1	
nit Letter	Section 33	Township 21-S	Range 27-E NMPM	County EDDY	

ctual Footage Location of Well:
1400 feet from the EAST line and 2230 feet from the SOUTH line

round level Elev. 3122	Producing Formation ROCK SALT	Pool WILDCAT	Dedicated Acreage: 40 Acres

1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

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☐ Yes ☒ No If answer is "yes" type of consolidation

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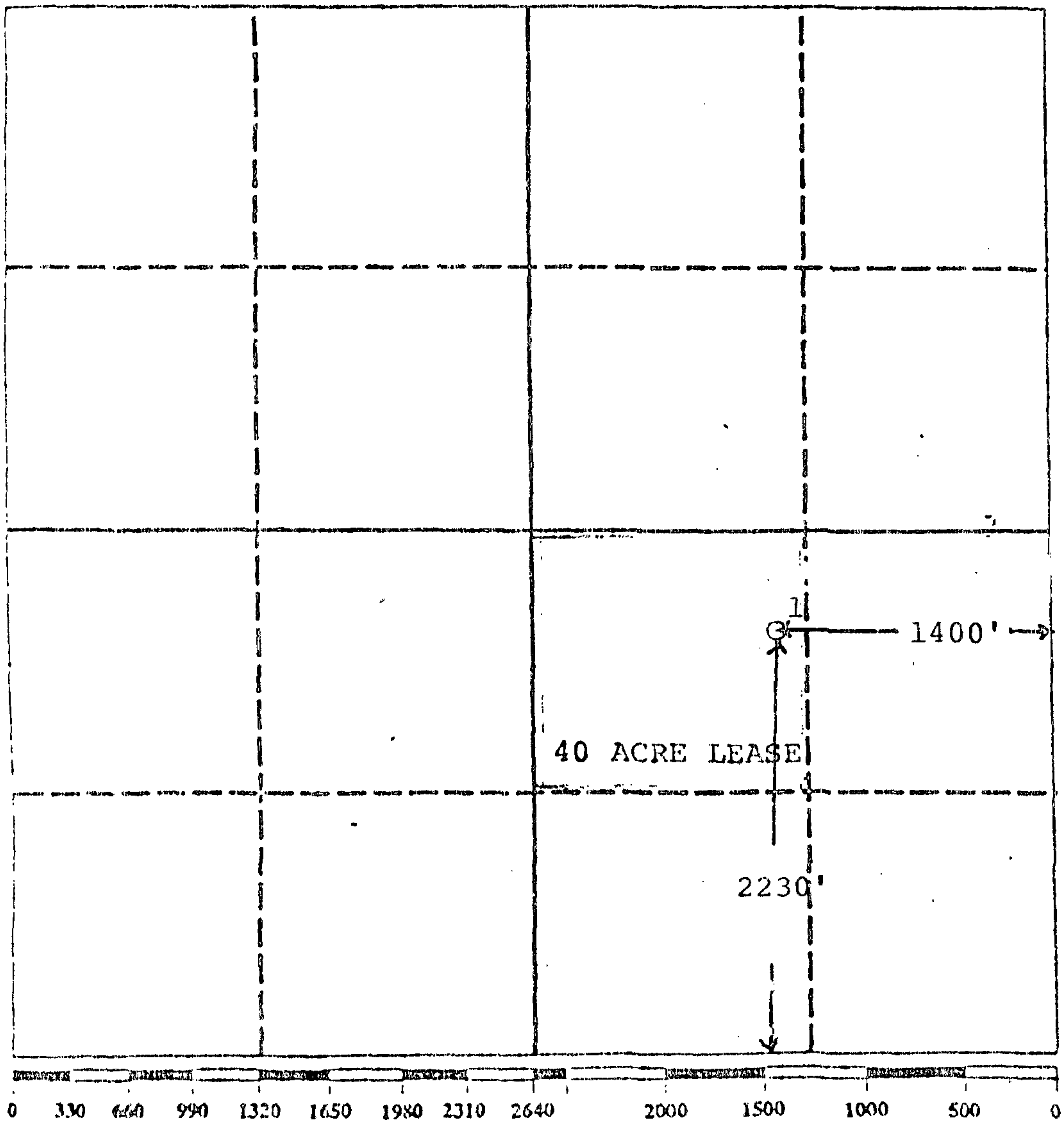

OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature Marvin J Reynolds

Printed Name
Marvin J. Reynolds

Position
Vice President - Operations

Company
THE PERMIAN CORPORATION

Date
February 14, 1991

SURVEYOR CERTIFICATION

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

Date Surveyed
February 18, 1991

Signature & Seal of Professional Surveyor

5412

Certificate No.
NM PE&PS NO. 5412

Solution Mining Test Site—Carlsbad Basin, New Mexico

D.A. Shock
J.G. Davis
Continental Oil Company
Ponca City, Oklahoma

Shock called 4-19-73
405 762-3456
EXT 65

ABSTRACT

This paper discusses the physical plant and types of experiments conducted at the solution mining test site in New Mexico. The primary purpose of the experiment was to test the ability to use the hydraulic fracturing along with solution extraction to perform a well to well extraction of values from thin-bedded potash deposits. The well configuration and a summary of the tests performed will be discussed.

The development of the salt cavern storage cavity via horizontal hydraulic fracturing and solution as reported in our paper to the Second Salt Symposium seemed sufficiently successful to warrant investigation of the technique in solution mining potash (Shock, 1966). A location where an adequate section of salt and potash, where water, gas and electricity were available was thought desirable.

Search for a suitable pilot test site centered in the Carlsbad Potash Basin Area of New Mexico. There, several ore zones are being mined conventionally; and the potash reserves have been reasonably well-mapped. Also, the mineral deposits are fairly uniform with a minimum of cross-bedding and folding.

A consulting geologist familiar with the area was hired during the search for available potash leases. Land with potash reserves of probable commercial size was found, but asking prices were too high for speculation on an unproven process. Fortunately, less desirable deposits under Federal and State Lands were also available—these via permits and leases for nominal annual rentals. Federal potassium prospecting permits were subsequently obtained on several tracts totaling some 2,000 acres in the vicinity of the existing potash mines (Fig. 1).

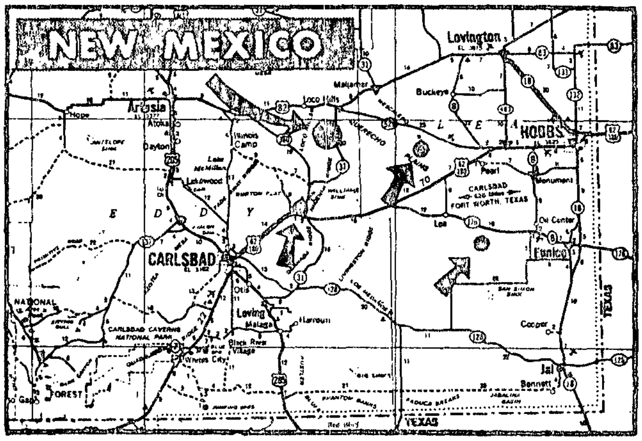

Figure 1.

Several factors influenced the decision to conduct the pilot test at the location finally selected. Freeport Sulfur drilled a core test on the tract several years ago, recovering about two feet of 30 per cent KCl ore from the Third Ore Zone at a depth of 1,100 feet. In addition, the area is reasonably accessible by car or truck; water for process use is common in the surface sands; fuel gas is available within two miles; a primary electric transmission line crosses the property; in addition CONOCO conducts oil field operations out of a nearby office at Maljamar.

The local geologic profile shows about 600 feet of alluvium, sand, limestone and dolomite above the 1,000 foot thick Salado Salt Section (Fig. 2). The Salado contains as many as twelve potash ore zones scattered through its upper 700 feet. These are known by numbers starting with the first ore deposit as the lowest zone. The first and third ore zones were of interest to us at the best probabilities for the test work. The first (which is the zone mined by Southwest Potash) was found to be all carnallite at our location. The third zone therefore was used.

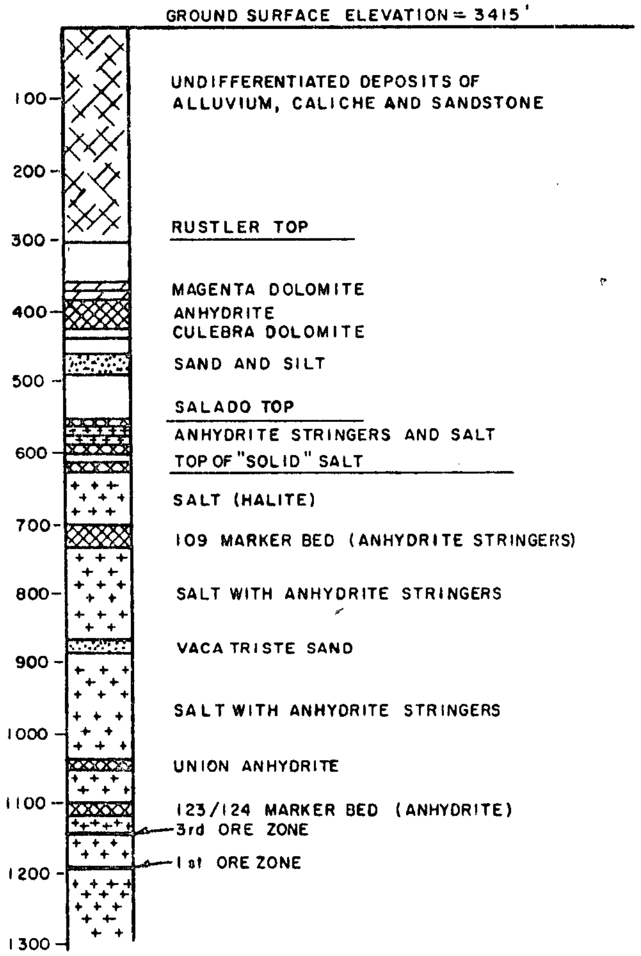

Figure 2. Geological section at the test site.

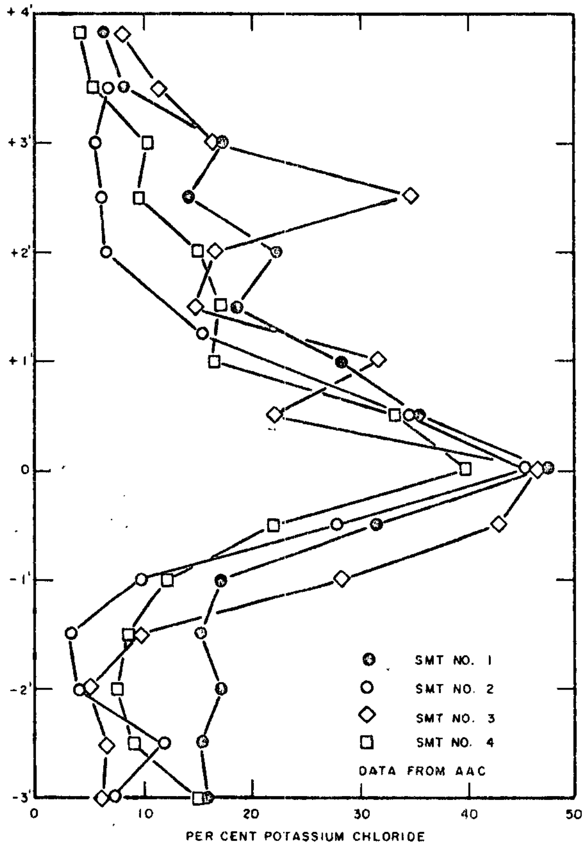

Figure 3. Four well composite of KCl content of third ore zone.

The third ore zone under the test site consists of about four feet of potash ore averaging approximately 15% K_2O. A composite of the ore zone based on log and core data from several wells is shown on Figure 3. The ore was quite thin, but usable for the test. This thinness actually may have been good for the test, because it required more finesse to precisely establish the floor and roof levels.

Although the site was acquired for the solution mining of potash, its usefulness is not limited to this work, since numerous thick sections of halite are available for additional work in either solution mining or cavity construction.

The prospecting permit expired after the completion of the test set out in the original research proposal. Because of the potential value of the site for further work, CONOCO has applied for a lease on the permit area.

TEST SITE DEVELOPMENT

A large location was cleared for a pattern of four wells and for the associated surface equipment. The test wells were drilled in a triangular pattern as shown in Figure 4, and the center well was planned as the fracture well. It was not known at the time the pattern was drilled if all three outside wells could be intersected with a fracture. Extensive work in fracturing has shown that horizontal fractures are seldom circular and that they nearly always show a preference to travel outward in one direction more than in others.

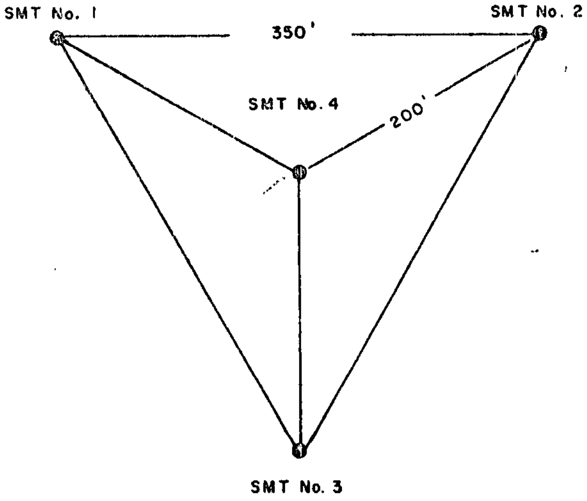

Figure 4. Well pattern for New Mexico pilot test.

The general well program was to drill to the top of the Salado Salt and to set 8 5/8 inch casing with cement to the surface. A hole was then drilled to the base of the 123/124 Marker Bed, about 20 feet above the third ore zone. Four inch cores were cut in all wells from this point through the ore to a total depth of about 1,150 feet. These cores included the first ore zone in one well.

Drilling and coring the salt section was done using a special diesel oil mud. The results were excellent and we got good cuttings, gauge holes, full diameter cores and excellent cement jobs. Figure 5 shows the core cut from the third zone.

Numerous well logs were run to define the entire geologic section and to see if quantitative interpretations could be made in the potash ore. The logs included the gamma, neutron, caliper, compensated sonic, and formation density.

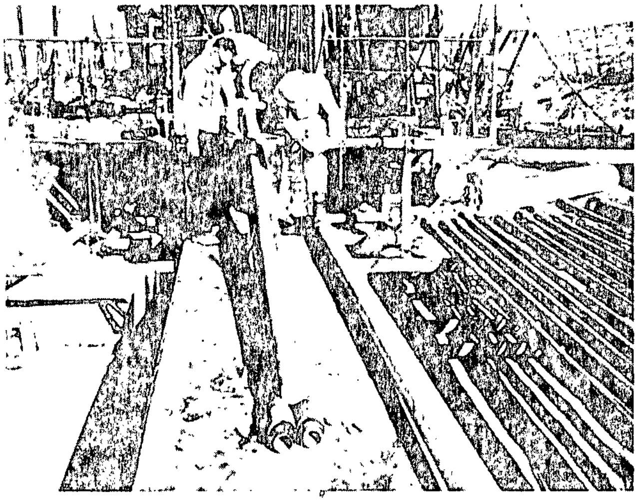

Figure 5. Potash core SMT No. 3.

Five and one-half inch casing was set and cemented in the three outer wells at the base of the 123/124 Bed. This pipe was set high as a research requirement so that we could locate the fracture if it drifted above the ore zone in the center (frac) well. Two earthen pits were built with a total capacity of about 9,000 barrels to store water for the hydraulic fracturing experiment.

The fracturing operation was done by Halliburton. The center well was fractured with water at rates up to about thirty barrels a minute. Communication was obtained with all three outer wells. The fracture reached the well to the south in about five minutes and the other two wells in about ten minutes. Subsequent caliper surveys in the target wells 200 feet away showed the fracture had dropped about eight feet from its point of initiation.

With the fracture successfully completed, equipment was installed for the solution mining test. Electrical power was brought in from Central Valley Coop., who had a primary transmission line about a mile from the test site. We set three 67 1/2 KVA Transformers and tied in to a master control panel for the pumps, lights, and other electrical equipment. Figure 6 and Figure 7 show the electrical panel, the water tanks, and one of the National pumps.

Water had been found in the surface sands, however when it was learned that water was being provided for a water-flood injection plant about two miles away, we purchased our water from their water supplier. A six inch water line was laid to the

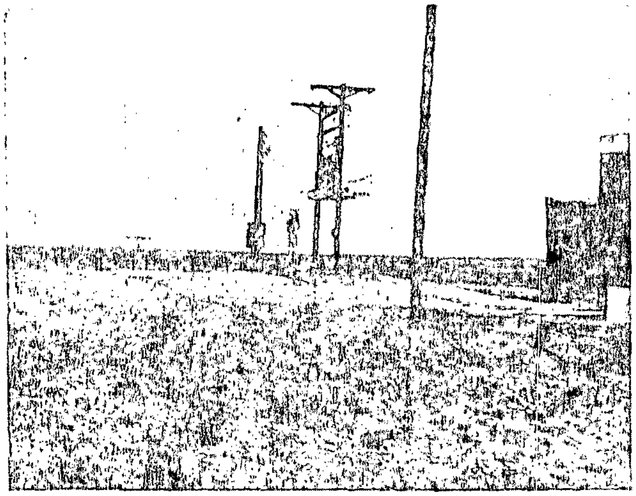

Figure 6. Power panel.

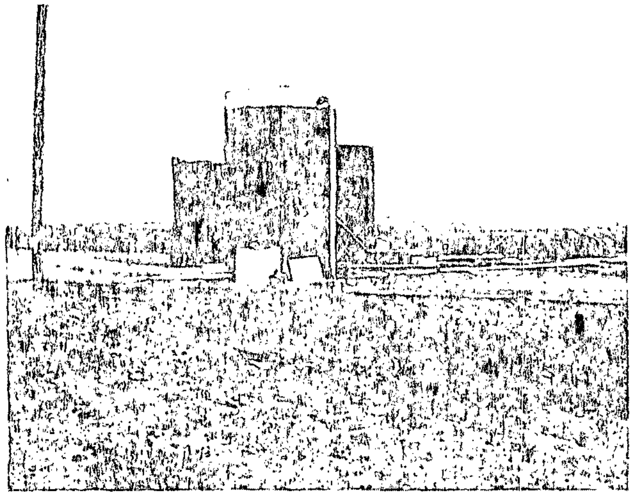

Figure 7. Storage tank and circulation pump.

test site and the water flow automatically controlled into a 500 barrel fresh water tank.

Another 500 barrel tank was provided for brine retention when desired during the test and a smaller tank for diesel storage. Diesel during the mining tests was used in the control of the upper level (roof level) of the mining. Two more 500 barrel tanks were moved in later for handling diesel in and out of the wells during the well-to-well mining when larger quantities of diesel were needed.

Water injection was handled with two National J-150 Triplex Pumps. These had a combined output as rigged of 4,000 BPD at 1,500 PSI and were skid-mounted. Diesel injection was handled with a smaller Bethlehem Triplex Pump. A single pole pulling unit was rented to manipulate pipe strings in the wells. A camping trailer was used as a laboratory and a house trailer was rented as on-site living quarters (Figs. 8 and 9). Data gathering equipment used during the test included recording pressure gauges, a densometer on the brine production line, and a small flame photometer for brine analysis. A diagram of the equipment layout for the test site is shown in Figure 10.

New Mexico laws were changed while the test was in progress to prohibit the surface disposal of brines. Therefore, the use of the two pits for brine

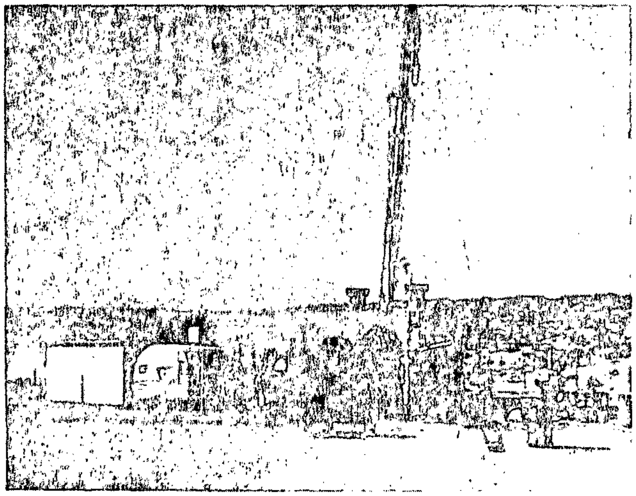

Figure 8. Laboratory and well equipment SMT No. 3.

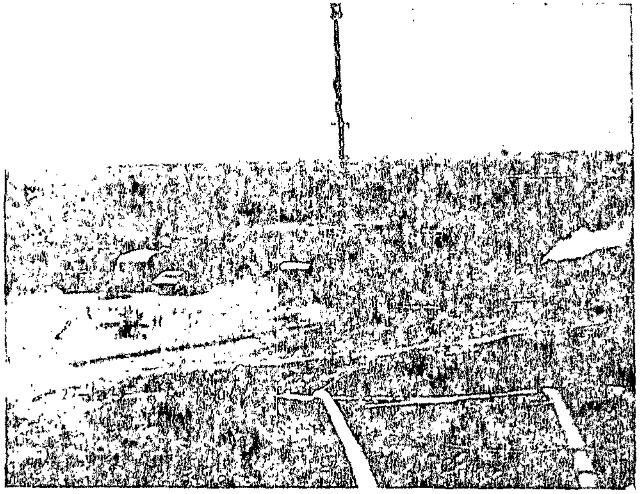

Figure 9. Field trailer and well SMT No. 3.

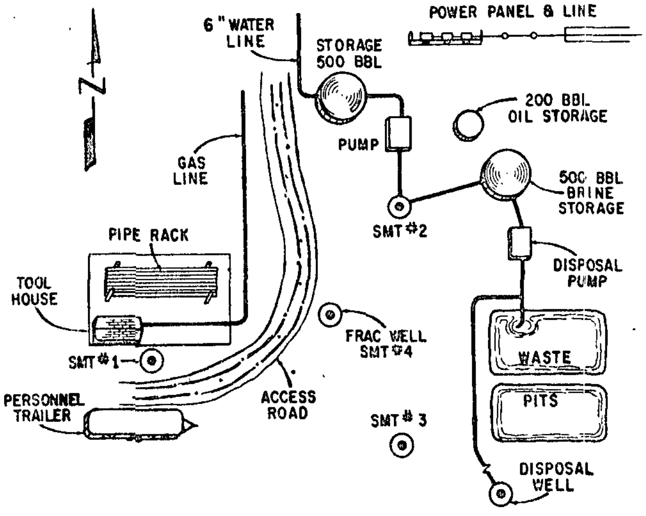

Figure 10. SMT–Test site–Loco Hills, N.M.

disposal was stopped and a disposal well was drilled into salt water zones at a depth of about 500 feet. This well accepted salt water very easily.

TEST PROGRAM

The test program carried out was to (1) test the initiation and propagation of hydraulic fractures in salt, (2) test the rate of solution for both salt and potash in a single well cavity (3) establish the cavity radius vs. height for a single well, (4) check the solution rates of salt and potash from the roof of single well cavities and (5) test the possibility of selective mining the thin potash zone in a well to well system.

The fracture test reported in our paper "Hydrofracing as a Mining Technique" was successfully completed with the fracture staying below the potash bed (Shock and Davis, 1969). Single well tests, run in wells SMT No. 1 and SMT No. 2 verified our conclusions that we could reproduce our laboratory results with respect to single cavity solution. Figure 11 shows the laboratory model of a test to create a cavity of limited height with maximum width. Figure 12 shows the model of the field cavity in SMT No. 1 based on data from a sonar survey. The conclusion of this test was that the laboratory solution experiments could be scaled to field condition. The final field experiment was a well to well test conducted between wells SMT 4 and SMT 3. The conclusions of this test were reported in a recent paper (Davis and Shock, 1969).

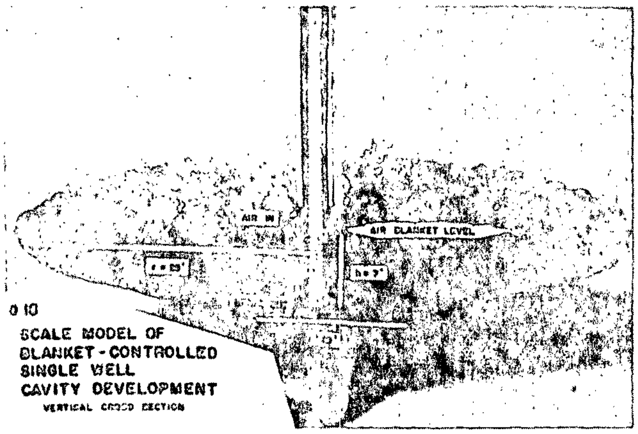

Figure 11.

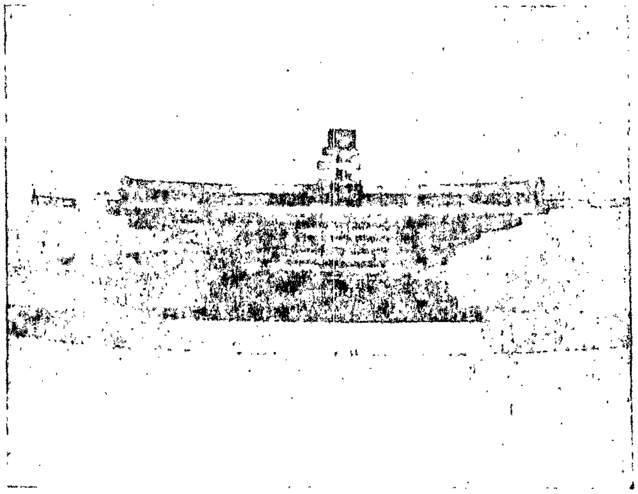

Figure 12. Sonar model of field cavity.

CURRENT STATUS

Several additional tests have been proposed for the test site. These include additional fracturing and potash solution tests as well as evaluation of anhydrous ammonia storage in salt. At the present potash solution tests have been suspended due to the lack of commercial incentive to mine potash. It is anticipated that work will be resumed when it becomes evident that there is sufficient commercial incentive. Meanwhile the site stands a potential test center for numerous solution extraction and salt storage experiments. Its use will depend on the need for the field data.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Continental Oil Company for their permission to publish this paper and to the many members of the Conoco Production Department and Research and Development Department whose efforts went into making this project successful.

REFERENCES

Davis, J.G. and Shock, D.A., 1969, Solution mining of thin bedded potash, presented at the Annual Meeting of the AIME, Washington, D.C., February 16-20.

Shock, D.A., 1966, Use of hydraulic fracturing to make a horizontal storage cavity in salt *in* Second Symposium on Salt: Northern Ohio Geol. Soc., p. 406-410.

Shock, D.A., and Davis, J.G., 1969, Hydrofracing as a mining technique, presented at the Annual Meeting of the AIME, Washington, D.C., February 16-20.

CAVITY WASHING TEST: No. 7
SOURCE OF SALT: Potash Ore, Good Grade, New Mexico
CONDITION OF TEST: 7" x 12" fracture, 11" between wells
MANNER OF TEST: Inlet and Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
15	770	770	51.4	1.152	84.5	84.5	9.1
15	800	1,570	53.3	1.148	85.8	170.3	9.3
15	765	72,335	51.0	1.147	81.6	251.9	9.3
15	755	3,090	50.3	1.145	79.0	330.9	9.5
15	770	3,860	51.4	1.132	73.9	404.8	10.4
15	760	4,620	50.7	1.117	64.5	469.3	11.7
*15	980	5,600	-	1.098	69.6	538.9	14.1
15	700	6,300	46.7	1.102	51.6	590.5	13.5
**30	1,100	7,400	-	1.122	97.5	688.0	11.3
15	655	8,055	43.7	1.139	65.9	753.9	10.0
***15	630	8,685	42.0	1.129	58.7	812.6	10.7
15	720	9,405	48.0	1.132	68.8	881.4	10.5
15	780	10,185	52.0	1.158	89.4	970.8	8.7
15	765	10,950	51.0	1.158	87.5	1,058.3	8.7
15	750	11,700	50.0	1.157	85.3	1,143.6	8.8
****15	775	12,475	51.7	1.158	89.0	1,232.6	8.7
15	775	13,250	51.7	1.158	89.0	1,321.6	8.7
15	765	14,015	51.0	1.157	86.8	1,408.4	8.8
15	770	14,785	51.3	1.156	87.2	1,495.6	8.8
15	795	15,580	53.0	1.155	89.3	1,584.9	8.9
*****15	610	16,190	40.7	1.139	61.4	1,646.3	1.0
†11	900	17,090	-	1.153	99.7	1,746.0	9.0
Drained	2,160	19,250	-	1.134	209.0	1,955.0	10.3

Total volume of cavity from amount drained = 2,160 cc

No mold made, see pictures

Width at inlet = 9-1/2 inches

Width at outlet = 8-1/4"

Width at midpoint = 8-1/2"

Depth at inlet = 1-1/16"

Depth at outlet = 7/8"

Depth at midpoint = 1"

Length overall = 14-1/2"

*Found air in cavity and flushed out with water.

**Found air to still be in cavity. Turned specimen over to purge of air and found small air leak to one side of inlet end of block. Plugged air leak and purged of air and continued.

***Checked for and found same place as in ** leaking slightly. Repaired and purged of air.

****Took sample for analysis.

*****Found air leaking in again at the same place. Attempted to seal fracture and purged of air and continued.

†Found air still leaking in and filled cavity with water and shut down.

Hydraulic Fracturing in Salt and Potash Formations

Edgar A. Manker
Garrett Research and Development Company, Inc.
LaVerne, California

ABSTRACT

Extensive development programs have been conducted for the past several years to devise techniques for the economical solution mining of potash from the deeper areas of the large Canadian potash deposit. Economic considerations indicate that mining procedures utilizing wells connected by hydraulic fracturing could be attractive. Initial attempts to establish a fracture communication between adjacent wells by initiating a fracture at the base of a potash seam were not productive. The communication appeared to be established momentarily, but it could not be maintained. The selected fracture point was a clay seam which, although thin, appeared to be continuous and to provide a weak plane in the deposit. Analysis of the experiment appeared conclusive in demonstrating that a fracture path along the clay seam was not established and consequently that these weakness planes were not suitable for fracture propagation.

A different technique was developed and applied successfully. This new technique offers a high probability of success in initial fractures and virtually guarantees a high percentage of successful fractures in a production well field. In addition to potash deposits, this technique should be applicable to salt deposits and most other soluble mineral deposits. The results of the experimental program and the development of the techniques are presented in this paper.

Hydraulic fracturing was originally developed as a technique for stimulating production of oil wells. The creation of a fracture by fluid injection enlarged the surface area exposed for oil flow, thus increasing the effective permeability and production rate of a given oil bearing formation.

The same basic technique was later applied to fracturing soluble salt formations, in particular to sodium chloride (rock salt) deposits. In contrast to oil field fracturing where the production of a single well is stimulated, these soluble mineral fractures require the establishment of a communication or flow path between two or more wells to allow dissolving or "solution mining" of the salt deposit. The hydraulic fracture technique has been utilized to establish this communication between wells.

Typical salt fracturing operations were described at the two earlier Salt Symposia (Gilbert, 1963; Jacoby, 1963; Mair, 1963; Shock, 1966). The fracturing procedure in rock salt mining invariably utilizes a salt-shale interface for a cleavage plane to initiate and propagate the fracture (Bays, U.S. Patent, Bays, 1960; Pullen, U.S. Patent; Redlinger, U.S. Patent). By following these salt-shale interfaces successful fractures are often obtained, and communication paths have been established between wells several hundred feet apart.

More recently the same fracture techniques have been applied to the creation of cavities for natural gas and other hydrocarbon storage (Shock, 1966; Shock and Davis, 1969), where the cavities are created by solution mining of a salt formation. Cavity volumes of 100,000 barrels and greater volumes have been established by this method. The general convenience of underground storage indicates these cavity storage systems will become even more common.

Potash formations.

The application of hydraulic fracturing to potash solution mining is also of considerable interest. One experimental program has been described (Davis and Shock, 1969) and other unpublished tests have taken place. Of particular interest are the deeper portions of the large Saskatchewan potash deposit where the rich ore zones are too deep for conventional shaft mining to be economical.

Interest in these deposits led to an experimental program to establish hydraulic fracture communication between potash solution mining wells. The initial program followed conventional procedures wherein a weak clay stratum was selected as the fracture point in the potash zone of interest. A well was drilled into the formation, cased, cemented and subsequently notched at the clay stringer. A second well which was cased only to the top of the ore zone, with an open hole extending well below the zone, was used as a target well.

After the completion of the injector well and notching of the casing, suitable pumping equipment and fluid reserves were established at the site. The injection of fluid was begun with the initial condition of the well as shown in Figure 1, and observation of injection pressure clearly indicated a positive fracture, as represented in Figure 2. The indicated thickness of the fracture was determined in retrospect rather than in initial estimates and planning.

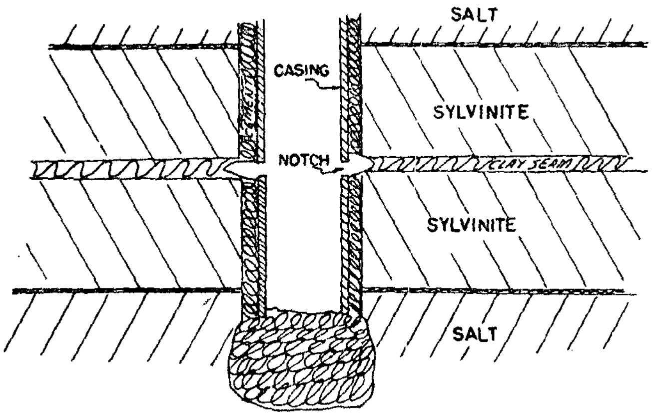

Figure 1. Initial well structure.

With this conventional procedure, all that remained to be done was to maintain the injection of fluid, and at the same time monitor the target well for signs of success. These signs of success failed to appear, and after very large quantities of fluid had been injected and no communication had been established, fluid injection to the injector well was stopped. A further attempt to establish communication was made by injection into the target well with the original injector well serving as the target. This also failed to establish a successful communication. Additional manipulations were tried with additional lack of success in creating any flow between the wells.

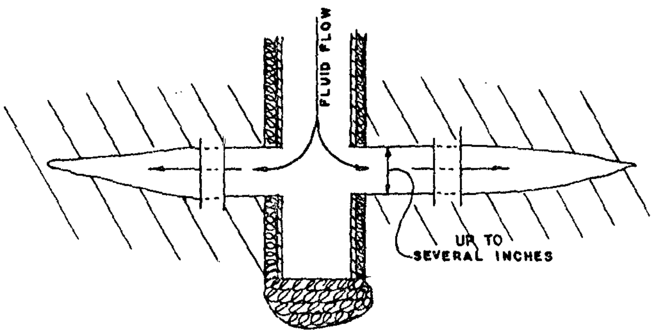

Figure 2. Fracture propagation.

Analysis of results.

The negative results of this fracture experiment, coupled with several observations of unusual and unexpected behaviour during and after the tests prompted a detailed evaluation and analysis of the procedure. The volume of fluid injected, and the known distance the fluid had not travelled in at least one direction, strongly suggested that the fracture thickness was of the order of inches as shown previously in Figure 2.

In contrast, most literature on hydraulic fracturing suggests that fractures are only a fraction of an inch thick. Results of some fracturing operations (Gilbert, 1963; Shock and Davis, 1969) confirm that the obtained fractures were only one or two tenths of an inch thick.

The thickness of a fracture clearly depends upon the mechanical properties of the target formation and the pressures used in the fracture operation. Initiation and propagation of a fracture can only be accomplished by applying and maintaining a pressure higher than the static formation (overburden) pressure. The excess pressure causes a compression of the formation to create the fracture opening. The thickness of this opening may be estimated from the formation mechanical properties and the pressures used in fracturing.

In a completely isotropic formation, a fracture should propagate equally in all directions, producing a circular envelope. It is well known, of course, that variations in the structure of geological formations (Jacoby, 1966) result in an areal propagation of a noncircular nature as represented in Figure 3. *Fluid injected into the well will tend to follow the* path of least resistance, and variable resistance of the formation results in the asymmetrical areal propagation.

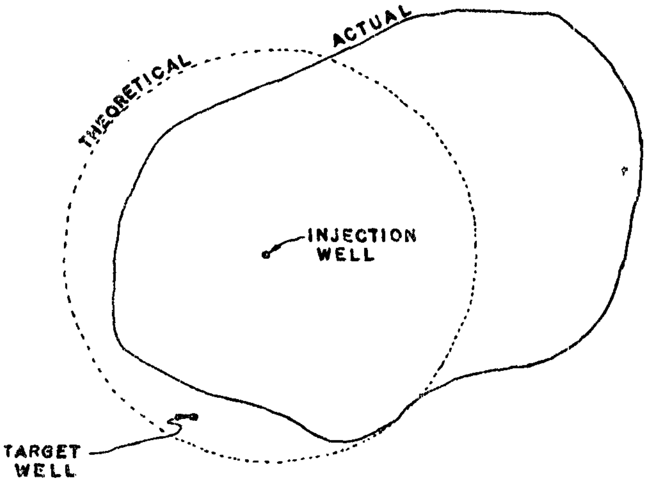

Figure 3. Areal propagation.

The path of least resistance will also tend to direct the fracture upward under average conditions. Again the lack of an isotropic structure may cause any given fracture to go upward, downward or horizontally. In the first fracture experiment, the extensive open hole section in the target well and later results of logging and other tests suggested that the established fracture had probably travelled upward from the initiation depth. There was no absolute evidence for this conclusion, but it appeared, as shown schematically in Figure 4, to be the most probable situation.

The "path of least resistance" principle further suggests that the drilling of the target well may be an invitation to failure. It is inevitable that the drilling process mechanically alters stresses in the formation around the well, and magnifies the disturbance by altering temperature profiles adjacent *to the well. These disruptions may cause weakness* paths which neatly circumvent the target well.

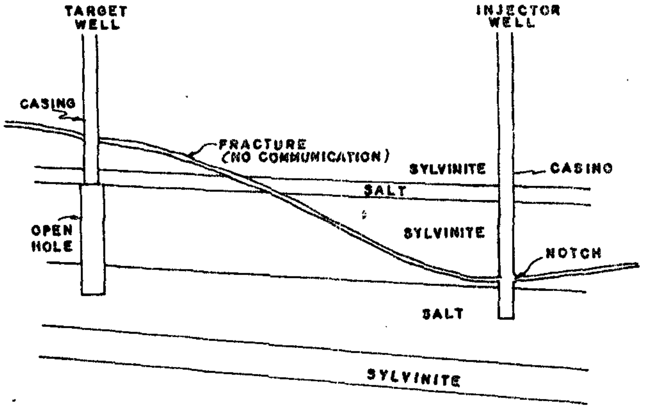

Figure 4. Fracture path and behavior.

One of the more interesting observations was the behavior of the injection well during and after the tests. When the well was shut in a pressure of about 2500 psi existed at the well head, corresponding to a pressure at the fracture depth of about 4500 psi. When the well head valve was opened there was an initial high flow of fluid from the well, but this slowed fairly quickly and within less than an hour had reduced to only a few gallons per minute. At first it was assumed the reduction in flow was due entirely to plugging of the well by material coming back out of the fracture. Subsequent injection and flow tests clearly demonstrated that the restriction only occurred on withdrawal of fluid and that reinjection encountered no similar flow resistance. The true behavior may be seen in Figure 5 which shows schematically the shut in condition, and in comparison the situation with the well head open. It may be noted that with a high flow rate from the

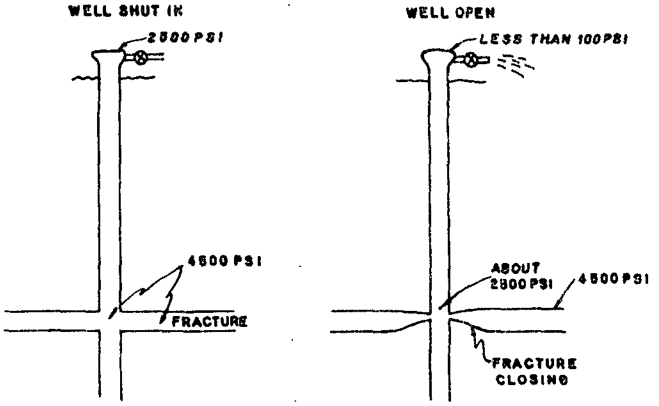

Figure 5. Behavior of well on pressure release.

well head, the down hole pressure near the fracture is reduced considerably, and in fact reduced below the level necessary to keep the fracture open. Consequently, the fracture starts to close in the vicinity of the well, reducing the flow rate. As the flow rate is reduced, the down hole pressure adjacent to the fracture is even further reduced, and eventually the flow out of the well head is slowed to a mere trickle.

Typical pressure behavior at the well head is shown in Figure 6. Here the well, initially shut in, is at a static pressure sufficient to keep the fracture open. When the well head is opened there is an immediate drop in pressure, followed by a more gradual decrease to nearly zero pressure at the well head. Correspondingly when the well head is opened there is initially a high flow rate, which soon decreases to a level just above zero. If the well is then shut in, the pressure will return nearly to the original pressure indicating that conditions in the fracture and the well are again stabilized. At this point the well could be opened again, and a repetition of the initial behavior will be obtained. Alternately, further injection could be carried out, with only a small increase in the well head pressure required to obtain significant injection flow rates.

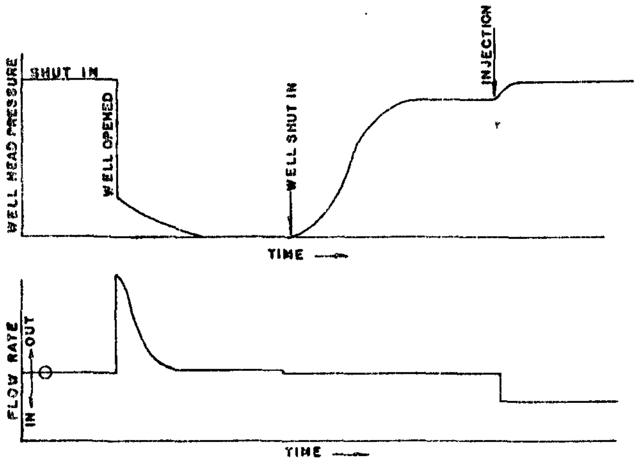

Figure 6. Well pressure behavior.

The well and fracture system is thus analogous to a balloon which may, within reasonable limits, be blown up or let down at will. What has actually been established underground might best be described as a "fracture pool." This fracture pool is a reservoir from which fluid may be withdrawn, or which may be extended by the injection of additional fluid.

New fracturing procedure.

Careful consideration of all the above factors suggested a very different approach to establishing communication between wells (Manker, Garrett, and Wachtell, 1967). This procedure is based upon establishing a fracture pool, then either estimating or measuring the shape and extent of the fracture pool and subsequently drilling a well communicate with the pool. What must be done is simply blow up a balloon within the deposit and then direct one or more darts into the balloon.

Since the initial experiment had established a very significant fracture pool within the potash deposit, that portion of the procedure was already accomplished. What remained was to determine the location of the pool, and then drill a well into it. The areal extent of the established pool could be estimated. It is also quite probable that injection to establish the fracture pool creates disruptions which are transmitted to the ground surface where they could be measured. Since "tilt meter" instruments capable of measuring extremely small angular deflections are available, the progression and extent of the "fracture pool" probably could be determined by surface measurements. This, however, had not been done during the initial experimental program, so the existing fracture pool was estimated. Calculations indicated its radius should be approximately twice the well spacing used in the initial test. It, therefore, seemed almost certain that a well drilled with the same well spacing (more than 300 feet) would intersect the fracture pool and establish the desired communication.

It was anticipated that when the new well intersected the fracture pool, the high pressure in the pool (compared to the fluid head in the well) would cause the well to "blow-in." This "blow-in" would, of course, be short-lived since the low pressure at the well head would lead to the previously noted constriction of the fracture adjacent to the well, and a corresponding reduction in flow from the well.

A new well was drilled and encountered the fracture pool exactly as anticipated. After the fracture pool was encountered, flow from the well subsided as predicted and a successful communication had been established. The initial path between the wells was sufficiently clear that only 50 psi differential was required to obtain flow rates in excess of 125 gallons per minute through the fracture. It is certain that additional wells could be communicated with the same fracture pool and injector well with a high degree of success.

This new and relatively simple procedure is summarized in Figure 7 where, after selection of a desired well spacing and some basic calculations are made, the fracture is initiated and fluid is injected to establish the desired pool. Either surface deflection observations or a calculated injection volume may be used to establish the size of the pool. A second well is drilled into the pool to complete the communication. The fracture pool can, if desired, be extended by · drilling additional wells in the pool, so that a multi-well operation can be established on a given pool. Occasionally new wells may not intersect the pool, but they can, of course, be used as injector wells to establish additional pools adjacent to the original pool. Alternately they may, when fluid is injected, communicate with the original pool. Thus, the number of successful fracture completions in a well field operation can exceed 90%.

1. SELECT DESIRED WELL SPACING
2. ESTIMATE FRACTURE THICKNESS
3. DETERMINE FLUID VOLUME REQUIRED
4. INJECT AND OBSERVE SURFACE DEFLECTIONS
   OR
   INJECT TO CREATE ABOUT TWICE DESIRED RADIUS
5. DRILL SECOND (AND ADDITIONAL) WELLS TO
   COMPLETE THE COMMUNICATION
6. ESTABLISH ADDITIONAL "FRACTURE POOLS"
   AND WELL FIELDS AS DESIRED

Figure 7. Establishment and location of fracture pool.

At the same time, the controllability of the method assures that a relatively high percentage of any given surface area can be mined by this technique. Figure 8 shows the application in a fixed surface area. An initial fracture pool is established in the area, and intersection wells are drilled. Additional pools are created as desired, and based on data from earlier wells, their behavior can readily be predicted. In some cases it would be desirable to establish a large initial pool, and if the pool was following desired strata, simply extend the single pool toward the area boundary. The major advantages of the procedure are summarized in Figure 9.

The procedure offers several economies beyond good controllability and a high degree of success. Establishment of the fracture pool can be done with conventional pumps since the pool can be easily maintained during any necessary pump shutdown. Intersection wells may be drilled as convenient and scheduled according to specific production requirements. Reduced costs for intersection wells will normally be obtainable because of reduced well logging costs and because casing and cementing does not need to be designed for high fracturing pressures.

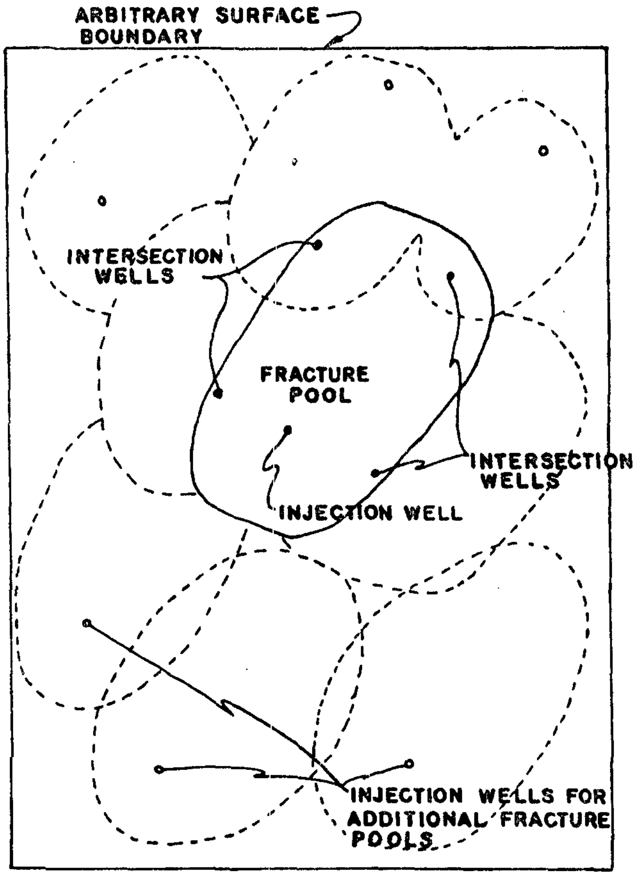

Figure 8. Mining in a fixed surface area.

1. CONTROLLED OPERATIONS
2. NO ABSOLUTE LIMIT ON WELL SPACING
3. SUCCESSFUL COMMUNICATIONS CAN EXCEED
   NINETY PERCENT
4. HIGH PERCENTAGE OF GIVEN SURFACE
   AREA CAN BE MINED

Figure 9. Advantages of procedure.

Beyond its demonstrated applicability to potash deposits, this new procedure is particularly applicable to salt solution mining, and for establishing underground storage cavities in salt formations. It can also be applied, with the use of suitable solvents, as a mining method for a wide variety of underground mineral deposits.

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Hydraulic Fracturing and the Extraction of Minerals Through Wells

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ABSTRACT

"Hydraulic Fracturing" is a method used to create artificial fractures for the purpose of increasing flow capacity around a well or enhancing communication between two adjacent wells. The present paper reports on some theoretical, laboratory and field studies aimed at improving the knowledge of hydraulic fracture orientation and initiating pressure. Only vertical fractures are considered in detail, as they are the most abundant type encountered in the field.

The fractures are theoretically assumed to be tensile ruptures extending in a plane perpendicular to the direction of the smaller horizontal principal compressive stress. It is found that the pressures required to initiate and extend vertical fractures depend on the principal tectonic stresses, the porous-elastic parameters of the rock and its tensile strength.

Experimental work on simulated wells in laboratory rock samples under triaxial loading is described. Results confirm theoretical predictions of fracture type, fracture initiation pressure and fracture orientation.

In the field, oriented impression packers were used to determine the fracture azimuth at the wellbore. Results indicate that wells belonging to a common field yielded hydraulic fractures of approximately same orientation. This seems to substantiate the theoretical and laboratory conclusion that the smallest tectonic horizontal compressive stress direction determines the fracture orientation.

INTRODUCTION

Mining through wells is a common method used for the extraction of minerals like salt, potash, sulphur and especially petroleum. Sometimes the entire mining process necessitates one well only. Often it requires an injection well in addition to the production well. Whether the purpose is to increase flow capacity around one well, or to enhance communication between the injection and production wells, it is frequently necessary to induce artificial fractures in the ore bearing formation. The method usually employed is that of "hydraulic fracturing." It consists of sealing off a section of the well and pressurizing it by injecting in a "fracturing fluid" like water, brine, oil, etc. The pressure in the isolated interval is continuously raised until fracture occurs. The pressure then drops momentarily, but if pumping is continued vigorously the fracture opens up and propagates. Propping agents are sometimes introduced into the fracture to keep it from closing back when pumping is stopped. If the fracture is large enough and extends in the right direction, it can vastly increase production.

One of the unsolved problems of hydraulic fracturing is the ability to predict the inclination of the fracture plane and the direction it will follow. Knowledge of fracture orientation can be extremely valuable, for example, in the design of well layout in a producing field. Another problem, related mainly to the design of a fracturing job is the capability to foresee the maximum pressure required to cause formation breakdown. The present report concerns itself mainly with these two latter problems. First it is shown that theoretically there is a close relationship between the state of stress in the earth and both the breakdown pressure and fracture direction. Then some laboratory tests on simulated wellbores are described. These tests seem to support the theoretical analysis. Finally a field method for detecting fracture direction is described, and a number of encouraging field results presented.

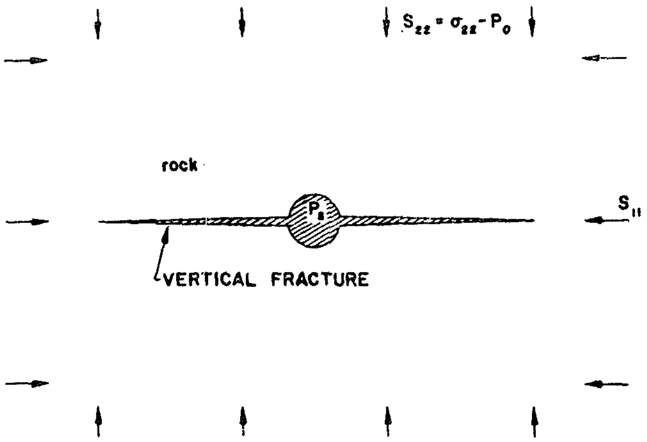

Figure 1. Cross section of vertically fractured well.

THEORETICAL CONSIDERATIONS

The theory of elasticity of porous materials can be used to estimate the pressures required to initiate and extend hydraulic fractures and their orientation and direction. To do so, a theoretical model is constructed based on some limiting assumptions regarding the materials involved. It is assumed that the formation to be fractured is brittle elastic, porous*, isotropic and homogeneous. The fluid flow through the formation is laminar and follows Darcy's Law. The state of stress in the formation, prior to drilling of wellbore, is generally nonhydrostatic with one of the principal stresses (S_{33}) assumed to be acting in the vertical direction. The latter assumption is justified especially in formations of gentle dip (Anderson, 1963, p. 12). When a vertical circular wellbore is drilled the initial horizontal principal tectonic stresses (S_{11}, S_{22}) redistribute around the cylindrical cavity in a manner defined by Hirsch solution (Haimson, 1967, p. 311).

The pressurization of the open hole in the well generates two additional stress fields, one due to the radial pressure on the well wall, and the other due to fluid flow into the formation resulting from the difference between the well pressure (P_w) and the reservoir fluid pressure (P_o). The complete distribution of horizontal stresses around the wellbore is found by superposing the three mentioned stress fields (Haimson, 1967, p. 312). At the vertical wall of the open hole, and away from the hole ends, the most vulnerable stress is the tangential ($S_{\theta\theta}$). Under normal in-situ stress conditions, this stress is the first to reach tensile values, as the wellbore pressure P_w rises, finally causing a vertical tensile rupture that originates at the well's wall. Looking at a cross section of the well, the fracture is most likely to initiate at two diametrically opposed points, whose connecting line is perpendicular to the larger tensile principal tectonic stress (S_{22}), (Fig. 1). In terms of effective stresses $\left[\sigma_{ij} = \begin{array}{ll} S_{ij} + P & \text{for } i = j \\ S_{ij} & \text{for } i \neq j \end{array}\right]$, the tangential stress at these two points is given by

$$\sigma_{\theta\theta} = 3\sigma_{22} - \sigma_{11} + \left(2 - \alpha \frac{1 - 2\nu}{1 - \nu}\right)(P_W - P_O) \quad (1)$$

where:

α = parameter of a porous elastic material; can be determined in the laboratory (Mann, 1960).

$0 \leqslant \alpha \leqslant 1$

ν = Poisson's ratio of the rock.

Failure in tension occurs when P_w reaches a critical value (P_c^p), also called breakdown pressure, at which $\sigma_{\theta\theta} \geqslant \sigma_t$, where σ_t is the tensile strength of the rock in the horizontal plane. Hence the minimum critical pressure necessary to induce a vertical fracture is (Haimson, 1967, p. 312):

$$P_c^p - P_o = \frac{\sigma_t - 3\sigma_{22} + \sigma_{11}}{2 - \alpha \frac{1 - 2\nu}{1 - \nu}} \quad (2a)$$

where:
$$0 \leqslant \alpha \frac{1 - 2\nu}{1 - \nu} \leqslant 1$$

If the formation permeability to the fracturing fluid is negligible, the third mentioned stress field is zero and the critical pressure (p_c^i) then becomes:

$$P_c^i - P_o = \sigma_t - 3\sigma_{22} + \sigma_{11} \quad (2b)$$

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* This includes nonporous formations as a special case.

From equations (2a) and (2b) it can be easily verified that $P_c^i \geqslant P_c^p$, or in other words, the breakdown pressure in a permeable formation is usually lower than the pressure required to fracture an impermeable but otherwise identical zone.

The rock parameters σ_t, ν, α can be measured in the laboratory in rock cores corresponding to the formation in question, and under conditions of loading and pore pressure similar to the in-situ ones.

It is assumed that the vertical tensile fracture initiated at the wellbore will extend along a plane perpendicular to the direction of the larger horizontal principal tectonic stress (S_{22}). This assumption is based on the theory that a fracture follows the path of least resistance. The downhole pressure of the fracturing fluid necessary to keep the fracture open (P_s) is the instantaneous shut-in pressure, and is given by:

$$P_s - P_o \geqslant - \sigma_{22} \tag{3}$$

It should be noted that the values of P_c and P_s are usually recorded by a pressure versus time plot taken during a fracturing job.

The case of horizontal fracturing initiation will not be considered here. Theoretical relationships and experimental results related to horizontal fractures can be found elsewhere (Haimson, 1968). There is, however, the possibility that fractures that are initiated in the vertical plane, due to the stress distribution at the wellbore, may change orientation and become horizontal away from the wellbore, so as to be perpendicular to the smallest compressive stress. Under normal in-situ stress conditions this possibility is rather remote, but when it occurs it is very hard to detect.

From equations (2, 3) it is evident that if the magnitudes of σ_{11} and σ_{22} are known, the breakdown pressure (P_c) and the pressure required to keep the fracture open (P_s) can be predicted. Moreover, it can be assumed that within a certain formation and depth, the tectonic stresses remain constant in an area which is undistributed geologically. It is expected therefore that in the same "neighborhood" of a producing field, wells will yield fractures oriented essentially parallel to each other. The magnitudes of P_c and P_s for these wells should not vary considerably from one well to the next.

In those locations where the two horizontal principal tectonic stresses are approximately equal ($\sigma_{11} \cong \sigma_{22}$) there is no preferred direction for the vertical fracture and a weakness in the rock close to the wellbore can determine the fracture orientation. Such a weakness may be in the form of a natural crack or an induced one (vertical notch). The orientation of fractures at the wellbore can be detected as described elsewhere in this report. If the fracture directions in a number of neighbor wells seem to be oriented at random, the horizontal state of stress is probably hydrostatic and by vertical notching fracture direction can actually be controlled.

LABORATORY EXPERIMENTAL PROGRAM

In an attempt to verify the relationships outlined in the theoretical section between the orientation and breakdown pressure of vertical fractures and the magnitude and direction of the horizontal principal tectonic stresses, a series of tests were run on simulated wellbores in laboratory samples.

Rectangular rock specimens (5.0 inches × 5.0 inches ×. 5.5 inches), with a vertical central hole (.30 inch in diameter), were loaded triaxically in a specially built steel frame. By use of four flat-jacks mounted between the sides of the sample and the internal walls of the frame, two unequal and independent horizontal compression loadings were applied. The vertical loading was transmitted, through a specially built upper platen by a hydraulic compression tester. The upper platen also provided the fracturing fluid channeling into the internal hole of the samples (Haimson, 1968). The unequal external triaxial loading on the sample closely simulated the most general state of tectonic stresses in the earth. In those tests where no horizontal loading was applied, cylindrical samples were used (usually 6.0 inches high, 3.5–5.0 inches in diameter).

The simulated wellbore in the sample was an open hole, 2.0 inches long, terminated by the rock itself at one end and by a hollow metal plug at the other. Through this hollow plug, pressurized fracturing fluid was forced into the open hole.

To run a test, the predetermined external triaxial loading was first applied and kept constant throughout the rest of the experiment. Then the fracturing oil was introduced into the internal hole, pressurizing it at a constant rate (usually 6–15 psi/sec.). The pressure versus time curve was recorded in an X-Y plotter. At some critical (breakdown) pressure (P_c), a sudden drop in pressure was observed, indicating fracture. The test was then stopped, the external loading removed and the sample observed, sectioned and photographed. The experimental data was recorded and checked against the theoretical predictions.

Different types of impermeable and permeable rock were tested. The natural rock was obtained from quarries throughout the country. The artificial rock was a mixture of water and gypsum cement (hydrostone), which when allowed to set formed a solid material of rock-like properties (Haimson, 1969).

The results of the laboratory tests can be summarized as follows:

1. All the hydraulic fractures obtained were tensile ruptures oriented either in the vertical or the horizontal plane, depending on the loading conditions.
2. In those cases where vertical fractures were obtained they were always perpendicular to the smaller horizontal compressive loading, notwithstanding the amount of oil penetration into the rock. Figure 2 shows a typical vertical fracture in impermeable Tennessee Marble. Figure 3 shows that the occurrence of a precrack in the impermeable charcoal granite sample did not interfere with the direction of the fracture normal to the smaller horizontal load. In permeable rock, like hydrostone and Berea Sandstone, shown in Figures 4, 5, fracturing fluid (hydraulic oil) leak-off into the sample did not affect the predicted direction of the fracture.
3. When the horizontal loading was hydrostatic, the direction of the vertical fracture was at

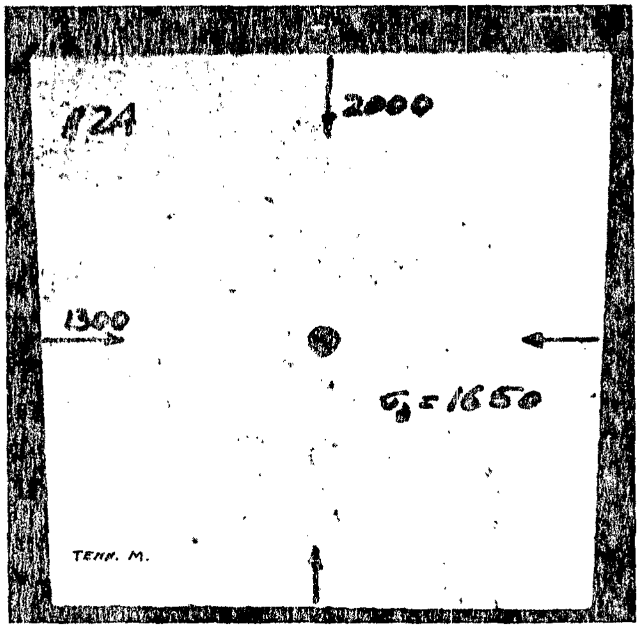

Figure 2. Vertical fracture in Tennessee Marble.

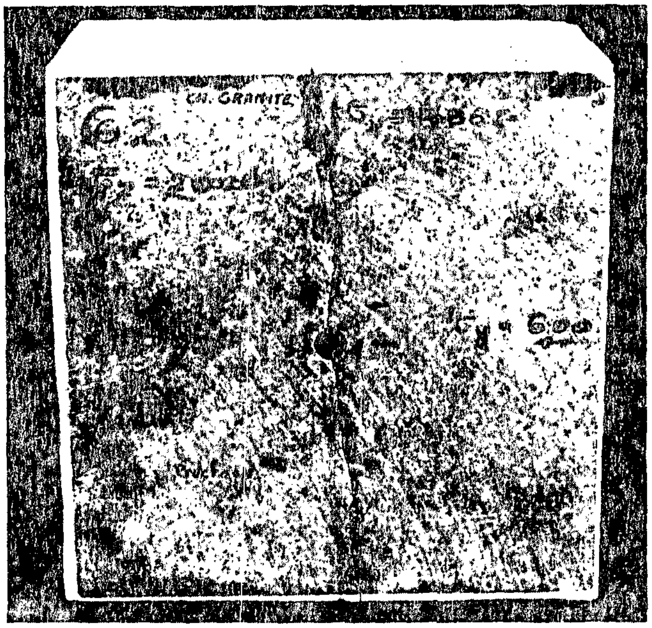

Figure 3. Vertical fracture in Charcoal Granite with precrack.

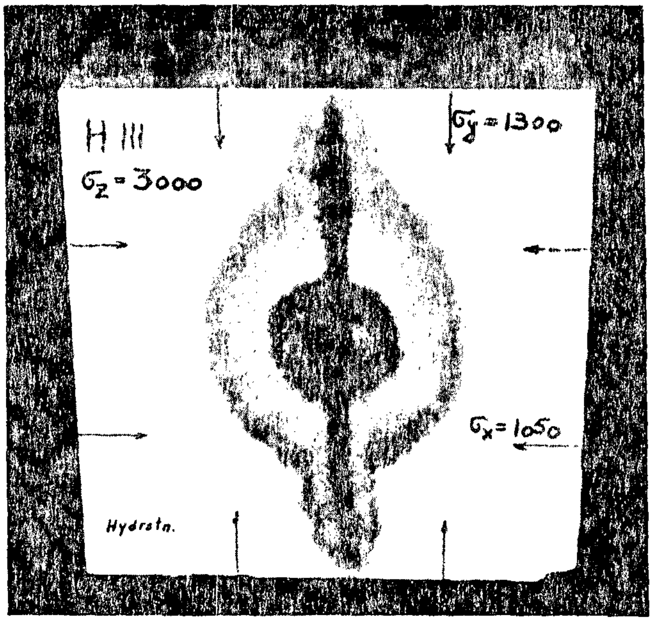

Figure 4. Vertical fracture in hydrostone, also showing the amount of fluid penetration.

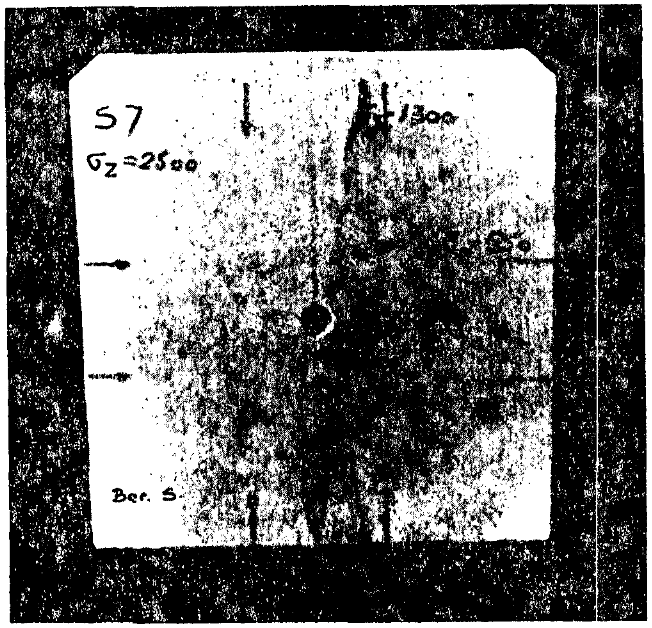

Figure 5. Vertical fracture in highly permeable Berea Sandstone.

random (Fig. 6) and sometimes more than two fractures were observed (Figs. 7 and 8). In a number of samples, vertical notches were induced in the simulated wellbores prior to the fracturing tests, by use of a hydraulic jetting technique. With no horizontal loading, the tips of these notches provided the weakest points around the hole and all fractures initiated there and extended in the general

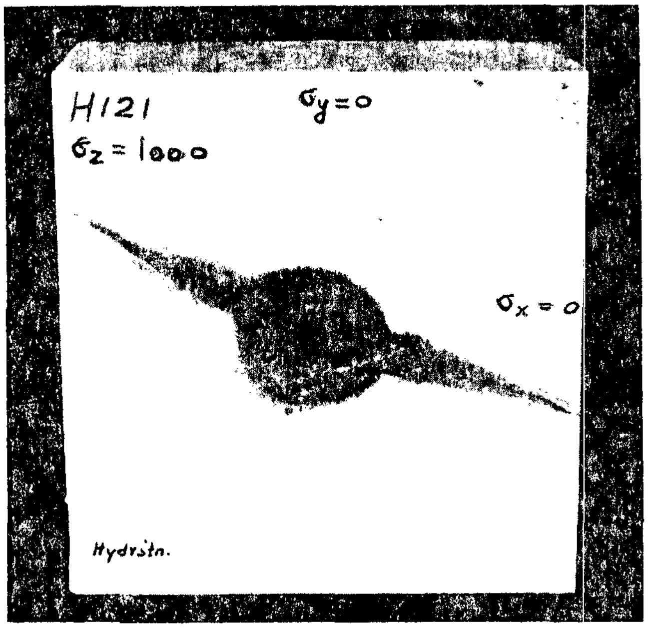

Figure 6. Vertical fracture at random in hydrostone under horizontal hydrostatic stress condition.

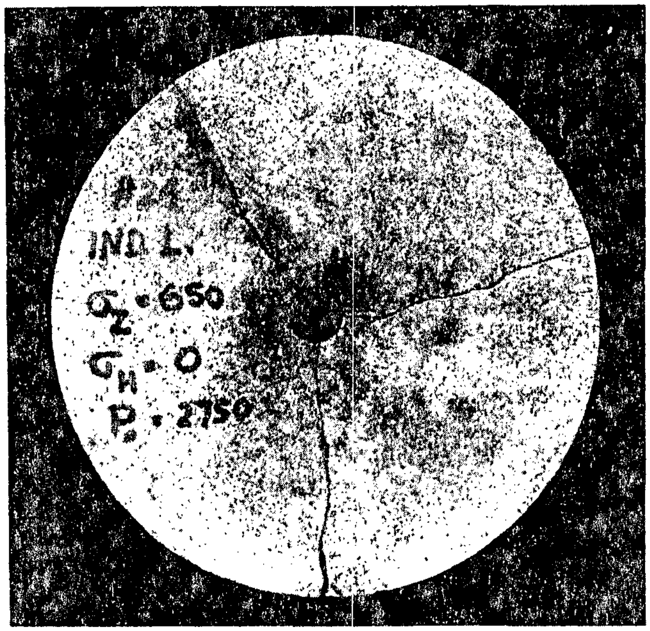

Figure 7. Three evenly distributed vertical fractures in Indiana Limestone under no horizontal loading.

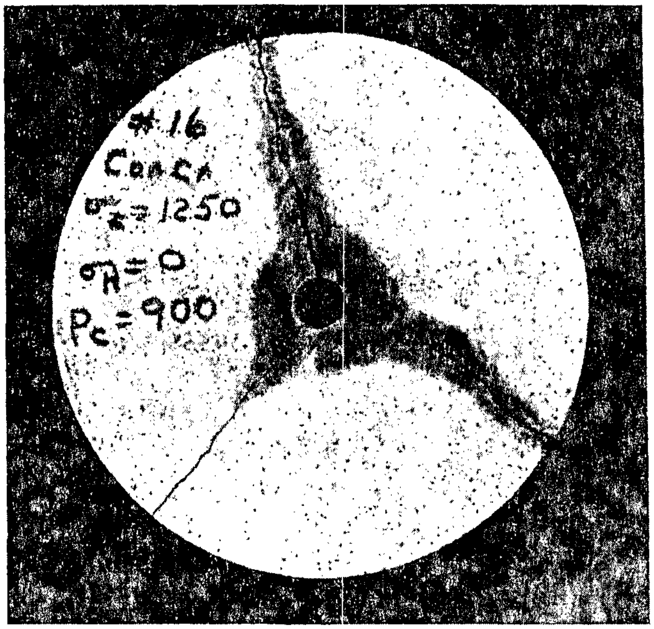

Figure 8. Three evenly distributed vertical fractures in Cordova Cream under no horizontal loading.

direction of the notch. Figures 9 and 10 show typical fractures in notched wellbores. The horizontally sectioned samples of Ohio Sandstone and Cordova Cream, respectively, exhibit vertical fractures that were affected by the presence of notches. The latter not only controlled the direction of induced fractures, but also lowered considerably the breakdown pressure. For example, in Ohio Sandstone the P_c decreased from 1800 psi to 1100 psi, and in Cordova Cream from 1050 psi to 400 psi.

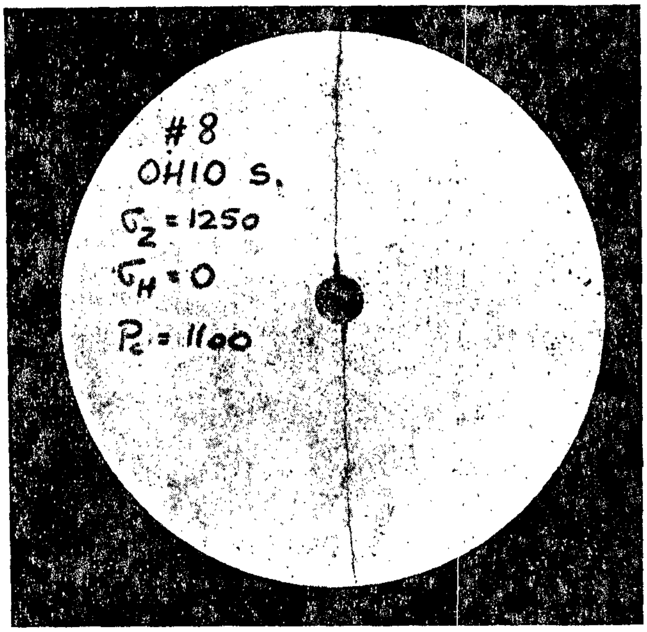

Figure 9. Hydraulic fracture in vertically pre-notched Ohio Sandstone.

Figure 10. Hydraulic fracture in vertically pre-notched Cordova Cream.

4. In unnotched samples, the pressure required to initiate vertical fractures was close to that predicted by equations (2). Figure 11 shows the relationship between the experimental points and the theoretical curve in the case of the impermeable Charcoal Granite. $\sigma_{\theta\theta}$ is given by $\sigma_{\theta\theta} = 3\sigma_{22} - \sigma_{11}$. Figure 12 shows the same relationship in the case of permeable hydrostone. The experimental points are not as close to the theoretical curve for P_c^p as the granite points are to P_c^i (Fig. 11), but it should be remembered that two more rock parameters are involved in the permeable case. Hence the predictions are not as accurate.

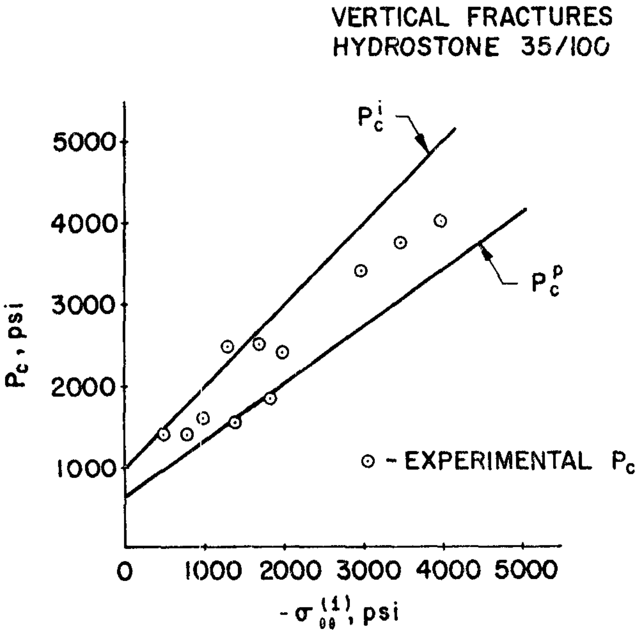

Figure 11. Relationship between theoretically predicted P_c^i and experimental values of breakdown pressure in impermeable Charcoal Granite.

5. In a number of tests, two vertical holes were drilled in 5.0 inch diameter cylindrical

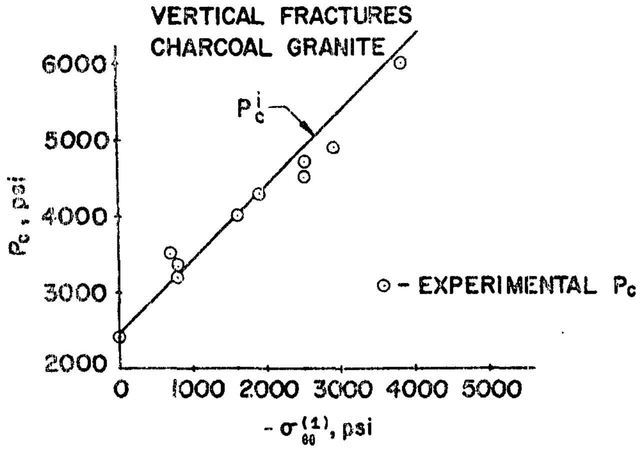

Figure 12. Relationship between theoretically predicted P_c^i and P_c^p and experimental values of breakdown pressure in hydrostone 35/100 (35 parts hydrostone to 100 parts water by weight).

samples, to simulate an injection-production set of wells. The distance between the holes was eight times the hole diameter. In these tests no horizontal loading was applied, and the average vertical load was 500 psi. The simultaneous pressurization of both holes resulted in a vertical fracture that emanated from one hole and did not necessarily extend in the direction of the other (Fig. 13). The separate pressurization of each hole yielded fractures that extended at random (Fig. 14). However when vertical notches were induced in the simulated wellbores, the chances of connecting the holes through fracturing were vastly increased. Figure 15 shows a horizontal section of an Indiana Limestone sample in which one of the holes had been vertically notched prior to its fracturing. The notch, as observed, had been directed towards the other well and its direction was followed by the fracture. When the other well was then pressurized, the resulting fracture easily linked to the former. Note the lower breakdown pressure required in the notched hole. Figure 16 depicts another method designed to eliminate guesswork from communicating. Here both wells had been vertically notched in mutually perpendicular planes. The hydraulic fractures joined at some short distance from the production well. This method of double-notching is especially recommended for the field where one cannot expect a hydraulic fracture to extend in a perfect straight line. With two

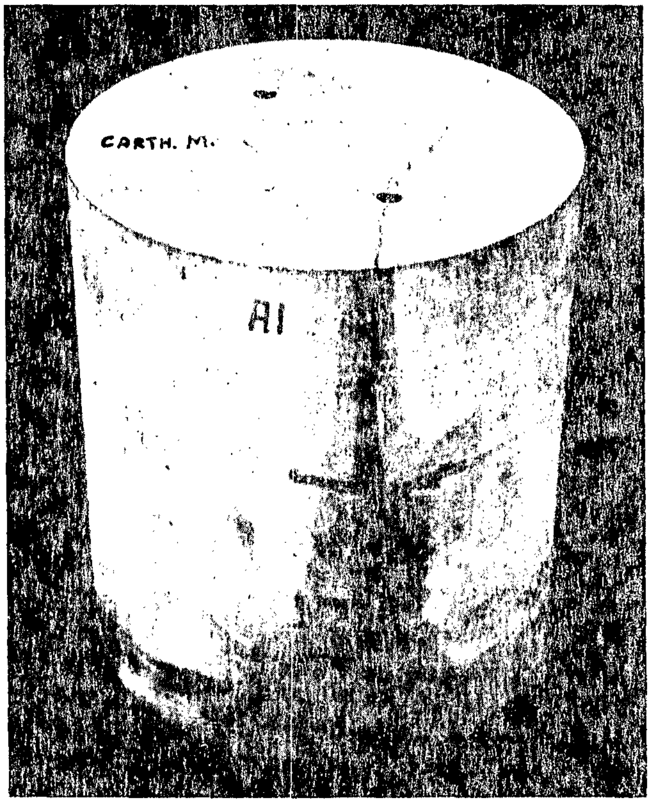

Figure 13. Vertical fracture in Carthage Marble caused by simultaneous pressurization of both wells.

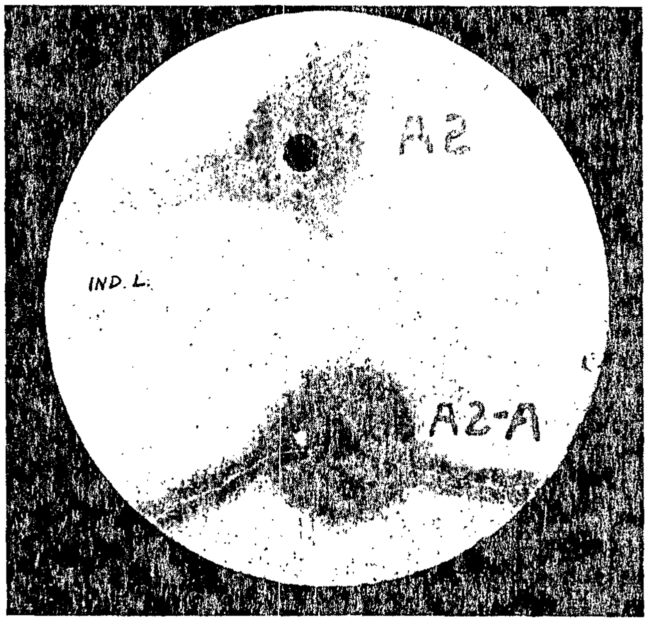

Figure 14. Vertical fractures in Indiana Limestone obtained by separate fracturing of both wells.

perpendicular fractures, they are always bound to meet at some distance from the target well.

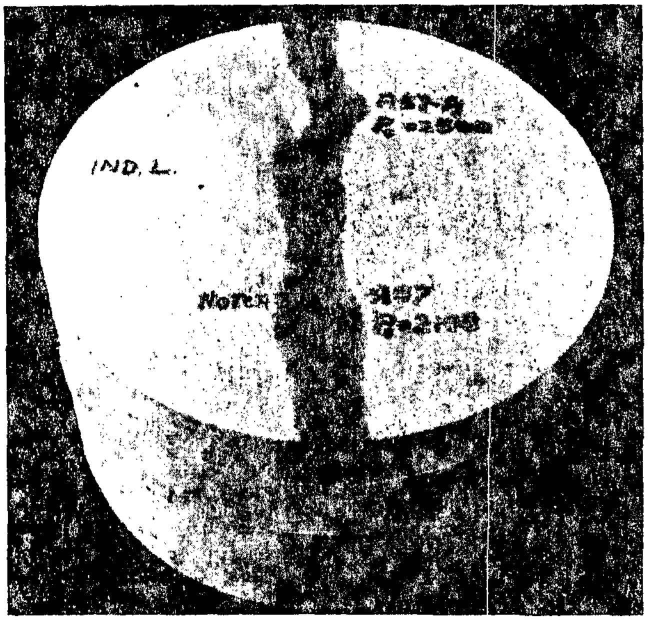

Figure 15. Vertical fractures in Indiana Limestone, obtained by separate fracturing of the wells, with one well being vertically prenotched in the direction of the other.

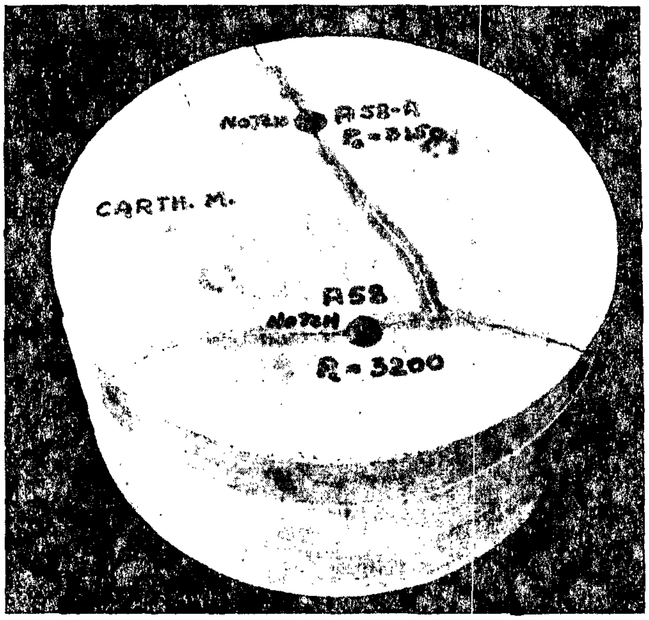

Figure 16. Vertical fractures in Carthage Marble where both wells were pre-notched in mutually perpendicular planes.

FIELD TESTS

One of the main obstacles to a better understanding of the hydraulic fracturing phenomenon is the great difficulties encountered in conducting scientific testing in the field. A fracturing job is conducted by remote control, from the surface, and there is no access to the pay formation for the purpose of verifying the direction and size of the fracture. Many researchers have suggested the use of different geological phenomenon as an indication of vertical fracture orientation. Occurrence of normal faults (Hubbert, 1957), regional dip in formations (Frazer, 1962), strike of surface joints (Overby, 1968) have all been theoretically correlated to orientation of vertical fractures. In areas where strong evidence of faulting exists or where a surface joint survey is done, the approximate direction of hydraulic fracturing can possibly be predicted. However, a proven testing tool for verifying fracture azimuth at the wellbore, notwithstanding the availability of geological data, is the oriented impression packer.

Such packers were used in the field tests described below. They consisted of a replaceable rubber sleeve, 10 or 20 feet long, mounted on an aluminum mandrel. The sleeve was made of cured reinforced rubber coated on the outside with a layer of uncured rubber. The lower portion of the mandrel contained a pressure relief valve and a landing seat for orientation of a compass running case. The packer was lowered on tubing into the well to the interval under investigation and then the rubber sleeve was hydraulically inflated. Perforations in the mandrel permitted an even distribution of pressure within the packer. The packer was inflated until full contact with the wellbore wall was achieved. The pressure in the packer was maintained for about one hour at a maximum of 300 psi above the reservoir pressure. This allowed the uncured rubber of the sleeve to expand and conform to the wellbore wall, while a magnetic compass was used to determine the orientation of the tool. The compass was lowered into the well after the packer was inflated and fixed in its landing seat at the bottom of the mandrel. Multiple compass pictures were taken from a camera located in the running case, and where possible two separate compasses were used on each test. At the conclusion of the test the pressure relief valve was opened and the impression packer removed from the well. From the location of the machined groove on the compass landing seat and the photographs during the test, the magnetic north on the packer was established. Thus, the orientation of any fractures or other irregularities, recorded permanently on the impression packer, could be easily determined.

Studies using impression packers were conducted in New York, Ohio and Illinois. The purpose of these studies was to determine the type and orientation of hydraulically induced fractures in oil producing formations. The breakdown and instantaneous shut-in pressures were also recorded. The reservoir studied in New York was the Richburg Oil Sand in Alma Township, Allegany County. In Ohio, the study included the Clinton Sandstone in Falls Township, Hocking County, and in Illinois, a carbonate reservoir was investigated. Locations of the tested wells in two of the areas are shown in Figures 17 and 18.

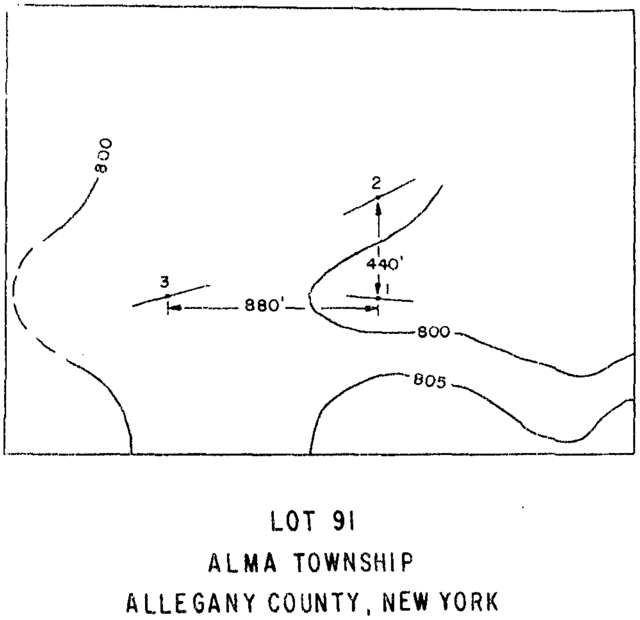

Figure 17. The distribution of the treated wells, and the direction of vertical fractures in the New York field.

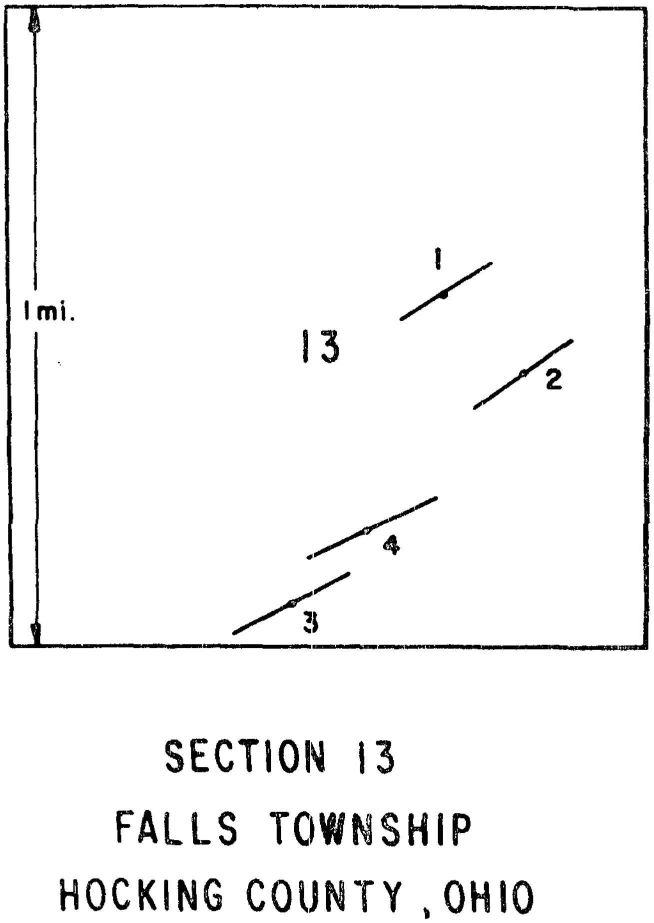

Figure 18. The distribution of the treated wells, and the direction of vertical fractures in the Ohio field.

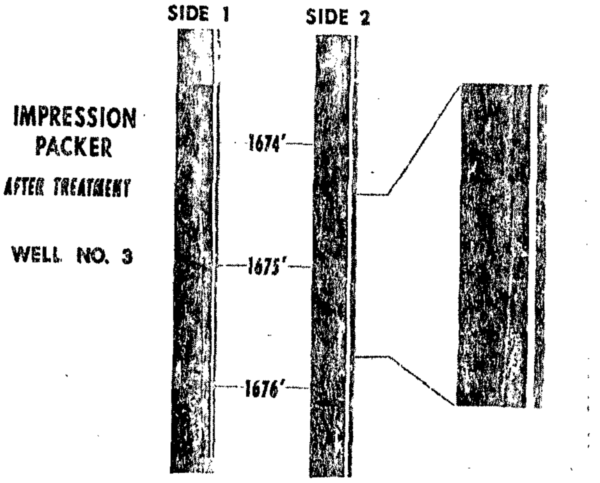

Figure 19. Packer with typical vertical fracture impression from well No. 3 in New York.

The impression packer results show that fractures created in each of the wells were vertical over the major portion of the treatment interval (Fig. 19). The average azimuth of these fractures in each well is given in Table 1 and shown diagrammatically (except for Illinois) in Figures 17 and 18. Table 2 enumerates some of the physical properties of the formations. It can be easily verified that in each of the three fields the induced fractures were

TABLE 1. Hydraulic Fracturing Results in Three Field Tests

Location	Well No.	Depth Feet	Critical Breakdown Pressure P_c, psi	Instantaneous Shut-in Pressure P_s, psi	Fracture Azimuth East of True North
New York	1	1607-16	5264*	1864	93°
	2	1677-82	5848*	2013	65°
	3	1671-79	3256	2161	74°
Ohio	1	2622-32	2938	2238	62°
	2	2634-52	-	-	59°
	3	2671-81	2934	2259	67°
	4	2662-71	3054	2154	68°
Illinois	1	314-332	539	-	49°
	2	321-338	643	393	67°
	3	314-323	588	338	72°
	4	310-327	738	338	58°
	5	298-318	733	333	66°

* Recently completed cable tool hole. The mud, still lining the hole, accounts for the unusually high values of breakdown pressure.

TABLE 2. Physical Properties of Three Formations Tested

Location	Tensile Strength psi	Porosity %	Permeability md.	Poisson's Ratio	Reservoir Pressure psi
New York	575	13.5	0.5	0.1	530
Ohio	1000	15.0	33.0	0.2	600
Illinois	725	22.0	8.0	0.2	0

nearly parallel to each other. Table 1 also gives the breakdown (critical) pressures and the instantaneous shut-in pressures in the fractured wells. Again, a striking closeness between the values of the fracturing pressures in each of the fields can be observed. Based on our hypothesis relating in situ stresses to hydraulic fracturing pressures and directions, it appears that in each of the studied formations there was one constant tectonic stress field. By hydraulically fracturing a sample of wells like any of the three samples mentioned in this paper, one could get enough information to help design more scientifically the layout of a newly prospected field, or determine whether hydraulic fracturing may be feasible in an established producing field.

CONCLUSIONS

The present report is merely an attempt to improve the existing knowledge of vertical hydraulic fractures. Theoretically it is shown that the breakdown and shut-in pressures, usually recorded during a fracturing job, as well as the direction of fracture, are directly related to the principal tectonic stresses that exist in the formation. Indeed, laboratory tests on simulated wellbores indicate that the theoretically predicted breakdown pressures, in both porous and non-porous rock, were close to the experimental results. Moreover, as theoretically expected, vertical fractures were always tensile ruptures that initiated and extended in a plane perpendicular to the direction of the smaller simulated horizontal compressive principal tectonic stress. In samples where the simulated horizontal in situ stress condition was hydrostatic vertical fractures extended at random and sometimes three rather than two ruptures were obtained. Notching appeared to be a helpful tool in controlling direction of fractures in such hydrostatic cases and was instrumental in achieving communication between two wells. The three field tests reported here merely recorded the breakdown and shut-in pressures during hydraulic fracturing operations, and the azimuth at the wellbores of resulting vertical fractures from impression packer readings. The closeness between the pressures and directions in each of the fields leaves little doubt as to the relationship between fracturing and tectonic stresses. Each of the three groups of wells belong to the same production field in a rather uniform geological system. Hence there is no reason to expect that tectonic stresses would vary considerably from one well to another. The field results verify this assumption. It seems that a sample of wells, intelligently picked and hydraulically ruptured, could provide with the necessary information about direction of fractures, breakdown pressures, and communication possibilities in an entire field. If results in the sample are hardly uniform as far as fracture direction, it is probably because of the tectonic stresses in the horizontal plane being hydrostatic. In such a case, vertical notching of wells may prove very beneficial.

NOMENCLATURE

P = fluid pressure

P_o = reservoir pore fluid pressure

P_c = breakdown (critical) pressure

P_c^i = breakdown pressure in impermeable rock

P_c^p = breakdown pressure in permeable rock

P_s = wellbore instantaneous shut-in pressure

P_w = wellbore pressure prior to fracturing

S_{ij} = stress tensor

S_{11} = smaller horizontal principal tectonic stress (tension taken as positive)

S_{22} = larger horizontal principal tectonic stress

S_{33} = vertical principal tectonic stress

α = parameter of a porous material

ν = Poisson's ratio

σ_{ij} = effective stress tensor

σ_{ij} = effective stress tensor around the wellbore due to tectonic stresses

$\sigma_x, \sigma_y, \sigma_z$ = compressive loads applied to specimens

σ_t = tensile strength in the horizontal plane as applied to hydraulic fracturing.

ACKNOWLEDGEMENTS

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Solution Mining Operations in the Presence of Vertical Fracture Systems

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ABSTRACT

Data is presented on experimental models involving the use of both vertical and horizontal fractures in two-well systems in which the fractures may exist initially adjacent to an insoluble or inert bed or located with massive salt above the fracture. Results of mathematical simulation and experimental model data are presented. Different solution patterns are developed depending on the mode of fracture system. Shape of cavities formed in massive salt sections are affected more by solution at the roof surface while cavities formed in which insoluble beds appear as roof members take on the appearance which is expected from vertical surface exposure.

Introduction and purpose.

Though fracturing operations are frequently carried out in making .connections between wells which are to be used in developing brine production, rather limited information is available on the effect of orientation of the fracture plane. Numerous authors (Bays, Peters and Pullen, 1960; Shock, 1965; Shock and Davis, 1969) have presented data on fracturing techniques for use in salt solution mining operations, and recently Davis and Shock (1969) reported results of mining thin bedded potash salt beds exposed by horizontal fracture planes. With the advent of deeper and deeper exploration for minerals which may be recovered through solution mining, the probability of utilizing induced fractures becomes greater. This study was undertaken because formation of vertical fractures occurs at greater frequency with depth, and because no direct experimental evidence is available regarding the solution of salt in such fractures.

Experimental work.

The experimental work involved use of solid salt blocks obtained from the Grand Saline, Texas, mine of Morton Salt Company and from the United Salt mine at Hockley, Texas. In the case of the test in which an insoluble bed above the fracture was simulated, a cut approximately 1-2 mm in thickness was made with a saw into a previously smoothed face. Depth of the simulated fracture was 2 1/2 inches, and its length was 14 1/2 inches. After sealing a 1/4-inch Lucite sheet to the salt surface with Hysol, the whole block was sealed, with the same material, in a wooden frame so as to assure no leakage during the test period. Inlet and outlet wells were drilled through the Hysol seal and Lucite plate. All cuttings, including a small amount of salt, were removed by jetting with high pressure air.

The washing system was comprised of two needle valves and a pressure regulator to control the rate of flow of water, a calibrated rotameter to measure the volume of inlet water, and several large cylinders to measure the volume of effluent. Specific gravity of the brine was determined with hydrometers.

In order to eliminate air from the system an inverted Tee was placed in the feed water line at the highest elevation. Thus, any air which might be trapped in the salt cavity being formed during washing could be removed by turning the whole salt block over and allowing air to rise through the flexible nylon wash tubing and be expelled.

The washing procedure was started by filling the fracture with water while the salt block was oriented in an upright position. The air present was removed. Next, the block was placed in a flat position with the inlet and outlet tubes at the top. Then, if no air bubbles could be seen in the flow stream, the block was inverted. Water now entered the bottom of the fracture and was produced from the bottom. Washing was continued in this manner, and readings were made every 15 minutes of the volume, rate, specific gravity of effluent, and amount of solids. The solids, consisting of fine anhydrite crystals, were removed when it appeared flow was impeded. This occurred only once with this particular salt block which contained only 1-2 percent insoluble material. Some small amounts of water from the cavity were lost during such an operation, but since these volumes were small in comparison with the total volume of water measured or salt removed was introduced.

Data for this test are shown in Table 1. A cavity with a total volume of 3835 cc was formed. Time of washing was 717 minutes (approximately 12 hours). The rate of flow was decreased from an initial value of 200 cc per minute to an average of 45-50 cc per minute after the first 45 minutes of circulation. The specific gravity of the effluent increased from 1.082 to 1.164 after about 1 hour and 15 minutes and remained at near this saturation for the next 5 hours and 45 minutes. The saturation of the effluent then decreased and the specific gravity remaining fairly constant at 1.115 during the last 4 hours and 45 minutes. The average flow rate during this time was 50 cc per minute whereas that during the previous 5 hour 45 minutes leaching was 44 cc per minute. There appears to be a direct relationship between the circulation rate and the saturation of effluent, indicating control of the development of the cavity was related to the rate of flow, since at no time was the effluent brine saturated. In other words, though there was an ever-increasing surface exposed to attack, which should have provided greater solution of salt based on previous studies of solution rates in single well systems, (Durie and Jessen, 1964) the flow mechanism was such that a lesser efficiency of salt removal resulted. Thus a maximum width to depth (or heigth of fracture) ratio probably exists for commercial utilization in mining rather thin beds by solution techniques.

The final cavity shape is shown in Figure 1 whereas the progression with time is indicated in Figure 2. From a consideration of Figure 1 the volume may be expressed as

$$V = 2/3\ y\ a\ h - 2/3\ a\ x\ (h - b)$$

or

$$V = 2/3\ a\ b\ (x + y) \qquad (1)$$

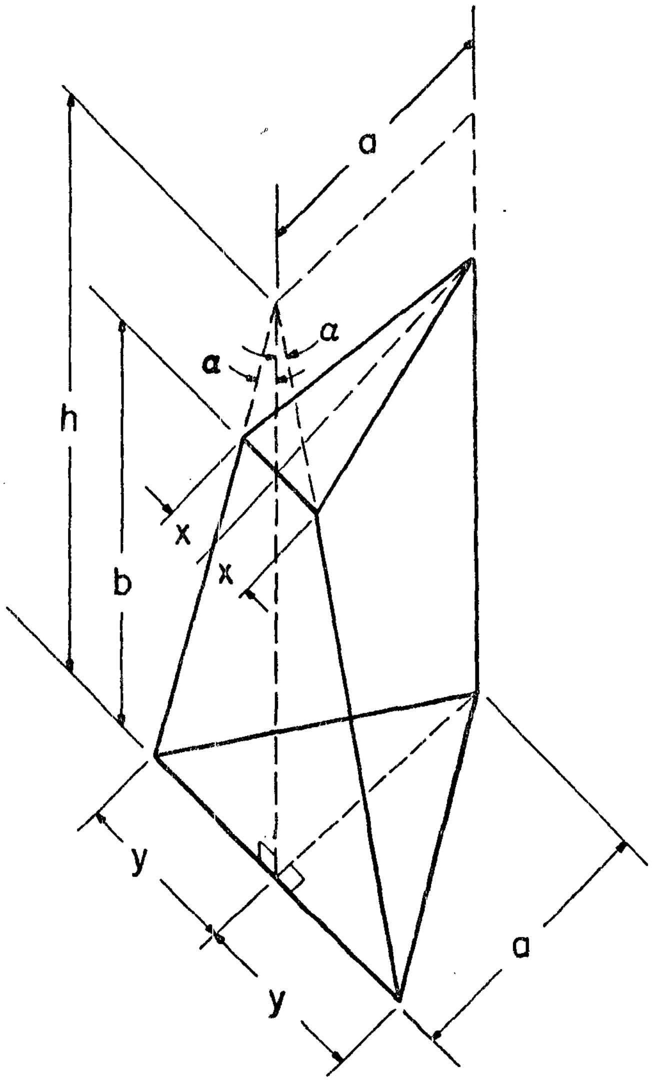

Figure 1. Insoluble bed above the fracture.

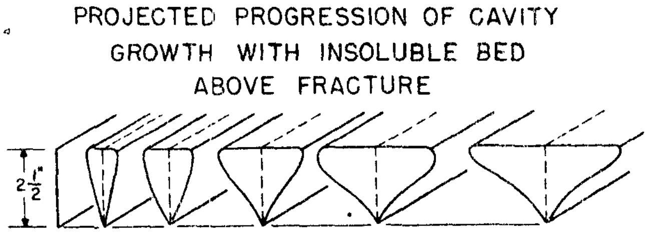

Figure 2.

Substituting the corresponding values of a, b, x, and y at the end of the test into Equation 1 results in a value of

V = 2/3 × 2 1/2 × 16 (5-3/8 + 4 1/8)
V = 261.25 cubic inches, or
V = 4281 cubic centimeters.

Table 1. Washing Data For Vertical Fracture Impermeable Bed Above Fracture

Source of Salt: Grand Saline Mine
Morton Salt, Co., Grand Saline, Texas

Initial Fracture Length = 13 inches
Initial Fracture Width = 3 mm
Initial Fracture Depth = 2 1/2 inches

Time Interval Minutes	Volume of Water cc		Flow Rate cc/Minute	Specific Gravity Effluent	Salt Removed cc/Stage	Cumulative Volume of Cavity cc
	Per Time Interval	Cumulative				
8.5	1,700	1,700	200.	1.082	91.4	91.4
4.0	800	2,500	200	1.1	57.6	149.0
5.0	640	3,140	128	1.107	30.2	179.2
5.0	640	3,780	128	1.121	32.5	211.7
5.0	640	4,420	128	1.128	32.4	244.1
5.0	670	5,090	134	1.128	34.9	279.0
5.0	640	6,730	128	1.126	34.8	313.8
13.0	1,750	8,480	134	1.122	138.0	451.8
7.8	390	8,870	50	1.121	30.2	482.0
8.0	400	9,200	50	1.130	32.1	514.1
8.0	345	9,545	43	1.144	31.7	545.8
12.0	490	10,035	40	1.160	48.1	594.9
5.0	180	10,285	36	1.170	19.35	604.3
10.0	445	10,730	44.5	1.173	47.5	651.8
10.0	390	11,120	39.0	1.172	42.2	694.0
13.0	425	11,545	32.3	1.176	46.7	740.7
10.0	490	12,035	49.0	1.175	53.7	794.4
10.0	420	12,455	42.0	1.170	44.99	839.3
10.0	465	12,920	46.5	1.165	47.7	887.0
10.0	360	13,280	36.0	1.170	38.5	925.5
12.0	360	.3,640	30.0	1.176	35.3	960.8
15.0	650	14,290	43.0	1.172	69.2	1,030.0
15.0	600	14,890	40	1.170	64.0	1,094.0
15.0	780	15,670	54	1.162	83.0	1,177.0
15.0	780	16,450	54	1.156	76.8	1,253.8
15.0	700	17,100	48	1.158	70.0	1,323.8
15.0	780	17,880	52	1.155	76.5	1,400.3
15.0	730	18,610	48.5	1.154	71.0	1,471.3
15.0	685	19,295	45.7	1.154	66.8	1,538.1
15.0	650	19,945	43.3	1.156	64.0	1,602.1
15.0	600	20,545	40.0	1.158	59.75	1,661.85
15.0	700	21,245	46.7	1.158	68.2	1,730.0
15.0	650	21,895	43.3	1.148	64.0	1,794.0
5.0	200	22,095	40.0	1.188	23.7	1,817.7
32	1,640.0	23,735	51.0	1.170	174.5	1,992.2
13.0	640.0	24,375	50.0	1.144	58.35	2,050.5
15.0	570.0	24,945	38.0	1.14	51.5	2,102.0
7.0	760.0	25,705	110.0	1.119	58.5	2,160.5

Time Interval Minutes	Volume of Water cc		Flow Rate cc/Minute	Specific Gravity Effluent	Salt Removed cc/Stage	Cumulative Volume of Cavity cc
	Per Time Interval	Cumulative				
8.0	560.0	26,265	70.0	1.125	45.2	2,205.7
15.0	650.0	26,915	43.0	1.138	57.5	2,263.2
15.0	770	27,685	51.0	1.142	70.0	2,333.2
15.0	640	28,325	42.0	1.144	58.5	2,391.7
15.0	855	29,180	57.0	1.136	75.3	2,467.0
15.0	1,420	30,600	94.	1.12	110.5	2,677.5
15.0	985	31,585	65.6	1.107	68.5	2,746.0
15.0	870	32,455	58.0	1.110	61.5	2,807.5
15.0	835	33,290	55.6	1.113	60.7	2,868.2
15.0	790	34,080	52.6	1.115	58.7	2,926.9
15.0	770	34,850	51.3	1.114	57.0	2,983.9
15.0	785	35,635	52.2	1.113	57.5	3,041.4
15.0	660	36,295	44.0	1.115	49.0	3,090.4
15.0	640	36,935	42.6	1.114	47.4	3,137.8
15.0	605	37,540	40.3	1.122	47.7	3,185.5
15.0	620	38,160	41.3	1.123	48.5	3,234.0
15.0	685	38,845	45.6	1.123	54.2	3,290.2
15.0	635	39,480	42.3	1.123	50.5	3,340.7
15.0	645	40,125	43.0	1.123	55.0	3,395.7
	Removed 4050 cc of saturated brine; specific gravity =			1.198	442.0	
					Total	3,837.7

The total volume recovered through washing was 4050 cc, representing a difference of 231 cc, or an error of 5 percent in calculated and observed volumes. The fact that the model assumes solution to take place on the slanting side to the very bottom of the fracture depth should result in a somewhat higher volume. As may be seen from Figure 3, final shape of the washed cavity reveals the lower portion of the initial vertical fracture still in existence. In view of this, agreement of the calculated and observed volumes is excellent.

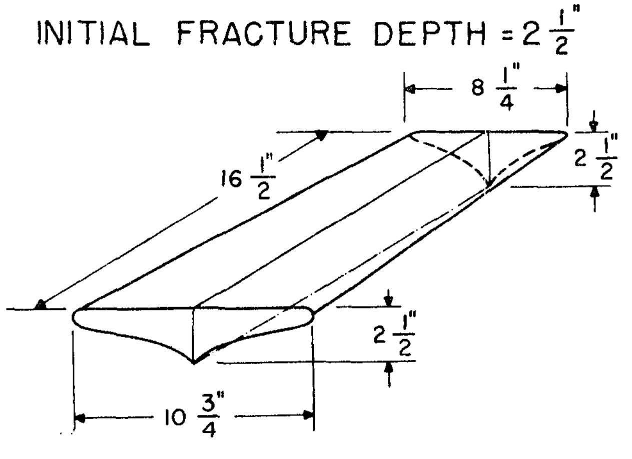

Figure 3. Final cavity shape.

For the case in which a vertical fracture is formed in massive salt, resulting in a system wherein soluble material exists above the top of the fracture plane, the salt block was sawed, a Lucite 1/4" thick plate sealed to the cut surface, and again the entire block sealed into a wooden box with Hysol. The particular salt specimen was 12 inches wide, 24 inches long by 10 inches high. The cut was made 3 inches deep and the well spacing was 18 1/2 inches. Preparation for leaching operations was identical with that previously described except that provision was made to remove accumulated solid material by installing a glass Tee section just below the entrance of the water to the injection well. By inverting the entire block, fluid entry and production were at the bottom of the fracture.

The washing of this salt fracture system was continued for 18 1/2 hours during which a total of 75,582 cc of water was circulated and a cavity having a total volume of 9160 cc was formed. Solids (anhydrite) withdrawn during the experiment and at the end of the run amounted to 812 cc.

This volume is included in the total cavity volume. Rate of flow was adjusted so that only partially saturated brine was produced. The specific gravity of the effluent during the first 6 hours and 40 minutes averaged 1.125 (67-70 percent saturation) while during the remainder of the test the corresponding values averaged 1.165, i.e., 87 percent saturation. Nearly saturated brine was produced at the end of the run. The data are tabulated in Table 2.

Projected progression of the cavity shape is shown in Figure 4 while the final configuration obtained is represented in Figure 5. It is immediately apparent that the two shapes developed, Figure 1 and Figure 5, are similar only to the degree that both have a triangular section. Figure 5 shows the growth of the cavity also in the exposed "roof" area while this growth is denied the cavity wherein an impermeable layer overlies the vertical fracture, i.e., where the fracture terminates in an insoluble bed.

PROJECTED PROGRESSION OF CAVITY
GROWTH - NO INSOLUBLE BED
ABOVE FRACTURE

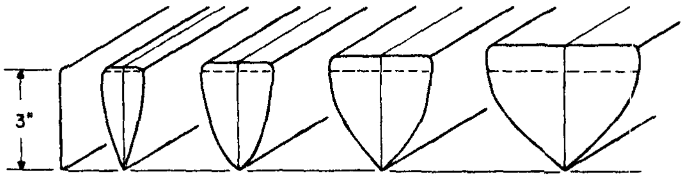

Figure 4.

Using the same analytical approach to calculate the volume of cavity formed, the simplifying assumption is made that the progression is defined by two sections, the upper one that of a rectangle, the lower part that of a triangle. This leads to the geometric representation of Figure 6. In this case, the volume may be expressed as,

$$V = \frac{2}{3} ab(x + y) + \frac{2}{3} [\frac{1}{2} \sqrt{1_1^2 + 4 y^2}\, h_1 (\frac{21_1 \; y}{\sqrt{1_1^2 + 4 y^2}})]$$

$$-\frac{2}{3} [\frac{i}{2} \sqrt{1_2^2 + 4 y^2}\, (h_1 - b) (\frac{21_2 \; x}{\sqrt{1_2^2 + 4 x^2}})]$$

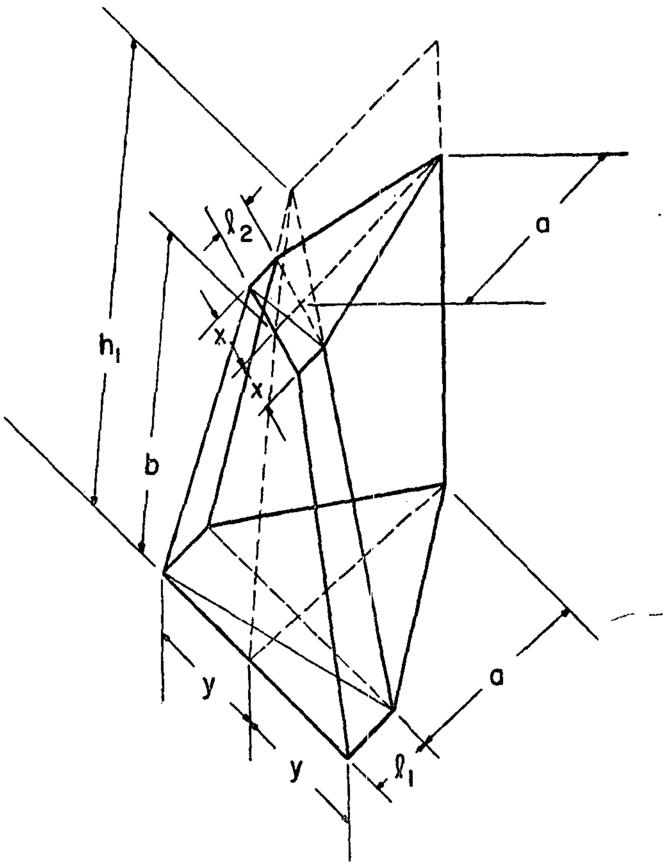

Figure 5. With soluble bed above the fracture.

$$V = \frac{2}{3} ab\,(x + y) + \frac{2}{3} [1_1 \; y\, h_1 - (h - b)\, 1_2 \; x]$$

h_1 can be derived, since

$$\frac{\sqrt{1_2^2 + 4 x^2}}{\sqrt{1_1^2 + 4 y^2}} = \frac{(h_1 - b)}{h_1}$$

or

$$h_1 = \frac{\sqrt{1_1^2 + 4 y^2}}{\sqrt{1_1^2 + 4 y^2} - \sqrt{1_2^2 + 4 x^2}} \cdot b$$

Table 2. Washing Data For Vertical Fracture Ending In Massive Salt

Source of Salt: United Salt Company Mine
Hockley, Texas

Initial Fracture Length = 18 1/2 inches
Initial Fracture Width = 3 mm
Initial Fracture Depth = 3 inches

Time Interval Minutes	Volume of Water cc		Flow Rate cc/Minute	Specific Gravity Effluent	Salt Removed cc/Stage	Cumulative Volume of Cavity cc
	Per Time Interval	Cumulative				
15.0	1,400	1,400	93.33	1.10	91.5	91.5
15.0	1,315	2,715	87.66	1.105	91.4	182.9
15.0	1,120	3,835	76.66	1.166	84.5	267.4
15.0	975	4,810	65.0	1.126	79.1	346.5
15.0	1,020	5,830	68.0	1.126	83.1	429.5
15.0	1,015	6,845	67.7	1.125	82.0	511.5
15.0	1,010	7,855	67.3	1.125	82.0	593.5
15.0	1,000	8,853	66.7	1.126	81.5	675.0
15.0	977	9,832	65.1	1.127	79.7	754.7
15.0	940	10,772	62.60	1.170	100.6	855.3
15.0	1,015	11,787	67.66	1.133	86.4	941.3
15.0	1,090	12,877	72.66	1.126	88.5	1,030.8
30.0	1,920	14,799	64.0	1.126	156.0	1,186.2
15.0	1,050	15,847	70.0	1.125	84.9	1,271.0
15.0	1,050	16,897	70.0	1.125	84.9	1,356.0
15.0	955	17,852	63.66	1.125	76.5	1,432.5
15.0	880	18,732	58.66	1.100	57.7	1,490.2
15.0	880	19,612	58.66	1.060	35.45	1,525.6
15.0	1,020	20,632	68.0	1.125	82.3	1,607.9
15.0	980	21,612	65.3	1.127	81.0	1,688.9
30.0	2,270	23,880	75.6	1.134	195.2	1,884.1
15.0	1,030	24,912	68.33	1.137	90.6	1,974.7
15.0	930	25,842	62.0	1.137	82.0	2,056.7
15.0	1,030	26,872	69.5	1.137	97.0	2,153.7
10.0	720	27,592	72.0	1.260	86.8	2,240.5
15.0	1,420	29,012	94.66	1.156	140.0	2,380.5
15.0	1,460	30,462	97.30	1.173	154.0	2,534.5
15.0	1,200	31,662	80.0	1.154	123.0	2,658.3
15.0	830.0	32,492	55.3	1.144	76.2	2,734.5
15.0	1,180	33,672	78.6	1.139	106.0	2,840.5
15.0	1,000	34,672	66.6	1.134	86.5	2,927.0
15.0	1,200	35,872	80.0	1.154	116.5	3,043.5
15.0	1,440	37,312	96.0	1.152	138.5	3,182.0
15.0	1,360	38,672	90.6	1.144	121.5	3,303.5
15.0	1,175	39,847	78.3	1.142	106.2	3,409.7
15.0	1,350	41,197	90.0	1.188	153.3	3,569.0
15.0	1,440	42,637	96.0	1.172	135.3	3,704.3
15.0	1,230	43,862	82.0	1.153	114.8	3,819.1
15.0	1,180	45,047	78.6	1.154	109.3	3,928.4
15.0	1,030	46,077	68.6	1.146	97.0	4,085.4

Time Interval Minutes	Volume of Water cc Per Time Interval	Volume of Water cc Cumulative	Flow Rate cc/Minute	Specific Gravity Effluent	Salt Removed cc/Stage	Cumulative Volume of Cavity cc
15.0	920	46,997	61.3	1.147	85.8	4,110.2
15.0	940	48,037	62.6	1.147	87.5	4,197.7
15.0	935	49,072	62.3	1.147	87.0	4,284.7
15.0	895	49,967	59.6	1.150	85.3	4,370.0
15.0	1,280	51,247	85.3	1.184	146.3	4,516.3
15.0	1,360	52,607	90.6	1.164	140.5	4,656.8
15.0	1,025	53,432	68.3	1.150	97.5	4,754.3
15.0	1,050	54,482	70.0	1.150	100.5	4,854.8
15.0	1,055	55,537	70.3	1.146	98.5	4,953.3
15.0	1,005	56,542	67.0	1.146	93.2	5,046.5
15.0	1,010	57,582	67.3	1.145	93.5	5,140.0
15.0	980	57,432	65.3	1.145	91.0	5,231.0
15.0	1,035	58,467	69.0	1.144	93.0	5,324.0
15.0	960	59,427	64.0	1.144	88.1	5,412.1
15.0	970	60,397	64.6	1.144	89.0	5,501.1
15.0	1,000	61,397	66.6	1.144	91.6	5,592.7
15.0	1,005	62,402	67.0	1.144	92.2	5,684.9
15.0	1,300	63,702	86.6	1.152	117.5	5,702.4
15.0	780	64,482	52.0	1.184	88.5	5,790.9
15.0	850	65,332	56.6	1.184	94.5	5,885.4
15.0	860	66,192	57.3	1.18	96.7	5,982.1
15.0	820	67,012	54.6	1.177	86.2	6,068.3
15.0	805	67,817	53.6	1.176	88.7	6,157.0
15.0	810	68,627	54.0	1.176	89.5	6,246.5
15.0	820	69,447	54.66	1.174	89.2	6,335.7
15.0	830	70,277	55.33	1.173	90.0	6,425.7
15.0	820	71,097	54.66	1.170	87.5	6,513.2
15.0	810	71,907	54.00	1.170	86.5	6,599.7
15.0	1,890	73,797	126.	1.132	145.5	6,745.2
15.0	615	74,412	41.0	1.192	72.7	6,817.9
15.0	560	74,972	34.3	1.190	63.5	6,881.4
15.0	610	75,582	40.66	1.187	71.0	6,952.4

Removed 9160 cc of saturated brine; Specific gravity = 1.2

Solids obtained during washing and at time of final evacuation of cavity = 812 cc

Total 8,929.4

Then, substituting values for the conditions at the end of the test,

h_1 = 51.765 inches 1_1 = 3.0 inches a = 1.4375 inches
y = 4.875 inches 1_2 = 2.5 inches
b = 21.0 inches x = 2.8125 inches

$$V = \frac{2}{3} [\, 3 \times 4.875 \times 51.765 - 30.765 \times 2.5 \times 2.8125 + 1.4375 \times 21 \times 7.6875]$$

$$V = \frac{2}{3} \times 773.4155$$

$$V = 515.61 \text{ cubic inches,}$$

or

$$V = 8449.3 \text{ cc.}$$

The measured volume of the cavity, including the insoluble anhydrite was 9160 cc. The difference in volume, readily seen to occur because of the simplifying assumption of straight slant sides, is 711

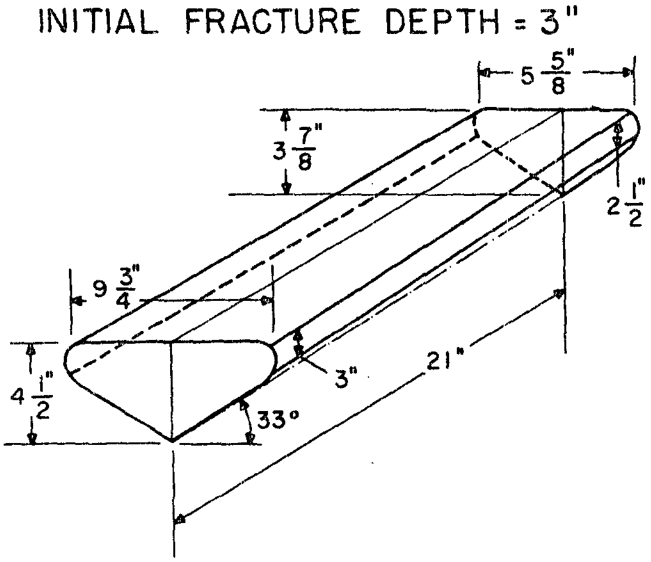

Figure 6. Final cavity shape.

cc, or 717 percent. A somewhat more rounded side results when no insoluble material is present in a salt. The photographs showing the end views of the model illustrate this point remarkably well.

To relate the change in volume with time, the data were analyzed and a curve-fit computer program, by L.N. Johnson (1969) available from the Computation Center of The University of Texas at Austin, was utilized. The general form of the equation for the volume V, as a function of time is

$$V = \frac{C_{10}}{T} + C_1 + C_2T + C_3T^2 + C_4T^3 + C_5T^4 .$$

For the case in which an impermeable bed exists immediately above the vertical fracture, the constants yield the following equation:

$$V_{(t)} = \frac{-5.48}{T} + 48.75 + 133.4T - 15.97T^2 + 2.42T^3 - 0.11T^4.$$

Similarly, for the case where the fracture ends in massive salt,

$$V_{(t)} = \frac{-33}{T+} 133.4 + 23.8T + 17.67T^2 - 0.96T^3 + .016^4$$

where $V_{(t)}$ is the volume in $ft^3 \times 10^{-4}$

T is time in hours.

The increase in volume with time of cavities of the types formed in these experiments is shown in Figure 7. A first approximation, using only the first order term of time (T) gives a linear relationship in both instances.

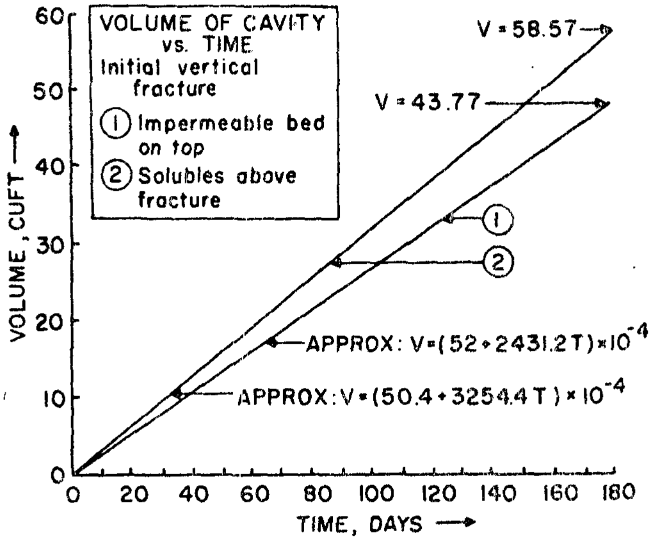

Figure 7.

Summary.

Laboratory model studies of progression of cavities in salt formed by solution in vertical fracture, between two wells are reported. A triangular shaped cavity results when the solution takes place in a fracture bounded by an impermeable bed on top. There appears to be a limiting width to depth of salt bed even when little insoluble material is present. Action forms a cavity with expanding roof area and solution on the sides as solution progresses in a vertical fracture ending in massive salt. A definite limiting slope of 34 degrees of the sides results when as much as 10 percent anhydrite is present as insoluble material. Prediction of the volume of cavity formed is possible through the use of equations developed which describe the volume changes as a function of time. Proper scaling should permit utilization for developing field cavities.

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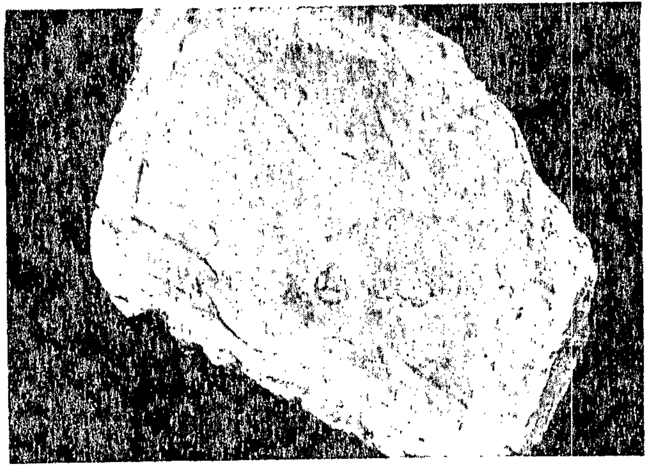
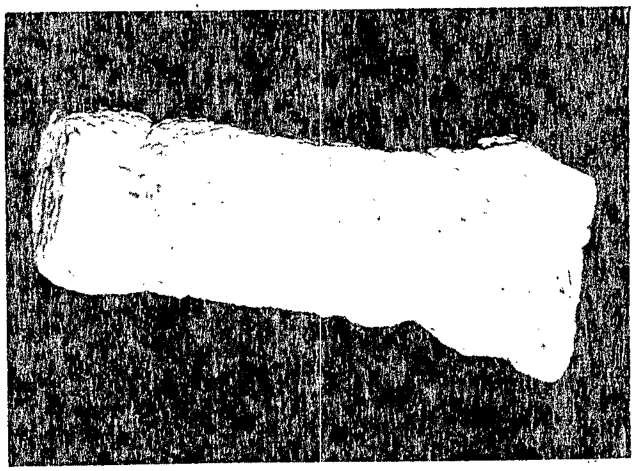
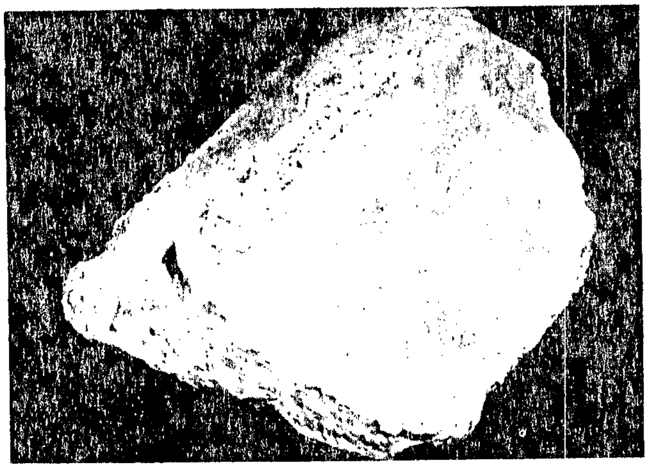


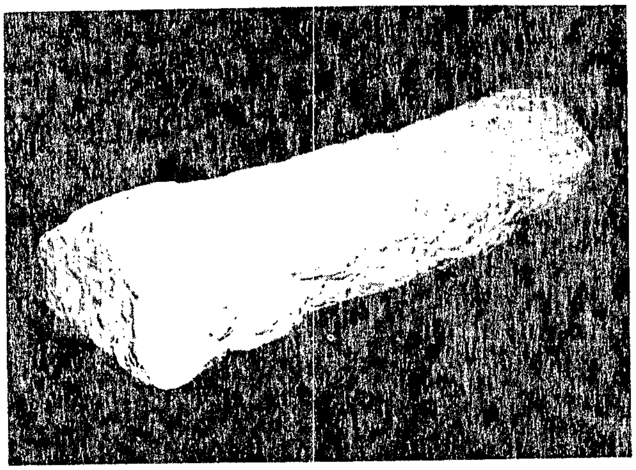
Top View, Final Cavity Impermeable bed Above Vertical Fracture



Top View of Final Cavity Vertical Fracture Ending in Massive Salt

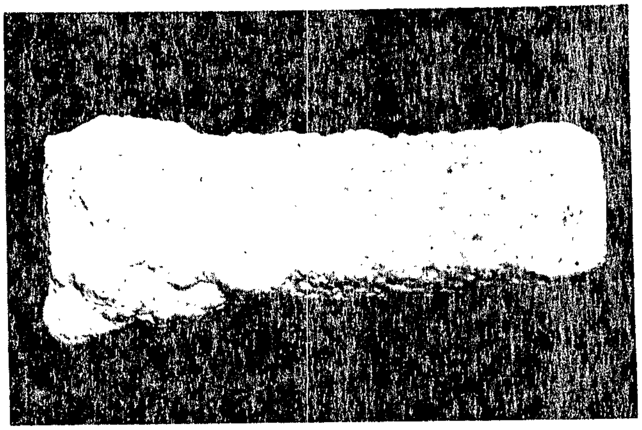


End and Side View, Final Cavity Impermeable Bed Above Vertical Fracture



End and Side View of Final Cavity Vertical Fracture Ending in Massive Salt.

Bottom View, Final Cavity Impermeable Bed Above Vertical Fracture



Bottom View, Final Cavity Vertical Fracture Ending in Massive Salt

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Solution of Salt in a Horizontal Fracture System Between Wells

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ABSTRACT

Data is presented on experimental models involving the use of both vertical and horizontal fractures in two-well systems in which the fractures may exist initially adjacent to an insoluble or inert bed or located with massive salt above the fracture. Results of mathematical simulation and experimental model data are presented. Different solution patterns are developed depending on the mode of fracture system. Shape of cavities formed in massive salt sections are affected more by solution at the roof surface while cavities formed in which insoluble beds appear as roof members take on the appearance which is expected from vertical surface exposure.

Introduction and Purpose

Brine production is obtained in many areas through solution of salt beds which have been penetrated by wells that have been connected by leaching operations. In other cases direct communication between drilled wells is attempted by the hydraulic fracturing technique. When fractures are formed and washing of soluble beds continues in the fracture, the progressive growth of the cavity formed becomes of interest because of possible means of modifying washing procedures and possible subsidence caused by relatively large widths of cavities formed. Still another aspect of the importance of information concerning cavity growth is related to the question of future fractures emanating from other wells which may or may not be directed into a cavity.

This study was undertaken to determine, through the use of laboratory models, the general shape of cavity developed from an initial horizontal fracture between two wells and to develop a relationship between the growth of the cavity volume with time. Some idea as to the probable ultimate configuration was also believed possible as a result of the investigation.

Experimental Procedure

In order to determine the type of cavity produced between two wells connected by a fracture a system was devised to simulate the conditions to be expected in field operations. For this purpose salt blocks of various size were utilized. To establish the fracture, or path of the fluid introduced initially, a 1/32" to 1/16" thick metal plate was laid on a smooth surface salt block, and fixed in position by means of molding clay. The edges of the salt block were then raised by means of the same clay, and Hysol #R8-2038 with hardener H2-3475, obtained from the Hysol Corporation, Olean, New York, was poured on the surface of the salt. Preliminary to this, of course, the block of salt was levelled so that a uniformly thick coating of plastic material could be obtained. After the resin had hardened the molding clay was removed, and the metal plate, used to form the initial fracture condition, was taken very carefully from the salt surface so as not to extend the fracture in any manner. Later fractures were completed without the use of any metal strips or plates, and just sufficient amount of molding clay was placed to allow a fracture opening of about 1/16th inch in depth.

In order to seal the entire salt surface, other than the fracture, a piece of Lucite 1/4 inch thick was cut to the exact size of the salt block and was cemented to the block with Hysol. Inlet and outlet connections were provided in the plastic sheet to fit the particular fracture dimensions. No difficulty was experienced in obtaining complete coverage and sealing of the salt surface, though it was necessary to have the specimen block level, to employ a thin layer of Hysol solution for the final sealing, and to apply a small uniform load on the plastic plate.

After the Hysol had dried, the block was inverted and washing operations begun. In this manner, progression of solution of salt was that which would be possible with a fracture at the base of a soluble salt bed.

Water was used directly from the tap. A needle valve served as a means of regulating the flow rates and, in addition, a by-pass was provided to assure somewhat better control when fluctuations in pressure occurred. No difficulty whatsoever was encountered in establishing a uniform flow rate. The rate was measured by means of a rotameter placed in the line on the upstream side of the salt specimen, and direct measurement was made of the brine produced from the outlet well.

The amount of salt removed was determined from the volume of fluid flow during each definite time interval and the average specific gravity of the fluid during this time. At the end of each experiment brine was drained from the cavity. This volume was measured and the specific gravity determined. Finally, after drying, the insoluble material was removed and weighed. From the known specific gravity of this material (anhydrite) the volume of such was determined. Total volume was the sum of the volume of fluid drained and the volume of insoluble material. Further, a Plaster of Paris mold was made to give the configuration of the cavity, and a volume was also computed from the mold weight and determined specific gravity. In practically every instance the final volume of the cavity was established well within 10 per cent by the three means described.

A brief description of each leaching experiment follows. The results are tabulated to show the progression of each cavity during the period washed.

With some of the test blocks, in order to forestall a leak occasioned by a break or crack in the salt, the entire salt block was encased in Hysol. Another box, made of wood, was used to hold the salt. The Hysol was poured around the salt, and to a depth sufficient to cover the plastic plate used on top of the salt to seal the salt and furnish the fracture and well spacing.

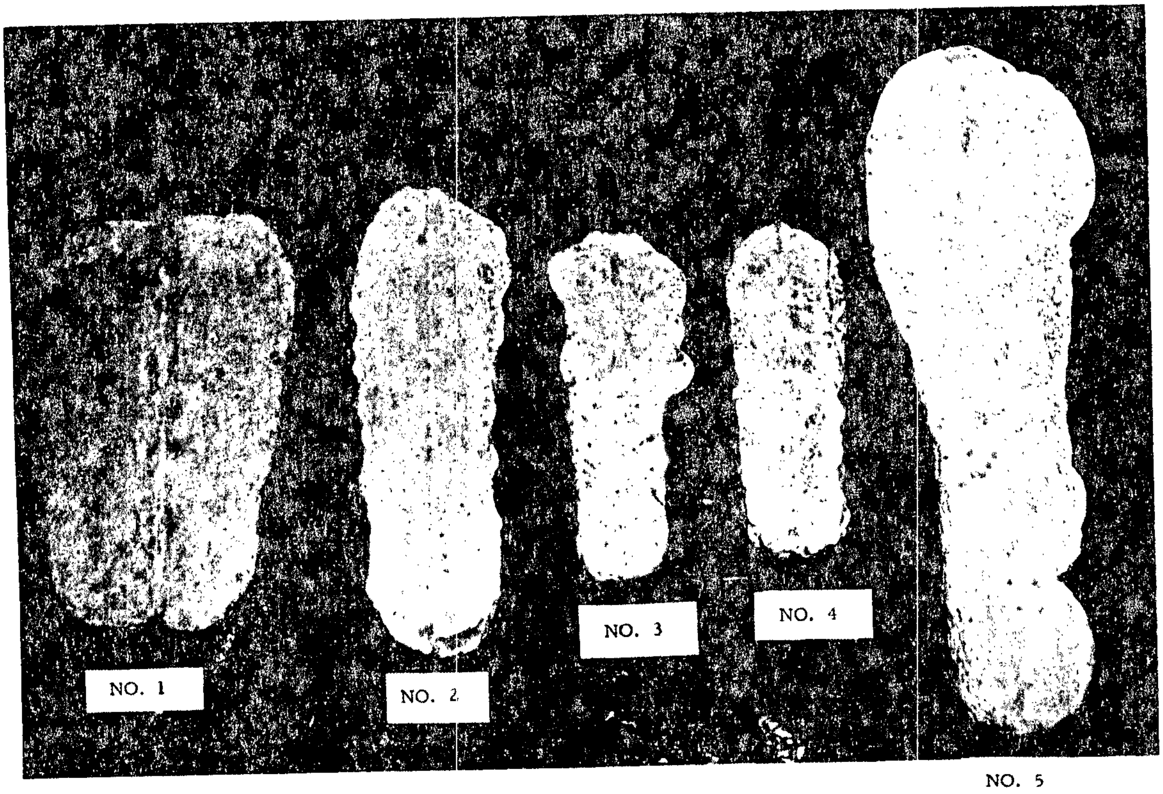
Experiment No. 1 was set up in the manner described and washing was continued for twenty-two hours and twenty minutes. A cavity of 3440 cc. was produced using a cumulative volume of water of 30,580 cc. A plaster mold of the cavity was prepared. This mold served well to measure the dimensions of the cavity formed and yielded a final volume of 3240 cc.

Experiment No. 2, the block for this test was prepared and totally enclosed in plastic as before. Initial fracture was one inch by sixteen inches. While washing, air kept leaking in through the bypass valve. Both valves were replaced and the air was purged from the cavity and the mining continued for an elapsed time of seven hours and fifteen minutes. A cumulative volume of 36,445 cc. of water was used producing a cavity of 1541.4 cc. A plaster mold was made of the cavity and the dimensions recorded. Total final volume of mold was 1515 cc., an excellent agreement with the value obtained from the washing data. See photograph showing molds of various cavities formed by using this procedure.

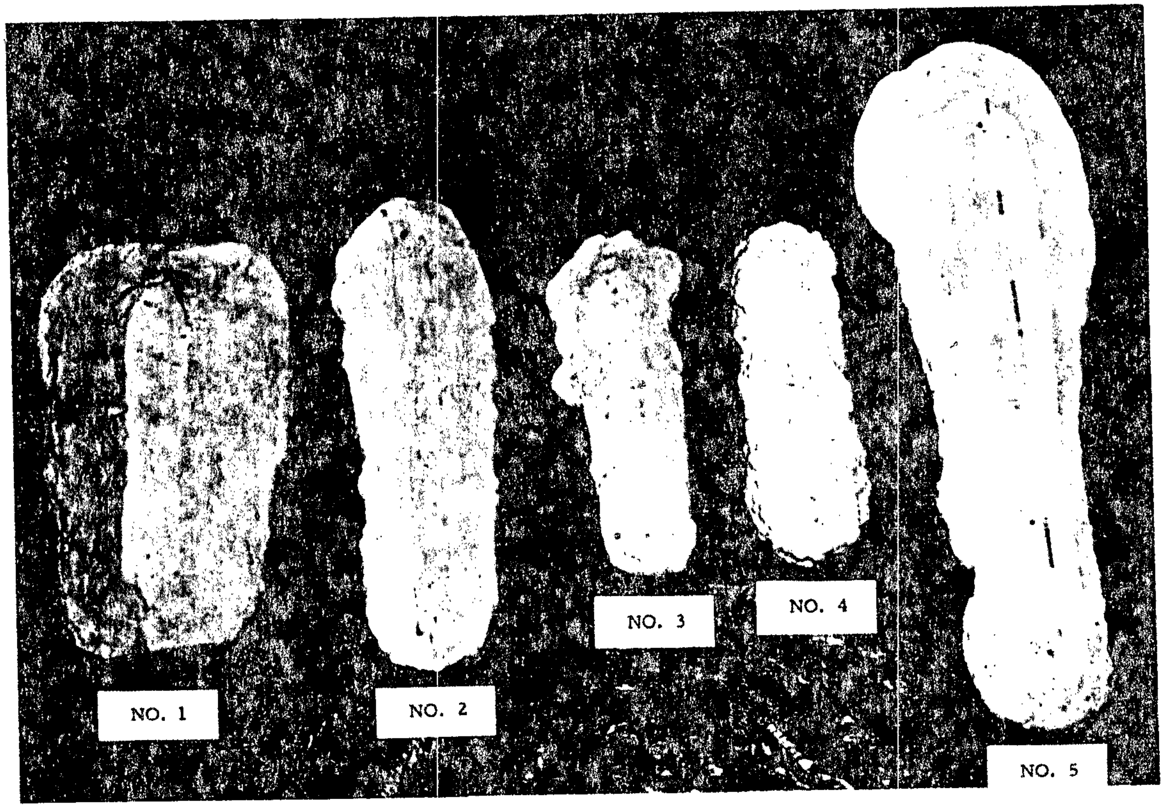
Experiment No. 3 was conducted with a block having a two-inch by ten-inch initial fracture. The block appeared to be massive and it was decided to try to run the experiment without sealing it in plastic. The block was set up, but after 1600 cc. of water were circulated it was found a crevice leak existed. The block was sealed in plastic and was again set up and leaching continued. The cavity was formed with an elapsed time of five hours. A total volume of 9895 cc. of water was used producing a cavity of 850.0 cc. A plaster mold of the cavity was made and the dimensions recorded. The solution of salt which resulted from fluid following the fracture was quite evident as a projection on one side of the mold. Volume determined from mold was 740 cc.

Experiment No. 4, in which for the first time a low-grade potash ore was used, was set up in a block with an initial fracture one inch by ten inches. This block again appeared to be massive and was set up without sealing it in plastic. The block was set up and mined, using fresh water. Solution of the potash salt was continued for five hours and thirty minutes using 10,860 cc. of water. A cavity having a calculated volume of 1050 cc. was formed. A plaster mold showed a volume of 935 cc. Very good symmetry was observed. The physical dimensions were recorded from the mold.

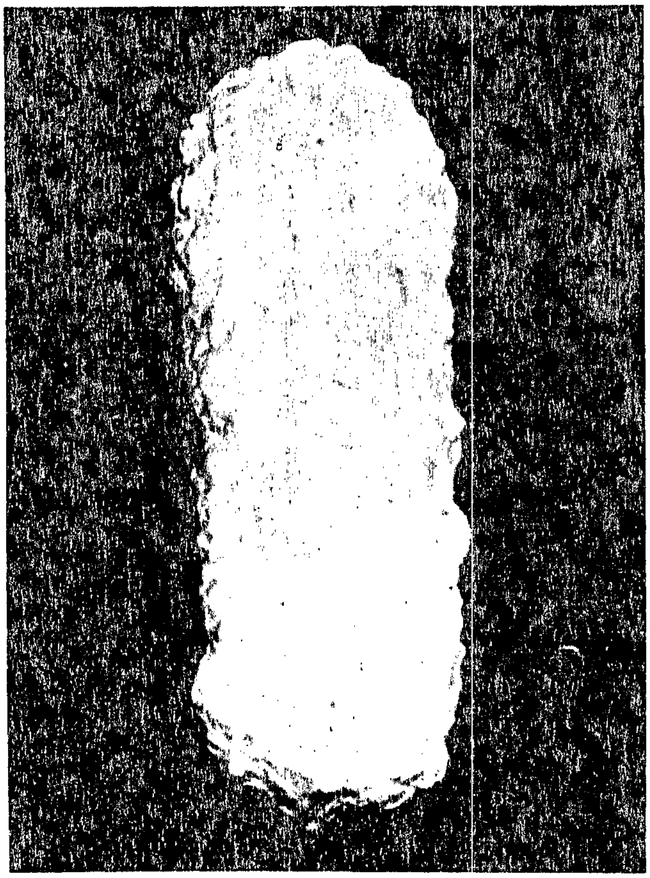
Experiment No. 5 was run on a block with an initial fracture of four inches by twenty-three



Plaster molds of leached cavities—top view.



Plaster molds of leached cavities—bottom view.



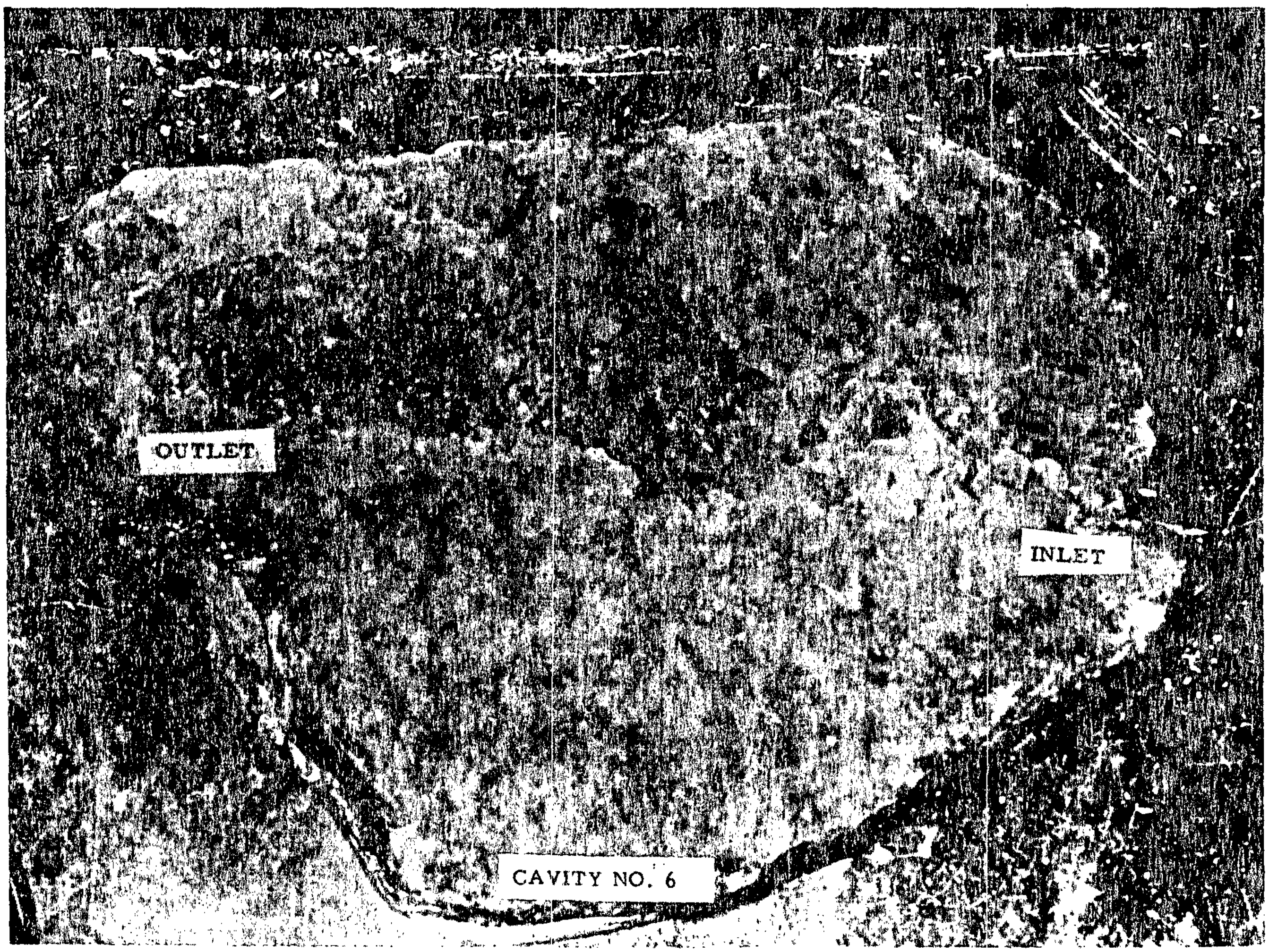
Plaster mold of Cavity No. 4—note symmetry.

inches with a distance of twenty-one inches between wells. The mining was continued for a period of sixteen hours and ten minutes. A volume of 34,670 cc. of fresh water was used to produce a calculated cavity volume of 3847.2 cc. A plaster mold was made of the cavity from which the physical dimensions of the cavity were recorded. The measured volume from the mold was 3660 cc. This cavity was the largest formed and also represented the cavity having the longest course between wells. A photograph of the cavity mold shows the details of the configuration. As in the case of each cavity formed, the roof (top) of the cavity was perfectly smooth.

Experiment No. 6 was conducted with a one-and-one-half inch slab of potash ore with a one-inch by ten-inch fracture. The slab was completely sealed in plastic and set up and mined by circulating salt water with a specific gravity of 1.118. The water was supplied by a gravity flow system from a storage reservoir. The leaching was continued for five hours and fifty-five minutes using 11,440 cubic centimeters of salt water. A cavity of 545 cc. was produced. The cavity was irregular due to fractures in the potash ore slab and a mold of the cavity was not made. A photograph showing the irregularities found near the inlet end and toward the middle of the cavity is included. It appears some selective solution of sylvinite (sylvite) may have taken place. However, the same pattern was developed as in previous instances, namely a flat, smooth roof and widening of the initial fracture width. Apparently, the use of salt water as a circulating medium does not change the basic mechanism of solution, but, as expected, greater volumes of brine must be circulated to remove a unit volume of ore.

Experiment No. 7, again utilizing potash ore, was set up and run on a block using an initial fracture width of seven inches, with a distance of eleven inches between wells. The washing with fresh water took five hours and forty-one minutes using 19,250 cc. of fresh water. A cavity of 2160 cc. was

Plaster mold of Cavity No. 5—bottom view.



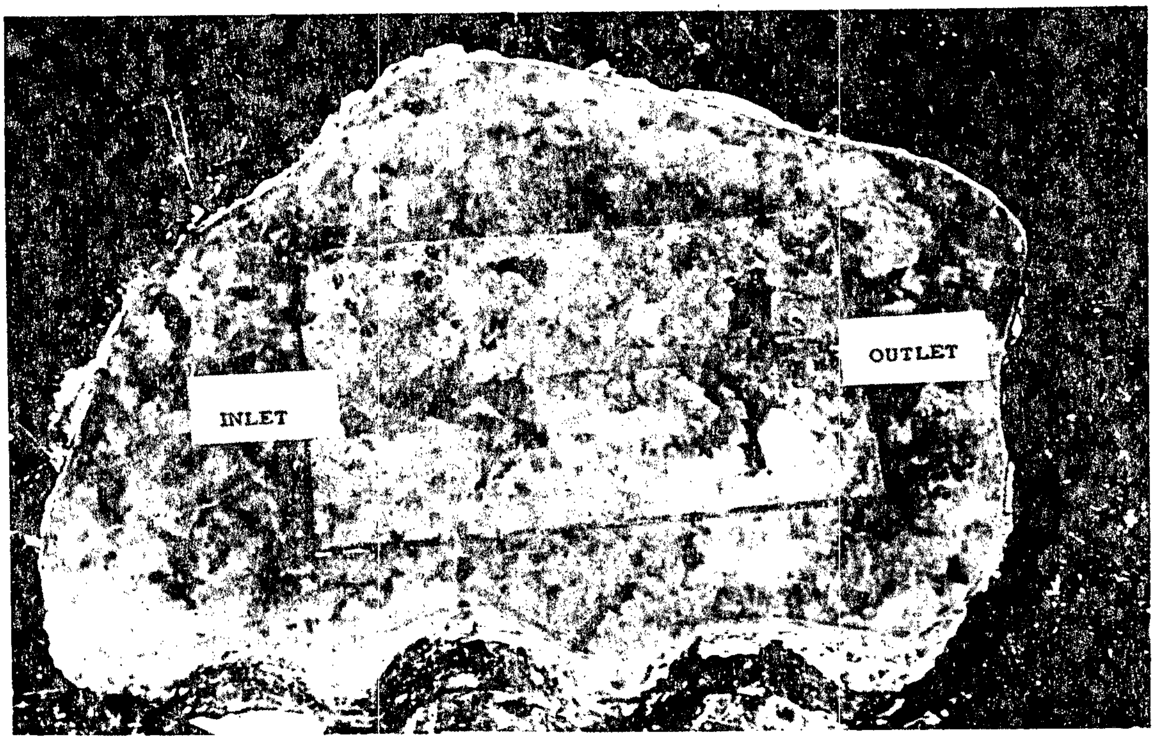
Note ragged, uneven solution at inlet and smooth roof at outlet.

formed. The block was not sealed in plastic and an air leak developed along a small fracture. The air leak was plugged with clay and was stopped for two to three hours but finally caused the mining to be terminated. The cavity was measured and the measurements recorded and several pictures of the cavity made. The typical configuration was obtained. The effect of having a larger initial width-to-length ratio of the fracture is to decrease the time required to reach a particular saturation of brine. This means, of course, that with a wide fracture existing between wells, a greater amount of salt (potash) could be removed in the early stages of washing. It would mean further that greater volumes of water could be employed initially and throughout the leaching operations.

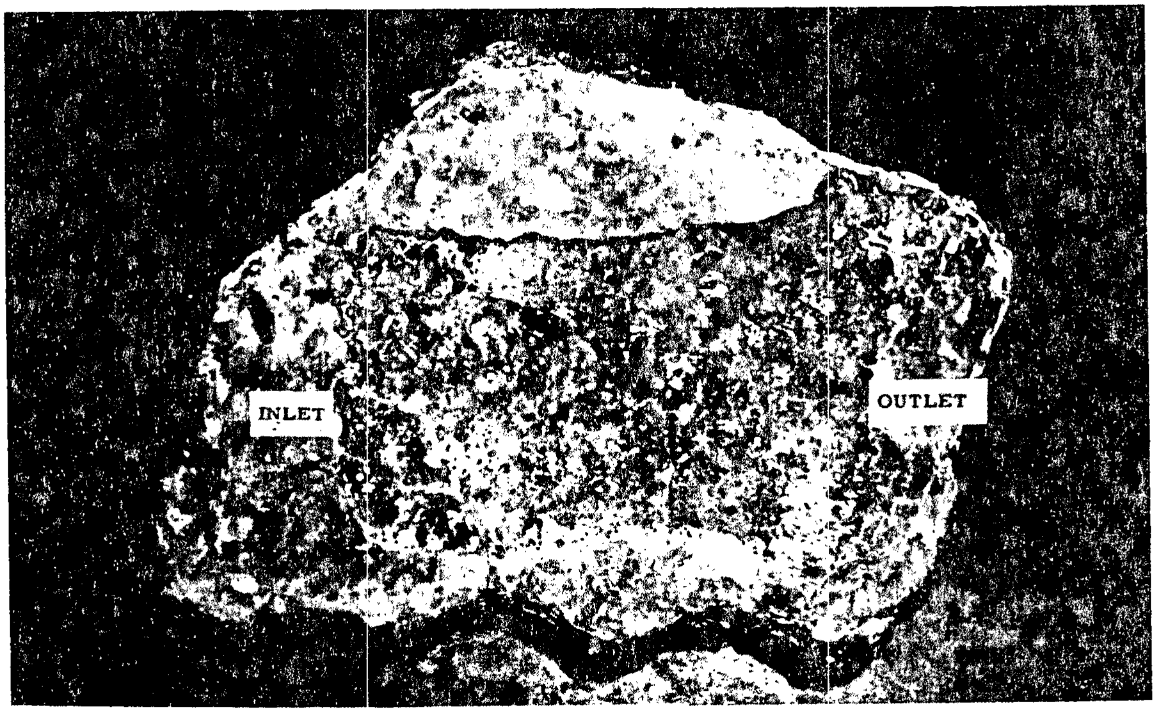
MATHEMATICAL ANALYSIS

The objective was to obtain a function for volume of salt removed as a function of time so that at any time the rate of removal and the cavity may be predicted.

The experimental work performed indicated the concentration of salt solution is constant along any horizontal plane, resulting in a flat roof and flat floor for the cavity, with all progression being in the positive and negative vertical directions. The approach to the solution of the problem then centered on finding the curve for the outline of the cavity as viewed from above and then to integrate this function over the thickness of the cavity to obtain the volume.



Cavity No. 7 before leaching.



Cavity No. 7 after leaching.

First in line in this approach was the streamline analogy. It was felt that since concentration was constant on any horizontal plane, a model based on the source-sink analogy of fluid mechanics would closely approximate the outline shape. It did indeed do this fairly well for fluid velocities in a suitable range; however, the streamline function resisted integration and so was abandoned.

The next approach was to analyze the cavities leached in the laboratory and to develop equations which represented the configuration with time of washing. All cavities leached had approximately the same shape given below.

The volume was calculated first by approximating the darkened lines in Figure 1(b) and Figure 1(c) by parabolas and then integrating over the outline indicated in Figure 1(a).

For the parabola approximating the curve in Figure 1(c), the assumption was made that

$$Y = a_1 X^2 + b' X + c_1$$

where:

$$Y(a) = b, \ Y(a) = 0, \ Y(c) = 0$$

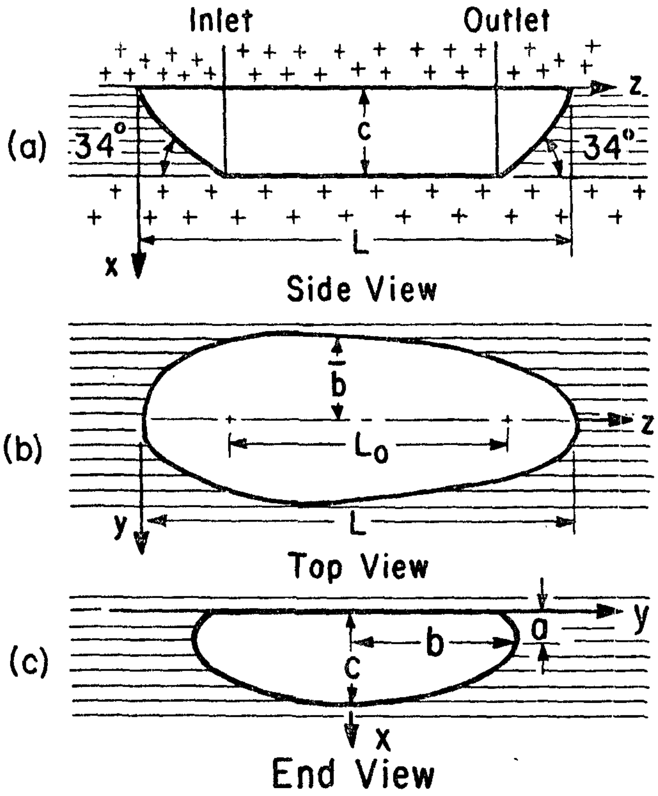


Figure 1. Section taken half way down the length of the cavity: z = L/2

This results in three linear equations

$$b = a_1 a^2 + b_1 a + c_1$$

$$2a_1 a + b_1 = 0$$

$$a_1 c^2 + b_1 c + c_1 = 0$$

whose solution is

$$a_1 = \frac{-b}{(a-c)^2}, \quad b_1 = \frac{2ab}{(a-c)^2}, \quad c_1 = \frac{bc(c-2a)}{(a-c)^2}$$

and thus the approximating parabola is

$$Y = \frac{1}{(a-c)^2} \left[-bX^2 + 2abX + bc(c-2a) \right]$$

Likewise the equation for the curve indicated in Figure 1(b) was approximated by

$$Z = \frac{L}{Z\bar{b}^2} Y^2$$

and the area given for the top is

$$A = \frac{4}{3} \bar{b} L$$

where $\bar{b}$ is the variable representing the half-width as one moves up and down the thickness (at $Z = \frac{L}{2}$); $\bar{b}(a) = b$

The volume for the complete cavity then is given by

$$V = \frac{8}{3(a-c)^2} \Big\} \int_0^c \frac{-bLX^2 dX}{2} + \int_0^c abLXdX$$

$$+ \int_0^c \frac{bc}{2} (c-2a) \, LdX + \int_0^c b \tan 34^\circ X^3 \, dX$$

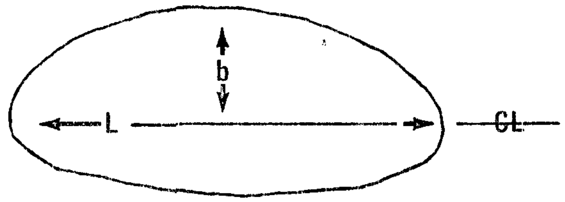
$$- \int_0^c 2ab \tan 34^\circ X^2 \, dX$$

$$- \int_0^c bc(c-2a) \tan 34^\circ X \, dX \Big\{$$

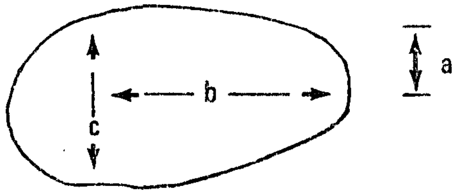
or

$$V = \frac{4\ bc^2\ L}{3\,(a\text{-}c)^2}\left[\frac{5c}{3} - 3a\right] + \frac{8\ bc^3\ \tan 34°}{3\,(a\text{-}c)^2}\left[\frac{a}{3} - \frac{c}{4}\right]$$

where a, b, c, L are the dimensions indicated below



Top View



Cross Section

In the following examples application of this formula is made for cavities washed in the laboratory to indicate the precentage error.

Cavity No. 1

$$V = \frac{4\ bc^2\ L}{3\,(a\text{-}c)^2}\left[\frac{5}{3}\ C - 3a\right] + \frac{8\ bc^3\ \tan 34°}{3\,(a\text{-}c)^2}\ \frac{a}{3} - \frac{c}{4}\,]$$

where

$a = \frac{5}{16}$ inches, $b = \frac{77}{16}$ inches,

$c = \frac{22}{16}$ inches, $L = \frac{266}{16}$ inches.

$V = 3200$ cc

The measured volume was 3250; the predicted volume is 3200 cc. % error is = 1.6%.

Cavity No. 2

Where

$a = \frac{5}{16}$ inches, $b = \frac{44}{16}$ inches,

$c = \frac{19}{16}$ inches, $L = \frac{306}{16}$ inches.

$V = 1670$ cc

The measured volume was 1470 cc.; the predicted volume is 1670 cc. % error is = 14%.

Cavity No. 3

Where

$a = \frac{6}{16}$ inches, $b = \frac{33}{16}$ inches,

$c = \frac{21}{16}$ inches, $L = \frac{227}{16}$ inches.

$V = 1000$ cc

The measured volume was 817 cc.; the predicted volume is 1000 cc. % error is = 22%.

Cavity No. 4

Where

$a = \frac{8}{16}$ inches, $b = \frac{36}{16}$ inches,

$c = \frac{22}{16}$ inches, $L = \frac{218}{16}$ inches.

$V = 918$ cc

The measured volume was 935 cc.; the predicted volume is 918 cc. % error is = 1.8%.

Cavity No. 5

Where

$$a = \frac{12}{16} = .75 \text{ inches,} \qquad b = \frac{96}{16} = 6 \text{ inches,}$$

$$c = \frac{29}{16} = 1.80 \text{ inches,} \qquad L = \frac{368}{16} = 22.8 \text{ inches}$$

$$V = 4000 \text{ cc.}$$

Measured volume was 4175 cc.; predicted volume is 4000 cc. % error = 5%.

In order to make this volume (V) function a function of time, it was necessary to determine experimentally how a, b, c, and L depend on time. Once this had been accomplished, the resulting formulas were substituted into the volume (V) function resulting in the desired relationship of volume (V) as a function of time.

First the b values were plotted versus time to get the form of the curve relating b, c, a, and L, to t. This graph (Figure 2) indicates these dimensions are linear functions of time.

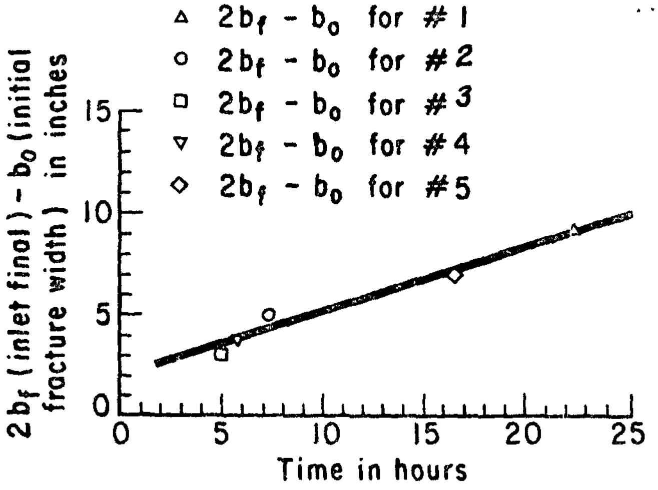


Figure 2.

On the basis of Figure 1 we may assume, since $b_{(t)}$ is a linear function that

$$2b(t) = b_1 t + b_o$$

where b_o is the initial fracture width. Also, b_1 is the slope of the line in Figure 1 and is seen to be

$$\frac{5}{16} \text{ in/hr. or } 0.026 \text{ ft/hr.}$$

b(t) then is given by

$$b(t) = 0.013t + \frac{b_0}{2}$$

Likewise L(t) is given by

$$L(t) = 0.013t + L_o$$

If the water is near saturation at the outlet the experiment shows that c changes at the ratio $\frac{11}{32}$ of the rate of change of L. Thus:

$$c(t) = 0.0045t$$

Also, *a* changes at the ratio $\frac{4}{15}$ as fast as does c. Therefore:

$$a(t) = 0.0012t.$$

The volume in cubic feet as a function of time then is given by

$$V(t) = [\frac{4(0.013t + \frac{b_0}{2})(0.0045t)^2 (0.013t + L_0)}{3(-0.0033t)^2}]$$

$$[(\frac{5}{3})(0.0045t) - 3(0.0012t)]$$

$$+ [\frac{16(0.013t + \frac{b_0}{2})(0.0045t)^3}{9(-0.0033t)^2}]$$

$$[\frac{0.0012t}{3} - \frac{0.0045t}{4}]$$

Simplifying,

$$V(t) = [(\frac{10.4}{10^3}) (0.013t + \frac{b_0}{2}) (0.013t + L_0) (t)]$$

$$- [(\frac{11.2}{10^6}) (0.013t + \frac{b_0}{2}) (t)^2]$$

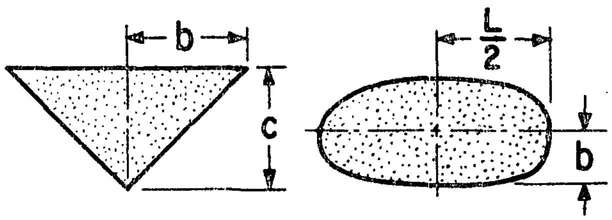
As an example, assume a calculation of the volume removed after 100 hours from an initial cavity defined by: $b_o = 50$ feet, $L_o = 400$ feet.

$$V(100) = (\frac{10.4}{10^3}) [(0.013)(100) + \frac{50}{2}] [(0.013)(100)$$

$$+ 400] - [(\frac{11.2}{10^6}) (1.3 + \frac{50}{2}) (100)^2]$$

$$V(100) = 10{,}976 - 2.83 = 10{,}973 \text{ ft}^3$$

Two methods were employed to determine surface areas. The first method was based on a model with flat sides such as occurred when insoluble material was present, and the other was based on a prolate spheroid.



End view

Top view

Figure 3.

Surface area for the slab side model is given by:

$$S.A. = \pi\, b \frac{L}{2} + 2L \sqrt{b^2 + c^2}$$

Where the first term gives the surface area of the elliptical top and the second term gives the surface area of the sides.

For the prolate spheroid model the surface area is given by

$$\text{SURFACE AREA} = \pi \left(\frac{Lb}{2} + b^2 + \frac{Lb}{2\epsilon} \sin^{-1} \epsilon \right)$$

Where:

$$\epsilon \equiv \frac{\sqrt{L^2 - 4b^2}}{L}$$

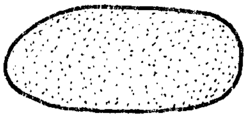


Figure 4.

It should be pointed out that this model is good only in the latter stages of the washing when the cavity does begin to assume the shape of half a prolate spheroid.

Summary

1. A study has been made in the laboratory by leaching salt blocks in which horizontal fractures connected two wells.

2. Fracture width and length were varied. The minimum fracture width was 1 inch. The corresponding length was 10 inches. The maximum width of fracture was 7 inches with 12 inches between wells. Maximum length between wells was 23 inches, corresponding fracture width was 4 inches.

3. The resulting configuration of cavity formed may be described in mathematical terms which permit prediction of the volume of cavity formed with time.

4. When the initial fracture width is relatively large in comparison with the length between wells practically all the solution of salt takes place on the roof of the cavity, and relatively little widening of the cavity occurs with time.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support of Continental Oil Company in carrying out this research. Thanks are due Mr. O.N. Goode, Jr. and Mr. Wm. Blackburn who assisted with the laboratory experimental work.

CAVITY WASHING TEST: No. 1
SOURCE OF SALT: Hockley Salt Mine, United Salt Company, Houston, Tex.
CONDITION OF TEST: Fracture, 10" long, 1" wide
MANNER OF TEST: Inlet and outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
	700 cc getting set up						
60	960	1,660	16	1.107	125	125.0	7.6
60	900	2,560	15	1.138	86.5	211.5	10.4
60	900	3,460	15	1.148	97.2	308.7	9.2
60	900	4,360	15	1.150	97.2	405.9	9.2
60	870	5,230	14.5	1.152	95.5	501.4	9.1
	400 cc used setting up						
60	855	6,485	14	1.160	140.5	641.9	8.8
60	870	7,355	14.5	1.156	94.0	735.9	8.30
60	900	8,255	15	1.157	99.0	834.9	9.1
60	1,450	9,705	22	1.150	157.0	991.9	9.2
60	1,075	10,780	18	1.146	114.0	1,105.9	9.4
60	1,100	11,880	18.5	1.150	119.0	1,224.9	9.2
60	1,090	12,970	18	1.153	120.0	1,344.9	9.0
60	985	13,955	16.5	1.155	107.5	1,452.4	9.1
20	1,000	14,955	20	1.170	120	1,572.4	8.3
60	825	15,780	15	1.156	90.0	1,662.4	9.1
60	925	16,705	20	1.140	92.5	1,754.9	10.0
120	1,875	18,580	20	1.137	178.5	1,933.4	10.5
60	1,450	20,030	20	1.131	133.5	2,066.9	10.8
30	750	20,780	20	1.123	64.0	2,130.9	12.7
	Drained 2650 cc			1.133	244.0	2,474.9	10.8
60	1,350	24,780	20	1.156	147.0	2,621.9	9.2
60	1,000	25,780	20	1.165	Shut in	2,733.4	9.0
60	900	26,680	20	1.182	114.0	2,847.4	7.9
30	650	27,330	20	1.178	83.5	2,930.9	7.8
	3,250	30,580		1.162	374.0	3,304.9	8.7
				Dried and weighed 400 gm anhydrite			
				Insoluble material 135.5		3,440.4	

Volume (mold) = 3,240 cc
Length = 16.25 inches Height at inlet = 2-1/4 inches
Width at inlet = 10.25 inches Height at inlet = 2-7/8 inches
Width at outlet = 8.00 inches
Width at midpoint = 9.25 inches

CAVITY WASHING TEST: No. 2

SOURCE OF SALT: Hockley Salt Mine, United Salt Company, Houston, Tex.
CONDITION OF TEST: Fracture, 1" Wide 16" Long
MANNER OF TEST: Inlet, Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc per time interval	Vol. of Water cc cumulative	Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
15	1,000	--	--	--	start up, flushed air from system, set rate		
15	800	1,800	53	1.047	25.8	25.8	31
15	1,750	3,550	117	1.058	73.0	98.8	24
15	2,150	5,700	143	1.048	77.0	175.8	28
15	1,450	7,150	97	1.040	41.5	216.3	35
Flushed out with air, 1,500 ml, no data taken, Sp. Gr. of solution was 1.041							
		(8,650)					
8	725	9,375	91	1.034	17.5	233.8	41
28	Flushed with air, 1,100 ml, no data taken, changed valves while shutdown						
		(10,475)					
17	1,400	11,875	82	1.022	21.6	255.4	65
15	1,060	12,935	71	1.022	14.0	269.4	75
5	1,100	Flushed air out of cavity, no data taken					
		(14,035)					
10	910	14,945	91	1.034	22	291.4	41
15	1,310	16,255	87	1.029	27	318.4	48
15	1,350	17,605	90	1.015	14.5	332.9	92
30	3,800	21,405		Tried to flush out air, connection broke, repaired, tried to flush air second time			
5	460	21,865	92	1.017	63.3	396.2	-) air
				1.017			-) in
10	980	22,845	98	1.012			-) cavity
Shut down, awaiting assistance in attempt to remove all air from cavity							
10	1,000	23,845	Flushed out system, no data taken				
				(1.074)			
10	600	24,445	60	1.090	39.5	435.7	15
10	750	25,195	75	1.110	83.0	518.7	9
15	1,150	26,345	76	1.115	95.0	613.7	12
15	1,150	27,495	77	1.114	93.5	707.2	12
15	1,100	28,595	73	1.113	90.5	797.7	12
15	1,130	29,725	75	1.114	92.5	890.2	12
15	1,170	30,895	78	1.116	100.0	990.2	12
15	1,450	32,345	96	1.114	120.5	1,110.7	12
15	1,150	33,495	76	1.112	95.0	1,205.7	12
15	1,100	34,495	67	1.111	87.0	1,292.7	13
15	970	35,365	65	1.098	70.5	1,363.2	14
15	1,080	36,445	72	1.097	79.5	1,442.7	14
15	Drained 1,400 ml, Sp. Gr. 1.062, Stopped test				61.5	1,504.2	
				Dried and weighed 110 gm anhydrite			
				Insoluble material	37.2	1,541.4	

CAVITY WASHING TEST: No. 2 (Continued)

Cavity Dimensions after making plaster of Paris mold:

Width at inlet end = 6"
Width at outlet end = 5-1/4"
Depth = 1-1/8", uniform over length
Width at midpoint = 5-1/2"
Length over-all = 19"
Volume (from mold) = 1,515 cc

CAVITY WASHING TEST: No. 3

SOURCE OF SALT: Hockley Salt Mine, United Salt Company, Houston, Tex.
CONDITION OF TEST: Fracture 2" Wide, 10" Long
MANNER OF TEST: Inlet, Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
Set up and purged air, ran in 100 ml, allowed to set 24 hours							
Started to run, found air leak, fractured salt segment, total of 1,600 ml run, Sp. Gr. = 1.032, shut down to seal fracture					(37)	(37)	-
Sealed block of salt in Hysol							-
Started up again							-
10	500	2,100	50	1.045	16.6	53.6	30
15	460	2,560	31	1.066	22.0	75.6	21
20	590	3,150	30	1.098	41.6	117.2	14
30	800	3,950	27	1.117	67.2	184.4	12
30	860	4,810	29	1.125	78.0	262.4	11
30	860	5,670	29	1.128	79.5	341.9	11
30	790	6,460	26	1.129	73.8	415.7	11
60	1,620	8,080	27	1.132	155.0	570.7	10
30	680	8,760	22	1.135	66.0	636.7	10
30	720	9,480	24	1.137	71.5	708.2	10
15	415	9,895	28	1.139	41.5	749.7	10
Stopped test, drained 810 cc of fluid, Sp. Gr. = 1.130					67.5	817.2	-
				Dried and weighed 100.3 gm anhydrite			
				Insoluble material	33.7	850.9	

Cavity dimensions after making plaster of Paris mold:

Width at inlet end = 5-1/2"
Width at outlet = 3-5/8"
Width at midpoint = 4-1/8"

Depth = 1-5/16"
Length over-all = 14"
Volume (from mold) = 740 cc

CAVITY WASHING TEST: No. 4
SOURCE OF SALT: Low Grade Potash Ore—New Mexico
CONDITION OF TEST: Fracture 1" Wide, 10" Long
MANNER OF TEST: Inlet, Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
5	540	540	108	1.052	20.4	20.4	27
10	420	960	42	1.062	18.2	38.6	23
15	460	1,420	31	1.083	27.6	66.2	17
15	450	1,870	30	1.102	33.2	99.4	14
15	460	2,330	31	1.112	37.4	136.8	12
15	460	2,790	31	1.117	39.1	175.9	12
15	440	3,230	29	1.121	38.6	214.5	11
15	460	3,690	31	1.125	41.6	256.1	11
15	445	4,135	30	1.129	41.7	297.8	11
15	460	4,595	31	1.130	43.6	341.4	10
15	460	5,055	31	1.132	43.9	385.3	10
15	450	5,505	30	1.135	43.9	429.2	10
15	450	5,955	30	1.138	44.8	474.0	10
15	650	6,605	43	1.140	66.0	540.0	10
15	350	6,955	23	1.142	35.8	575.8	10
30	850	7,805	29	1.145	98.5	665.3	8.6
30	860	8,665	29	1.149	93.0	758.3	9
30	880	9,545	29	1.150	95.5	853.8	9
15	465	10,010	31	1.151	50.8	904.6	9
15	850*	10,860	30	1.146	89.5	994.1	9
Drained an additional 600 cc of brine, Sp. Gr.				1.130	56.5	1,050.6**	

No insoluble material present.

Width at inlet end = 4-7/8"

Width at outlet end = 4-1/4"

Width at midpoint = 4-1/2"

Depth, uniform = 1-3/8"

Length = 13-5/8"

Volume from mold = 935 cc

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*Test stopped because of air leak caused by breakthrough at top of cavity which caused high flow just at end of last wash period of 15 min.

**Considering rate of flow to be normally 450 cc durg the 15 minute period, this would mean 400 cc of last 850 cc was drainage from cavity, thus volume of fluid, by drainage, would be 400 + 600 = 1,000 cc.

CAVITY WASHING TEST: No. 5
SOURCE OF SALT: Hockley Salt Mine, United Salt Company, Houston, Tex.
CONDITION OF TEST: 4" x 23" Channel, 21" between wells
MANNER OF TEST: Inlet, Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
17	700	700	-	1.053	27.1	27.1	26.5
13	580	1,280	44.6	1.050	21.2	48.3	26.6
15	500	1,780	33.3	1.052	19.9	68.2	25.1
15	420	2,200	28.0	1.069	20.9	89.1	20.1
15	510	2,710	34.0	1.089	32.9	122.0	15.5
15	465	3,175	31.0	1.103	34.7	156.7	13.4
15	475	3,650	31.7	1.110	37.7	194.4	12.7
15	450	4,100	30.0	1.116	37.8	232.2	11.9
15	445	4,545	29.6	1.120	38.6	270.8	11.5
15	410	4,955	27.3	1.124	36.7	307.5	11.2
15	500	5,455	33.3	1.129	46.6	354.1	10.7
15	510	5,965	33.9	1.132	49.5	403.6	10.3
30	950	6,915	31.7	1.135	92.0	495.6	10.3
30	935	7,845	31.2	1.139	93.9	589.5	9.96
30	950	8,800	31.7	1.145	98.6	688.1	9.7
30	950	9,750	31.7	1.150	103.0	791.1	9.2
30	930	10,680	31.0	1.152	102.0	893.1	9.1
30	875	11,555	29.2	1.150	94.8	987.9	9.2
10	320	11,875	32.0	1.150	34.7	1,022.6	9.2
15	540	12,415	36.0	1.164	64.1	1,086.7	8.4
15	475	12,890	31.7	1.165	56.7	1,143.4	8.4
15	450	13,340	30.0	1.160	52.1	1,195.5	8.6
15	485	13,825	32.3	1.154	54.0	1,249.5	9.0
30	880	14,705	29.3	1.153	97.6	1,347.1	9.0
30	930	15,635	31.0	1.153	103.0	1,450.1	9.0
30	1,080	16,715	36.0	1.152	118.6	1,568.7	9.1
30	1,070	17,785	35.7	1.149	115.7	1,684.4	9.2
30	1,010	18,795	33.7	1.147	107.8	1,792.2	9.4
30	990	19,785	33.0	1.149	106.9	1,899.1	9.3
30	930	20,715	31.0	1.151	101.5	2,000.6	9.2
30	1,020	21,735	34.0	1.151	112.5	2,113.1	9.1
30	1,200	22,935	40.0	1.150	131.5	2,244.6	9.1
30	1,360	24,295	45.3	1.146	143.8	2,388.4	9.4
30	1,290	25,585	43.0	1.143	133.4	2,521.8	9.6
30	1,310	26,895	43.7	1.144	136.5	2,658.3	9.6
30	1,500	28,395	50.0	1.144	156.5	2,814.8	9.6
30	1,320	39,715	44.0	1.144	138.5	2,953.3	9.5
30	1,275	30,990	42.5	1.145	134.2	3,087.5	9.5
30	1,230	32,220	41.0	1.146	130.5	3,218.0	9.4

CAVITY WASHING TEST: No. 5 (Continued)

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
30	1,200	33,420	40.0	1.147	128.0	3,346.0	9.4
30	1,250	34,670	41.7	1.147	133.2	3,479.2	9.4
Drained 3,700 cc of water, Sp. Gr.				1.139	368	3,847.2	
				Insoluble material	328	4,175.2	

Volume from mold = 3,660 cc

Width at inlet = 9 inches

Width at outlet = 4-1/2"

Width at midpoint = 6 inches

Length overall = 28"

Depth, uniform = 1-7/8"

CAVITY WASHING TEST: No. 6
SOURCE OF SALT: Potash Ore, low grade, New Mexico
CONDITION OF TEST: 1" x 10" cavity, 10" between wells
MANNER OF TEST: Used salt water as fluid S.G. 1.118,
Inlet and Outlet at bottom of fracture
RECAPITULATION OF DATA

Time Interval Min.	Vol. of Water cc		Flow Rate cc/min	Specific Gravity Outlet Brine	Calculated Vol. Salt Removed cc/stage	Cumulative Volume of Cavity cc	Vol. Water / Vol. Cavity formed
	per time interval	cumulative					
10	400	400	40.0	1.118	0	0	165
15	430	830	28.6	1.126	2.6	2.6	165
30	1,025	1,855	34.2	1.140	16.1	18.7	63.7
30	930	2,785	31.0	1.152	24.4	43.1	38
30	1,000	3,785	33.3	1.162	31.8	74.9	31.2
30	920	4,705	30.7	1.168	32.7	107.6	28.6
30	920	5,625	30.7	1.169	33.2	140.8	28.7
30	780	6,405	26.0	1.172	36.1	176.9	21.3
30	940	7,345	31.3	1.174	34.3	211.2	27.4
30	900	8,245	30.0	1.174	36.5	247.7	24.6
30	840	9,085	28.0	1.175	34.5	282.2	24.3
30	970	10,055	32.3	1.176	40.7	322.9	23.8
30	840	10,895	28.0	1.176	35.2	358.1	23.8
	545	11,440	-	1.169	20.1	378.2	27.1

Drained Cavity

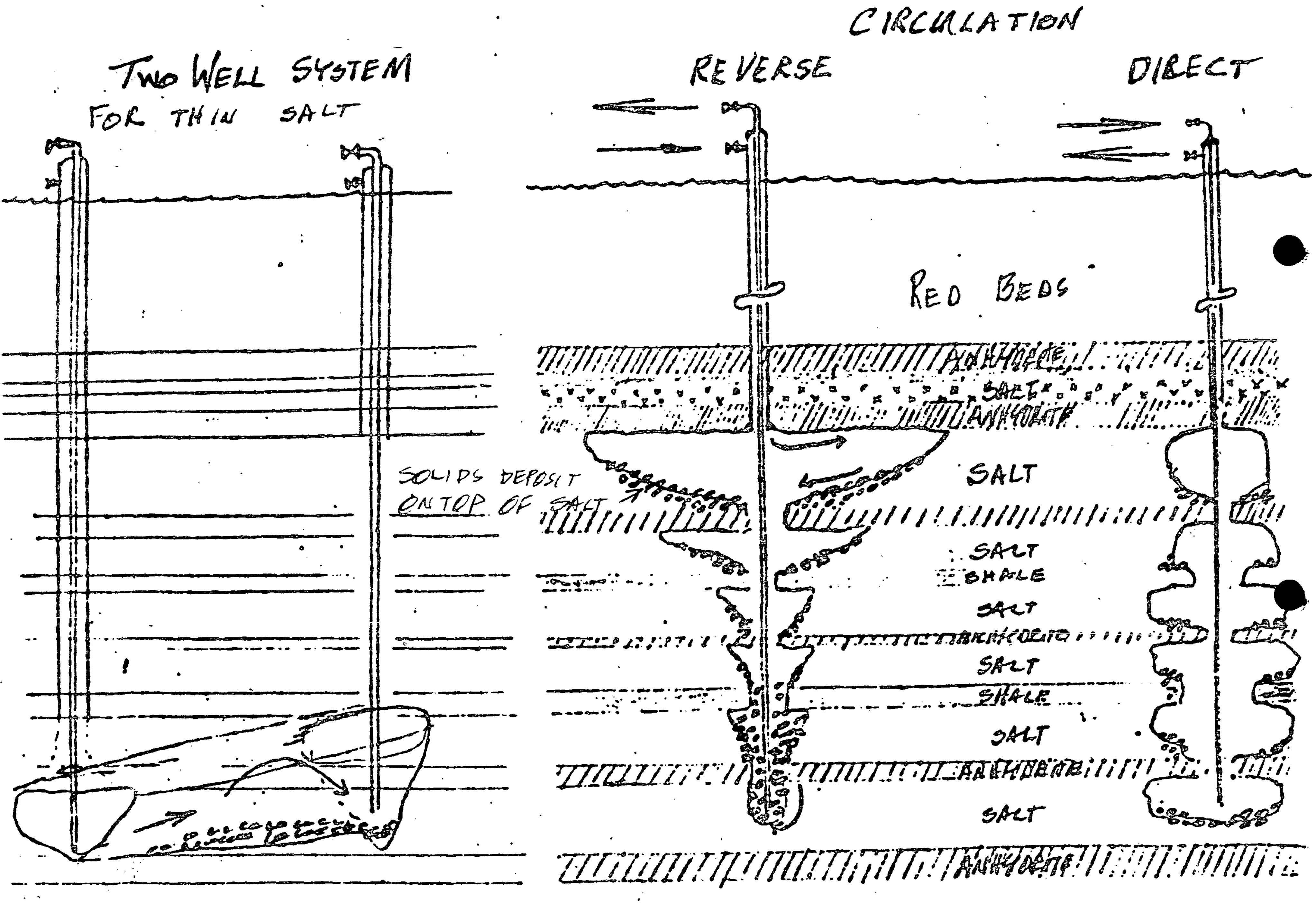
Checked S.G. 8/11/65 at 1.119

Volume of cavity from amount drained at end of test = 545 cc

No mold made, see picture

Width at inlet = 3-1/4"
Depth at inlet = 1-1/2"
Width at outlet = 2-3/4"
Depth at outlet = 3/8"
Width at midpoint = 3-1/4"
Depth at midpoint = 1"
Length, overall = 12-1/2"

TYPICAL BRINE WELL CONFIGURATION



3-15-91

The Permian Corp. - (Applicant Review)
Request for new brine extraction facility
@ 21S 27E Sec. 33

1) Wells in Area - Oil ¼ mi

Oxy Tracy #1-D: W-SW, will reenter & test Morrow csg to 3000' 415'

Humble #1: 2½ mi N shows salt from 400' to 500'; csg to 4800' P&A?

Warseil #2A ½ mi S.; surface csg. @ ~~[illegible]~~ 420'

Lots of Wells drilled in area

2) Water Wells in Area

- None w/in ¼ mile; water supplied by city pipeline
- Well #85: ½ mi. N; Water @ 145' alluvium
  249' Rustler (perfed + producing)

No quality given

3) Surface Water

Canal ≈ 1000' away to SW

4) Casing Plan

- 7⅝" set thru fresh water & cement circ. Set ≈ 400'
- 5½" set @ 450' & 525' & cement circ + pressure tested to 500psi. No cores, no deviation check.
- No packers intended cause 2 casing strings

5) Stimulation Plan

Fracture @ 800psia taking approx. 15 min. @ 8 bpm

3-15-91 KMB

SUBJECT: Phone Conversation with A.L. Hickerson on Collapse Potential from salt mining - new Brine Well

Yes, could be some potential for collapse/subsidence, but feels from literature and past experience that it won't occur. Procedure is to have your injection well injecting near the base of the salt. Fracture across to a second well, hopefully along an anhydrite or clay seam (ID w/log or cuttings). This should be a weaker zone (bedding plane) and the fracture should propogate along this. You're taking a gamble on whether the fracture hits the second well, but take certain measures to increase the chances ie.

1. Dissolve salt around the second well @ tubing to make a larger target zone
2. Know, by literature and experience, the amount of water and time it'll take to reach the second well. If don't see a pressure decrease in this time shut down the frac job and try again later.
3. ~~After~~ If frac. is successful, and know w/in approx. 15 minutes then still need to keep pumping for 2-3 hours to pump out ~~overcome~~ low pressure fracture?

~~4~~ Use frac pump~~s~~ to pump water through fracture and clean out frac

4. Form a triangular cavern at well bore and estimate amount of dissolving of fracture is minimal.

Other notes of interest.

1) A.L.H. has done 3 wells like this in West Texas where fracture between 2 wells, also did B&E wells

Crawford Tx
Sara OK
Snyder Tx

2) Conoco did a pilot test for dissolving potash, and this has good reference information. Will send

3) Lots of literature from NY & MI area where have salt fields and drill a # of wells and frac. between.

4) Can determine shape of cavity using a sonar survey. V. expensive. Tool cost ~ $50,000. Must pull tubing and run in open hole. Radioactive, so if lose tool also lose hole.

5) Determined size of cavity by pumping propane into cavity - where? Found cavity diameter 106'

6) TPC wants to drill these wells because B&E won't sell them brine + Roland trucking brine well gives priority to their trucks.

ALH - Will send more info. on subsidence
Will send the missing C-101 for Well No.
C-102 for Well No.

KMB 1/2

March 12, 1991

Bill Hanberg 1-835-5808
U.S. Burea of Mines - Soccoro, NM

RE: Concern of collapse in Carlsbad area due to
salt extraction via brine well operations
B&E operating in area for 10+ years
The Permian Corp. requesting permit for new operation

B.H. - Yes, there should be a concern over possible
collapse and/or subsidence dt mining.
There's a significant potential for problems.

Factors Effecting Collapse:

1) Framework - After salt is dissolved what kind of framework is left? If you leave an interconnected framework of more resistive materials (ie. siltstones, resistive evaporites, carbonates) then this would help prevent collapse/~~dissolu~~subsidence
2) Overlying material. - Actual composition of materials is not as significant as the bedding. The more layers (thinly bedded) the less competent, layering is exponentially related to competence (cubed). thin $10 \times 0 = 10^3$ thick $100 = 100^3$

{Surprised mining salt here dt east of here Salado has
been dissolved away @ Pecos River. See alot of
collapse in Ohio/Penn/Wyo ass^{ed} w/ shallow coal mining}

KMB 2/2

Monitoring & Survallence

There should be some type of monictoring to record any changes which might ~~[illegible]~~ identify subsidence and possible collapse.

1) Tiltmeters - used both on the surface and @ shallow depths in a borehole. Record tilt of beds. Would need to set up a grid - to cover ($\$1500^{00}$ per meter) area would cost approx \$10,000 to \$20,000.
2) Surveying - could have surveys made of surface features to detect deformation and subsidence.
3) Shallow seismic Survey - to determine any collapse or tilting of strata. Approx $\$5000^{00}$/mile.
4) Gravity Modeling - An indirect method for determining the shape of the cavity. Run gravity lines @ surface to determine shape - a less precise method.
5) Emphirical Methods - Used with coal mining alot. Use the rate of production, volume and brine concentration to estimate/calculate amount of salt removed. The deeper the cavity the Assumes → wider, but the less influence & possibility for collapse

REFS. Bureu of Mines Memoir #24 $\$30^{00}$

GSA - Reviews in Engineering; Man Induced Land Subsidence (Chp. 2 Coal + Insitu Mining)

A. L. Hickerson

PROFESSIONAL ENGINEER
TEXAS #11830K

6067 W. TENTH ST.
ODESSA, TEXAS 79763

OFFICE PHONE:
(915) 381-0531
(915) 563-4730
FAX 915/381-9316
DIRECT LINE: (915) 381-8420

RESIDENCE:
3216 BAINBRIDGE DRIVE
ODESSA, TEXAS 79762
PHONE: (915) 362-4814

CONSERVATION DIVISION
RECEIVED
'91 MAR 7 AM 9 28

March 6, 1991

Mr. William J. Lemay
Director of Oil Conservation Division
State of New Mexico
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

RE: Requested by Kathy Moore, here is the supplemental information for the brine well we requested on February 12, 1991. NW/4 of SE/4 of Section 33, T-21-2, R-27-E.

Dear Sir:

MAPS AND PLATS

Attached is a map prepared by the County Surveyor, which shows the proposed site of the Permian Corporation wells on Orchard Lane, the canal across the west half of SE/4 of Section 33, and the location of the Gregory Steel property. Also we attached a survey of the property and a plat of the Industrial Development Parks properties to the east.

NEARBY WELLS

The closest oil well is the Oxy Tracy #1-D, now being re-entered. This well is approximately 1690 feet west and 470 feet south of the the TPC brine wells. This is more than 1/4 mile away. Attache is a copy of the upper part of a log of a well about 1/2 mile south, which has surface casing set at 400 feet, and the log of another oil well drilled about 2 1/2 miles NE of the TPC site. Attached is a copy of the C-101 and C-102 for the Oxy Tracy #1-D well.

Attached is a copy of a map showing all oil wells drilled in the entire area. The ground water in the area will not be effected by this operation.

WATER WELLS

There have been no water wells drilled within 1/4 mile, because water is provided to the Orchard Lane Industrial Parks area from a city of Carlsbad water line lying along the west side of Orchard Lane.

WATER WELLS CONTINUED

Attached is a copy of a log of a water well drilled about 1/2 mile north of the TPC site. This log shows water sands at 145 feet and at 249 feet. The water zone at 150 feet is probably the alluvium and the water at 249 feet is probably the Rustler zone.

USGS MAP

Attached is a copy of a part of a USGS map which shows the surface drainage to be toward the southwest toward Orchard Lane and the canal. The canal at its closest point is approximately 980 feet from the center of the TPC tract.

GEOLOGY AND WELL SKETCH

Attached is sketch #G-K of the two well casing plan on which is shown the geologic formation encountered.

CONSTRUCTION PROCEDURE

The 7 5/8 inch surface casing will be set through all fresh water aquifers and cement circulated. The 5 1/2 inch production string will be set inside the 7 5/8 inch and again cement circulated. After this production string is cemented, a cement bond log will be run. The well and casing will then be pressure tested to 500 PSIG. At this shallow depth, no deviation check will be necessary. Also no cores of the rock salt will be necessary.

STIMULATION

This is not an injection well where produced water is pumped into a porous zone.

No stimulation is planned. The rock salt is impervious, and as the salt is dissolved by the injection of fresh water the brine is returned to the surface to surface storage tanks for subsequent movement to oil well drilling sites for use as a drilling fluid. No stimulation is necessary as the fresh water introduced down well No. 2 will readily dissolve the rock salt as it travels across to well No. 1.

Because the rock salt section in this area is only about 100 feet thick, it is necessary to drill two wells into the salt, initiate a fracture through the rock salt across to No. 1 well, where the brine goes up the well bore to storage after becoming saturated by traveling through the 300 feet of salt section.

FRACTURE PROCEDURE

The fracture between the wells is made by first circulating fresh water into the No. 1 well down the tubing and out the casing annulus until a hole several feet in diameter is dissolved between the tubing T.D. and the casing seat. This operation creates a larger "target" for the fracture to be initiated from the No. 2 well.

To fracture, fresh water will be pumped down the No. 2 well at a rate of 8 BBLS per minute and it should reach the "target" hole below the No. 1 well in about fifteen minutes. The fracture pressure will be about 800 PSIG for rock salt at this depth. After the fracture reaches the No. 1 well, fresh water is pumped until the fracture crack is washed out all the way to the No. 1 at which time, the water will circulate at a low pressure, at which time the fracture pump is stopped and connections made to permanent pumps and lines for normal operation.

OPERATION

The normal operation will be to pump fresh water down the tubing of the No. 2 well and, because the salt section is impervious, the water will be forced to travel through the fracture in the salt across to well No. 1 and up the tubing and into the brine storage tanks.

PACKERS

It will not be possible to install a packer in well No. 1, because the well will be circulated down the tubing and out the casing annulus while washing out the target well. It is felt that packers will not be necessary because of the extreme care being taken to protect the fresh water by installing and cementing <u>two</u> strings of casing through the fresh water zone.

REVISED FORMS C-101 & C-102 FOR WELLS NO. 1 AND NO. 2

Attached.

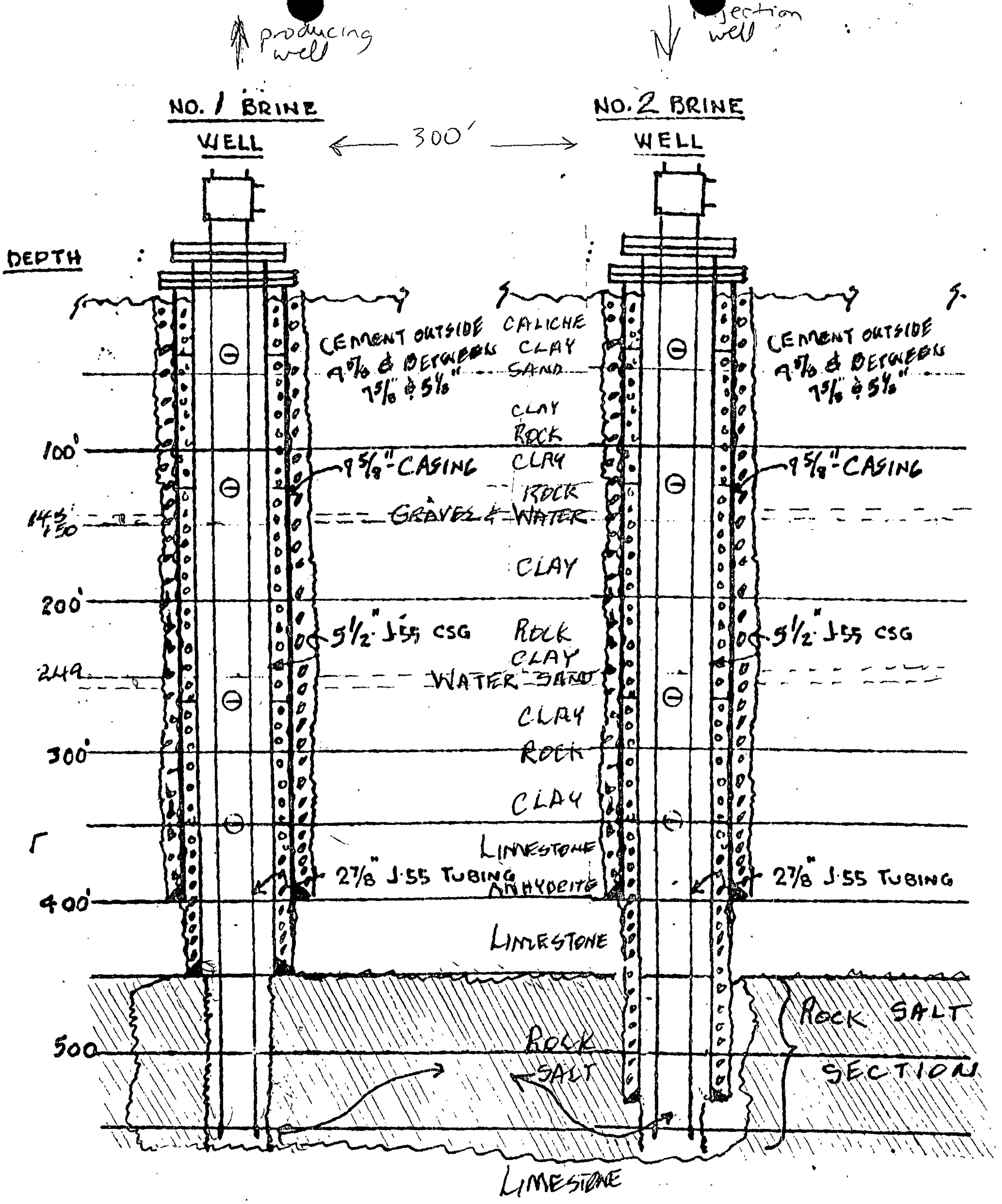
If you have any questions or additional information is needed, please call me (915-381-0531). If you feel that it would expedite approval, I can come to Santa Fe and meet with you.

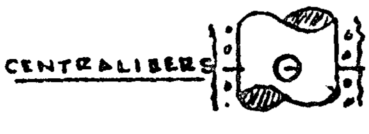
Very Truly Yours,

A.L. Hickerson

A.L. Hickerson

cc NMOC - District Office Artesia
Owen Mobley - TPC Houston
Larry Evans - TPC Midland
Richard Lentz - TPC Hobbs



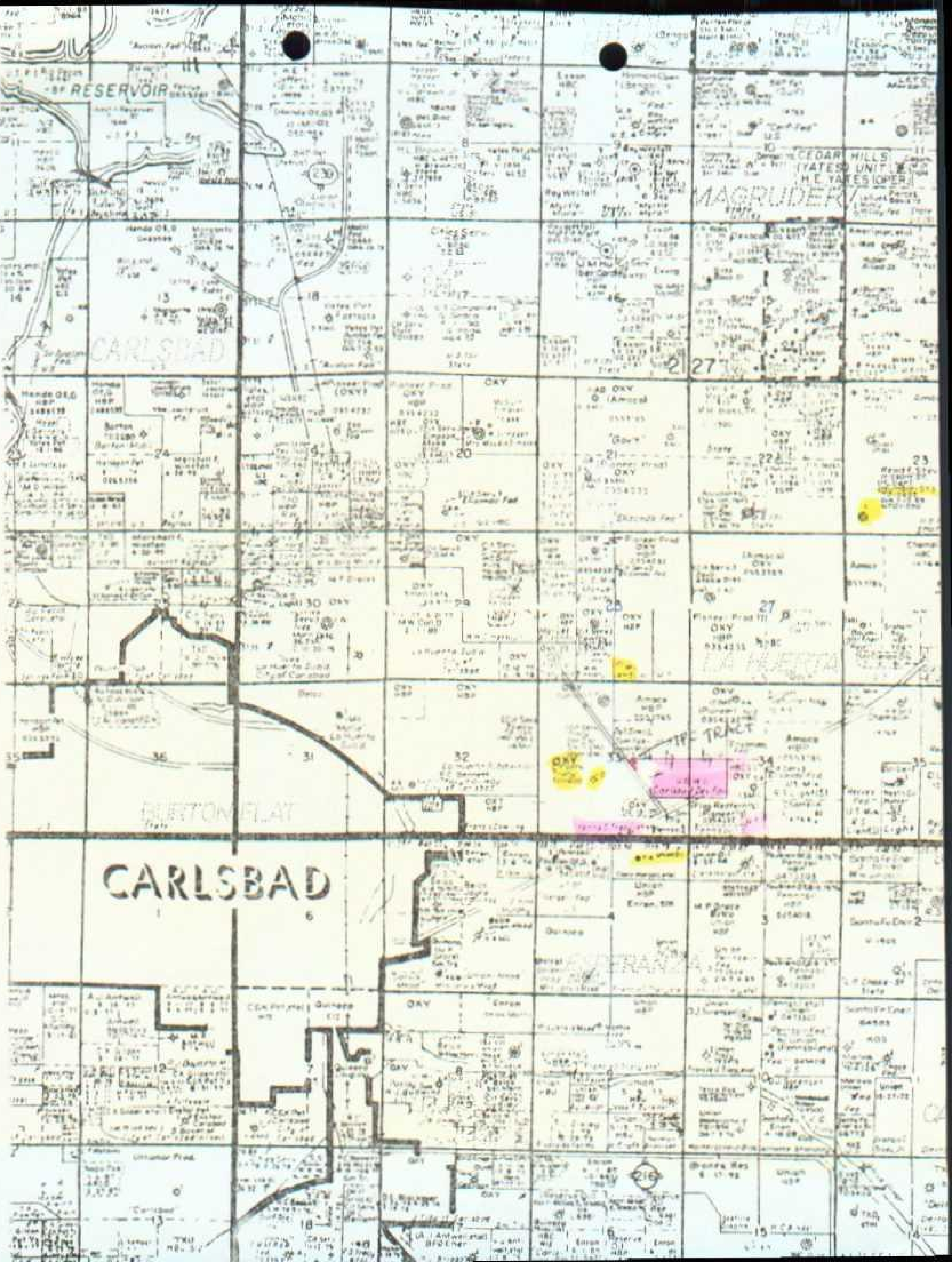


THE
PERMIAN CORPORATION
MIDLAND, TEXAS

BRINE WELL COMPLETIONS
CARLSBAD BRINE STATION

DRAWING NO. 6-K.

DATE 1-10-91 TEX. P.E. 9844


RESERVOIR
CARLSBAD
CEDAR HILLS (YATES) UNIT
H.E. YATES (OPER)
MAGRUDER
LA HUERTA
BURTON FLAT
ESPERANZA
TPE TRACT
CARLSBAD
OXY
Amoco
Pioneer Prod.
Union
Enron
"Govt"
230
216

Well # 85 Mailed 1-2-89

Revised

STATE ENGINEER OFFICE
WELL RECORD

Section 1. GENERAL INFORMATION

(A) Owner of well Jesse W. Laman, Sr. Owner's Well No.
Street or Post Office Address 1419 Eagle Avenue 505-885-2348
City and State Carlsbad, New Mexico 88220

Well was drilled under Permit No. C-2170 and is located in the:

a. W½ ¼ SW ¼ SE ¼ ¼ of Section 28 Township 21S Range 27E

b. Tract No. of Map No. of the

c. Lot No. of Block No. of the
Subdivision, recorded in Eddy County.

d. X= feet, Y= feet, N.M. Coordinate System Zone
the Grant.

(B) Drilling Contractor W.H.Taylor, Sr. License No. WD-604

Address 1401 W. Fox St., Carlsbad, New Mexico 88220

Drilling Began Nov. 28, 1988 Completed Dec. 30, 1988 Type tools Rotary Size of hole 8"

Elevation of land surface or at well is ft. Total depth of well 252'10" ft.

Completed well is ☒ shallow ☐ artesian. Depth to water upon completion of well 60'

Section 2. PRINCIPAL WATER-BEARING STRATA

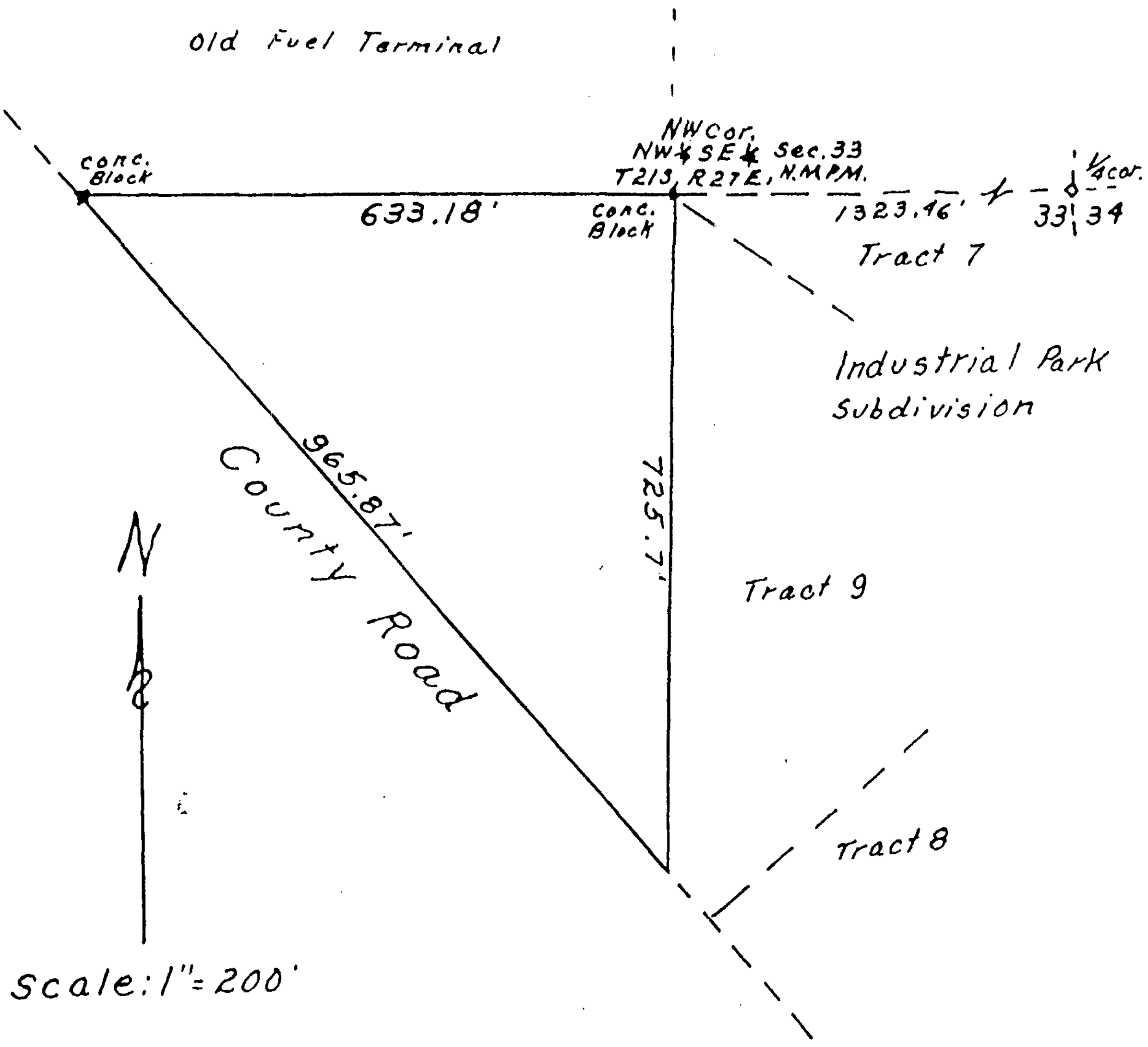
Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation	Estimated Yield (gallons per minute)
From	To			
249'	252'	3'	unknown washed it away	35 gal. Minute
				1 Horse pump

Section 3. RECORD OF CASING

Diameter (inches)	Pounds per foot	Threads per in.	Depth in Feet		Length (feet)	Type of Shoe	Perforations	
			Top	Bottom			From	To
5½			1'	252'10"	253'10"		232	252'10

Section 6. LOG OF HOLE

Depth in Feet		Thickness in Feet	Color and Type of Material Encountered
From	To		
0	11	11	white caliche
11	18	7	yellow caliche
18	33	13	gray clay
33	41	8	cream colored sand
41	80	39	gray clay
80	96	16	conglomerate rock
96	130	34	light brown clay
130	145	15	layers of dark brown clay and light gray clay
145	150	5	corse gravel and sand
150	205	55	dark brown clay and thin layers of gray clay
205	212	7	all most pure white clay with thin layers of b[illegible] y
212	218	6	conglomerate rock
218	238	20	grayish white clay
238	245	7	gray clay with some red clay in it
245	249	4	conglomerate rock
249	252	3	water



PLAT OF SURVEY

DESCRIPTION:

A tract of land in Eddy County, New Mexico, being a part of the NW¼SE¼ of Section 33, T.21S., R.27E., N.M.P.M., and being more particularly described as follows: Beginning at the Northeast corner of said NW¼SE¼, Thence South along the East line of said NW¼SE¼ 725.7 feet to the Northeasterly Right-of-Way line of County Road, Thence Northwesterly along said Right-of-Way line 965.87 feet to the North line of said NW¼ SE¼, Thence East along said North line 633.18 feet to the point of beginning, containing in all 5.274 acres of land, more or less.

This is to certify that the above plat was made by me from field notes of a survey made under my supervision and is true and correct to the best of my knowledge and belief.

NO. 1140
H. F. KANNADY

H. F. Kannady

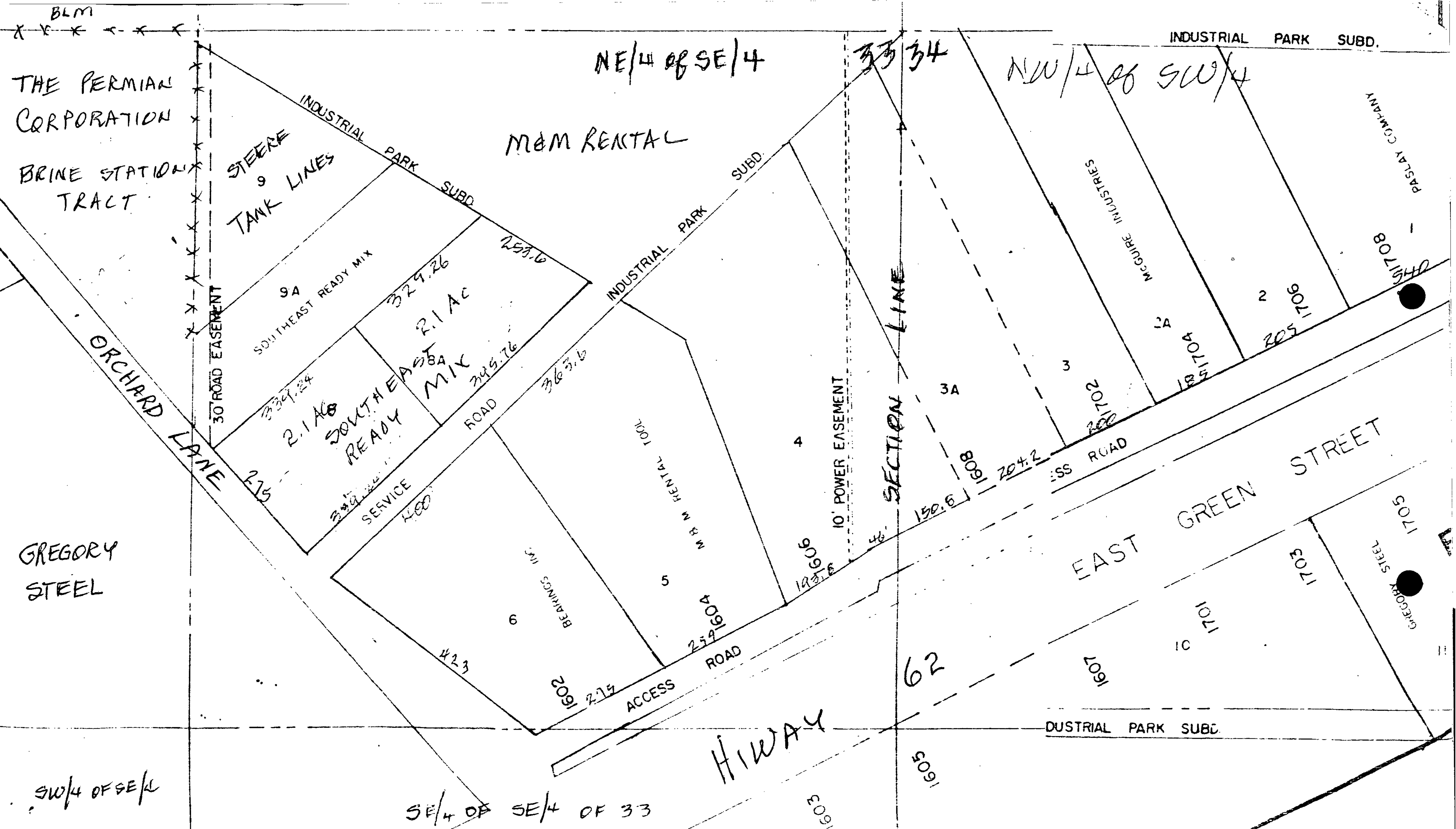
H. F. KANNADY, Registered
Professional Engineer and Land
Surveyor of New Mexico, No. 1140.

6-10-82

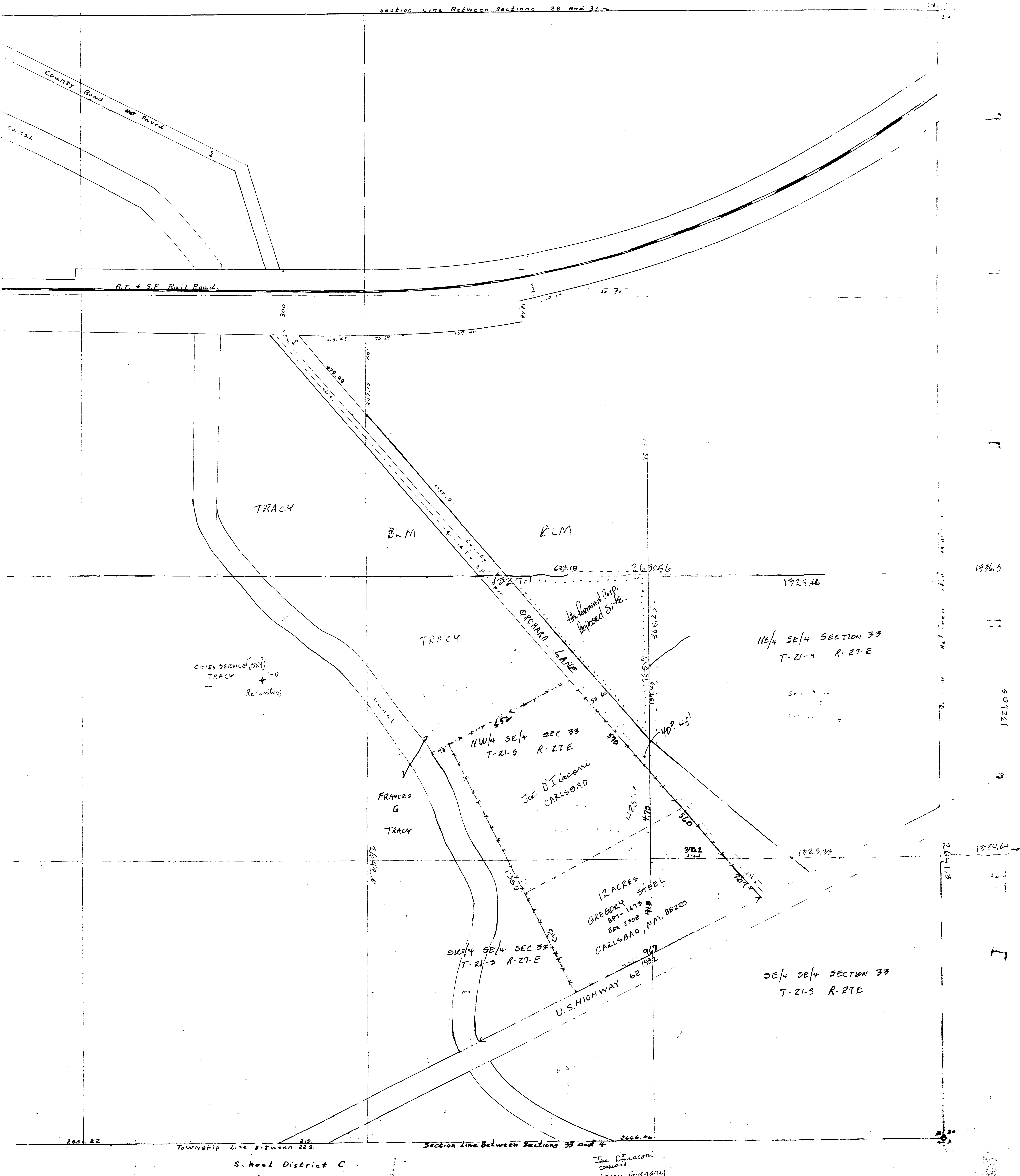
KANNADY ENGINEERING CO.

[redacted]

308 N. Canal
Carlsbad, New Mexico



PLAT OF PROPERTIES LOCATED EAST OF BRINE STATION



Joe D'Iaconi
Carlsbad
Larry Gregory
887-1673
Box 2308
Carlsbad 88220

This well about 1751' From TPC BRINE~~BLT~~ WELLS

Submit to Appropriate District Office
State Lease – 6 copies
Fee Lease – 5 copies

State of New Mexico
Energy, Minerals and Natural Resources Department

Form C-101
Revised 1-1-89

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

RECEIVED
DEC 3 '90
O. C. D.

API NO. (assigned by OCD on New Wells) 30-015-21631

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work:
DRILL ☐ RE-ENTER ☒ DEEPEN ☐ PLUG BACK ☐

b. Type of Well:
OIL WELL ☐ GAS WELL ☒ OTHER SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name
Tracy D

2. Name of Operator
OXY USA Inc.

8. Well No.
1

3. Address of Operator
P.O. Box 50250 Midland, TX. 79710

9. Pool name or Wildcat
Undesignated Morrow

4. Well Location
Unit Letter K : 1980 Feet From The South Line and 1980 Feet From The West Line
Section 33 Township 21S Range 27E NMPM Eddy County

10. Proposed Depth 11575'

11. Formation Morrow

12. Rotary or C.T. Rotary

13. Elevations (Show whether DF, RT, GR, etc.) 3119'

14. Kind & Status Plug. Bond Required/approved

15. Drilling Contractor Unknown

16. Approx. Date Work will start After permit approval

17.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
17 1/2"	13 3/8"	48#	415'	1000	Surface
12 1/4"	9 5/8"	36#	3000'	1075	Surface
8 3/4"	5 1/2"	17-20#	11575'	1300	Top of Wolfcamp

TD-11575'. It is proposed to re-enter and test the Morrow formation. 5 1/2" casing will be set @ 11575'. The Blowout Prevention program will be as follows:

Post ID-1
12-21-90
Re-entry

10" 5000# WP Blind and pipe rams
3000# WP annular preventor and
rotating head

APPROVAL VALID FOR 180 DAYS
PERMIT EXPIRES 6/13/91
UNLESS DRILLING UNDERWAY

Cities Service Oil Co. - Tracy D Com #1
DTD: 11,575 P&A 11-19-75

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE ZONE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

I hereby certify that the information above is true and complete to the best of my knowledge and belief.

SIGNATURE FA Vitrano TITLE Region Operations Manager DATE 11/29/90

TYPE OR PRINT NAME F.A. Vitrano (Prepared by David Stewart) TELEPHONE NO. 9156855717

(This space for State Use)

APPROVED BY ORIGINAL SIGNED BY MIKE WILLIAMS SUPERVISOR, DISTRICT II TITLE DATE DEC 14 1990

CONDITIONS OF APPROVAL, IF ANY:

Submit to Appropriate District Office
State Lease - 4 copies
Fee Lease - 3 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
[illegible]y, Minerals and Natural Resources Depart[illegible]

Form C-102
Revised 1-1-89

RECEIVED
DEC 3 '90
O. C. D.
ARTESIA, OFFICE

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

Operator OXY USA Inc.			Lease Tracy D		Well No. 1
Unit Letter K	Section 33	Township 21S	Range 27E NMPM	County Eddy	

Actual Footage Location of Well:
1980 feet from the South line and 1980 feet from the West line

Ground level Elev. 3119'	Producing Formation Morrow	Pool Undesignated	Dedicated Acreage: 320 Acres

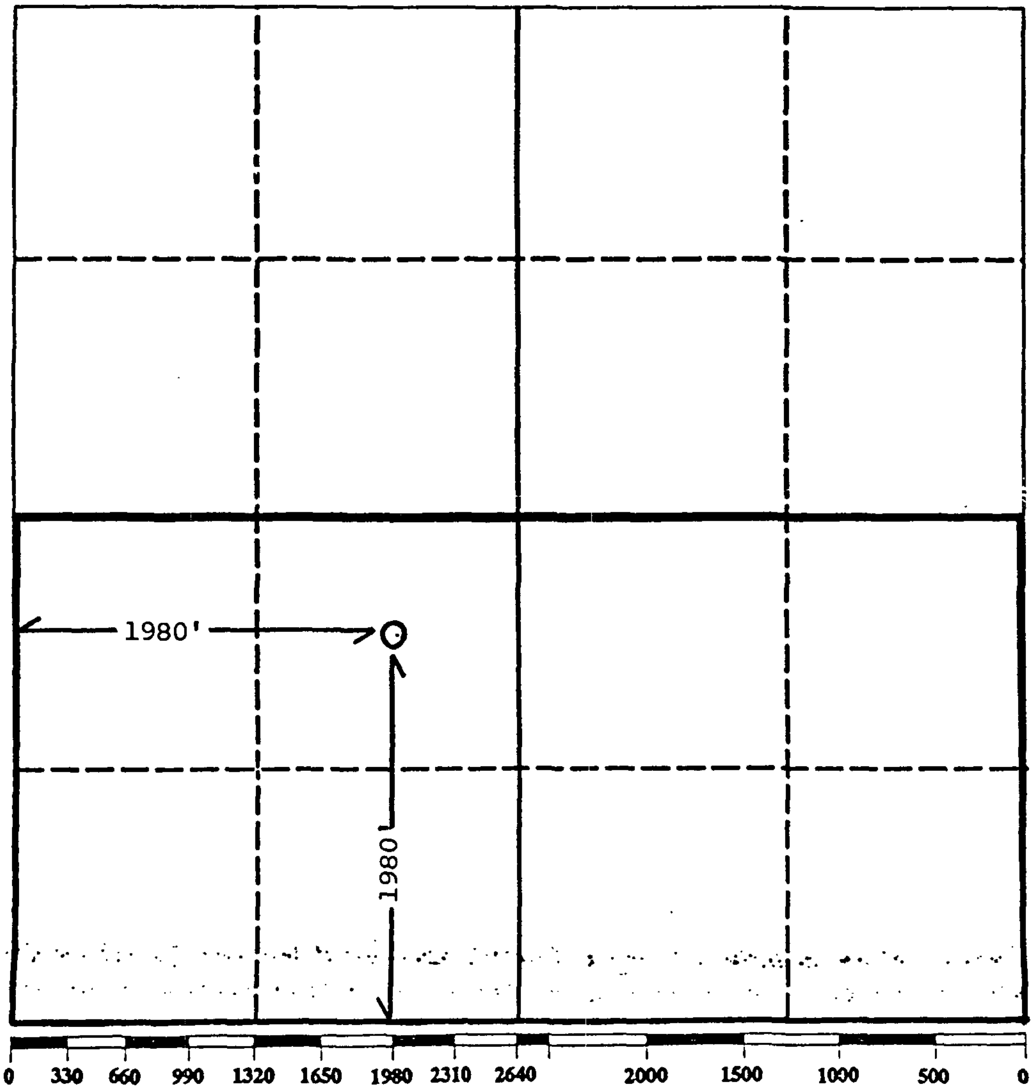
1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

3. If more than one lease of different ownership is dedicated to the well, have the interest of all owners been consolidated by communitization, unitization, force-pooling, etc.?
☐ Yes ☐ No If answer is "yes" type of consolidation ____

If answer is "no" list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if neccessary. ____

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interest, has been approved by the Division.



OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature FA Vitrano

Printed Name
F.A. Vitrano

Position
Region Operations Manager

Company
OXY USA Inc.

Date
11/29/90

SURVEYOR CERTIFICATION

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

Date Surveyed

Signature & Seal of Professional Surveyor

Certificate No.

Petroleum Information

a company of The Dun & Bradstreet Corporation

DENVER, COLORADO 80201

REFERENCE Y 3644N

19 API NO. 30-015-21069

SCHLUMBERGER PERFORATING DEPTH CONTROL

COUNTY
FIELD or WILDCAT
LOCATION
WELL HUMBLE STATE #1
COMPANY U. S. GEOLOGICAL SURVEY

COMPANY U. S. GEOLOGICAL SURVEY

WELL HUMBLE STATE #1

FIELD WILDCAT

COUNTY EDDY STATE NEW MEXICO

Location 660 FSL & 660 FWL

Sec. 23 Twp. 21-S Rge. 27-E

Other Services:

Permanent Datum: G.L. ; Elev.: 3230.2

Log Measured From G.L. Ft. Above Perm. Datum

Drilling Measured From K.B.

Elev.: K.B.

D.F.

G.L. 3230.2

Date	10-30-67		
Run No.	ONE		
Type Log	NEUTRON-PDC		
Depth — Driller	2950		
Depth — Logger	2939		
Bottom logged interval	2938		
Top logged interval	0		
Type fluid in hole	WATER		
Salinity, PPM Cl.			
Density			
Level	88		
Max. rec. temp., deg F.			
Operating rig time	3 HOURS		
Recorded By	OLSON		
Witnessed By	HISS		

BORE-HOLE RECORD			CASING RECORD			
Bit Size	From	To	Size	Wgt.	From	To
			9 5/8	40#	4800	700
			13 3/8		700	SURFACE

The well name, location and borehole reference data were furnished by the customer

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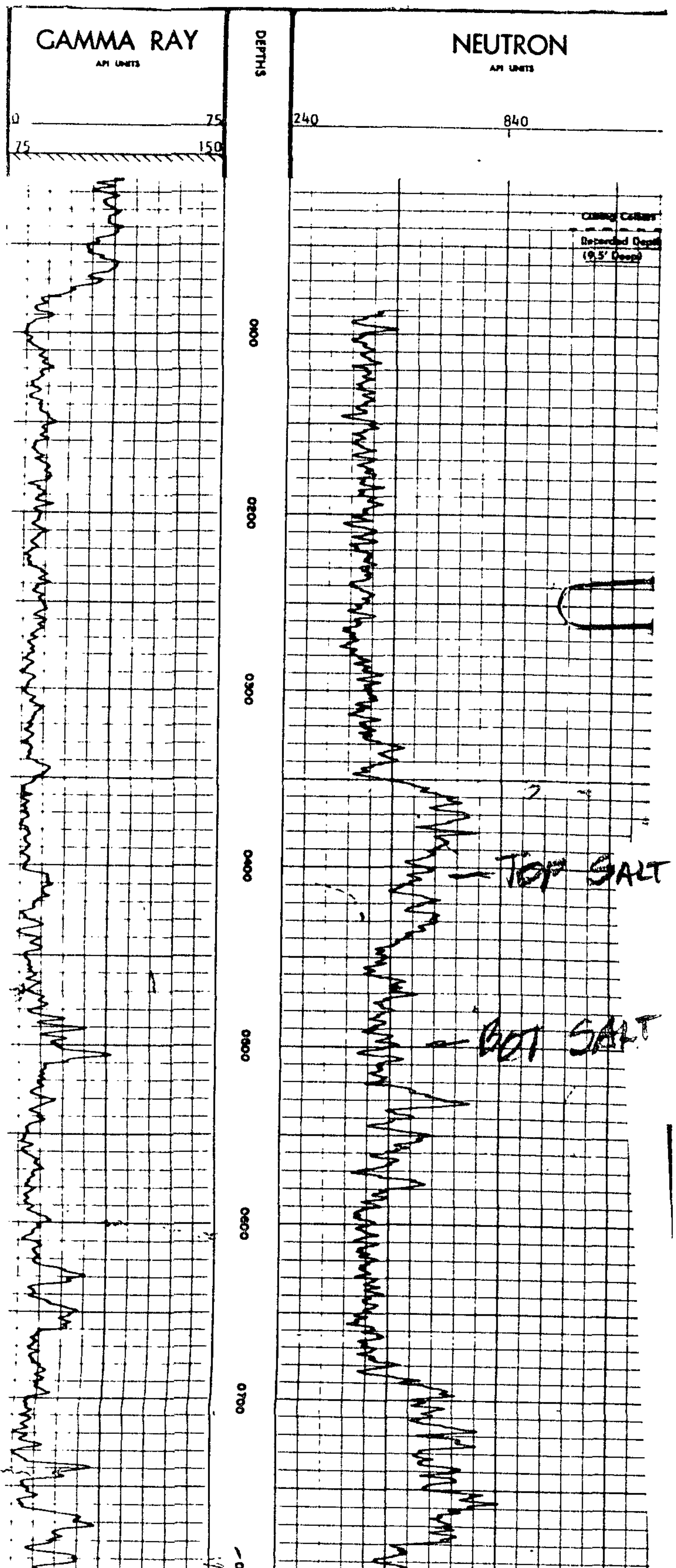


REPRODUCTION FOR RESALE IN WHOLE OR PART PROHIBITED

LITHO-DENSITY COMPENSATED NEUTRON

CSU

COMPANY: UNOCAL

WELL: MERSELL "A" NO. 2

FIELD: ESPERANZA DELAWARE
COUNTY: EDDY
STATE: NEW MEXICO
NATION: USA
LOCATION: 660' FNL & 1700' FEL

SEC: 4 TWP: 22S RGE: 27E

RECEIVED
DEC 21 '89
O. C. D.
ARTESIA, OFFICE

PERMANENT DATUM: GL
ELEV. OF PERM. DATUM: 3116.0 F
LOG MEASURED FROM: KB
16.0 F ABOVE PERM. DATUM
DRLG. MEASURED FROM: KB

ELEVATIONS-
KB: 3132.0 F
DF: 3131.0 F
GL: 3116.0 F

DATE: 2 OCT 89
RUN NO: ONE

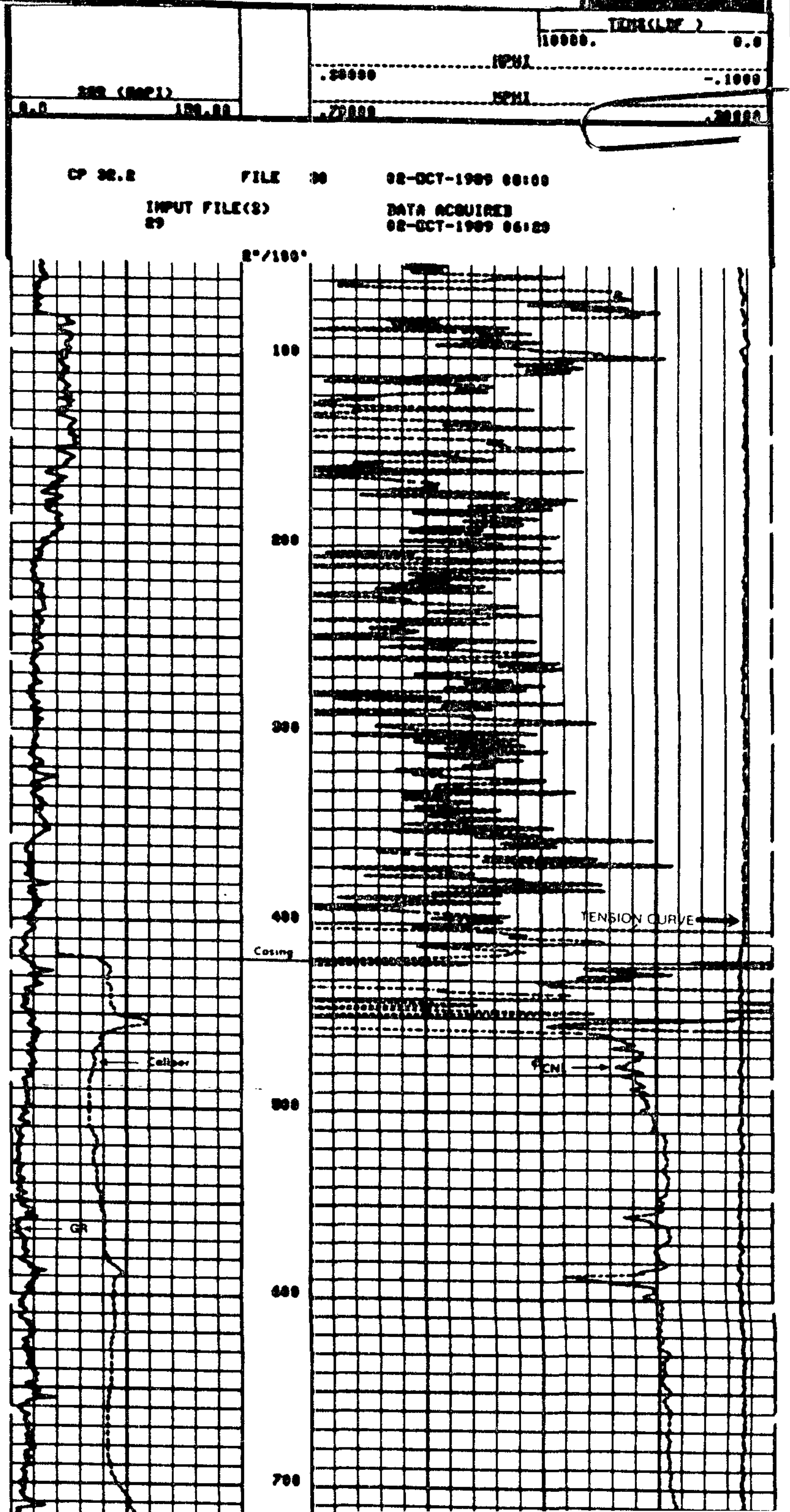
API SERIAL NO:

DEPTH-DRILLER: 4650.0 F
DEPTH-LOGGER: 4649.0 F
BTM. LOG INTERVAL: 4617.0 F
TOP LOG INTERVAL: 50.0 F

CASING-DRILLER: 420.0 F
CASING-LOGGER: 420.0 F
CASING: 8 5/8
WEIGHT: 24.0000 LB/F
BIT SIZE: 7 7/8"
DEPTH: 4650.0 F

OTHER SERVICES-
DLL/MSFL
NGT
LITHO-
CYBERLOOK

PROGRAM
TAPE NO:
32.2
SERVICE
ORDER NO:
321670



PROPOSED TRC BRINE WELL SITE

B&E BRINE STATION

Submit to Appropriate District Office
State Lease – 6 copies
Fee Lease – 5 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work: DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

b. Type of Well: OIL WELL ☐ GAS WELL ☐ OTHER Brine Well SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name Tracy Lease

2. Name of Operator The Permian Corporation

8. Well No. 2

3. Address of Operator PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat Wildcat

4. Well Location
Unit Letter 2 : 1600 Feet From The East Line and 2450 Feet From The South Line
Section 33 Township 21-S Range 27-E NMPM Eddy County

10. Proposed Depth 600'

11. Formation Rock Salt

12. Rotary or C.T. Rotary

13. Elevations (*Show whether DF, RT, GR, etc.*) 3124 GL

14. Kind & Status Plug. Bond #SU1326252/Utica Mut.

15. Drilling Contractor Not Let

16. Approx. Date Work will start 2 wks after approv.

17. PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
10 ½"	7 5/8"	24#	400'	125	circulate
6 3/4"	5 ½"	17#	525'	85	circulate

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE ZONE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

I hereby certify that the information above is true and complete to the best of my knowledge and belief.

SIGNATURE A. L. Hickerson TITLE Consultant DATE 2-11-91

TYPE OR PRINT NAME A.L. Hickerson TELEPHONE NO. 915-381-05

(This space for State Use)

APPROVED BY ____ TITLE ____ DATE ____

CONDITIONS OF APPROVAL, IF ANY:

Submit to Appropriate
District Office
State Lease - 4 copies
Fee Lease - 3 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

Form C-102
Revised 1-1-89

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

Operator THE PERMIAN CORPORATION		Lease TRACY		Well No. 1
Unit Letter	Section 33	Township 21-SOUTH	Range 27 - EAST NMPM	County EDDY

Actual Footage Location of Well:
2230 feet from the SOUTH line and 1400 feet from the EAST line

Ground level Elev. 3122	Producing Formation ROCK SALT	Pool WILDCAT	Dedicated Acreage: 40 Acres

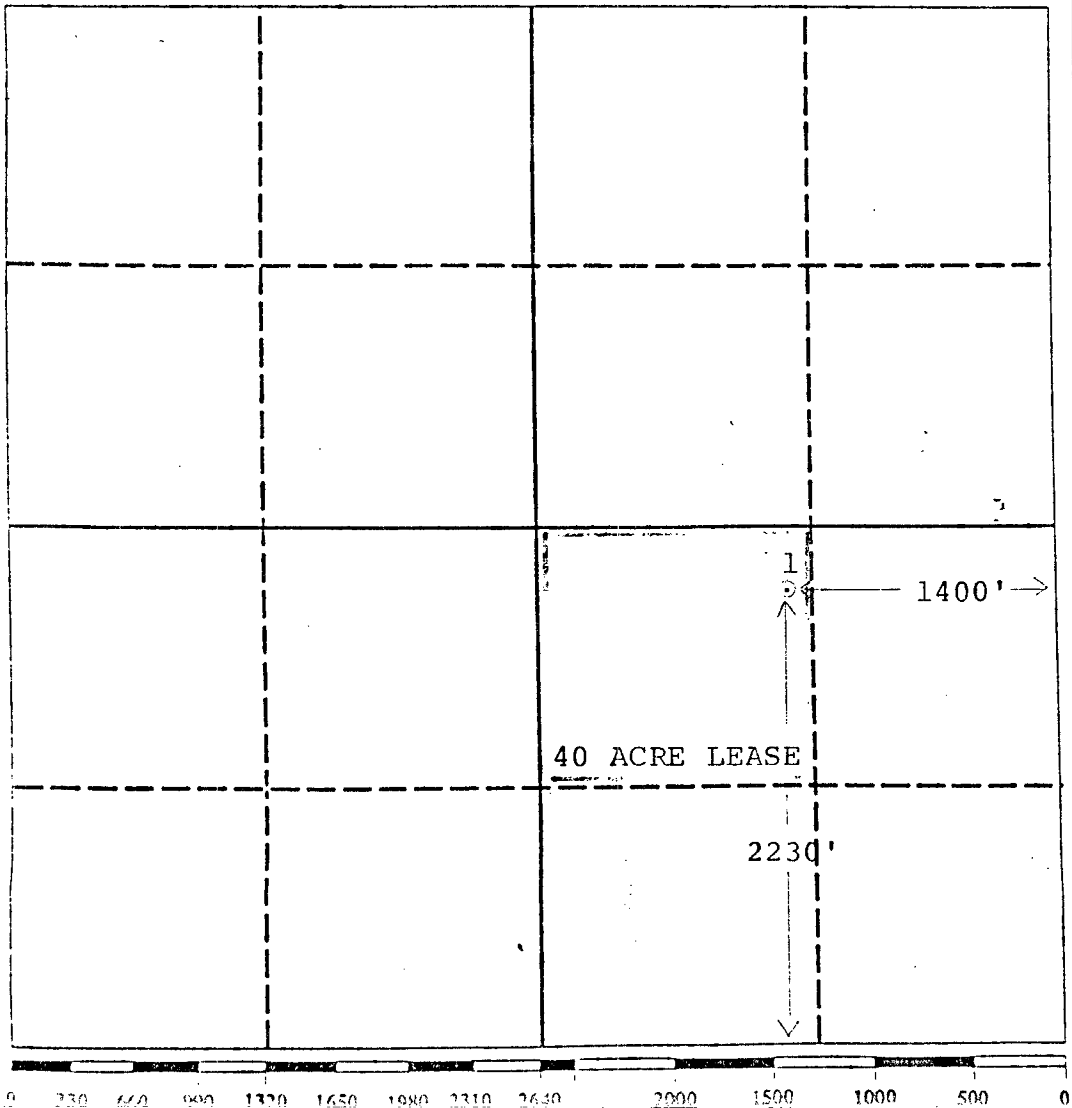
1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

3. If more than one lease of different ownership is dedicated to the well, have the interest of all owners been consolidated by communitization, unitization, force-pooling, etc.?
☐ Yes ☒ No If answer is "yes" type of consolidation ____________

If answer is "no" list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if neccessary. ____________

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interest, has been approved by the Division.



OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature
Marvin J Reynolds

Printed Name
Marvin J. Reynolds

Position
Vice President - Operations

Company
THE PERMIAN CORPORATION

Date
February 14, 1991

SURVEYOR CERTIFICATION

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

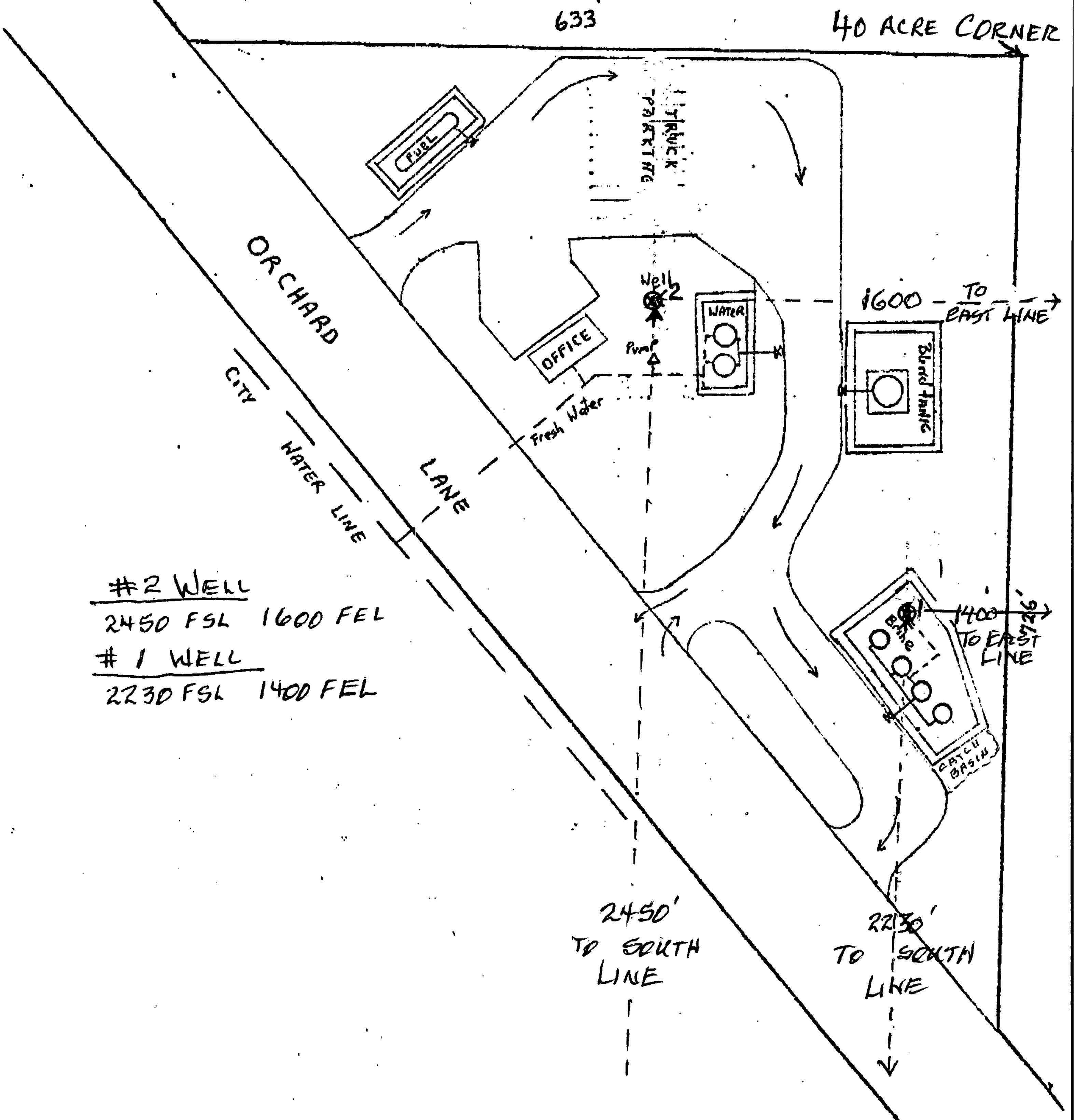
Date Surveyed
February 18, 1991

Signature & Seal of
Professional Surveyor

5412

Certificate No.
NM PE&PS NO. 5412

NW/4 SE/4
SECTION 33 T-21-S R-27-E



#2 WELL
2450 FSL 1600 FEL

#1 WELL
2230 FSL 1400 FEL

THE PERMIAN CORPORATION
CARLSBAD BRINE STATION LAYOUT

Scale 1" = 100'
2-11-91

A. L. Hickerson

OFFICE PHONE:
(915) 381-0531
(915) 563-4730
FAX 915/381-9316
DIRECT LINE: (915) 381-8420

PROFESSIONAL ENGINEER
TEXAS #11830K

6067 W. TENTH ST.
ODESSA, TEXAS 79763

RESIDENCE:
3216 BAINBRIDGE DRIVE
ODESSA, TEXAS 79762
PHONE: (915) 362-4814

CONSERVATION DIVISION
RECEIVED
'91 FEB 20 AM 9 35

February 12, 1991

Mr. William J. Lemay
Director of Oil Conservation Division
State of New Mexico
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

RE: Request for brine well permit for The Permian Corporation in Eddy County, NW/4 of SE/4 of Section 33, T-21-S, R-27-E.

Dear Sir;

Permission is requested to install a brine production facility (rock salt solution mining) in Eddy County.

This facility will be used for the production of saturated 10 lb. per gallon brine for use by the oil industry.

Attached is the application cover page, description of items I through XI, form C101 and C102, sketch of well casing plan, and a detail plot plan of the facility.

Your early and favorable consideration will be appreciated.

If you have any questions or if additional information is needed, please let me know (915-381-0531).

Very Truly Yours,

A.L. Hickerson

Enclosures

cc NMOC District Office-Artesia
Owen Mobley - TPC
Larry Evans - TPC
Richard Lentz - TPC

11/90

State of New Mexico
Energy, Minerals and Natural Resources Department
OIL CONSERVATION DIVISION
P.O. Box 2088
Santa Fe, NM 87501

DISCHARGE PLAN APPLICATION FOR BRINE EXTRACTION FACILITIES

(Refer to OCD Guidelines for assistance in completing the application.)

I. FACILITY NAME: TPC - Carlsbad Brine Station

II. OPERATOR: The Permian Corporation

ADDRESS: P.O. Box 1183, Houston Tx 77001

CONTACT PERSON: Owen Mobley PHONE: 713-787-2500

III. LOCATION: NW /4 SE /4 Section 33 Township 21 South Range 27 East
Submit large scale topographic map showing exact location.

IV. Attach the name and address of the landowner of the facility site and landowners of record within one-half mile of the site.

V. Attach a description of the sources and quantities of fluids at the facility.

VI. Attach a description of all fluid transferring and handling facilities.

VII. Attach a description of underground facilities.

VIII. Attach a contingency plan for reporting and clean-up of spills or releases.

IX. Attach geological/hydrological evidence demonstrating that disposal of oil field wastes will not adversely impact fresh water.

X. Attach such other information as is necessary to demonstrate compliance with any other OCD rules, regulations and/or orders.

XI. CERTIFICATION

I hereby certify that the information submitted with this application is true and correct to the best of my knowledge and belief.

Name: A.L. Hickerson Title: Prof. Engr. #11830K

Signature: A.L. Hickerson Date: 2-04-91

DISTRIBUTION: Original and one copy to Santa Fe with one copy to appropriate Division District Office.

BRINE WELL APPLICATION
FOR TPC CARLSBAD BRINE STATION

ITEM IV - Names and addresses of landowners within one half mile of site.

EDDY TRUST -
Dr. George D. Eddy, Jr., Trustee
809 Terrace Mountain Drive
Austin, Texas 78746

TRACY TRUST-
Charles D. Tracy, Trustee
1235 North Loop West, Suite 907
Houston, Texas 77008

TRACY TRUST -
Louise Tracy, Trustee
8603 Enchanted Forest Drive
Houston, Texas 77088

Joe D'Iaconi
South Country Club Road
Carlsbad, New Mexico 88220

Gregory Steel
Box 2308
Carlsbad, New Mexico 88220

Steere Tank Lines
921 N. Howard
Carlsbad, New Mexico 88220

Southeast Ready Mix
P.O. Box 638
Carlsbad, New Mexico 88220

DKK, Inc.
1604 E. Green
Carlsbad, New Mexico 88220

Bearings, Inc.
P.O. Box 1210
Carlsbad, New Mexico 88220

M & M Rental Tools
1604 E. Green
Carlsbad, New Mexico 88220

U.S. Land - Bureau of Land Management
Box 1449
Santa Fe, NM 87504

ITEM V - Description, source and quantity of fluid at the facility.

Source - Fresh water from the City of Carlsbad
quantity (2) 500 bbl tanks
estimated us age of 20,000 bbls a month

Brine Water fron brine wells. Fresh water is circulated through the underground rock salt section to dissolve the salt.

Quantity - Stored in (4) 500 bbl tanks for subsequent hauling to drilling sites for use as a drilling and completion fluid.

ITEM VI - Description of fluid transferring and handling facilities.
Pipelines - coated steel pipe and PVC pipe

Pumps - Deming Centrifugal pump or equivalent, with electical motor.

ITEM VII - Description of Underground Facilities

Casing and cementing as shown on attached sketch No. G-K for two wells.

ITEM VIII- Contingency Plan for Reporting and Clean Up of Spills or Releases.

The fluid handling area will be surrounded by an earthen dike so that there will be no releases from the area.

Minor spills from hose dis-connection will be contained in the buried plastic barrels provided. A plastic lined catch basin will be provided for retention of any brine spills so that it can be pumped back into storage.

Operator will be on site daily so that any major spills can be reported.

ITEM IX - No Disposal of Oilfield Wastes Will be Done at This Facility.

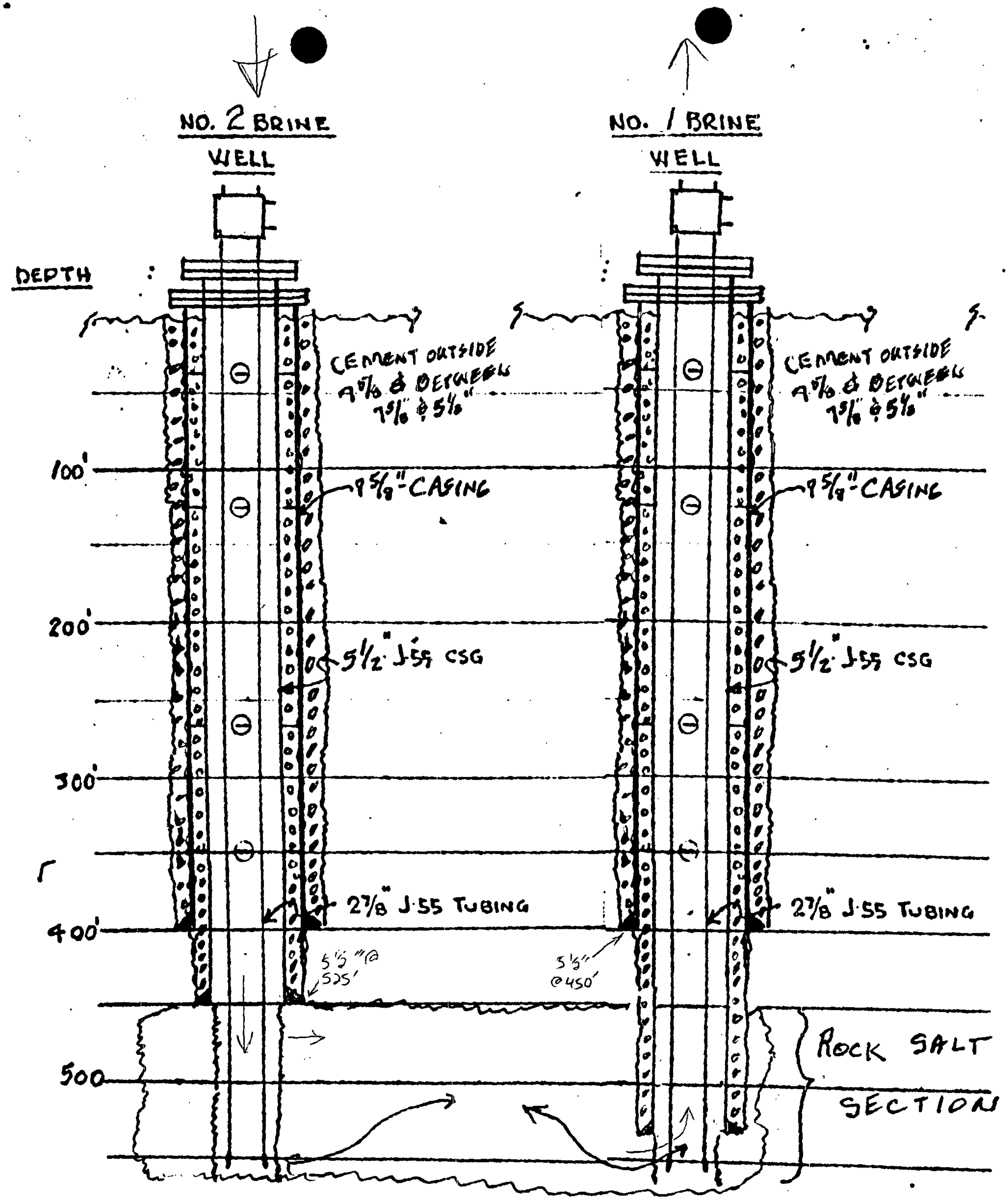
ITEM X - Attached are plats, sketch and form C-101and C102. Pressure integrity tests will be performed on each well to insure proper cementing before any operation is performed.

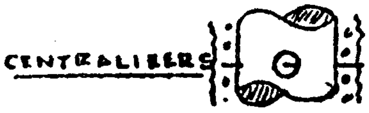
ITEM XI - Other information to demonstrate compliance with rules and regulations.

The surface casing (7 5/8") will be set and cement circulated through all fresh water zones. The deepest fresh water is about 360 feet and the casing will be set at 400 feet.

The production string (5 1/2") will be set inside the surface string and cement circulated. This string will be set through the lime and anhydrite to the top of the rock salt section, with cement circulated.

Open hole will then be drilled through the rock salt section, and fresh water circulated from the No. 2 well to the No. 1 well to dissolve the rock salt and make saturated 10 lb. per gallon brine for use as a drilling and completion fluid by the oil industry.





THE
PERMIAN CORPORATION
MIDLAND, TEXAS

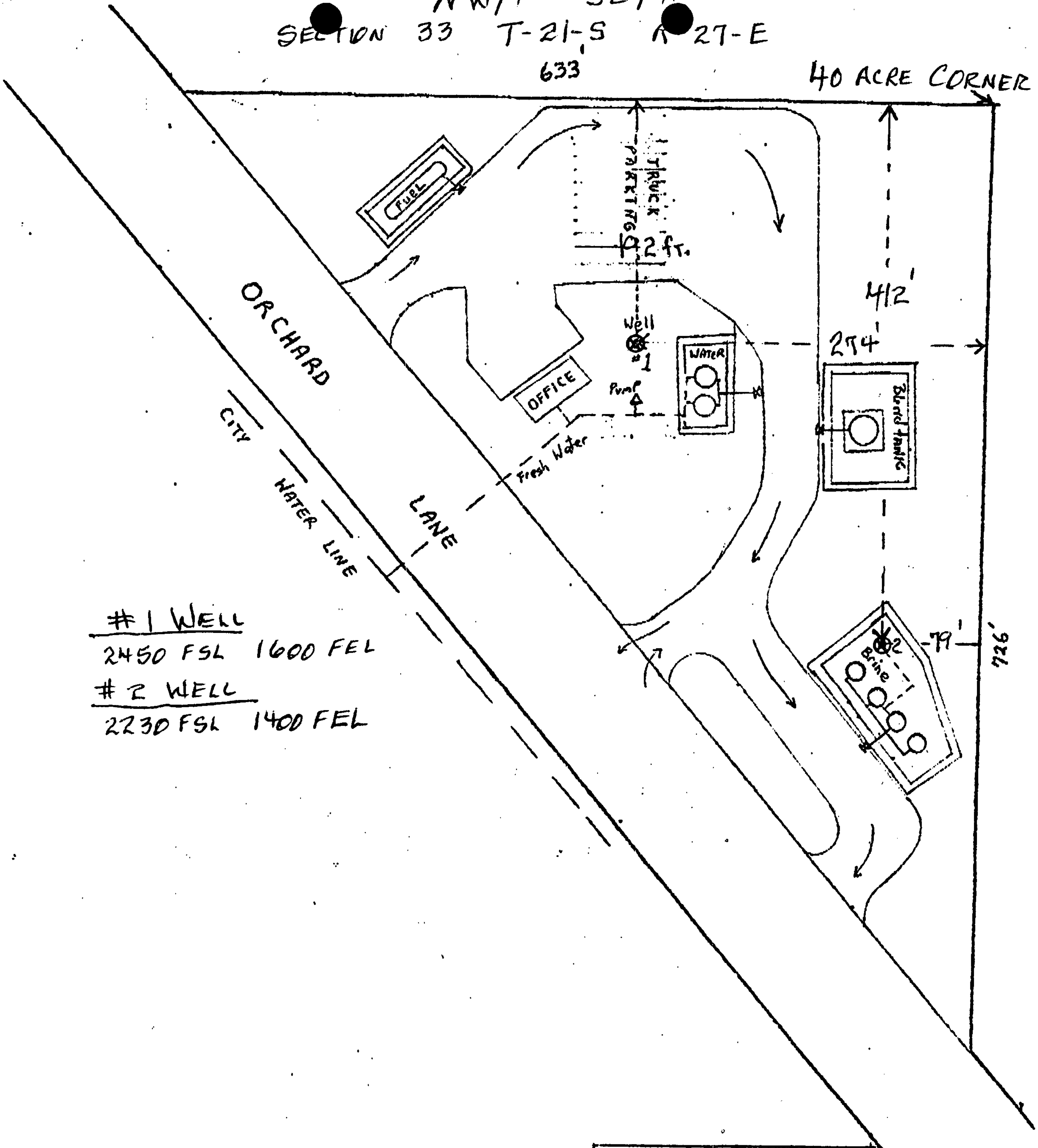
BRINE WELL COMPLETIONS
CARLS[illegible]AD BRINE STATION

DATE 7-10-91 Tex. P.E. 9844

DRAWING NO. 6-K.

Form 203 3-37—18288-D

NW/4 SE/4
SECTION 33 T-21-S R-27-E

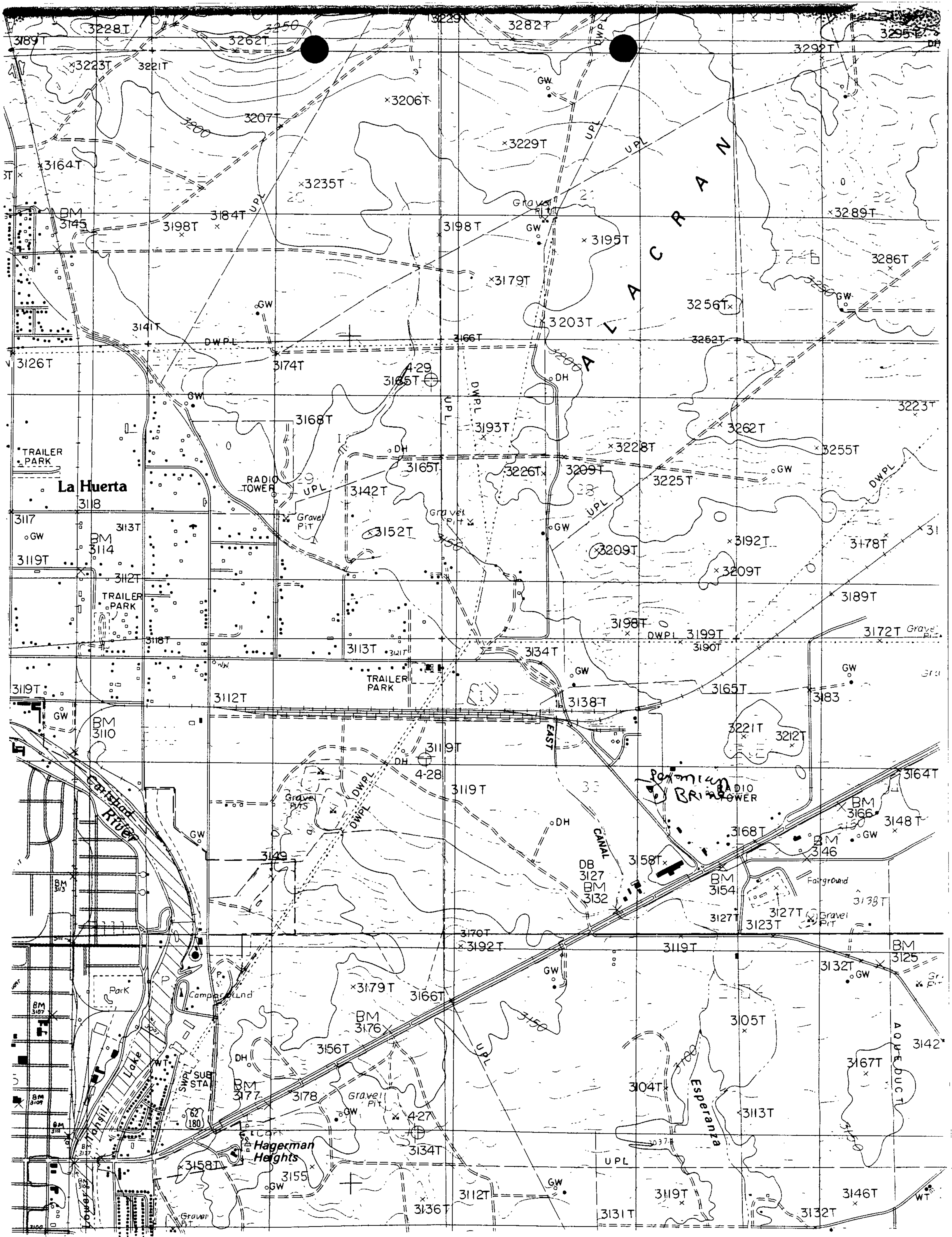


#1 WELL
2450 FSL 1600 FEL

#2 WELL
2230 FSL 1400 FEL

Scale 1" = 100'
2-11-91

THE PERMIAN
CORPORATION
CARLSBAD BRINE
STATION LAYOUT


A L A C R A N
La Huerta
TRAILER PARK
TRAILER PARK
TRAILER PARK
RADIO TOWER
RADIO TOWER
Carlsbad
River
Tansill
Lake
Lower
Hagerman Heights
Campground
Park
Fairground
Esperanza
CANAL
EAST
AQUEDUCT
SUB STA
62
180
Gravel Pit
Gravel Pits
UPL
DWPL
SWPL
GW
DH
WT
BM 3145
BM 3114
BM 3110
BM 3166
BM 3146
BM 3154
BM 3132
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3112T
3119T
3146T
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3131T
3132T
3200
3250
3150
3100
Permian
Brine

A. L. Hickerson

OFFICE PHONE:
(915) 381-0531
(915) 563-4730
FAX 915/381-9316
DIRECT LINE: (915) 381-8420

PROFESSIONAL ENGINEER
TEXAS #11830K

6067 W. TENTH ST.,
ODESSA, TEXAS 79763

RESIDENCE:
3216 BAINBRIDGE DRIVE
ODESSA, TEXAS 79762
PHONE: (915) 362-4814

OIL CONSERVATION DIVISION
RECEIVED
'91 FEB 20 AM 9 35

February 12, 1991

Mr. William J. Lemay
Director of Oil Conservation Division
State of New Mexico
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

RE: Request for brine well permit for The Permian Corporation in Eddy County, NW/4 of SE/4 of Section 33, T-21-S, R-27-E.

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Your early and favorable consideration will be appreciated.

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Very Truly Yours,

A. L. Hickerson

A.L. Hickerson

Enclosures

cc NMOC District Office-Artesia
Owen Mobley - TPC
Larry Evans - TPC
Richard Lentz - TPC

11/90

State of New Mexico
Energy, Minerals and Natural Resources Department
OIL CONSERVATION DIVISION
P.O. Box 2088
Santa Fe, NM 87501

DISCHARGE PLAN APPLICATION FOR BRINE EXTRACTION FACILITIES

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ADDRESS: P.O. Box 1183, Houston Tx 77001

CONTACT PERSON: Owen Mobley PHONE: 713-787-2500

III. LOCATION: NW /4 SE /4 Section 33 Township 21 South Range 27 East
Submit large scale topographic map showing exact location.

IV. Attach the name and address of the landowner of the facility site and landowners of record within one-half mile of the site.

V. Attach a description of the sources and quantities of fluids at the facility.

VI. Attach a description of all fluid transferring and handling facilities.

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Name: A.L. Hickerson Title: Prof. Engr. #11830K

Signature: A.L. Hickerson Date: 2-04-91

DISTRIBUTION: Original and one copy to Santa Fe with one copy to appropriate Division District Office.

BRINE WELL APPLICATION
FOR TPC CARLSBAD BRINE STATION

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Louise Tracy, Trustee
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U.S. Land - Bureau of Land Management
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Santa Fe, NM 87504

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Submit to Appropriate
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State Lease – 6 copies
Fee Lease – 5 copies

DISTRICT I
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DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. Type of Work: DRILL ☒ RE-ENTER ☐ DEEPEN ☐ PLUG BACK ☐

b. Type of Well: OIL WELL ☐ GAS WELL ☐ OTHER Brine Well SINGLE ZONE ☒ MULTIPLE ZONE ☐

7. Lease Name or Unit Agreement Name Tracy Lease

2. Name of Operator The Permian Corporation

8. Well No. 1

3. Address of Operator PO BOX 1183 HOUSTON TX 77001

9. Pool name or Wildcat Wildcat

4. Well Location
Unit Letter 1 : 1600 Feet From The EAST Line and 2450 Feet From The South Line
Section 33 Township 21-S Range 27-E NMPM EDDY County

10. Proposed Depth 600'

11. Formation Rock Salt

12. Rotary or C.T. Rotary

13. Elevations *(Show whether DF, RT, GR, etc.)* 3120 GL

14. Kind & Status Plug. Bond #SU1326252/Utica Mut

15. Drilling Contractor Not Let

16. Approx. Date Work will start 2 wks after approv.

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SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
10½"	7 5/8"	24#	400'	125	circulate
6 3/4"	5 ½"	17#	450'	75	circulate

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE ZONE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

I hereby certify that the information above is true and complete to the best of my knowledge and belief.

SIGNATURE A. L. Hickerson TITLE Consultant DATE 2-11-91

TYPE OR PRINT NAME A.L. Hickerson TELEPHONE NO. 915-381-05

(This space for State Use)

APPROVED BY ____ TITLE ____ DATE ____

CONDITIONS OF APPROVAL, IF ANY:

Submit to Appropriate
District Office
State Lease – 6 copies
Fee Lease – 5 copies

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DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

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1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
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Form C-101
Revised 1-1-89

API NO. (assigned by OCD on New Wells)

5. Indicate Type of Lease STATE ☐ FEE ☒

6. State Oil & Gas Lease No.

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a. Type of Work:

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9. Pool name or Wildcat Wildcat

4. Well Location
Unit Letter 2 : 1400 Feet From The East Line and 2230 Feet From The South Line

Section 33 Township 21-S Range 27-E NMPM Eddy County

10. Proposed Depth 600'

11. Formation Rock Salt

12. Rotary or C.T. Rotary

13. Elevations (*Show whether DF, RT, GR, etc.*) 3120 GL

14. Kind & Status Plug. Bond #SU1326252/Utica Mut.

15. Drilling Contractor Not Let

16. Approx. Date Work will start 2 wks after approv.

PROPOSED CASING AND CEMENT PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	SACKS OF CEMENT	EST. TOP
10 ½"	7 5/8"	24#	400'	125	circulate
6 3/4"	5 ½"	17#	525'	85	circulate

ABOVE SPACE DESCRIBE PROPOSED PROGRAM: IF PROPOSAL IS TO DEEPEN OR PLUG BACK, GIVE DATA ON PRESENT PRODUCTIVE ZONE AND PROPOSED NEW PRODUCTIVE NE. GIVE BLOWOUT PREVENTER PROGRAM, IF ANY.

ereby certify that the information above is true and complete to the best of my knowledge and belief.

NATURE A. L. Hickerson TITLE Consultant DATE 2-11-91

E OR PRINT NAME A.L. Hickerson TELEPHONE NO. 915-381-0532

is space for State Use)

ROVED BY TITLE DATE

DITIONS OF APPROVAL, IF ANY:

ıbmit to Appropriate
istrict Office
ate Lease - 4 copies
e Lease - 3 copies

STRICT I
). Box 1980, Hobbs, NM 88240

STRICT II
). Drawer DD, Artesia, NM 88210

STRICT III
)0 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

Form C-102
Revised 1-1-89

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

perator THE PERMIAN CORPORATION		Lease TRACY		Well No. 1
nit Letter	Section 33	Township 21-S	Range 27-E NMPM	County EDDY

ctual Footage Location of Well:
1600 feet from the EAST line and 2450 feet from the SOUTH line

round level Elev. 3122	Producing Formation ROCK SALT	Pool WILDCAT	Dedicated Acreage: 40 Acres

1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

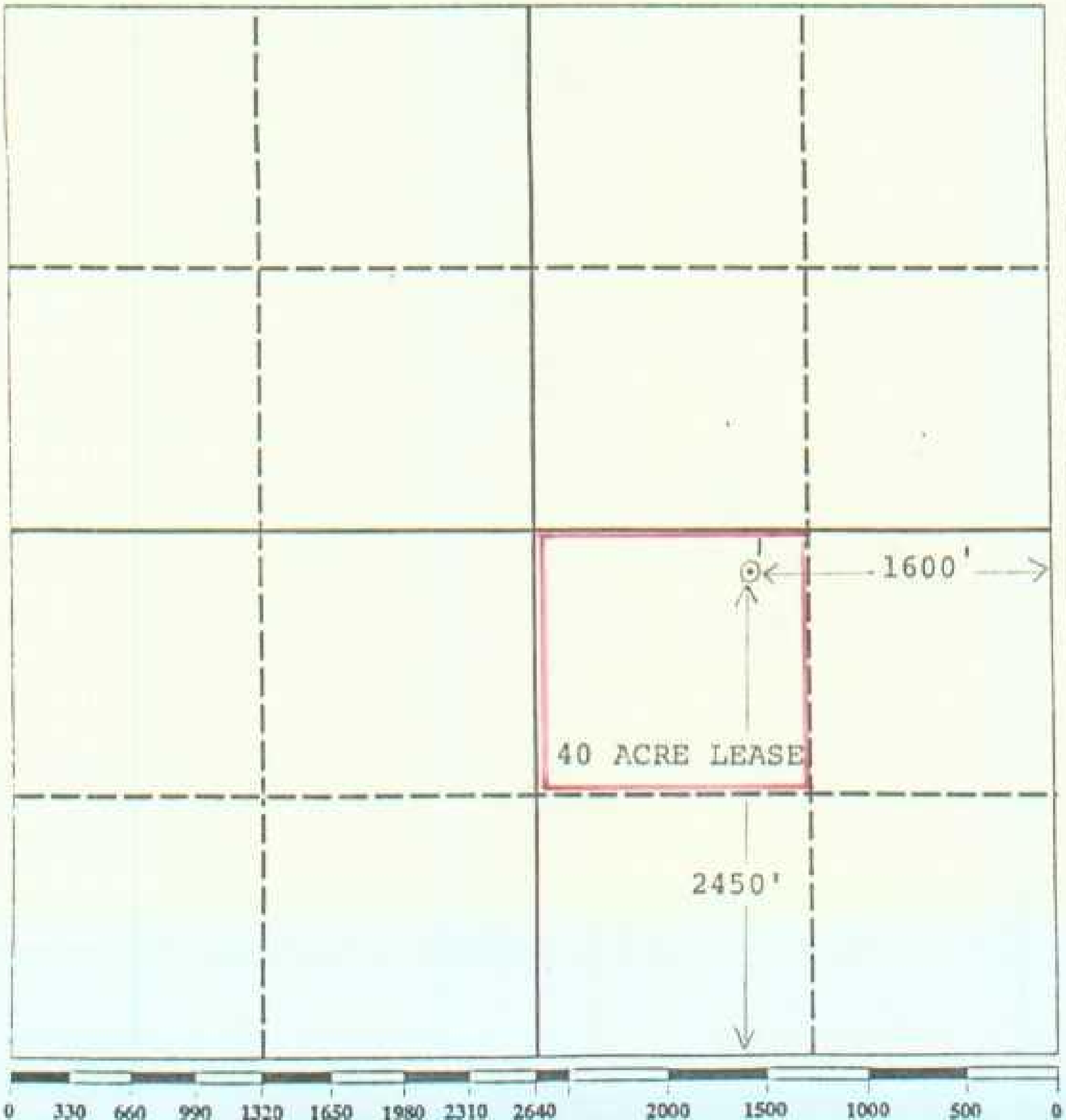
2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

3. If more than one lease of different ownership is dedicated to the well, have the interest of all owners been consolidated by communitization, unitization, force-pooling, etc.?

☐ Yes ☒ No If answer is "yes" type of consolidation ______

If answer is "no" list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if neccessary. ______

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interest, has been approved by the Division.



OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature
Marvin J Reynolds

Printed Name
Marvin J. Reynolds

Position
Vice President - Operations

Company
THE PERMIAN CORPORATION

Date
February 14, 1991

SURVEYOR CERTIFICATION

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

Date Surveyed
February 18, 1991

Signature & Seal of Professional Surveyor

5412

Certificate No.
NM PE&PS NO. 5412

Submit to Appropriate
District Office
State Lease - 4 copies
Fee Lease - 3 copies

DISTRICT I
P.O. Box 1980, Hobbs, NM 88240

DISTRICT II
P.O. Drawer DD, Artesia, NM 88210

DISTRICT III
1000 Rio Brazos Rd., Aztec, NM 87410

State of New Mexico
Energy, Minerals and Natural Resources Department

Form C-102
Revised 1-1-89

OIL CONSERVATION DIVISION

P.O. Box 2088
Santa Fe, New Mexico 87504-2088

WELL LOCATION AND ACREAGE DEDICATION PLAT

All Distances must be from the outer boundaries of the section

Operator THE PERMIAN CORPORATION			Lease TRACY		Well No. 2
Unit Letter	Section 33	Township 21-SOUTH	Range 27 - EAST NMPM	County EDDY	

Actual Footage Location of Well:
2230 feet from the SOUTH line and 1400 feet from the EAST line

Ground level Elev. 3122	Producing Formation ROCK SALT	Pool WILDCAT	Dedicated Acreage: 40 Acres

1. Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

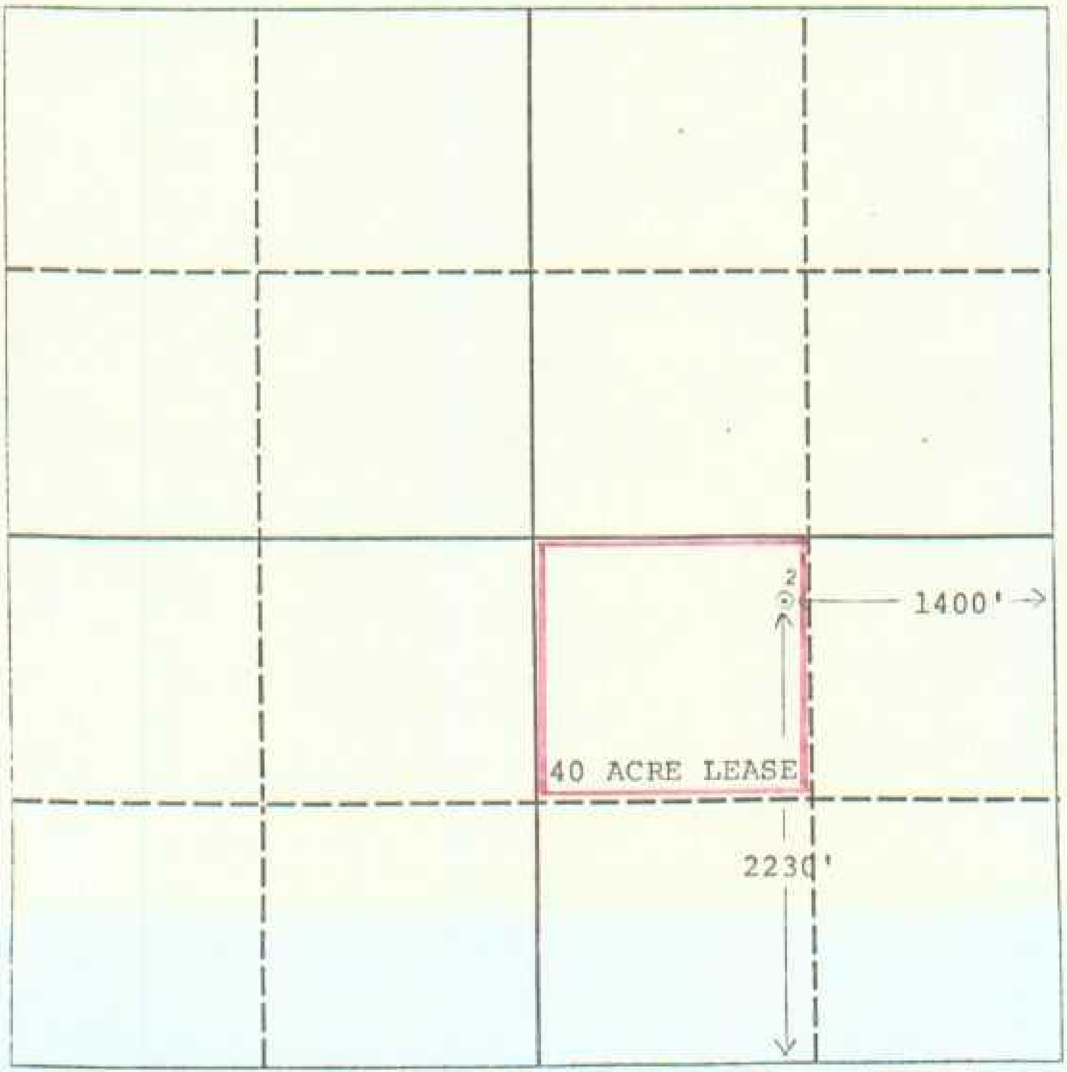
2. If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

3. If more than one lease of different ownership is dedicated to the well, have the interest of all owners been consolidated by communitization, unitization, force-pooling, etc.?

☐ Yes ☒ No If answer is "yes" type of consolidation

If answer is "no" list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if neccessary.

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interest, has been approved by the Division.



OPERATOR CERTIFICATION

I hereby certify that the information contained herein in true and complete to the best of my knowledge and belief.

Signature Marvin J Reynolds

Printed Name
Marvin J. Reynolds

Position
Vice President - Operations

Company
THE PERMIAN CORPORATION

Date
February 14, 1991

SURVEYOR CERTIFICATION

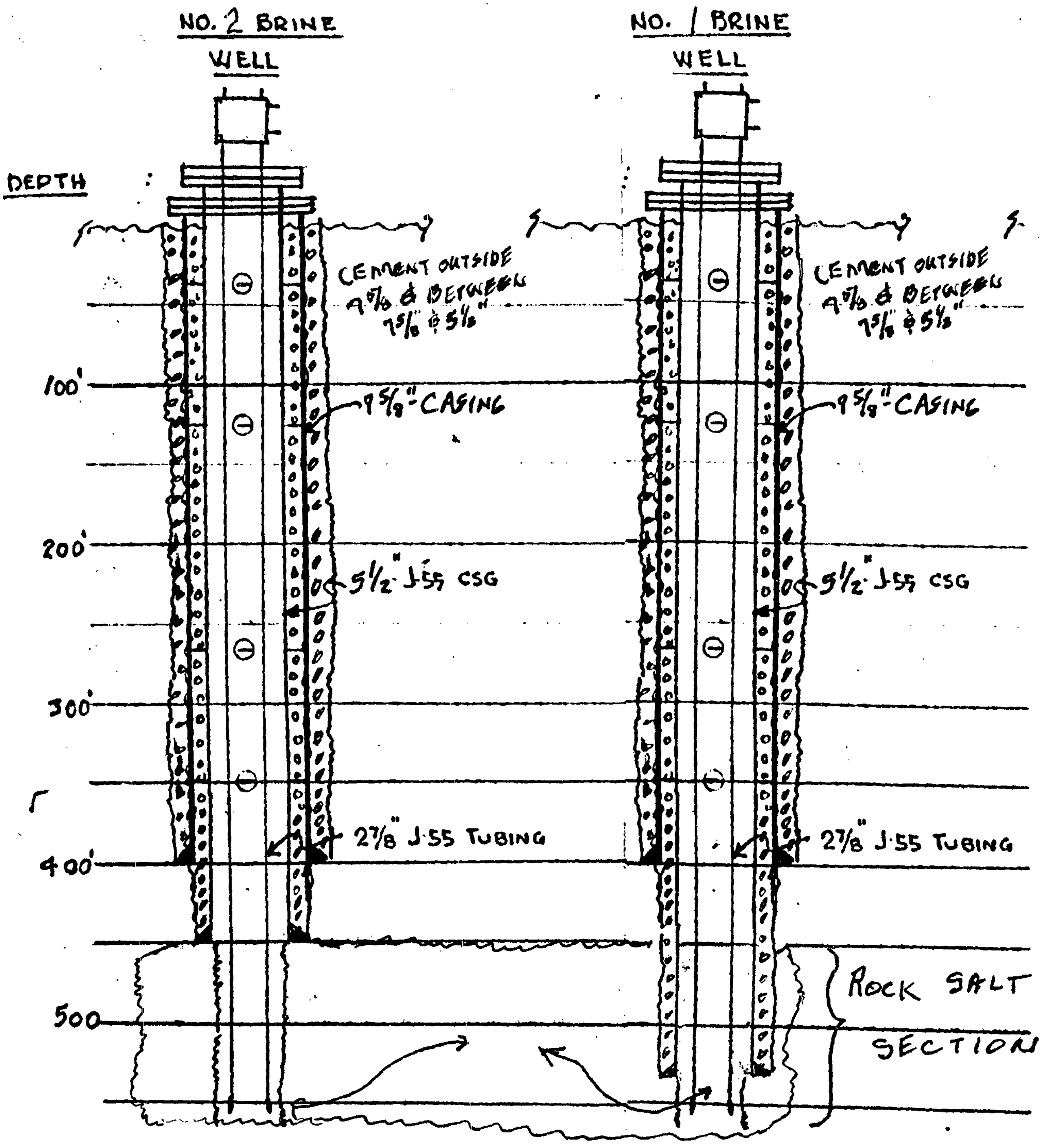
I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervison, and that the same is true and correct to the best of my knowledge and belief.

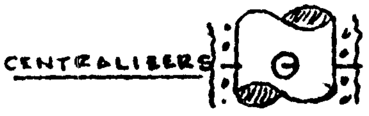
Date Surveyed
February 18, 1991

Signature & Seal of
Professional Surveyor

DAN R. REDDY
5412

Certificate No.
NM PE&PS NO. 5412





THE
PERMIAN CORPORATION
MIDLAND, TEXAS

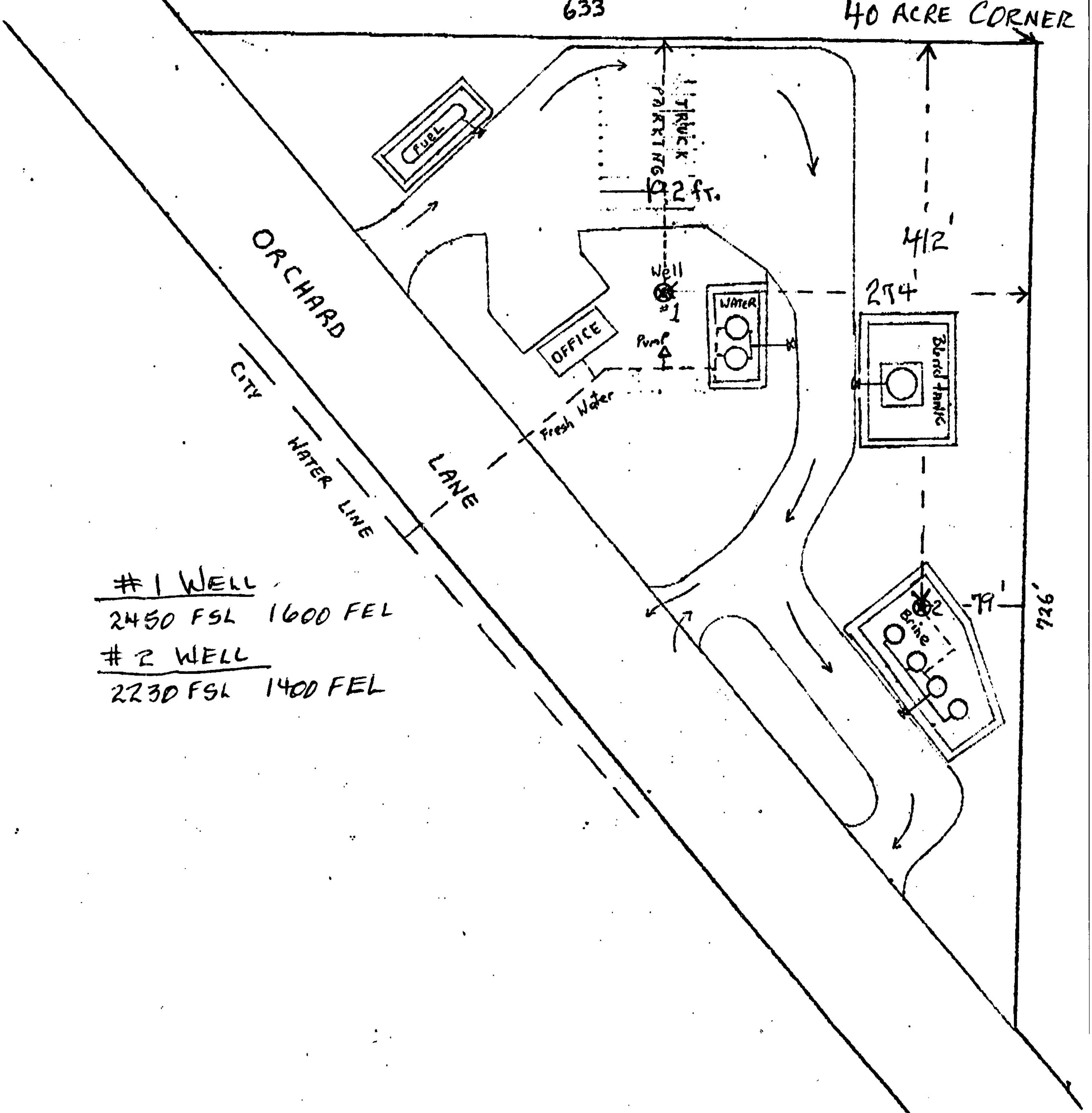
BRINE WELL COMPLETIONS
CARLSBAD BRINE STATION

DATE 7-10-91 TEX. P.E. 9844

DRAWING NO. 6-K.

NW/4 SE/4

SECTION 33 T-21-S R-27-E



#1 WELL
2450 FSL 1600 FEL

#2 WELL
2230 FSL 1400 FEL

Scale 1" = 100'
2-11-91

THE PERMIAN
CORPORATION
CARLSBAD BRINE
STATION LAYOUT

8/27/91

P/A Brine Well near Carlsbad (Dry hole)

The Permian Corp. No 2

AMB

8/27/91

The Permian Corp No. 1
P/A Brine Well near
Carlsbad (Dry hole)

KMB