PRUDHOE BAY
MISCIBLE GAS PROJECT

APPLICATION FOR ADDITIONAL RECOVERY
BY MISCIBLE ENRICHED HYDROCARBON GAS INJECTION

DECEMBER, 1983

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PURPOSE

ARCO Alaska, Inc., and Sohio Alaska Petroleum Company as joint operators, request approval by the Alaska Oil and Gas Conservation Commission (AOGCC) of the Prudhoe Bay Miscible Gas Project which will involve the injection of miscible hydrocarbon gas into the Permo-Triassic (Sadlerochit) Reservoir. In accordance with Article 5, Section 400, of the AOGCC Regulations, July 1981, the information required by 20 AAC 25.400.(B). (1-9) is submitted in this Application.

PROJECT SCOPE

The Prudhoe Bay Miscible Gas Project (PBMGP) will use the enhanced oil recovery technique of miscible gas displacement to increase the recoverable oil reserves in all or portions of Drill Sites 1, 3, 9, 12, 16, and 17 in the Eastern Operating Area and Well Pads R, M, S, and N in the Western Operating Area of the Prudhoe Bay Unit. This technique, which has been employed by the oil industry for several years, involves the injection of an enriched hydrocarbon gas into the oil zone alternating with the injection of water (WAG process). The injected gas forms a miscible bank with the reservoir oil through the exchange of hydrocarbon components and effectively sweeps nearly all of the oil which is contacted to the producing wells. The injected water helps maintain reservoir pressure, retards gravity segregation of the gas, and controls gas channeling. The Project was designed to fulfill the following objectives:

1. Increase recoverable reserves above that which can be obtained through waterflooding.

2. Provide additional oil production during a period when the Field is expected to be on decline.

The earliest date for miscible gas injection is in 1987 at an initial rate of approximately 180 MMSCF/D. Some 670 MBPD of water will be injected along with the miscible hydrocarbon gas in a WAG mode of operation. WAG injection will continue until more than a 10 percent PV slug of miscible gas has been injected into the Project Area. Implementation of this Project is expected to increase recovery by 5.2 percent OOIP, or 115 MMSTB, in the Project Area above that which is attainable through waterflooding and by some 20 percent OOIP above that which is attainable through natural depletion.

CONTENT

The following specifically addresses subsections (B). 1-9 of AOGCC Regulation 20 AAC 25.400.:

20 AAC 25.400.(B).(1): Operator(s)

ARCO Alaska, Inc.	Sohio Alaska Petroleum Company
P.O. Box 100360	50 Freemont Street
Anchorage, Alaska 99510	San Francisco, California 94105
Attention: L. E. Tate	Attention: B. E. Davies

20 AAC 25.400.(B).(2): Plat of Project Area and Offsetting Acreage

The Project involves target areas located in both the Eastern and Western Operating areas of the Prudhoe Bay Unit. In total the Project Area includes approximately 12,900 acres and is estimated to have originally contained 3,050 MMRVB of light oil. The Eastern Miscible Region encompasses all, or portions of, the following: Sections 1-3 and 9-24 in Township 10 N, Range 15 E; Sections 6, 7, 18, and 19 in Township 10 N, Range 16 E (Exhibit 1). The Western Miscible Region encompasses all or portions of the following: Sections 1, 2, and 12 in Township 11 N, Range 12 E; Sections 5, 6, 7, and 8 in Township 11 N, Range 13 E; Sections 35 and 36 in Township 12 N, Range 12 E; and Sections 29 through 33 in Township 12 N, Range 13 E. The miscible flood design and implementation will be similar in the Eastern and Western Miscible Regions, and the miscible injectant will be produced in a central Unit facility. As illustrated in Exhibit 2, the Eastern Miscible Region of the

Project Area will consist of inverted nine-spot patterns with 25 WAG injectors and 107 producers. The area, as presently envisioned, will be primarily developed on 80 acre spacing. Exhibit 3 illustrates the Western Miscible Region of the Project containing skewed inverted nine-spot patterns with 17 WAG injectors and 47 producers. Exhibits 4 and 5 indicate the surface boundaries of the Eastern and Western Miscible Regions, respectively, and the locations of all existing production and injection wells, and scheduled future wells. Flexibility exists to convert the Project Area to five-spot patterns or line drive patterns if warranted by actual performance considerations.

20 AAC 25.200.(B).(3): Current Zone of Completion

All existing and possible future development wells shown in Exhibits 4 and 5 are or will be completed in the Permo-Triassic (Sadlerochit) formation of the Prudhoe oil pool. Type logs in the Eastern and Western Miscible Regions of the Sadlerochit formation are provided in Exhibits 6 and 7.

20 AAC 25.400.(B).(4): Zone Affected by Injection

The light oil column of the Permo-Triassic (Sadlerochit) sandstone formation identified on the type logs in Exhibits 6 and 7 is the target producing formation of the Prudhoe oil pool to be affected by miscible hydrocarbon gas injection. Within the Eastern Miscible Region the top of the Sadlerochit varies in depth from 8514' TVD SS in the north to 8926' TVD SS in the south (Exhibit 8), and in the Western Miscible Region from 8500' TVD SS in the eastern part of the southern Fault Block to 8866' TVD SS in the eastern part of the northern Fault Block (Exhibit 9). The targeted light oil column varies in thickness from 71 feet in the south to 443 feet in the north in the Eastern Miscible Region. In the Western Miscible Region, the targeted light oil column varies in thickness from 128 feet in the eastern part of the northern Fault Block to 413 feet in the eastern part of the southern Fault Block.

20 AAC 25.400.(B).(5): Logs of Existing Injection Wells

Waiver of this requirement is requested since all well logs are submitted to the AOGCC in accordance with Conservation Order 145.

20 AAC 25.400.(B).(6): Injection of Well Casing Program and Testing

A. Casing Program

Wells drilled specifically for water or miscible gas injection service will be cased in a manner consistent with current production wells.

B. Casing Tests

All current and future casing strings have been and will continue to be tested in accordance with AOGCC Regulation 20 AAC 25.030 as a minimum.

Waiver of further submittal of information for this section is requested since well completion data including casing, cementing, and test programs are submitted for each well on the State of Alaska Oil and Gas Conservation Commission Form 10-407, "Well Completion or Recompletion Report and Log" in accordance with AOGCC Regulation 20 AAC 25.030 Casing Cementing.

20 AAC 24.400.(B).(7): Injection Fluid

The miscible gas injectant required for the Project will be obtained by removing intermediate hydrocarbons from separator off-gas using a refrigeration/condensation process. The facilities are designed to supply a ten-year average of 200 MMSCF/D of miscible hydrocarbon gas with a methane content of approximately 23 mole percent as shown in Exhibit 10. The injectant composition will be tailored to achieve multiple-contact miscibility with reservoir oil at prevailing pressures. Water will be injected alternately or concurrently with the miscible gas in the WAG injectors. Source water injection will begin in mid-1984 for most of the patterns. All patterns will be on waterflood prior to miscible gas injection.

20 AAC 25.400.(B).(8): Tabulation of Production Tests

Waiver of this requirement is requested since semi-annual well test data are submitted in accordance with Conservation Order 145. The last report was submitted as in July, 1983, on State of Alaska Oil and Gas Conservation Commission Form 10-409, "Well Status Report and Gas-Oil Ratio Tests."

20 AAC 25.400.(B).(9): Plan and Rate of Development

The following discussion is a summary of the planned development and operation of the Project. A more thorough description of the Project is provided in "Prudhoe Bay Miscible Gas Project - Application for Approval as a Qualified Tertiary Recovery Project for Purposes of the Crude Oil Windfall Profit Tax Act of 1980," which has been submitted concurrently with this Application.

PROJECT DEVELOPMENT

The PBMGP will be implemented in waterflood areas of the Field and will utilize the established inverted nine-spot patterns. All 42 injectors and 154 producers in the Project Area will be available before miscible gas injection begins in 1987. As shown in Exhibit 4, the Project in the Eastern Miscible Region will affect all or portions of Drill Sites 1, 3, 9, 12, 16, and 17 and the associated separation centers FS-1 and FS-2. Exhibit 5 shows the Western Miscible Region where all or portions of Well Pads M, N, R, and S and the associated separation center GC-2 will be affected by the Project.

PROJECT OPERATION

Waterflood injection will have been in progress for approximately three years prior to miscible Project start-up in the second half of 1987. Thus the proposed WAG injection wells will have injected substantial amounts of water during 1984 to 1987. The water injected into the Project Area before miscible flood start-up will dissipate any local areas of high gas saturation and create a safety margin between average reservoir pressure and minimum miscibility pressure of the miscible gas. Reservoir surveillance tools, such as pressure tests, production logs, and CNL logs, will be used to confirm these conditions.

At the commencement of Project start-up, a selected set of the water injectors will be converted to miscible gas injection for a period of one to three months. The average gas injection rate will be approximately 15-20 MMSCF/D per active injector. After this period source water will be injected into these initial wells at rates of approximately 15 MBWPD, thus beginning the

normal water-alternating-gas process, and another set of injectors will be converted from water to miscible gas injection. Several periods or sequences will be required before all the WAG injectors in the Project Area have received their first cycle of miscible gas.

For the planned injection period the reservoir pressure will be maintained above the minimum miscibility pressure. The expected gradual decline in reservoir pressure is one of the incentives for early EOR start-up. Continued injection beyond 10 percent pore volume will be predicated on our ability to maintain miscibility in the reservoir. If economically justifiable, miscibility may be maintained through increasing enrichment of the injectant to compensate for declining reservoir pressure.

FACILITIES

A centrally located refrigerated condensation/stabilization plant using vapor compression propane refrigeration to -35°F will produce miscible injectant for Enhanced Oil Recovery and NGL's for blending into crude oil to TAPS. Optimization of the process design and daily operation will determine the ultimate composition of the miscible injectant. Stream composition will be monitored to maintain miscibility.

Miscible injectant will be compressed at the central plant and distributed via high pressure pipelines to drill sites and well pads. The plant will produce miscible injectant at rates ranging from approximately 180 MMSCF/D in 1987 to 266 MMSCF/D in the year 1996. Some NGLs will be blended into crude oil for sale through TAPS. Residue gas, which includes field fuel, is estimated at 2.4 BSCF/D for a nominal 2.7 BSCF/D plant inlet rate.

An additional benefit of the Project will be to increase Field gas handling capacity. This will result in improved oil and condensate recovery. Since the current limit to gas handling is the Central Compression Plant (CCP), by shutting down the existing Field Fuel Gas Unit (FFGU) and by removing saleable NGL's, miscible gas, and fuel upstream of the CCP, more total gas can be handled in the Field. Total gas handling capacity will increase from 2.40 to 2.85 BSCF/D.

Miscible injectant will be distributed from the EOR Plant to injection wells at Drill Sites 3, 9, 12, 16, and 17 and Well Pads M, R, and S. A tie-in to the existing Flow Station 3 Injection Project distribution pipeline will be provided for possible future use as needed.

The Seawater Treatment Plant (STP), which will provide source water for the waterflood and the WAG projects, arrived at Prudhoe Bay in August 1983 and is in place at the extension of the west dock. Seawater Injection Plants (SIP) near Gathering Center No. 3 and Flow Station No. 1 are in place. Pipelines and manifolds are installed, and the STP and SIP's are being tied-in. According to current plans, injection of some 1.4 MMBWPD is expected to begin mid to late 1984 in the principal waterflood areas.

IMPACT ON EXISTING FACILITIES

The CCP currently consists of 13 General Electric MS 5001 Single Shaft Gas Turbines driving Dresser-Clark Centrifugal Compressors. Nine units are in first stage service, with four units in second stage service. The Plant is currently compressing separator off-gas which has a molecular weight of approximately 23.0. Approximately 160 MMSCF/D is withdrawn from the second stage suction as feed to the FFGU. With the EOR Plant in operation, the CCP will compress a residue gas with a lower molecular weight. Since the FFGU will be shut down, there will be no interstage draw required. The net results will be a small reduction in CCP gas handling capacity as long as the machines are restaged for the new composition. Studies have evaluated the capacity of existing CCP equipment under new operating conditions with several options for restaging the existing machines for increased capacity when compressing residue gas. In addition, the effects of gas transit line looping and adding a booster compressor upstream of the CCP were examined. Current plans are to provide a booster compressor to feed the gas processing plant.

The Flow Station 3 Injection Project will remain an individually certified project. The primary impact of the new EOR Project on the existing project at Flow Station No. 3 will eventually be to supply the FS3IP injection module with some of the NGL's or miscible injectant from the new plant to supplement declining injectant production from the FS3IP. The resulting injectant

composition will be similar, and no change in recovery is expected. The pipelines required for the distribution of miscible injectant to FS-3 drill sites remain the same regardless of injectant source.

PROJECT SURVEILLANCE

An extensive reservoir surveillance program is now being carried out for the Flow Station 3 Injection Project to monitor and optimize the miscible gas drive process. The existing field-wide reservoir surveillance program is supplemented by special DIL and CNL logging of an unperforated observation well, extensive coring, more frequent well surveys, and radioactive tracers. It is anticipated that the results of this surveillance program, when utilized in conjunction with a history matched simulation of the FS-3 Injection Project, will result in a comprehensive confirmation of the mechanisms of miscible flooding in the Sadlerochit. This information will be taken into account in designing a cost effective surveillance program for the PBMGP.

The PBMGP surveillance program will be designed as an addition to the surveillance proposals being developed for the waterflood project. Prior to the start of miscible gas injection, a comprehensive surveillance program specifically developed for this Project will be submitted to the AOGCC.

SUMMARY

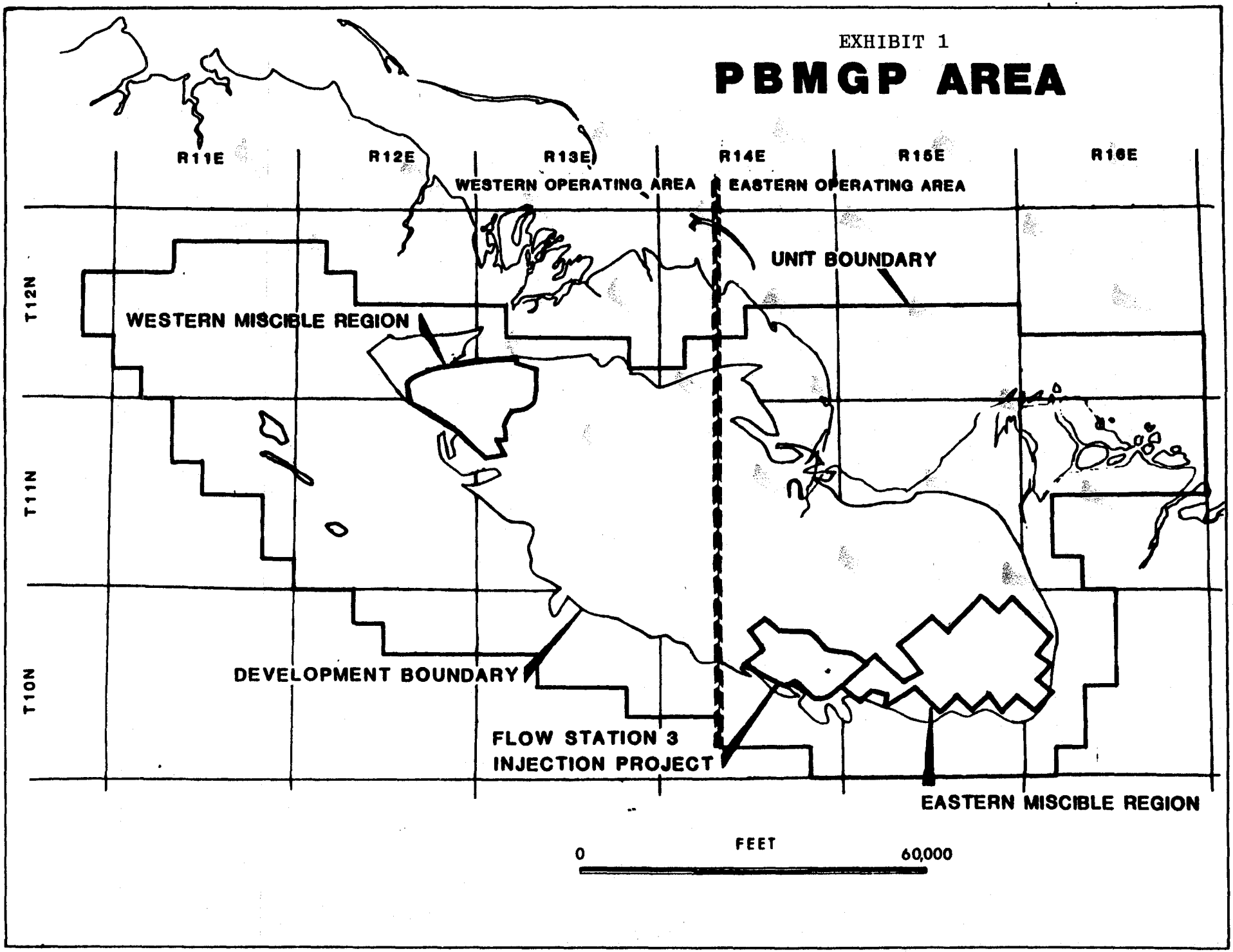
ARCO Alaska, Inc., and Sohio Alaska Petroleum Company request approval by the AOGCC of the PBMGP which will involve the injection of miscible hydrocarbon gas in a WAG process into the Sadlerochit reservoir. In accordance with Article 5, Section 400, of the AOGCC Regulations, July 1981, the information required by 20 AAC 25.400.(B). (1-9) is submitted in this Application.

The PBMGP will be implemented within the most suitable parts of the FS-2 and NWFB waterflood project areas of the Field and will utilize the established inverted nine-spot patterns, mainly on 80-acre spacing. There will be a total of 42 WAG injectors and 154 oil producers involved in the Project Area. A centrally located refrigerated condensation/stabilization plant will produce miscible injectant for EOR and NGLs for blending with the TAPS crude oil.

The Project is designed to increase recoverable reserves and provide additional oil production during a period when the Field production rate is expected to be on decline. Implementation of the WAG process is planned to begin during the second half of 1987 with an average miscible gas injection rate of 200 MMSCF/D and an average water rate of 70 MBPD. WAG injection will continue until more than a 10 percent pore volume slug of miscible gas has been injected into the Project Area in approximately ten years. The PBMGP is expected to increase recovery by 5.2 percent OOIP in the Project Area or 115 MMSTB of oil over waterflood.

EXHIBIT 1

PBMGP AREA



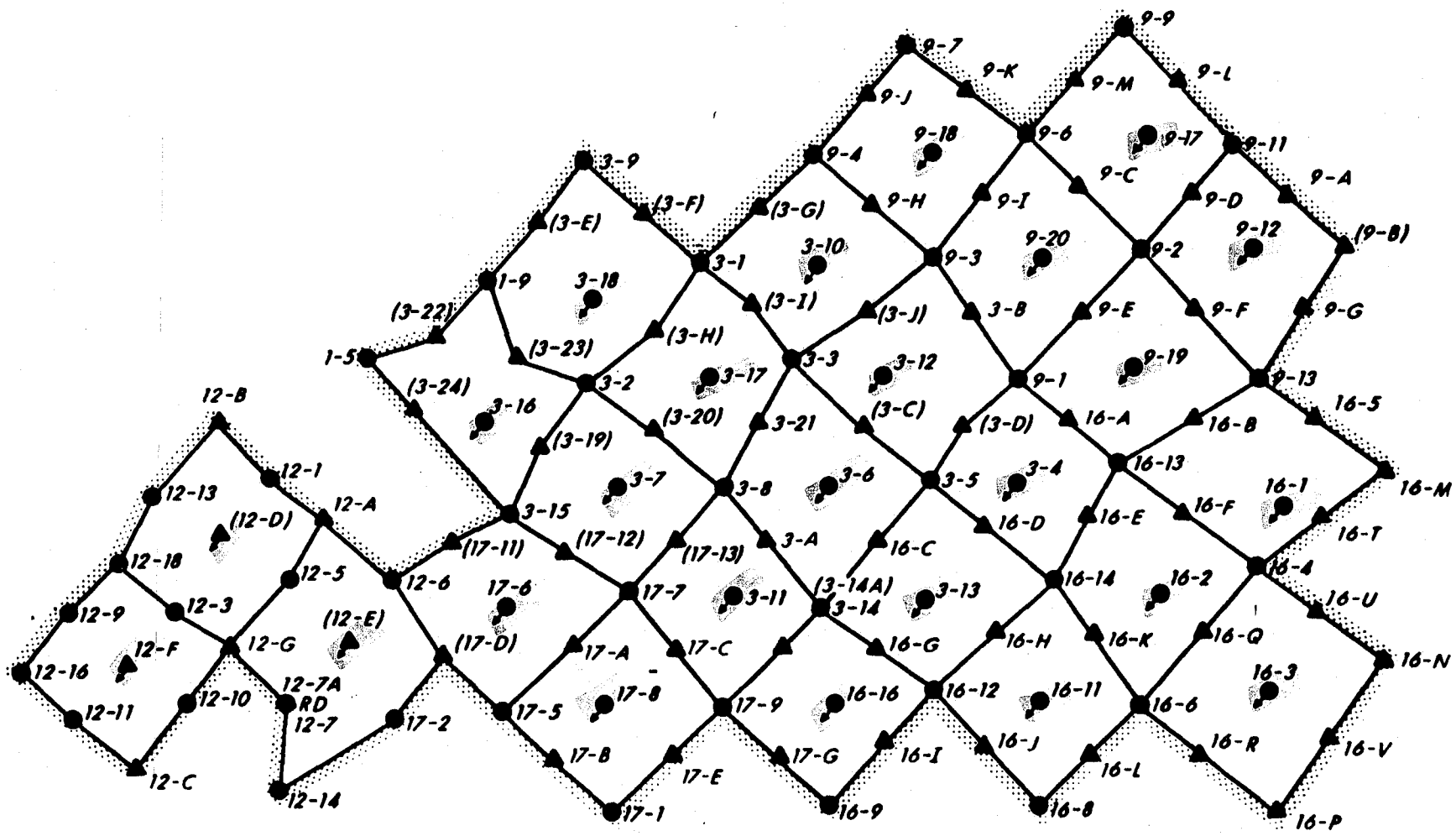
DWG. Nº PE-1-NS-S-1726

EXHIBIT 2

EASTERN MISCIBLE REGION DEVELOPMENT

Legend

- ● 160-ACRE WELL
- ▲ 80-ACRE WELL
- ▲● INJECTORS



DWG. No. PE-1-NS-8-1724

EXHIBIT 3

WESTERN MISCIBLE REGION DEVELOPMENT

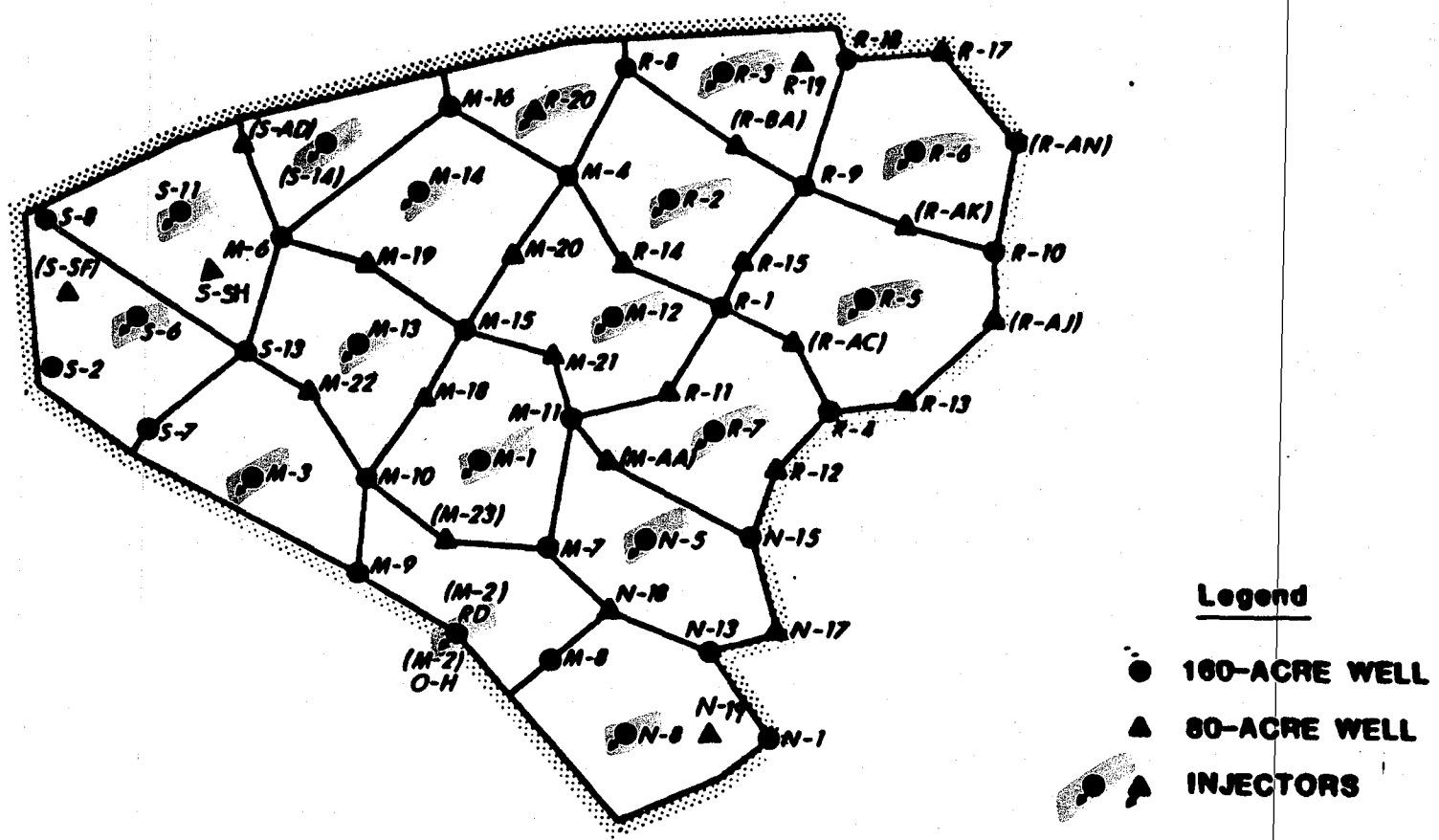


EXHIBIT 4

EASTERN MISCIBLE REGION BOUNDARY

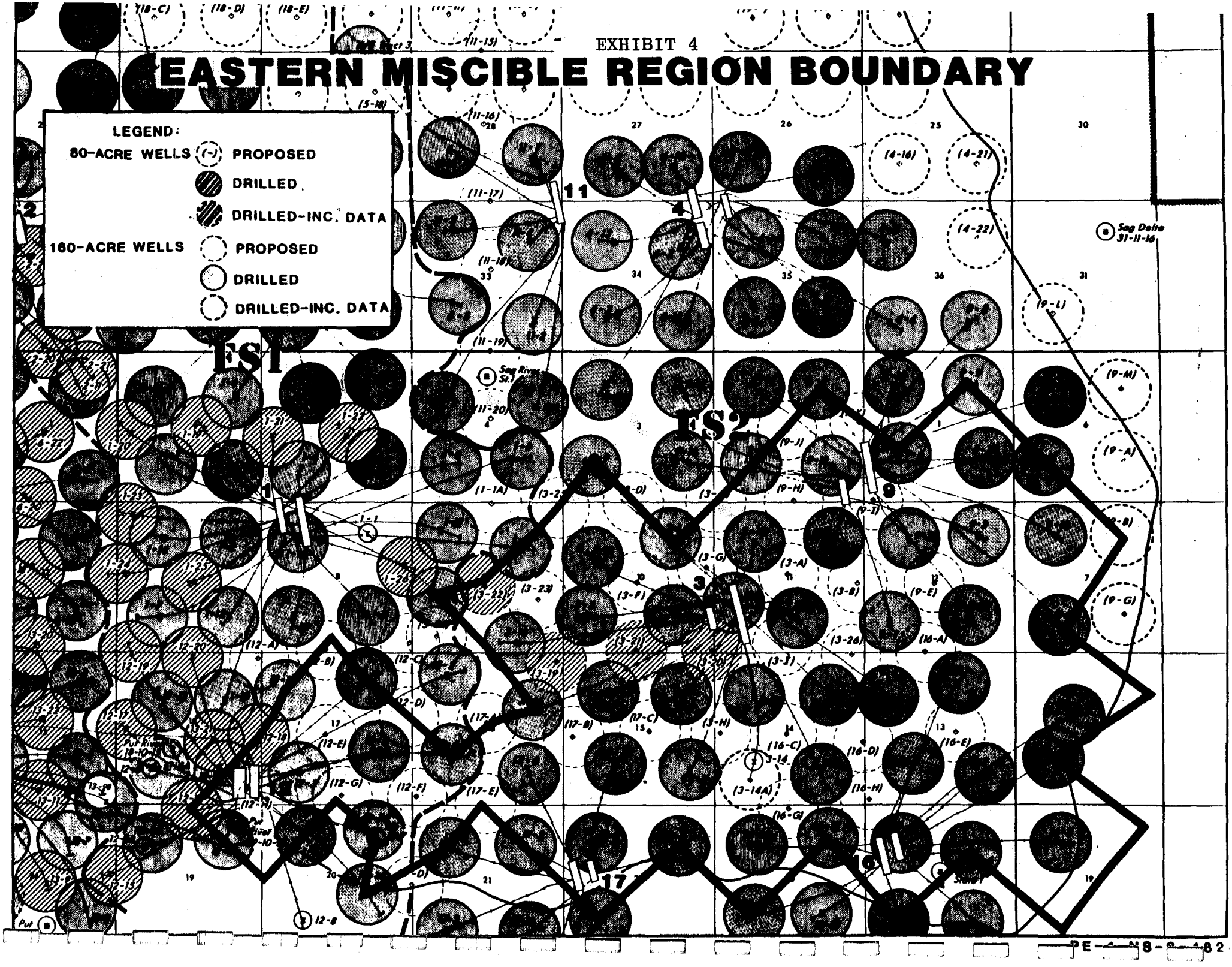


EXHIBIT 5

WESTERN MISCIBLE REGION BOUNDARY

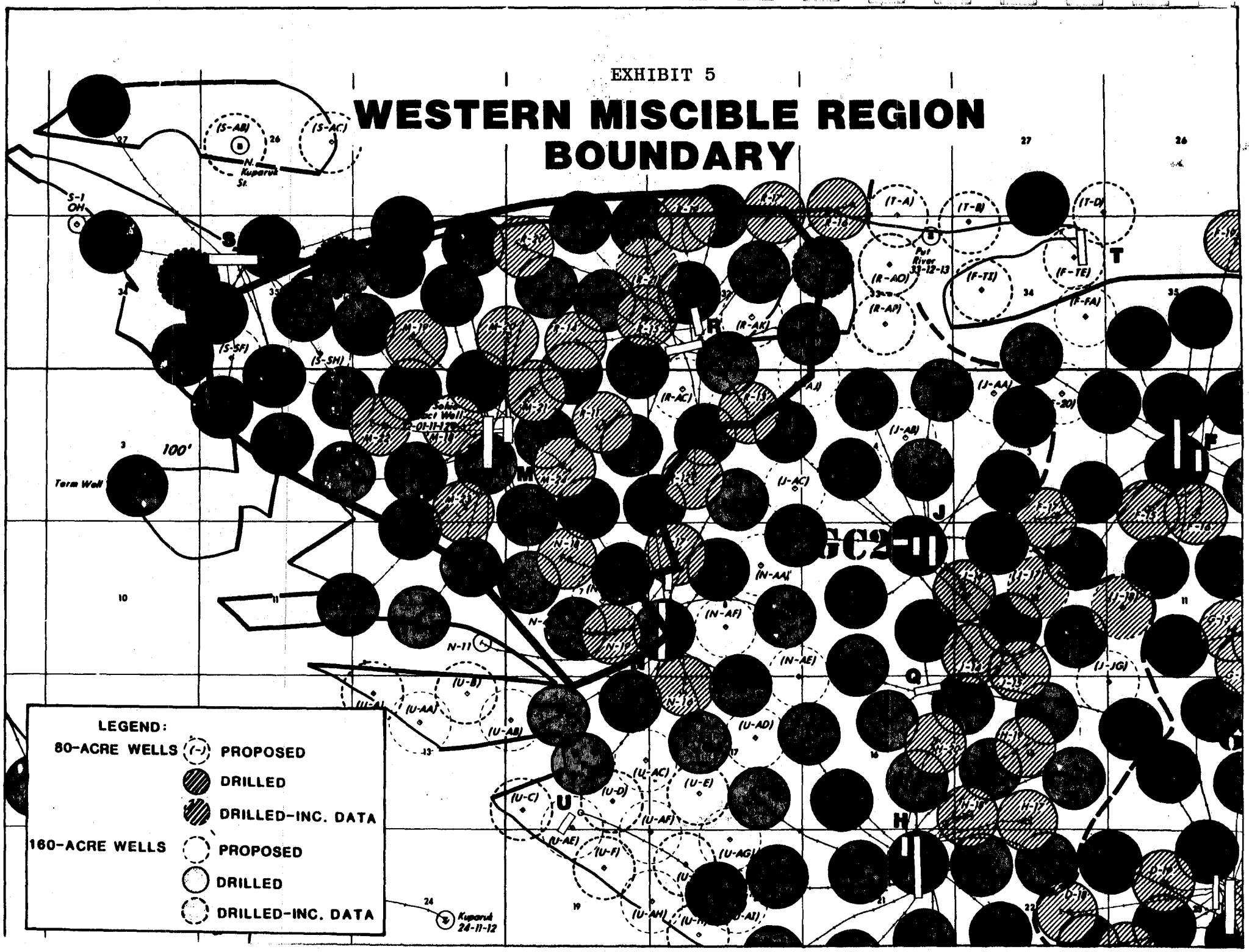


EXHIBIT 6

SAMPLE LOGS SHOWING VERTICAL DELINEATION OF PROJECT

Eastern Miscible Region

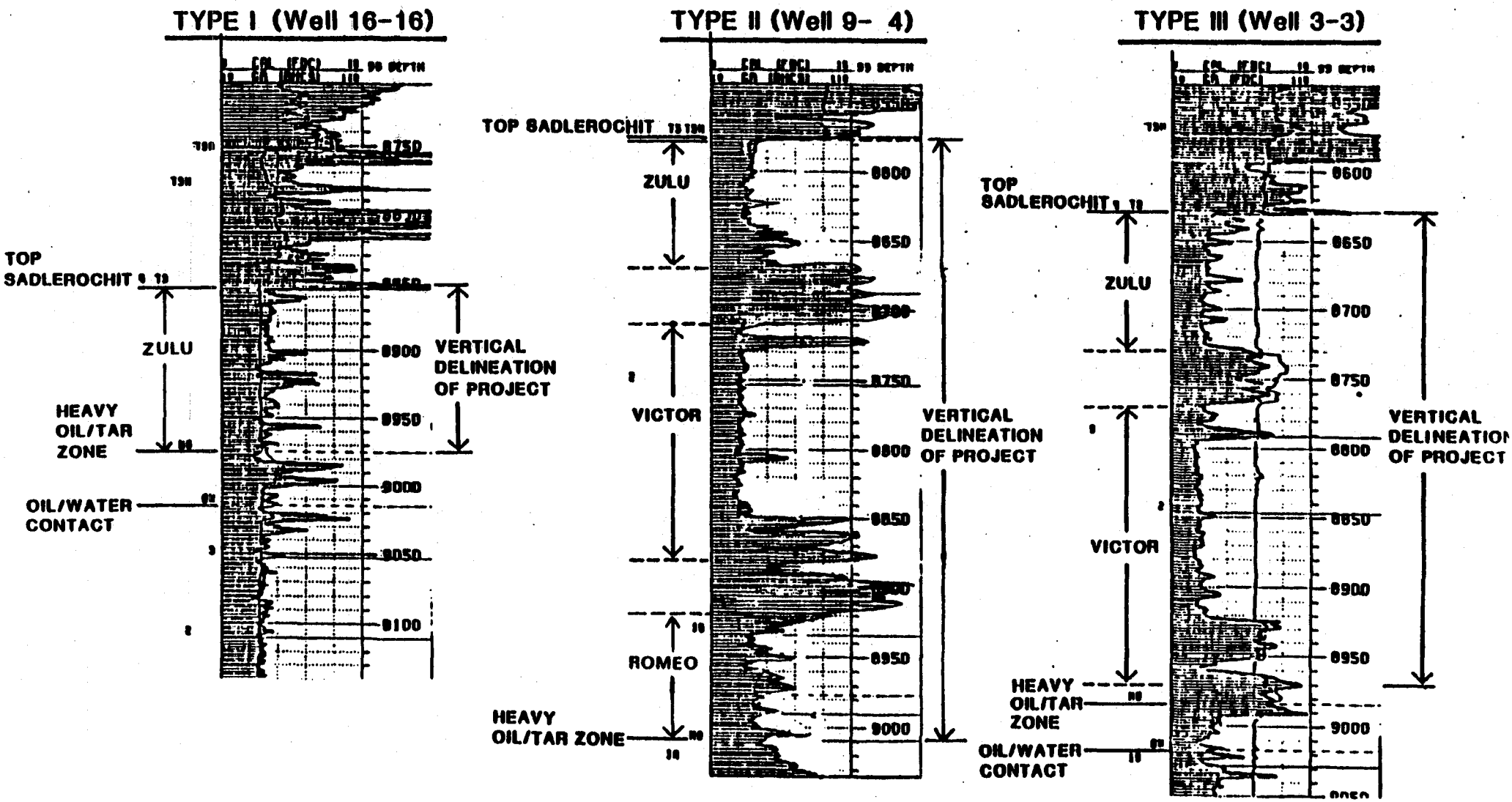
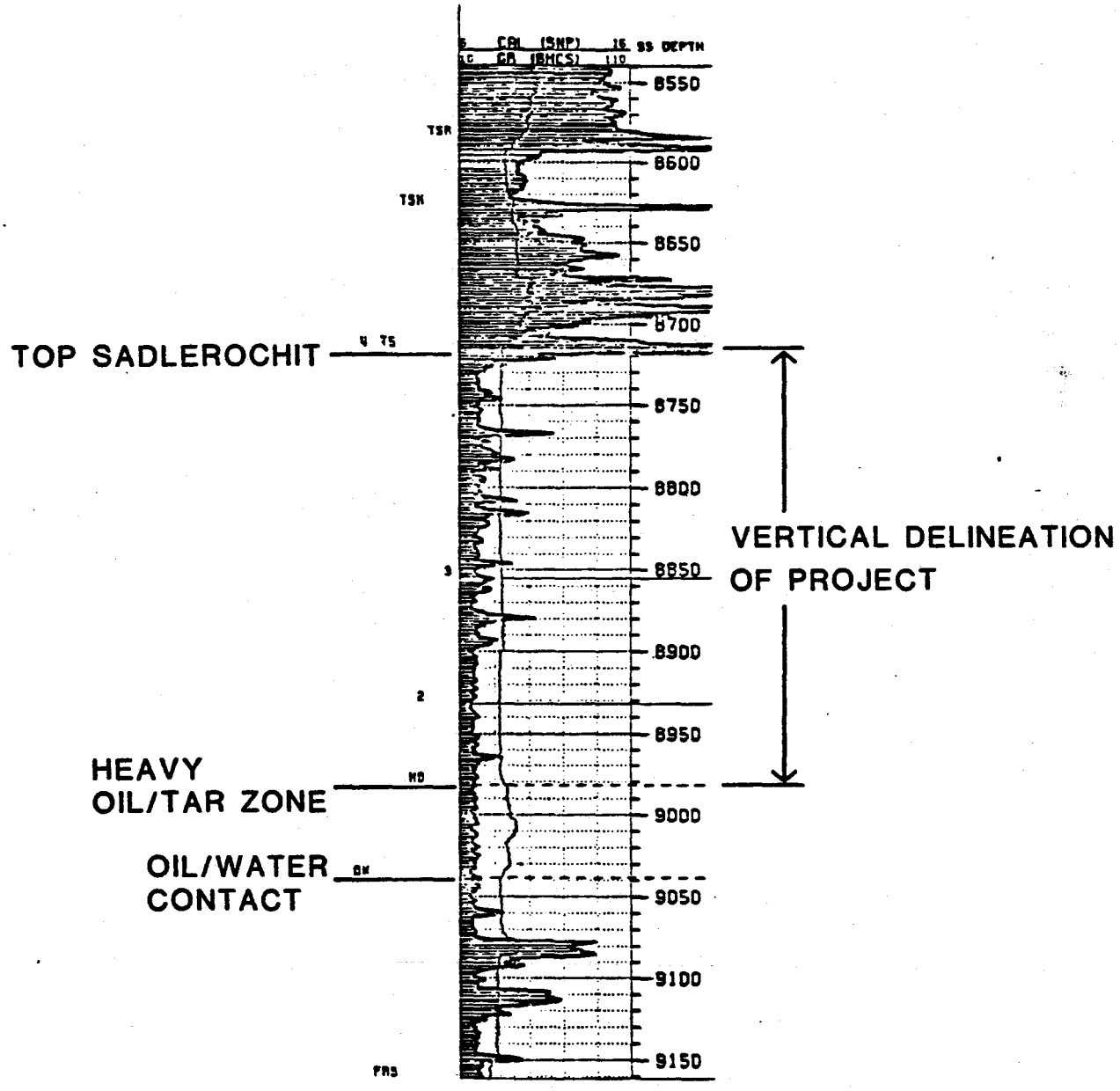


EXHIBIT 7

SAMPLE LOG SHOWING VERTICAL DELINEATION OF PROJECT

Western Miscible Region

(WELL M-4)



DWG. Nº PE-1-NS-S-1721

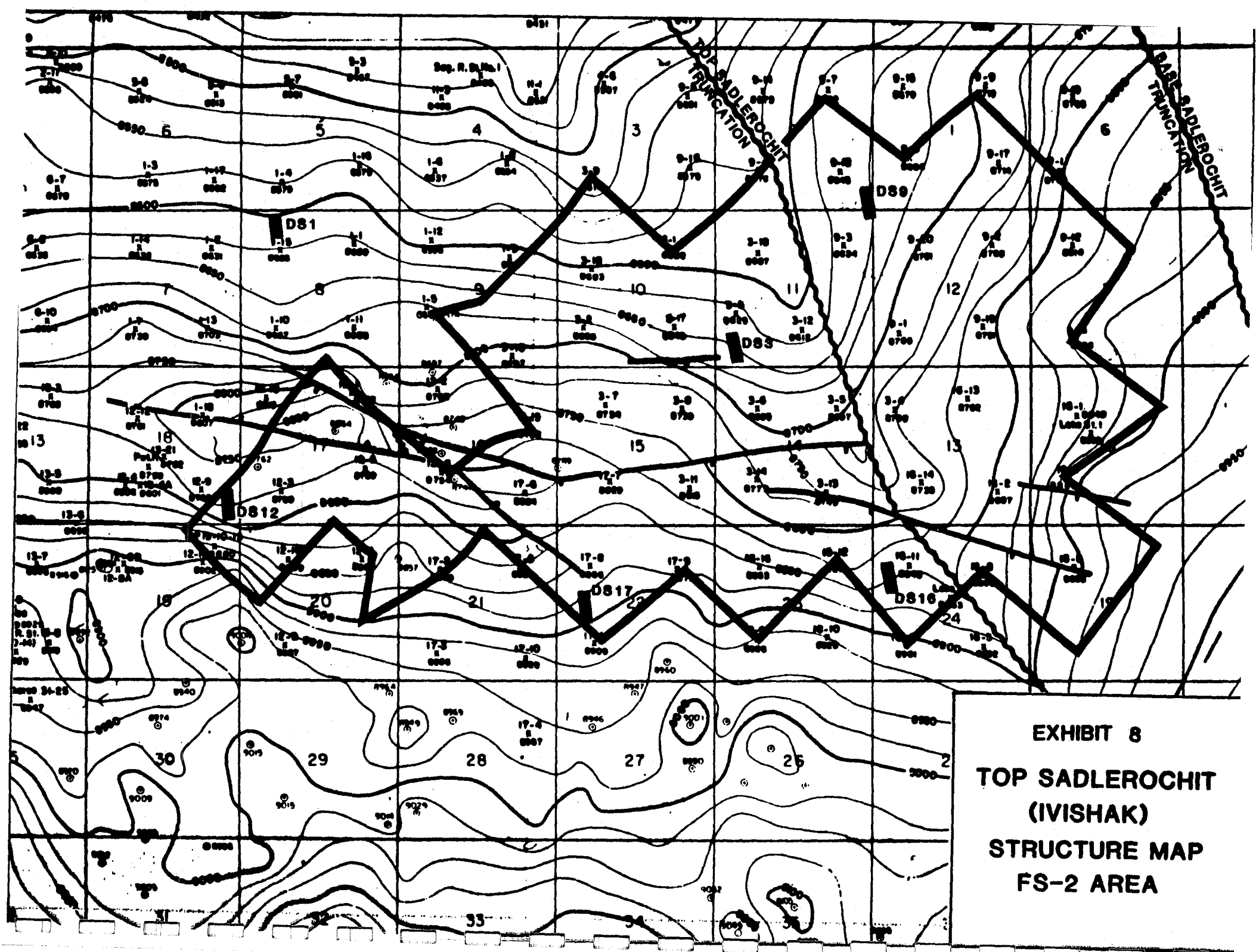


EXHIBIT 8

TOP SADLEROCHIT
(IVISHAK)
STRUCTURE MAP
FS-2 AREA

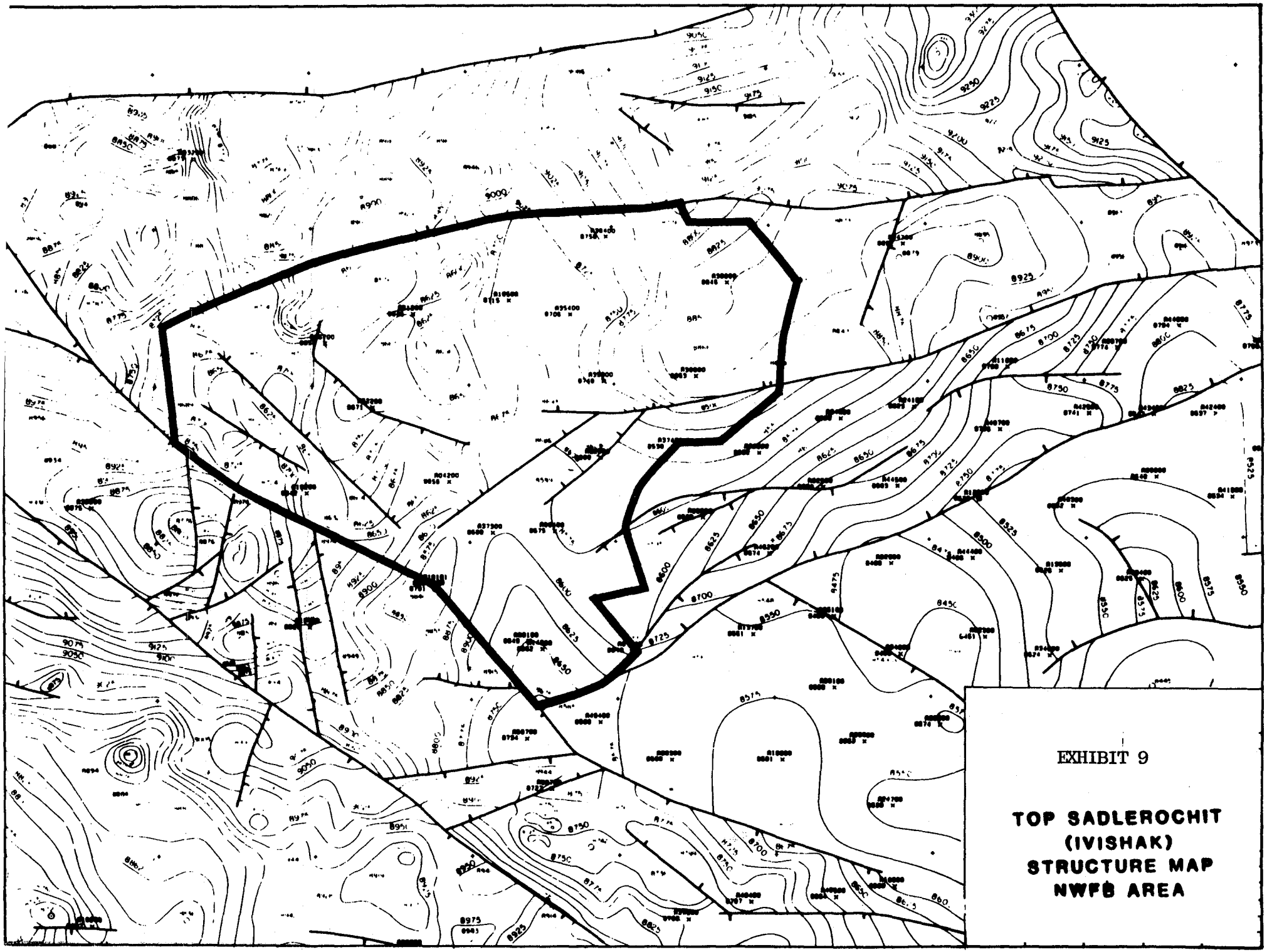


EXHIBIT 9

TOP SADLEROCHIT (IVISHAK) STRUCTURE MAP NWFB AREA

Exhibit 10

COMPARISON OF INJECTANT COMPOSITION

Component	FS3IP Mole %	PBMGP Mole %
N_2	0.13	0.01
CO_2	12.41	21.60
C_1	42.50	23.50
C_2	12.77	24.03
C_3	13.59	28.43
i-C_4	2.49	1.22
n-C_4	6.76	1.19
i-C_5	1.86	0.01
n-C_5	3.07	0.01
C_6	1.97	Trace
C_7	1.10	Trace
C_8	0.79	---
C_9	0.41	---
C_{10}	0.15	---
	100.00	100.00