Case 2366

CASING DATA - PROPOSED INJECTION WELLS
SHELL CARSON UNIT PRESSURE MAINTENANCE PROJECT
BISTI FIELD, SAN JUAN COUNTY, NEW MEXICO

WELL NO.	CASING SIZE	CASING WEIGHT	NUMBER SACKS CEMENT	EFFEC-TIVE DEPTH	PERFORATED INTERVAL	SURFACE CASING SIZE	SURFACE CASING DEPTH	TUBING SIZE	PROPOSED TUBING DEPTH
31-10	4-1/2"	14.9#	200	4933'	4830-39, 4844-51, 4887-97, 4904-09, 4914-18	8-5/8"	237'	2-3/8"	4820'
14-15	5-1/2	17	300	4860	4786-97, 4802-20, 4741-76, 4705-23	8-5/8	219	2-3/8	4695
22-11	4-1/2	9.5	150	5049	4918-50, 4984-98, 5002-12	8-5/8	107	2-3/8	4908
23-11	4-1/2	9.5	150	4938	4800-19, 4825-30, 4872-84, 4890-4904	8-5/8	106	2-3/8	4790
24-11	4-1/2	9.5	150	4925	4780-4804, 4808-14, 4853-64, 4869-79	8-5/8	110	2-3/8	4770
21-14	4-1/2	9.5	150	4908	4760-89, 4792-4801, 4835-48, 4856-70	8-5/8	101	2-3/8	4750
22-14	4-1/2	9.5	150	4927	4763-67, 4771-96, 4800-09, 4850-64, 4869-82	8-5/8	108	2-3/8	4753
23-14	4-1/2	9.5	150	5008	4807-32, 4843-54, 4872-81, 4888-99, 4904-21	8-5/8	104	2-3/8	4797
24-14	4-1/2	9.5	150	5010	4856-59, 4863-82, 4895-38, 4948-59, 4964-77	8-5/8	110	2-3/8	4846
21-23	4-1/2	9.5	150	4977	4874-94, 4902-14, 4923-35, 4941-57	8-5/8	109	2-3/8	4864
13-12	4-1/2	9.5	150	5041	4914-41, 4973-87, 4991-5007	8-5/8	108	2-3/8	4904
21-13	4-1/2	9.5	150	5002	4860-86, 4890-4900, 4940-54, 4958-74	8-5/8	103	2-3/8	4850
22-13	4-1/2	9.5	150	5034	4864-87, 4893-4906, 4943-53, 4962-70	8-5/8	121	2-3/8	4854
23-13	4-1/2	9.5	150	5004	4871-4900, 4907-16, 4946-51, 4956-70, 4974-84	8-5/8	101	2-3/8	4861
24-13	4-1/2	9.5	150	5031	4864-88, 4897-4905, 4932-38, 4946-58, 4964-78	8-5/8	111	2-3/8	4854
21-24	4-1/2	9.5	150	5002	4876-4904, 4939-50, 4956-68, 4973-90	8-5/8	107	2-3/8	4866
23-24	4-1/2	9.5	150	4980	4854-68, 4882-96, 4899-4910, 4914-26, 4936-47, 4952-68	8-5/8	103	2-3/8	4844
32-24	4-1/2	9.5	150	5002	4873-94, 4911-30, 4941-54, 4961-74, 4979-94	8-5/8	107	2-3/8	4863
24-7	4-1/2	9.5	150	5035	4910-32, 4956-66, 4972-86, 4992-5002	8-5/8	105	2-3/8	4900
21-18	4-1/2	9.5	150	5015	4883-4912, 4936-42, 4950-65, 4968-80	8-5/8	106	2-3/8	4873
22-18	4-1/2	9.5	150	5016	4881-91, 4895-4913, 4940-44, 4954-66, 4972-82	8-5/8	109	2-3/8	4871
23-18	4-1/2	9.5	150	5006	4875-91, 4901-13, 4944-51, 4954-70, 4974-84	8-5/8	102	2-3/8	4865
24-18	4-1/2	9.5	150	5007	4861-89, 4894-4902, 4934-41, 4946-60, 4963-76	8-5/8	106	2-3/8	4851
21-19	4-1/2	9.5	150	5022	4866-92, 4900-08, 4939-44, 4951-62, 4969-78	8-5/8	213	2-3/8	4856
22-19	4-1/2	9.5	150	5027	4868-88, 4898-4905, 4934-42, 4952-62, 4968-80	8-5/8	108	2-3/8	4858
11-30	4-1/2	9.5	150	4955	4834-49, 4861-70, 4873-77, 4879-89, 4893-4906, 4916-28, 4933-47	8-5/8	103	2-3/8	4824
11-20	4-1/2	9.5	150	5054	4906-26, 4937-48, 4979-85, 4992-5006, 5010-5022	8-5/8	104	2-3/8	4896
23-20	5-1/2	14-16#	200	5030	4870-90, 4902-09, 4940-47, 4955-69, 4974-84	8-5/8	211	2-3/8	4860
32-20	4-1/2	9.5	150	5015	4852-70, 4882-90, 4925-30, 4937-47, 4957-66	8-5/8	187	2-3/8	4842
41-20	4-1/2	9.5	150	5010	4909-18, 4922-28, 4936-45	8-5/8	183	2-3/8	4899
1*	5-1/2	14	150	4989	4883-94,	8-5/8	320	2-3/8	4873
23-17	5-1/2	14	200	5021	4872-76, 4881-83, 4888-96, 4934-36, 4949-55,4967-72	8-5/8	214	2-3/8	4862
24-17	4-1/2	9.5	150	5023	4870-87, 4892-4901, 4932-43, 4952-62, 4970-78	8-5/8	105	2-3/8	4860
31-17	4-1/2	9.5	150	5030	4910-30, 4938-54	8-5/8	107	2-3/8	4900
43-17	4-1/2	9.5	150	5095	4970-84, 5014-21, 5035-46, 5056-62	8-5/8	217	2-3/8	4960

* Sanda Wall

Attachment 2

ENGINEERING REPORT

AND

PLAN OF DEVELOPMENT

CARSON UNIT PRESSURE MAINTENANCE PROJECT

BISTI FIELD

SAN JUAN COUNTY, NEW MEXICO

FARMINGTON DIVISION
PACIFIC COAST AREA
FEBRUARY, 1961

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CARSON UNIT
PRESSURE MAINTENANCE PROJECT

TEXT

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INTRODUCTION

Pressure maintenance by water flooding should substantially increase the ultimate recovery from the Bisti-Lower Gallup reservoir above that obtainable by the present primary producing mechanism which is predominantly solution gas-drive.

Enclosed are 17 illustrations which analyze the Bisti-Lower Gallup reservoir and set forth a plan of water injection in that portion of the reservoir underlying the Carson Unit. The burden of the analysis is carried by the exhibits; the text merely serves to point out important features and to summarize results.

HISTORY

The Bisti Field is located in the San Juan Basin in San Juan County, New Mexico (see Index Map - Figure 1). The discovery well, El Paso Kelly State 1, which is located in Section 16, Township 25 North, Range 12 West (see Figure 2), was completed in October, 1955. Subsequent development progressed northwesterly and southeasterly until the present limits of the field were defined (approximately 30 miles long and 1 to 3 miles wide). That portion of the field which is dealt with in this report, namely the Carson Unit, is located approximately mid-way between the northwest and southeast extremities of the field. The Carson Unit represents approximately one-fourth of the surface area of the field.

STRUCTURE AND STRATIGRAPHY

The productive measures which are exploited in the Bisti Field are the Lower Gallup sand bar deposits. The gross section averages about 130 feet thick in the Carson Unit. The sands are fine grained, of extremely variable shaliness and cementation, and have heterogeneous appearance caused by reworking by marine organisms.

The productive section has been divided into three intervals known as the GC sand, the GD sand and the GE sand. These intervals are commonly referred to as the upper, middle and lower bench, respectively. The isopachs on Figure 2 are at five-foot intervals and represent the combined microlog pay in the GC and GD sands. These two intervals are the only intervals which contain sands of sufficient permeability to exhibit microlog separation. Figures 3 and 4 are isopach maps of the GC and GD sands, respectively, and Figure 5 is a Type Log showing the electric log markers. The microlog pay is considered to offer the only significant primary and secondary potential, and all recovery estimates are based solely on these better developed sands.

The elongated shape of the main sand bodies attests to their sand bar origin (see Figures 3 and 4), and as a result of the nature of these sands, a marked contrast in the continuity of the sand lenses is observed in different directions. For example, examination of some typical cross sections (Figure 6) reveals that the sand lenses are much more continuous on Section C-C', which runs parallel to the longitudinal axis of the GC sand than on the other two sections. The effect of this stratigraphy on the performance of the water flood has been recognized, and the recommended injection pattern is designed to take advantage of this orientation of the better sand continuity.

Structure contours on the top of the GC sand at 20-foot intervals are portrayed on Figure 7. These contours indicate a regional north to northeast dip (80 feet/mile or about 1°) toward the Basin center.

Oil occurrence in the Bisti Field is controlled by stratigraphy. No water table exists in the field and only small amounts of water production have been reported from the western portion of the field. A primary gas cap is located in the highest structural portions in the southeastern part of the field. A small portion of this gas cap extends onto the Carson Unit (see Figure 2).

RESERVOIR CHARACTERISTICS AND PRIMARY PERFORMANCE

Some of the more important reservoir parameters are summarized on Figure 8. The average petrophysical properties tabulated pertain only to the microlog net pay. The primary producing mechanism is predominantly solution gas-drive. The production performance is portrayed on Figure 9. Production had declined to 2200 barrels of oil per day, an average of 23 B/D per well, in December, 1960. Cumulative production from the expanded Carson Unit is about 4,300,000 barrels and 8,700,000 MCF as of January 1, 1961.

The ultimate production under primary operations is estimated to be 6,900,000 barrels, based on a study of individual well and lease production decline curves. This is equivalent to 18 per cent of the original oil in place (Figure 10) which leads us to considerations relevant to improved recovery by pressure maintenance.

PILOT TEST OF WATER INJECTION

In September and October, 1959, Sunray, as operator of the Central Bisti Unit with the cooperation of Shell, drilled and completed four water injection wells on the western boundary of Shell's Phillips No. 7 Lease. From Sunray's standpoint the prime reason for this project was to prevent the migration of hydrocarbons from their portion of the reservoir, which was to be repressured by LPG and dry gas, to our properties on which the reservoir pressure would continue to be depleted for some time. On the other hand, Shell regarded this project as a valuable pilot test of water injection in the Bisti Field and the information obtained to date has proven this to be the case. Additional information on the reaction of the Bisti reservoir to water flooding is available from five water injection wells (four old producers and one converted LPG injector) located near the west border of the Central Bisti Unit.

Injection at high rates and low surface injection pressures relative to the small thickness of net pay has been maintained in these wells (Figure 13). These rates have averaged almost 70 B/D per foot of microlog net pay for the West Water Barrier and 40 B/D per foot of microlog net pay for the East Water Barrier wells. The lower injection rates into the latter is merely a function of the capacity of the lift equipment installed on the Cliff House water source well serving this group of four injectors.

The production response to this injection has been satisfactory and in general the pilot flood results have shown that:

1. Relatively high water injectivity into the Gallup producing formation can be obtained.
2. It is possible to form an oil bank.
3. Water break-through generally is not premature. However, severe channeling can result as a result of an unsatisfactory completion technique in the injection wells.

FLOOD RECOVERY

Pressure maintenance by water injection will lead to the recovery of 6,600,000 barrels of oil, including 4,700,000 barrels of additional oil which would not be recovered by primary operations (Figure 10), bringing the combined primary and secondary ultimate recovery to 194 barrels per acre foot or 30 per cent of the original oil in place. The Unit Recovery Bar Diagram (Figure 11) shows how these estimates were made.

A prediction of performance for the Carson Unit Pressure Maintenance Project is made in Figure 12, a graph showing the flood oil production increasing from a low of 1200 B/D after the conversion of 35 producing wells to injection service, to a peak of 4,000 B/D (about 25 per cent of the injection rate) after 1.5 years of injection. After one year of producing at the peak rate the oil production then declines for 7.5 years to the economic limit of 350 B/D.

The total injected water requirement is estimated to be 60,000,000 barrels, on the basis of two floodable pore volumes injected to recover 6,600,000 barrels of oil. It is planned to inject at rates up to 20,000 B/D initially, but it is estimated the injection will average only 17,000 B/D for 5 years, at which time the minor injectors will be shut down and the injection will average 16,000 B/D for the remaining 5 years of the flood life.

FLOOD PLAN

The orientation of the better continuity of the sands was a large factor in the design of the injection pattern. Because we can expect the flood fronts to be distorted as they move preferentially in a direction parallel to the longitudinal axis of the sand bars, it is desirable that the spacing of the injectors be dense in the north-south direction. Similarly, it follows that the distance between injectors in the opposite direction, along the sand trend, can be made much greater. It appears that attempting to keep the flood fronts of a conventional five-spot pattern in balance would be practically impossible in a situation such as exists at Bisti. Therefore, a line-drive pattern has been chosen (Figure 13) that meets the above specifications, and should furnish adequate injection capacity to conclude the flood in a reasonable time. The plan includes 29 major injectors on the Unit, 5 major injectors on the west boundary, and 6 minor injectors. Two additional injectors are planned on the Mudge 6 Lease on the east boundary of the project. It is planned to inject an average of 500 B/D into each of the major injectors. The minor injectors are designed to drive some oil from the fringe areas into the fairway portions of the field, where it can be produced. The injectivity of these wells is expected to be low, about 150 B/D.

The pattern is modified in the southeastern portion of the Unit by the inclusion of a line of injectors (41-20, 32-20, and 23-20), designed to prevent the migration of oil into the gas cap. A "water barrier" line of injectors along the common boundary of the Carson Unit and the Mudge 6 Lease has been proposed and tentatively agreed to by the Operators currently forming the East Bisti Unit.

In general, the basic flood plan is to drive the oil banks from the injectors (20 row wells) to the key producers (40 row wells), located midway between the injection lines. As the oil banks pass the intermediate producers (10 and 30 row wells), these wells will be produced in the interest of increased flood efficiency. It is anticipated that it will be unnecessary to produce most of these intermediate wells for long periods of time at high water cuts.

WATER SOURCE

No suitable surface source of water for this project is available; however, the Point Lookout and Lower Allison-Menefee sands offer a satisfactory subsurface water source. These sands are shown on the Type Log (see Figure 14), which illustrates the formations encountered in the Bisti Field wells. Development of this source requires the drilling of several wells to 3800 feet. The Point Lookout and Lower Allison-Menefee ~~formations~~ waters are saline and compatible with the Gallup reservoir water, analyses for which are shown on Figure 15. These water bearing formations are of sufficient thickness and areal extent to provide an adequate volume of water for the project.

A relatively simple system for handling the makeup water and the produced water is planned, since these waters can be commingled and re-injected into the reservoir with a minimum of treatment. As seen on Figure 16, produced and makeup waters will be commingled, passed through a floatation cell for the removal of any residual oil and the larger suspended solids, and then through anthracite filter beds for final filtration. Control of bacteria, calcium carbonate scale deposition, and corrosion will be effected with commercially available chemicals. Figure 17 shows a typical injection well. Water will flow down 2-inch tubing, which is set on a packer, and into the formation through perforations in the casing. The tubing-casing annulus will be filled with inhibited fresh water prior to setting the packer.

WORKING INTEREST OWNERSHIP

Shell Oil Company is the sole working interest owner of all lands in the proposed Carson Unit Pressure Maintenance Project.

CONCLUSIONS

It is recommended that pressure maintenance by water injection be initiated in the Carson Unit in the manner set forth herein in order to effect the recovery of 4,700,000 barrels of additional oil.

RESERVOIR DATA
LOWER GALLUP POOL - BISTI FIELD

Average Depth (GD Marker)	4850 feet
Average Formation Dip	1°
Average Porosity (158 samples from 17 wells)	15%
Average Air Permeability (158 samples from 17 wells)	57 md.
Connate Water Saturation (Logs and capillary pressure)	25%
Residual Oil Saturation (Water base core saturation)	30%
Reservoir Pressure at Datum (+1500')	
Original	1550 psig.
At Start of Flood	500 psig.
Reservoir Temperature	140° F.
Bubble Point Pressure	1550 psig.
Formation Volume Factor	
Original	1.33
At Start of Flood	1.21
Gas Solubility (Including Tank Vapors)	
Original	530 cf/b
At Start of Flood	240 cf/b
Oil Gravity	39° API
Oil Viscosity - Reservoir Conditions	
Original	0.6 cp.
At Start of Flood	0.8 cp.

FIG. 8

VOLUMETRIC AND RECOVERY SUMMARY
LOWER GALLUP POOL - BISTI FIELD
EXPANDED CARSON UNIT

Productive Area	6,600 acres
Equivalent Net Pay Volume	59,000 ac.ft.
Tank Oil Originally in Place	38,700,000 bbl.
Total Number of Producing Wells (Dec. 1960)	124
Current Production Rate (Dec. 1960)	2,200 B/D
Estimated Cumulative Production at Start of Flood (Aug.1,1961)	5,000.000 bbl.
Primary Reserves as of August 1, 1961	1,900,000 bbl.
Estimated Ultimate Primary Recovery	6,900,000 bbl.
Estimated Ultimate Primary Recovery Efficiency	18 %
Water Flood Recovery (Includes Remaining Primary)	6,600,000 bbl.
Additional Reserves by Water Flooding	4,700,000 bbl.
Estimated Ultimate Recovery (Primary and Secondary)	11,600,000 bbl.
Estimated Ultimate Recovery Efficiency	30 %

FIG. 10

WATER ANALYSES

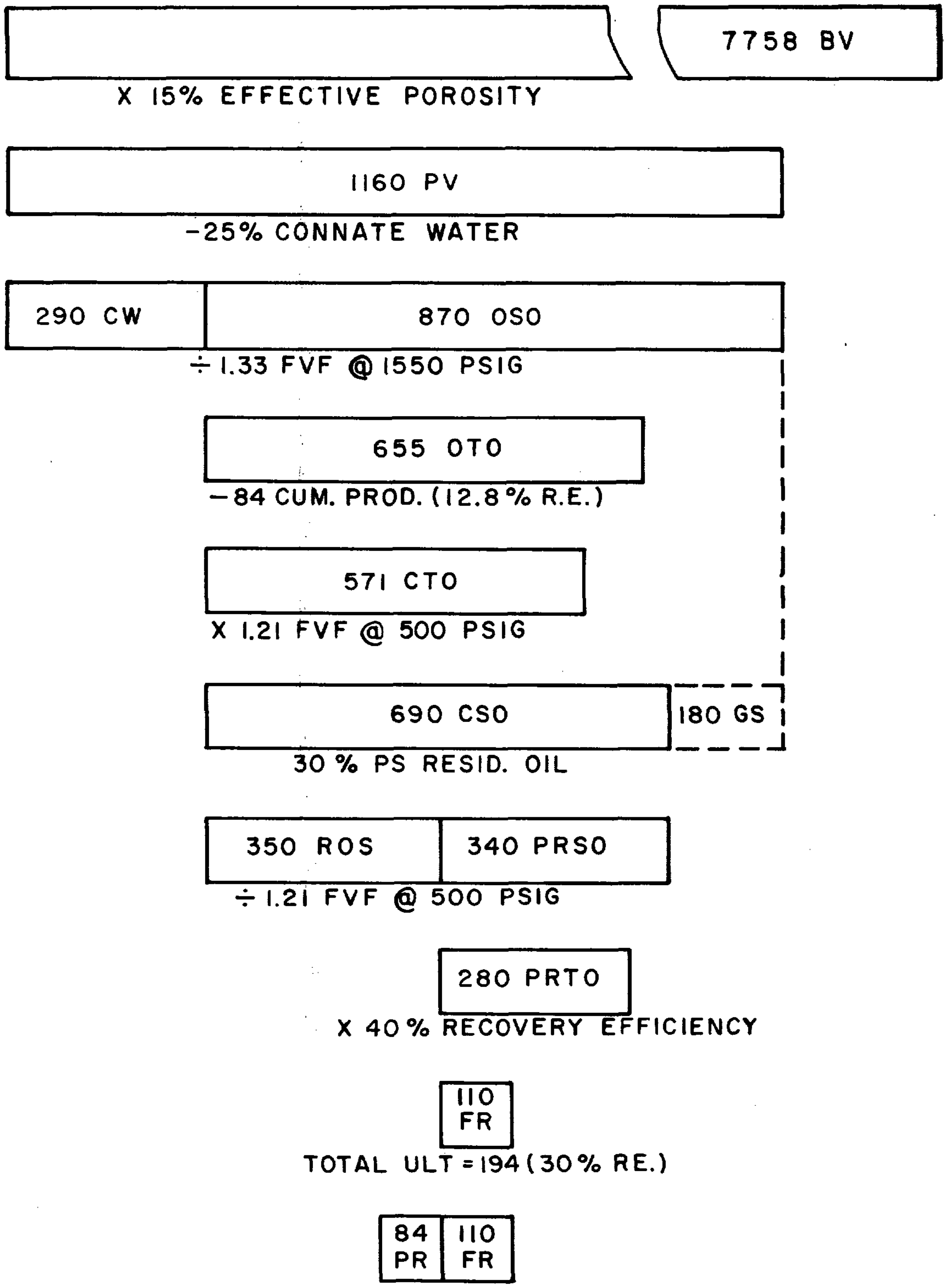
		POINT LOOKOUT (1)	GALLUP (2)
Carbonate	CO_3	0 ppm	0 ppm
Bicarbonate	HCO_3	1,074	523
Chloride	Cl	15,265	17,400
Sulfate	SO_4	23	15
Borate	B_4O_7	8	9
Sulfide	S	-	0
Barium	Ba	70	40
Calcium	Ca	156	392
Magnesium	Mg	70	125
Ammonium	NH_4	15	14
Iron	Fe	4	75
Sodium	Na	9,951	10,725
Salinity (NaCl)		25,155	27,200
Ph		7.65	6.40

(1) Shell Oil Company Carson 2 - Date of test 4-13-60

(2) Shell Oil Company Carson Unit 23-14 - Date of test 6-17-60

FIG. 15

UNIT RECOVERY BAR DIAGRAM - BISTI
PRESSURE @ 500 PSIG
ALL FIGURES ARE BBL./AC.FT.



LEGEND

BV	Bulk Volume
PV	Pore Volume
CW	Connate Water
OSO	Original Subsurface Oil
OTO	Original Tank Oil
CTO	Current Tank Oil
CSO	Current Subsurface Oil
GS	Gas Saturation
PS	Pore Space
ROS	Residual Oil Saturation
PRSO	Potentially Recoverable Subsurface Oil.
PRTO	Potentially Recoverable Tank Oil
FR	Flood Recovery
PR	Primary Recovery

Z 20-1237

FIG. 11

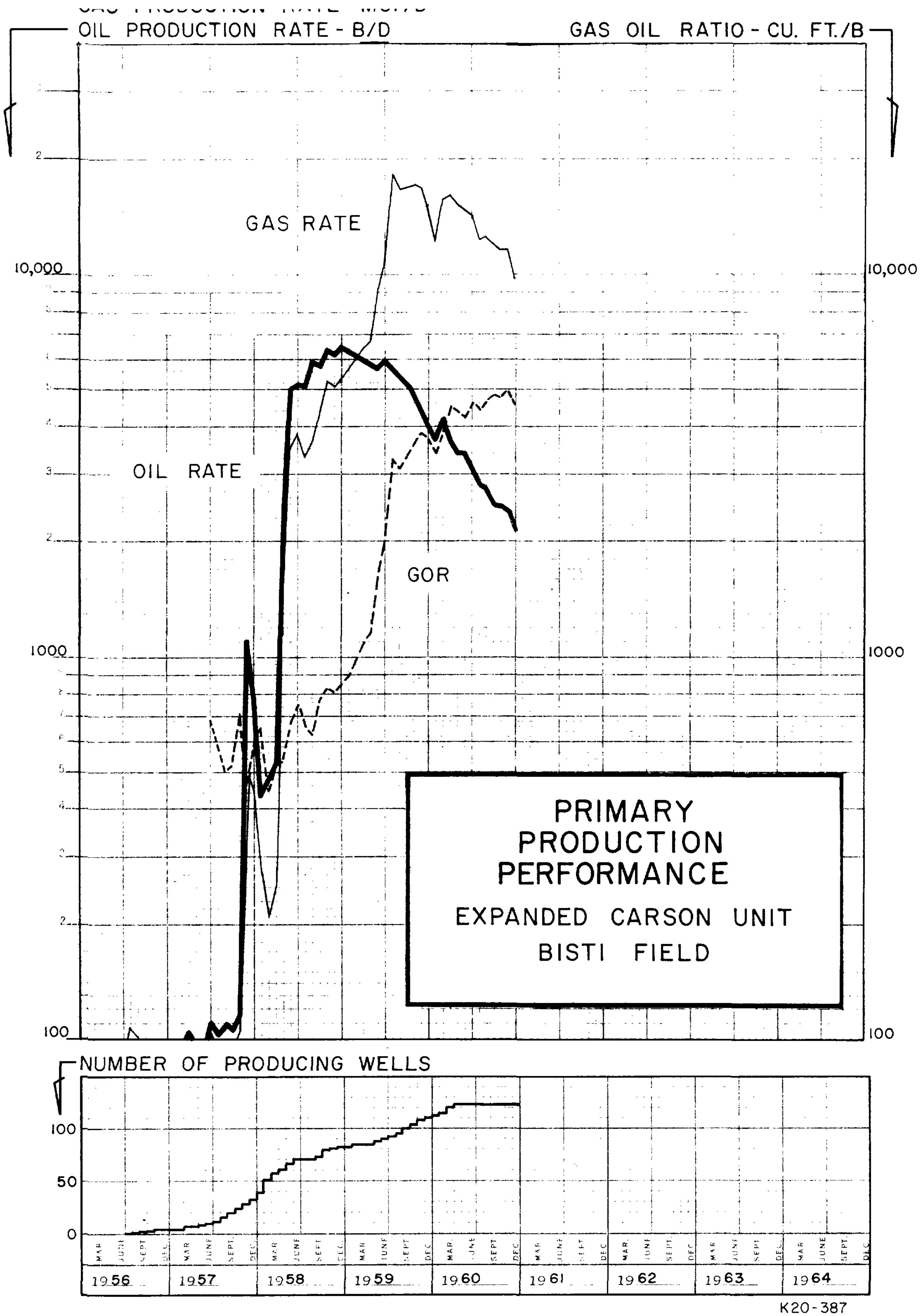
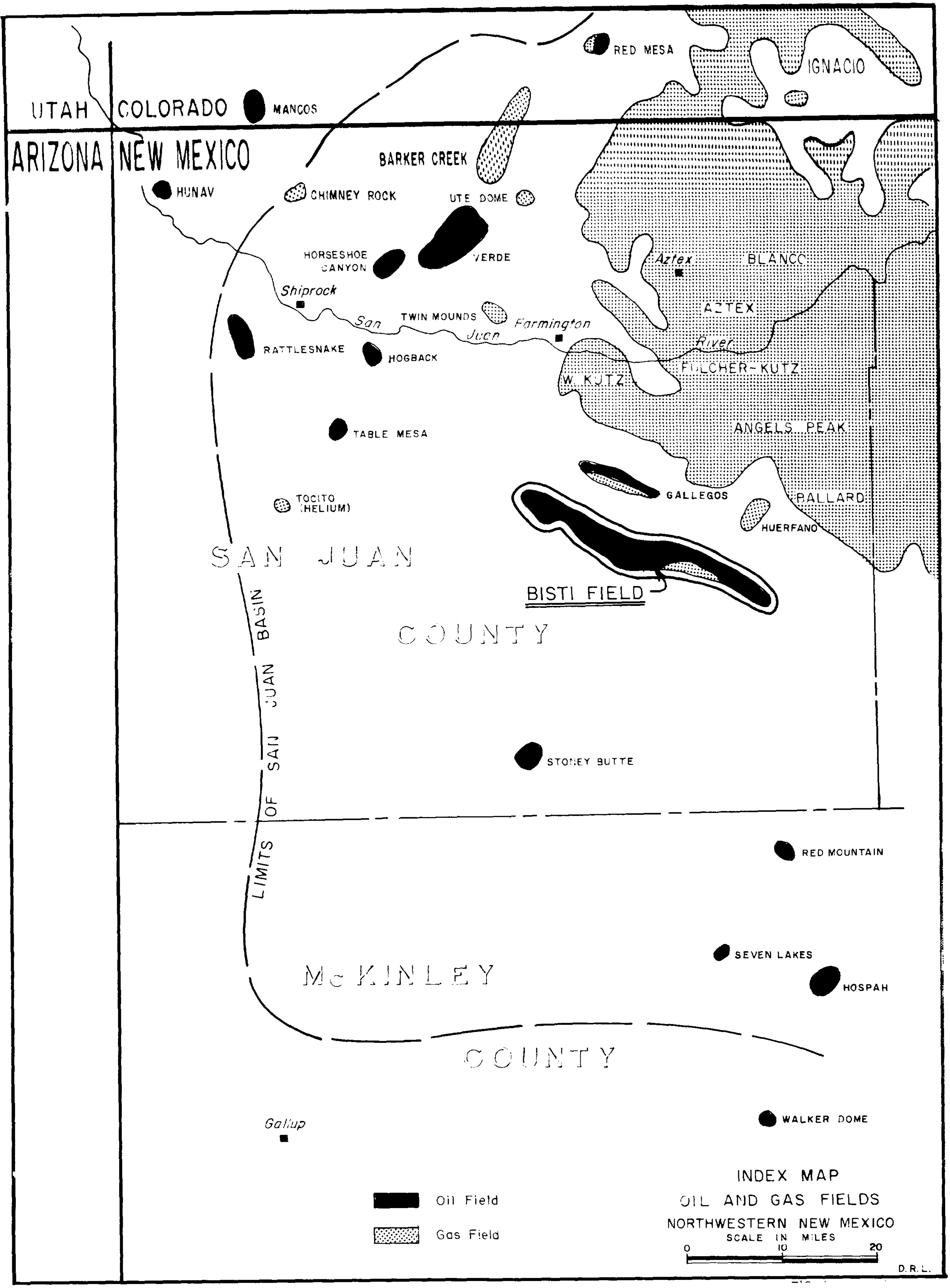

GAS PRODUCTION RATE - MCF/D
OIL PRODUCTION RATE - B/D
GAS OIL RATIO - CU. FT./B
10,000
1000
100
GAS RATE
OIL RATE
GOR
PRIMARY PRODUCTION PERFORMANCE
EXPANDED CARSON UNIT
BISTI FIELD
NUMBER OF PRODUCING WELLS
100
50
0
MAR JUNE SEPT DEC
1956
1957
1958
1959
1960
1961
1962
1963
1964
K20-387

FIG. 9


UTAH
COLORADO
ARIZONA
NEW MEXICO
RED MESA
IGNACIO
MANCOS
BARKER CREEK
HUNAV
CHIMNEY ROCK
UTE DOME
HORSESHOE CANYON
VERDE
Aztex
BLANCO
Shiprock
AZTEX
TWIN MOUNDS
San Juan River
Farmington
RATTLESNAKE
HOGBACK
W. KUTZ
FULCHER-KUTZ
ANGELS PEAK
TABLE MESA
GALLEGOS
TOCITO (HELIUM)
BALLARD
HUERFANO
SAN JUAN
BISTI FIELD
COUNTY
LIMITS OF SAN JUAN BASIN
STONEY BUTTE
RED MOUNTAIN
SEVEN LAKES
McKINLEY
HOSPAH
COUNTY
Gallup
WALKER DOME
Oil Field
Gas Field
INDEX MAP
OIL AND GAS FIELDS
NORTHWESTERN NEW MEXICO
SCALE IN MILES
0
10
20
D.R.L.