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PROGRESS REPORT ON THE GEOLOGY AND THE EVALUATION OF THE OIL SHALE

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PROGRESS REPORT ON THE GEOLOGY AND THE EVALUATION OF THE OIL SHALES OF THE GREEN RIVER BASIN

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Rock Springs, Wyoming
May 22, 1970

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ABSTRACT

The Green River basin of Wyoming contains oil shales of considerable value in the Lower Laney and Tipton members of the Green River formation, with the best oil shales in the Tipton with some depths exceeding 1500' in the southeastern portion of the basin. From data obtained by field work and the drilling of six wells by Union Pacific it is estimated that there are 435 square miles of Union Pacific land containing 55 billion barrels of shale oil in beds with an average content of 10 GPT or more. Where the oil content averages 20 GPT or more there are 300 square miles beneath Union Pacific lands containing at least 30 billion barrels.

The stand taken by the United States government during the week of May 18, 1970, by their decision not to consider leasing federal oil shale lands temporarily, puts Union Pacific in a very advantageous position with their tremendous resource of shale oil lands not under any restrictions but available for leasing or joint operation to develop a domestic supply of oil.

E R McClean

PROGRESS REPORT ON THE GEOLOGY AND THE EVALUATION OF THE OIL SHALES OF THE GREEN RIVER BASIN

INTRODUCTION

I have prepared several brief progress reports on the geology and oil shales of the Green River basin but this progress report is somewhat more detailed in its evaluation of the oil shales that occur within the Union Pacific Land Grant.

There is repetition of some data previously presented in the following reports: "General Data for Union Pacific Core Holes Drilled in the Green River Basin During 1967", "Oil Shale Progress Report, March 7, 1968", "Wells Penetrating the Green River Formation From Which Samples Were Collected During Summer of 1968", "Preliminary Report on the Geology and Oil Shales of the Green River Basin, April 1969, Revised April, 1970". Reference will be made to the information included in the above descriptions.

This study of Wyoming oil shales began early in the year 1967 with a perusal of available literature and the acquisition of pertinent published material not on hand.

In March, 1967 the locations for six cores of the Green River oil shales in the basin were selected and these cores were drilled from September through November, 1967. In the meantime, field work with assistant Alan Jones was begun and six measured sections and numerous attitudes were determined throughout the region of interest.

During the summer field season of 1968 the mapping of the basin continued with the assistance of George O'Hara.

During the winter months of 1968, 1969 and 1970, the data gained from the drilling of the Union Pacific cores and the assaying of the oil shale sections in addition to field interpretations provided information for the maps included with this progress report.

The study of the basin is not complete and much additional work will be required to evaluate completely the Union Pacific lands for their shale oil content.

Location and Relations of the Area

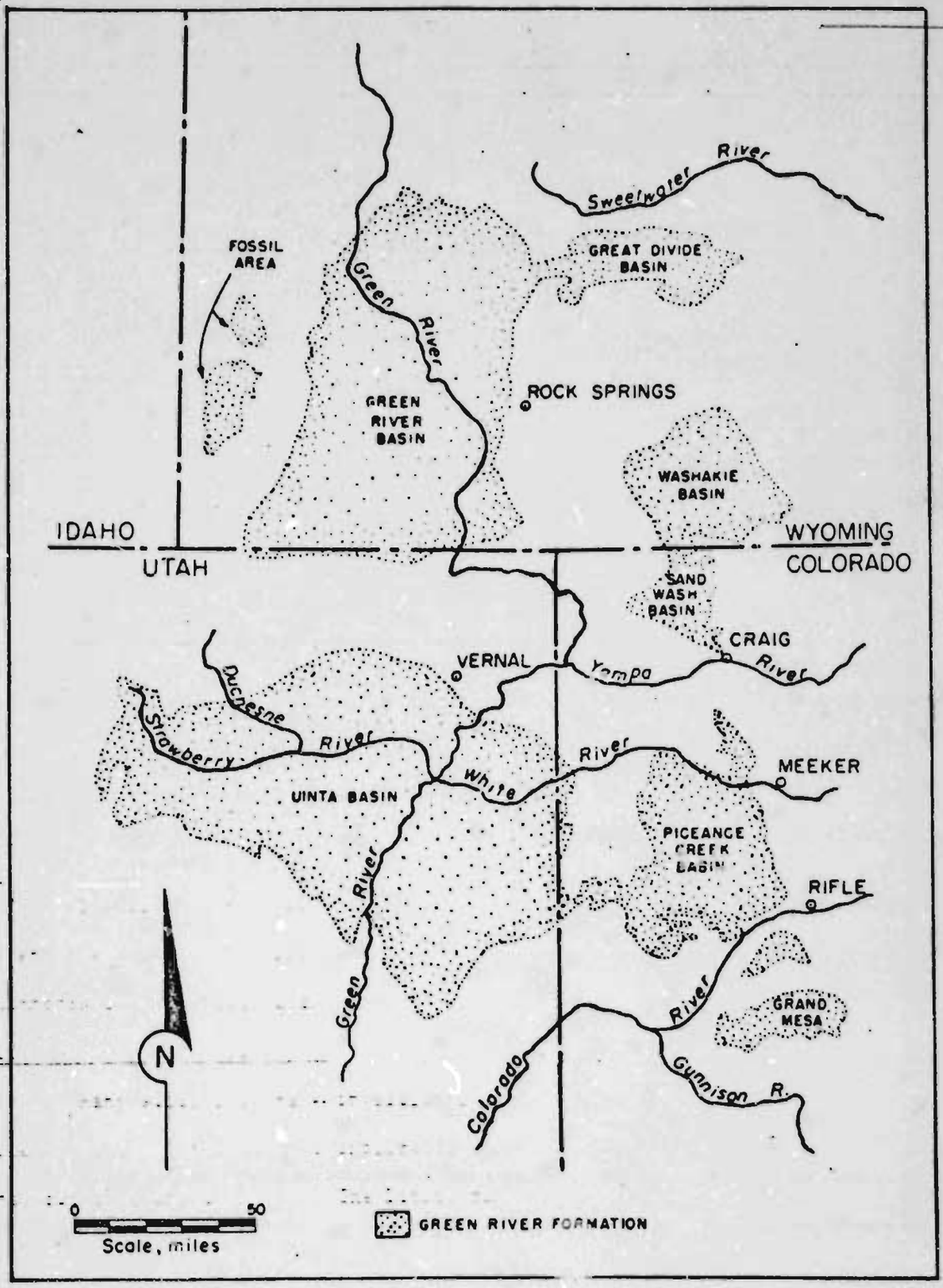
Figure A, page 3 indicates the areas underlain by the Eocene Green River formation where all of the important oil shales occur in Colorado, Utah, and Wyoming. In Wyoming the Green River formation includes about 5800 square miles from T12N to T29N, and from R105W to nearly R117W (See Figure B, page 4). To some geologists the Green River basin includes, in addition, all of those rocks that are situated in the Great Divide and Washakie and Sand Wash basins with the individual depressions of the Great Divide and Washakie basins separated from the Green River basin by the Rock Springs uplift. This idea has some merit in that Lake Gosiute in whose waters the Green River sediments were deposited probably covered all of that area simultaneously. However, in this report the Green River basin is that shown on Figure A.

Plate I is a topographic map of the Green River basin area with a scale of 1" = 4 miles. The center of the basin is difficult to describe but the axis trends roughly northerly from T14N to T22N in Ranges 109W to 111W. The Plates VI and VII, structure contours on the Tipton and Wasatch, illustrate this axial trend.

The city of Rock Springs is about 30 miles east of the north-south basin axis and the buildings of Little America are not far west of this axis. The city of Kemmerer is just west of the west edge of the Green River basin.

Earlier Geologic Investigations

Many scientists have investigated the Green River basin, though their studies generally involved the exploration for commodities such as oil, gas, and trona, rather than oil shale. The Bibliography at the end of the text lists important reference works.

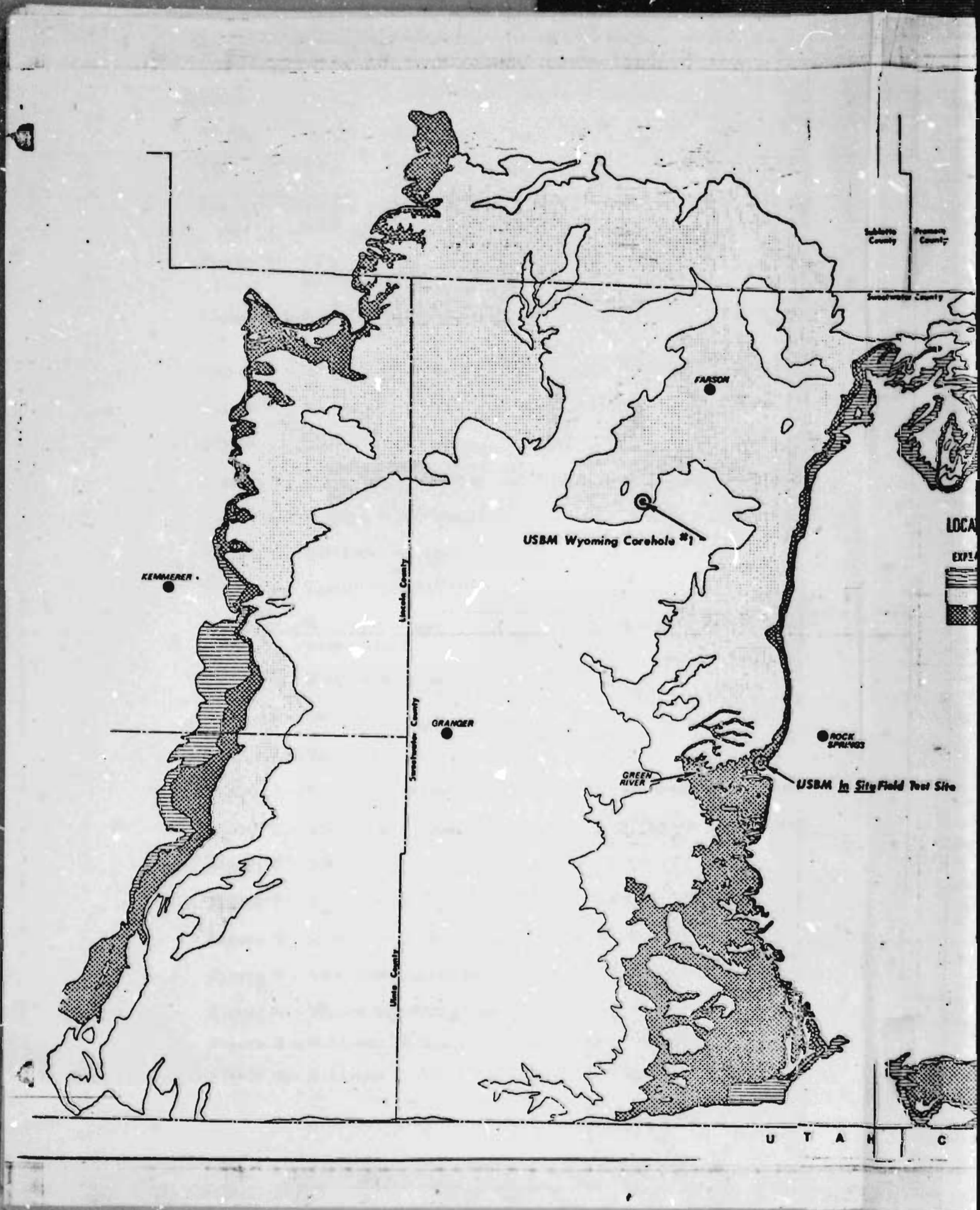


Extent of Green River Formation in Colorado, Utah, and Wyoming.

Figure A

MAP FILMED

IN SECTIONS


Sublette County
Sweetwater County
FARSON
USBM Wyoming Corehole #1
KEMMERER
Lincoln County
Sweetwater County
GRANGER
ROCK SPRINGS
GREEN RIVER
USBM In Situ Field Test Site
Uinta County
U T A H

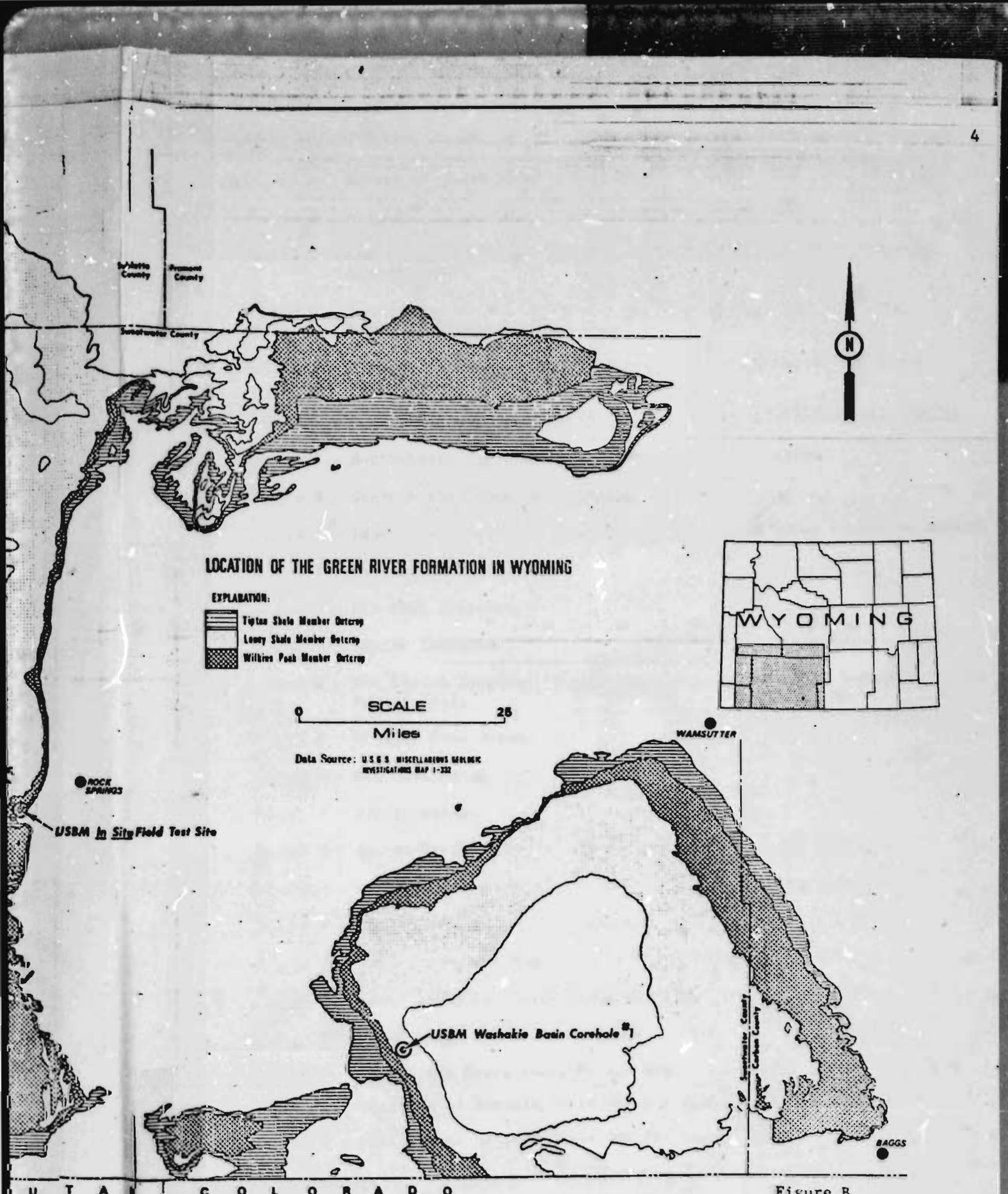

LOCATION OF THE GREEN RIVER FORMATION IN WYOMING
EXPLANATION:
Tipton Shale Member Outcrop
Laney Shale Member Outcrop
Wilkins Peak Member Outcrop
SCALE
0
25
Miles
Data Source: U.S.G.S. MISCELLANEOUS GEOLOGIC INVESTIGATIONS MAP I-332
WYOMING
N
WAMSUTTER
ROCK SPRINGS
USBM In Situ Field Test Site
USBM Washakie Basin Corehole #1
BAGGS
Sweetwater County
Carbon County
UTAH
COLORADO

Figure B

ILLUSTRATIONS

Figures

ILLUSTRATIONS (continued)

Plates

Plate I - Topographic map of the Green River basin, with a scale of 1" = 4 miles with Union Pacific cores located.

Plate II - Geological map of the Green River basin with oil shale, core, well, and field data. Scale: 1" = 2 miles.

Plate III - Extent of oil shales in the Green River basin with members of the Green River formation colored.

Plate IV - E-log cross-section #1 in Green River basin.

Plate V - E-log cross-section #2 in Green River basin.

Plate VI - Structural map of a portion of the Green River with the datum on top of the Tipton. Scale: 1" = 2 miles.

Plate VII - Structural map of a portion of the Green River basin with the datum on top of the Wasatch formation. Scale: 1" = 2 miles.

Plate VIII - Map of the oil shale area of the Green River basin showing locations of oil shale cores, proposed cores, measured sections, and proposed measured sections.

Tables

Table 1 - Green River basin stratigraphy.

Table 2 - Union Pacific Railroad core hole data - Green River basin - 1967 wells.

Table 3 - Core 2-19 Oil Shale beds with 10 GPT or more.

Table 4 - Core 4-7 Oil Shale beds with 10 GPT or more.

Table 5 - Core 22-15 Oil Shale beds with 10 GPT or more.

Table 6 - Core 41-23 Oil Shale beds with 10 GPT or more.

Table 7 - Core 44-3 Oil Shale beds with 10 GPT or more.

Table 8 - Core 44-19 Oil Shale beds with 10 GPT or more.

Table 9 - Statistics of Assayed Oil Shale Data for Union Pacific Cores.

Photographs - Upper Green River Formation Members.

Electrical Logs of Union Pacific core holes are in Pocket.

GEOGRAPHY

The Green River basin has west and east facing escarpments on two sides and in between the country is relatively rugged with typical badland topography over much of its extent. Interstate Highway 80 transects the basin in an east-west direction and there are other good paved roads north and south and an extensive network of trails elsewhere. The Green River, Black's Fork, Ham's Fork, and Henry's Fork drain the region. Even though the area is a widespread desert, several communities such as Rock Springs, Green River, Lyman, and Farson, supply the needs of the populace. Plate I is a topographic map of the area.

STRATIGRAPHY

The fluviatile sediments of the Eocene Bridger formation overlie the lacustrine layers of the Green River formation, also Eocene in age. The Green River formation is the series of immediate interest as it contains the best oil shales of the United States. Exposures of the lake beds are found only at the edges of the basin for the younger Bridger masks the inner basin strata quite effectively; for this reason the best information can come only from core drilling and sampling of strategic wells.

The general stratigraphic descriptions of the Green River basin are in Table 1 on page 8 and show that there are river and lake deposits consisting of sandstones, siltstones, marlstones, shales, tuff beds, saline mineral and oil shales. Figure C on page 9 is a sketch of the Green River depositional variations which indicate rapid intertonguing of the Green River and Wasatch sediments at the west and east reaches of the basin. Figure D on page 10 diagrams the Generalized Upper Tertiary Stratigraphy of both the Green River and Washakie basins and relates the oil shales. Figure E, page 11, indicates the stratigraphic positions of the most important oil shales of the Eocene sedimentary series. Figure F, adapted from Culbertson, is an outline of the position of oil shales in the basin and Figure G, page 13, is a north-south cross-section with the places of the oil shales colored in green; the line of this section A-A' is shown on Figure F; Figure G is also adapted from Culbertson. Pictures on pages 14 and 15 show upper Green River rocks.

TABLE 1

GREEN RIVER BASIN STRATIGRAPHY

	Formation	Member	Thickness	Lithology
TERTIARY EOCENE Upper (?)	Bridger		0-2300' (?)	Mudstone, gray, green, pink, tuffaceous sandstone - cherty limestone - white tuff layers - mammal and reptile remains. Fluvial deposition.
			******	
TERTIARY EOCENE Middle	Green River	Laney	0-1900'	Tuffaceous sandstone, siltstone, buff and white - mudstone and marlstone, gray buff and brown - brown to gray to orange tuffs. Oil shale - algal limestone and oolite beds. Plant remains and fish fossils prominent. The Tower sandstone (tuff) is at or near the base. Lacustrine beds.
		Wilkins Peak	0-1350'	Mudstone, green, gray and white; marlstone; thin oil shales; white to brown tuffaceous sandstones; tuffs (abundant) Saline minerals and trona in east and southeast. Lacustrine beds.
		New Fork Tongue of Wasatch	0- 400'	Somewhat correlative in time to Cathedral Bluffs of Washakie basin - mudstone gray to green with red to maroon layers coarse to fine grained sandstone. Fluvial beds.
		Tipton	0- 250'	Marlstone, brown to gray to buff - oil shale and abundant thin tuffs. Goniobasis gastropod and clam bed at base. Lacustrine beds.
		Fontenelle Tongue of Green River	0- 250'	Correlative of the Tipton in the western part of the basin - gray marlstone and shale with algal layers, sandy near base and top. No good oil shales. Lacustrine deposition.
			*******	
Early	Wasatch			Mudstone, and shale, gray to green to red, sandstone and siltstone, at top gray to blue-gray. Coarse sandstone. Coal beds. Fluvial beds.

FIG. D

GENERALIZED UPPER TERTIARY STRATIGRAPHY.

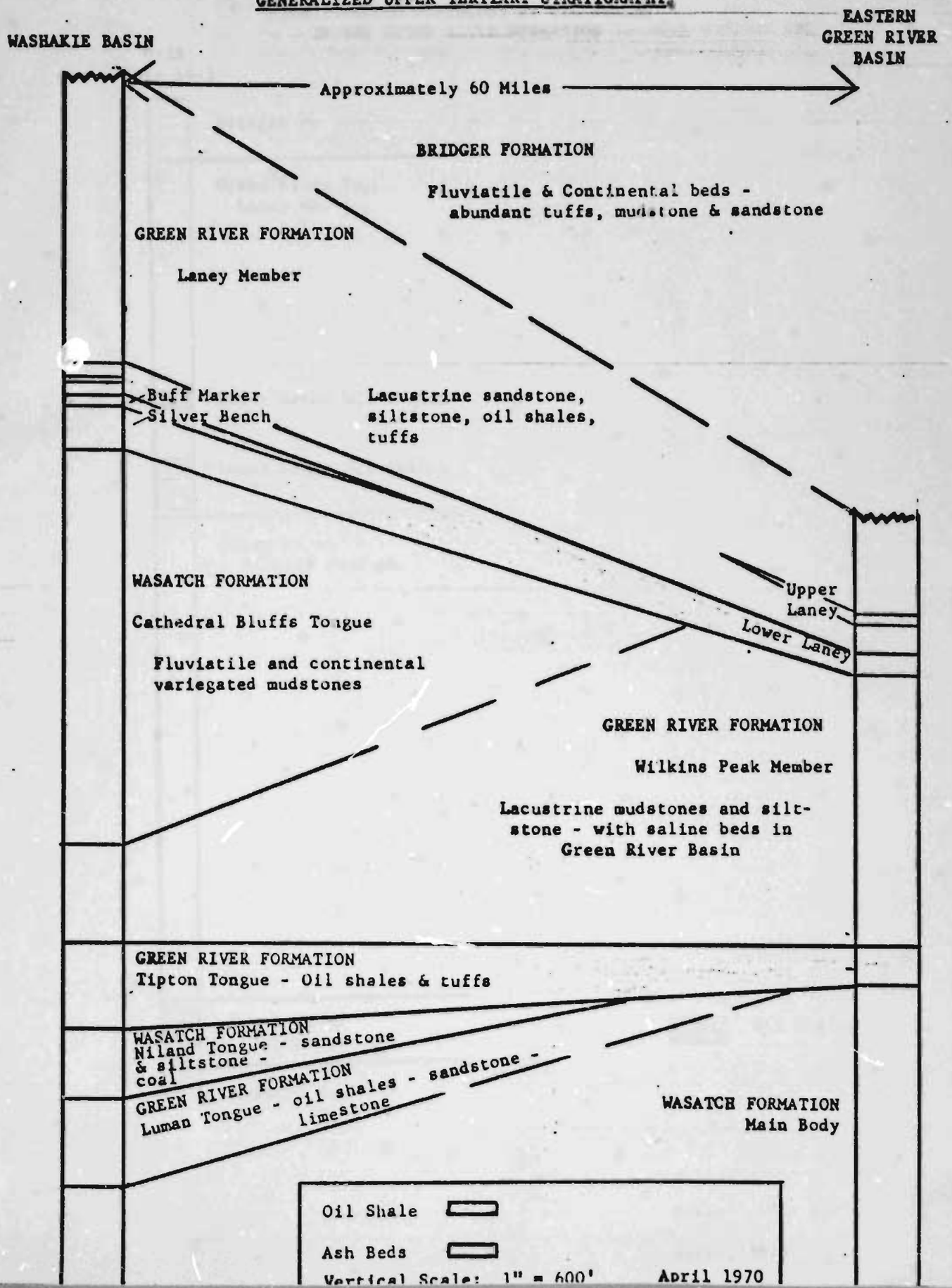
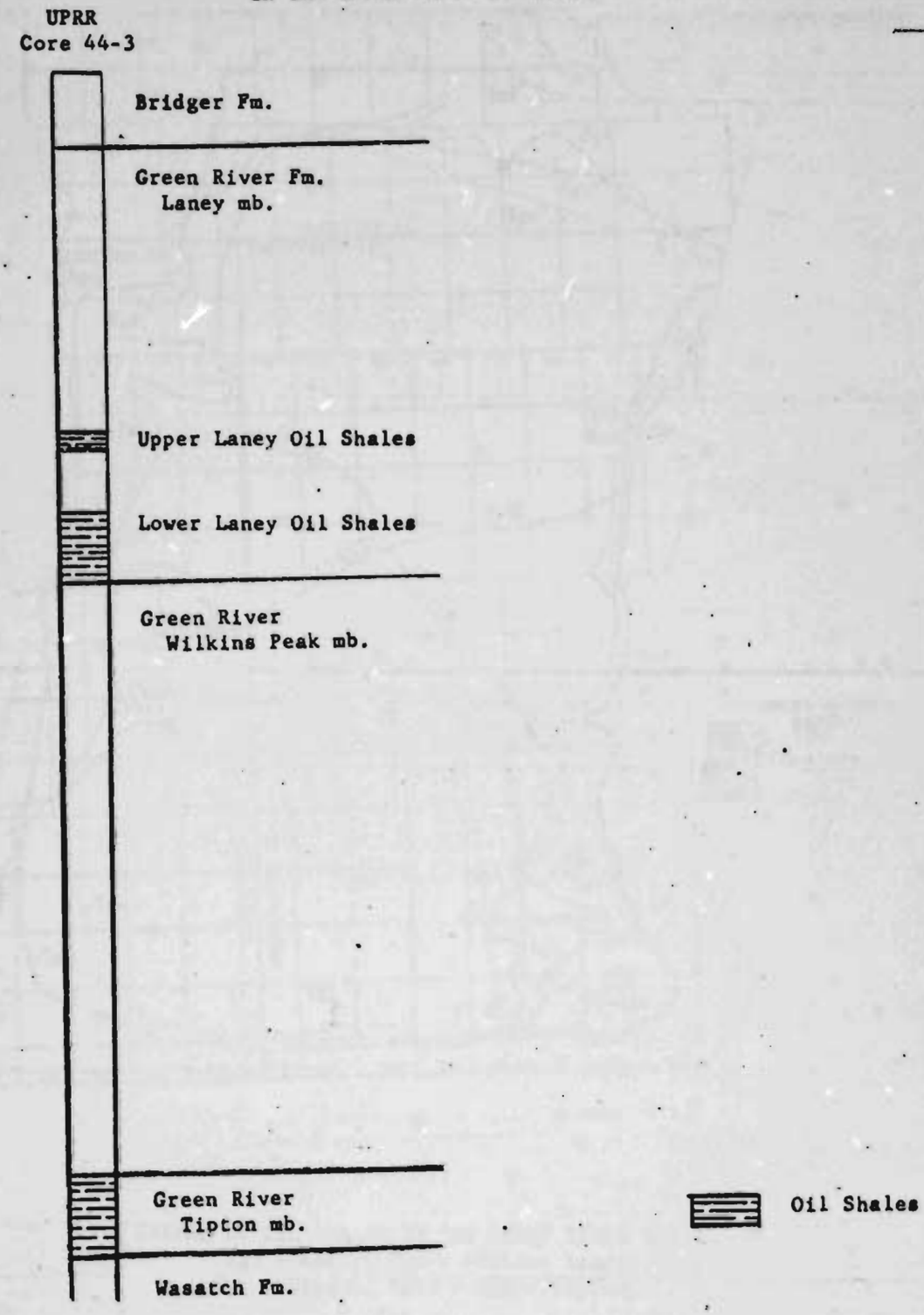


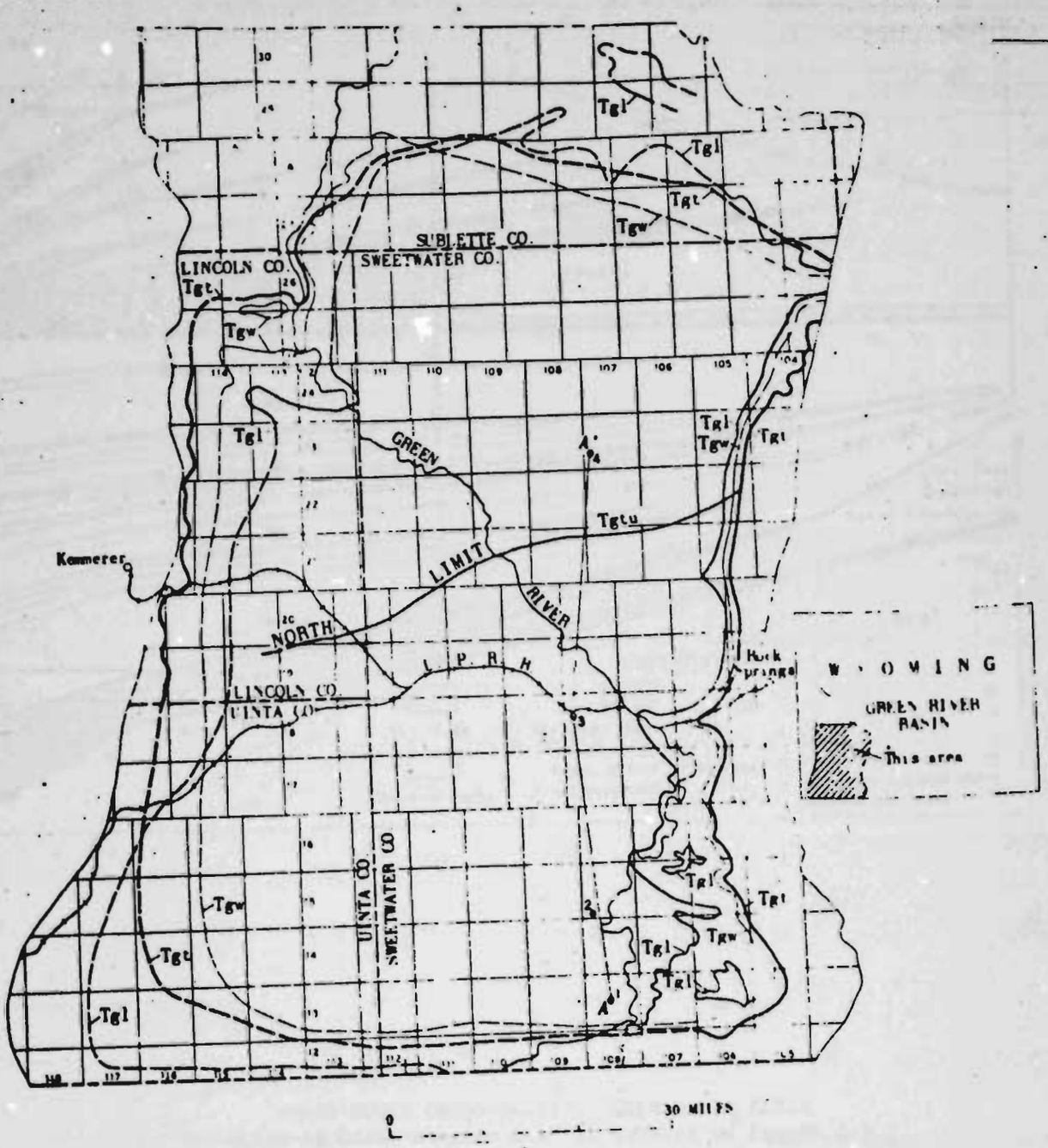
Fig. E

STRATIGRAPHIC POSITIONS OF OIL SHALES
IN THE GREEN RIVER FORMATION



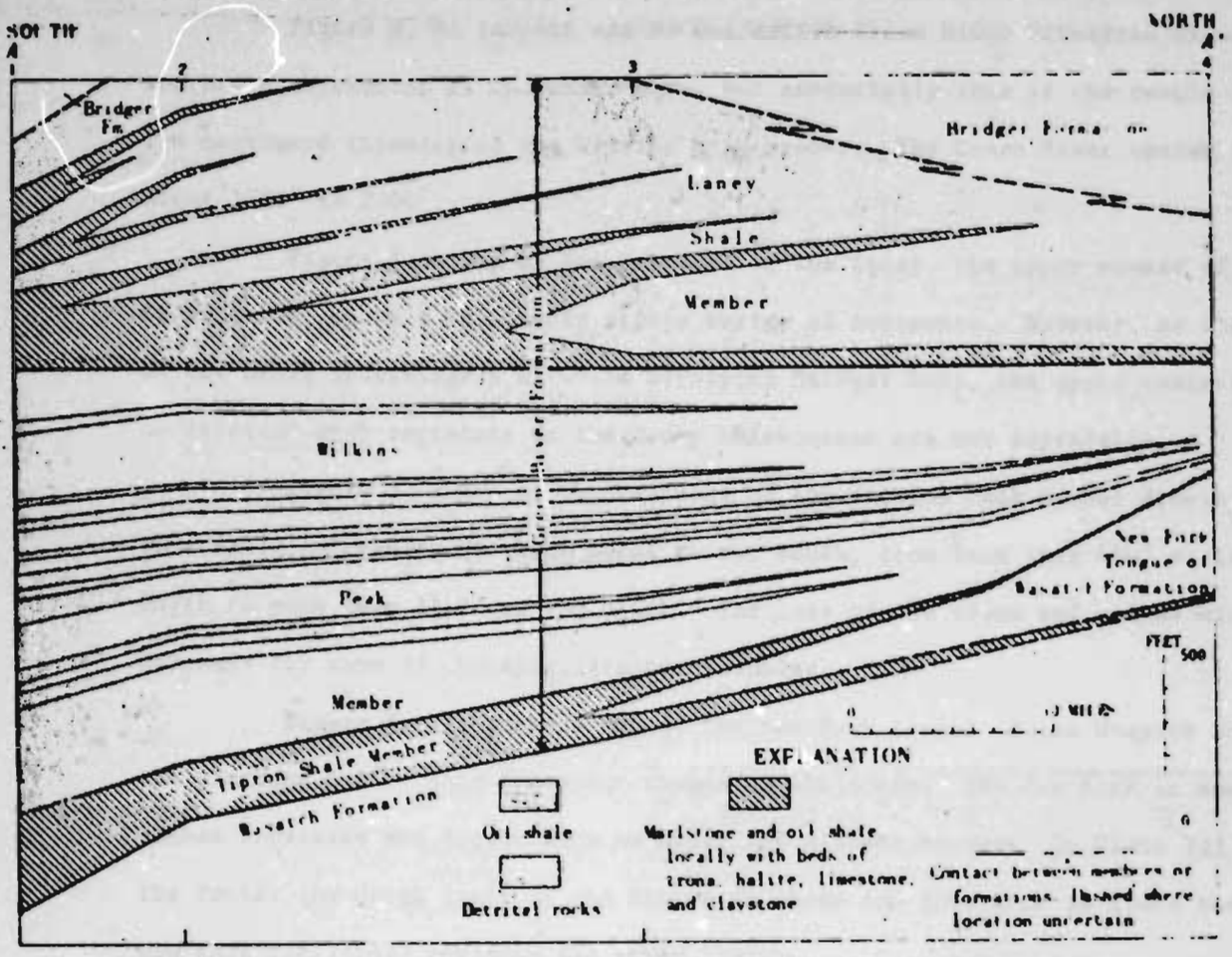
Scale: 1" = 300'

April, 1970



EXTENT OF OIL SHALES IN THE GREEN RIVER BASIN
Tgl - Laney; Tgw - Wilkins Peak;
Tgt - Tipton; Tgtu - Upper Tipton.

Figure F



NORTH-SOUTH CROSS-SECTION GREEN RIVER BASIN
(Line of Cross-section A-A' is located on Figure F.)

Figure G

From field, well, and core data maps of the members of the Green River were drawn and are next discussed, and appear in the Appendix.

Figure H, an isopach map of the entire Green River formation shows a southward thickening of the whole body, but essentially this is the result of the northward thinning of the Wilkins Peak member. The Green River varies from about 1750' to 2200'.

Figure I, a map of the Isopachs of the Laney, the upper member of the Green River, shows a relatively stable series of sediments. However, as the top of the Laney interfingers with the overlying Bridger beds, the upper contact cannot be selected with certainty so the Laney thicknesses are not dependable.

Figure J, a map of the Isopachs of the Wilkins Peak member displays a remarkable thickening of these rocks to the south, from less than 400' at the north to more than 1200' at the south. The loss of the trona and saline minerals accounts for some of the stratigraphic thinning.

Figure K. Isopachous map of the New Fork tongue of the Wasatch showing the pinching out of this sandstone tongue to the south. The New Fork in some places separates the Tipton into an upper and a lower member. On Plate III in the Pocket the north limit of the Tipton is shown and this line is where the New Fork completely replaces the upper Tipton.

Figure L. A map of the Tipton isopachs in the basin which includes the sediments of the New Fork tongue of the Wasatch. To the southeast where there are 150' of Tipton there are no New Fork sands, so this represents all of the Tipton.

Figure M. Isopachous map of the Net Tipton, that is, the Tipton thickness with the beds of the New Fork deleted from the total figure. The Tipton runs from about 20' at the north to more than 150' at the south.

Plate III is a map after Culbertson of the U.S.G.S., showing lateral extent of the various members of the Green River formation which contain oil shales, and these are denoted by shades of green. The non-oil shale bearing

Wasatch beds are in red. The dark green is indicative of the region of oil shales underlying Union Pacific lands.

Plate IV E-log Cross-section #1 is a north-south cross-section compiled from the logs of the Union Pacific coreholes and hung on the top of the Tipton. The relatively stable Laney, the large southward thickening of the Wilkins Peak, the variability of the Tipton thickness, and the entrance from the north of the New Fork tongue are indicated.

Plate V E-log Cross-section #2, northwest-southeast cross-section also hung on the Top of the Tipton, indicates a less rapid thinning of the Wilkins Peak to the northwest, but the Laney tops have not been selected so that the thickness of the Laney is not shown. At 44-3 there is no New Fork, but all the other logs include the New Fork tongue of the Wasatch. Wherever there is New Fork present it replaces oil shales of the Tipton. The stratigraphic changes that take place from well 44-3 to 4-7 are notable, but this is understandable when it is realized that the lake shoreline is being approached to the north and west.

A unit of rock deserving of some discussion is the so-called "Tower" sandstone which is at or near the base of the Laney and is often just above the oil shales of the lower Laney. The "Tower" is a tuffaceous sediment which Bradley believes is a crystal tuff and was transported from volcanic regions to the north and deposited in pods in small ponds of Lake Gosiute. The "Tower" is a discontinuous body of rocks which is not everywhere present and therefore is not a mappable unit. The "Tower" becomes younger to the south from Green River city where it is a light brown to orange appearing impressive mass of rock with disturbed layers which are chaotically bedded at the base. The chaotic appearance of the basal "Tower" may have been due to its deposition on the soft, not yet indurated layers, of future oil shale, or earthquakes may have caused the peculiar violently disturbed strata. During the summer of 1969 beds with typical "Tower" appearance, lithology, and disturbed bedding were mapped along the Kinney Rim in the Washakie basin. See pictures on pages 14 and 15.

STRUCTURE

General Features

The Green River basin is a structural and topographic basin with all sediments from the oldest to the youngest being downdropped in late Cretaceous and early Tertiary time. Plates VI and VII with datum on the Tipton and the Wasatch indicate the basin to be one where the deepest portion seems to be in a region south of the Union Pacific Land Grant in R110W, R111W, and R112W and T13N, T14N, and T15N with steep westerly plunges from the Rock Springs uplift to the east. The trough extends northerly from R111W through T14N-T22N, R109W. The Moxa-Church Buttes arch trending north-south is a prominent feature west of the basin axis.

On both the Tipton and the Wasatch contour maps the Firehole anticline raises the rocks in a southwesterly trend through Ranges 107W, 108W, and 109W, and T15N, T16N, and T17N.

Figure N, a datum map based on the Wilkins Peak shows the Firehole anticline, and the presence of the Green River basin trough, however, as the Wilkins Peak member thins rapidly to the north, a contour map on this horizon is not reliable. See Figure J for the amount of northward thinning of Wilkins Peak sediments. Figures N, O, and P are in the Appendix.

Figure O, a map with the top of the New Fork tongue of the Wasatch as datum shows a north-south syncline located relatively parallel with the Green River basin trough. The New Fork did not occur south of the 4500' contour line. See Figure K for isopachs of the New Fork and the zero line of deposition.

Figure P is a contour map on the top of the Tipton and is indicative of the major features of the Green River basin with the Firehole upwarp at the southeast of the map.

A contour map on top of the Green River formation, or the upper Green River member, the Laney, was not made as the contact between the Green River and Bridger formations is uncertain because of rapid and widespread fluctuations of

the level of Lake Gosiute and the consequential flood plain sediments of the Bridger beds. Figure C illustrates why no Laney structural map can be drawn.

ECONOMIC GEOLOGY

In the Green River basin many wells have penetrated the oil shales of the Green River formation. However, operators were primarily concerned with the search for crude oil, natural gas, trona, and uranium, and, therefore, paid little heed to the oil shale beds. The U.S.B.M. obtained cuttings from the operators and assayed more than one hundred thousand units. Unfortunately, most of the well samples were obtained by inexperienced and disinterested persons so that the reliability of the sample gathering methods is most uncertain. I have disregarded nearly all of the data from well cuttings unless I personally supervised the sample catching. The only reliable data is that gained by the drilling of the six Union Pacific core holes in 1967 and the oil shale evaluation is based on this information.

The first Union Pacific core was 44-3 in Section 3, T15N, R109W and cored the entire Green River formation, and was, as far as I know, the first well to core all of the Green River sediments. This well provided basic knowledge for the oil shale study.

It will not be necessary to include the Union Pacific core hole sample descriptions, core descriptions, and assay results here as this material was tabulated in a report dated March 11, 1969, titled "General Data for Union Pacific Oil Shale Core Holes Drilled in the Green River Basin During 1967" by E. R. McAuslan.

Table 2 on page 20 lists the locations, elevations, dates, total depths, stratigraphic data, number of cores, cored intervals, amount of footage assayed, and type of E-logs run of all of the six core holes.

Tables 3, 4, 5, 6, 7 and 8 are abstracts of the Union Pacific core and assay information indicating oil shales beds with 10 GPT or more. Table 9 on page 31 is a summary of oil shale thicknesses, shale oil content in GPT and in

TABLE FILMED

IN SECTIONS

Core	No.	Location	Elevation		Spud	Completed	TD Logger	TD Drlr.
El Paso	44- 3	SE SE SE 3-T15-R109 660'/E 660'/S Sweetwater County	6291' 6297'	G KB	9- 4-67	9-24-67	2337'	2359'
Blacks Fork	41-23	NE NE 23-T17-R109 Sweetwater County	6374' 6380'	G KB	10-17-67	10-26-67	2111'	2109'
Little America	2-19	C SW 19-T17-R110 Sweetwater County	6398.5' 6404.5'	G KB	9-26-67	10- 7-67	2452'	2437'
Granger	4- 7	C SE 7-T19-R111 Sweetwater County	6400' 6406'	G KB	10- 9-67	10-16-67	1855'	1855'
Blue Rim	44-19	SE SE 19-T21-R107 Sweetwater County	6823' 6829'	G KB	10-27-67	11-12-67	1761'	1758'
Peru	22-15	SE SE NW 15-T18-R108 Sweetwater	6562' 6568'	G KB	11-13-67	11-20-67	1930'	1930'
								12428

NOTE: Th - Thickness
AT - Above Tide

Rock Springs, Wyoming
February 27, 1970

KEM/lmm

ERM 4-21-70

Core	No.	Location	Elevation		Spud	Completed	TD Logger	TD Drlr.
El Paso	44- 3 ✓	SE SE SE 3-T15-R109 660'/E 660'/S Sweetwater County	6291' 6297'	G KB	9- 4-67	9-24-67	2337'	2369'
Blacks Fork	41-23	NE NE 23-T17-R109 Sweetwater County	6374' 6380'	G KB	10-17-67	10-26-67	2111'	2109'
Little America	2-19	C SW 19-T17-R110 Sweetwater County	6398.5' 6404.5'	G KB	9-26-67	10- 7-67	2432'	2437'
Granger	4- 7	C SE 7-T19-R111 Sweetwater County	6400' 6406'	G KB	10- 9-67	10-16-67	1855'	1835'
Blue Rim	44-19	SE SE 19-T21-R107 Sweetwater County	6823' 6829'	G KB	10-27-67	11-12-67	1751'	1758'
Peru	22-15	SE SE NW 15-T18-R108 Sweetwater	6562' 6568'	G KB	11-13-67	11-20-67	1910'	1930'
								12428

NOTE: Th - Thickness
AT - Above Tide

Rock Springs, Wyoming
February 27, 1970

ERM/lsm

Table 2

UPPER CORE HOLE DATA - GREEN RIVER BASIN - 1957 WELLS
(Re-evaluated 1970)

TD Logger	TD Drlr.	Surface Fm.	Fm. at TD	Laney	Wilkins Peak	Tipton	Wasatch
2337'	2339'	Bridger	Wasatch	150'? Th 859' AT 5147'	1009' Th 1168' AT 5288'	2177' Th 156' AT 4120'	2332.5' AT 3964'
2111'	2109'	Bridger	Wasatch	46'? Th 879' AT 6334'	925' Th 1025' AT 5455'	1950' Th 160' AT 4430'	2110' AT 4270'
2432'	2437'	Bridger	Wasatch	330'? Th 856' AT 6074'	1186'? Th 1113' AT 5218'	2299.5' Th 75' (Upper) AT 4105'	2375' (Ne AT 4029'
1855'	1855'	Bridger	Wasatch	?	872' Th 888' AT 5534'	1800' (Est.) Th AT 4606'	
1761'	1758'	Bridger	Wasatch	150' Th 920' AT 6679'	1070' Th 570' AT 5714'	replaced by twnf. (Newfork)	1731' (Ne AT 5098'
1980'	1930'	Bridger	Wasatch	50'? 835' AT 6518'	865' Th 929' AT 5683'	1214' Th 164' AT 4754'	1870' (Ne AT 4598'
	12428						

ERM 4-21-70

Wasatch	No. of Cores	Cored Interval	Footage Cored	Footage Recovered	Footage Assayed	Logs Run
332.9'	34	[illegible]-2360'	2156.85'	2121.3'	1115'	LES S/GR S/NR FDC
AT 964'						
110'	9	1570'-2112'	538.4'	534.2'	688'	IES FDC
AT 270'						
375' (Newfork)	9	1900'-2356'	453.45'	453.45'	497'	IES FDC
pper) AT 029'						
st.)	4	1403'-1560'	157.'	157.'	190'	IES FDC
731' (Newfork)	15	730'-1223' 1250'-1761'	1003.5'	985.7'	175'	IES FDC
AT 098'						
870' (Newfork)	8	1400'-1874'	474.'	473.1'	56'	IES FDC
AT 598'						
	79		4783.20'	4724.75'	2721'	

Table 3

CORE 2-19

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
2299 - 2302	3'	25.9	Tipton
2308 - 2312	4'	25.7	Tipton
2318 - 2352	32'	26.7	Tipton
	39'	26.5	Weighted Average
Lower Tipton	50'	20.	Estimated
	89'	22.9	

Laney averaged less than 10 GPT.

Wilkins Peak not cored. Yes 400. ft was cored by-passed

Tipton estimated 89' at 23 GPT

2322-51 28' @ 27 3/4

ERM 4-21-70

Table 4

CORE 4-7

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
1640 - 1700	6' x 10	14.9	Wilkins Peak

Laney not assayed.

Tipton not assayed nor drilled.

75' Tipton was drilled according to claim page 2

1620 - 1700 W.P.
60' @ 14.62
or
60' @ 15.83
from 1620 - 1680

Table 5

CORE 22-15

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
1813 - 1850	37'	22.9	Tipton OK
1859 - 1864	5'	11.1	Tipton
1867 - 1869	2'	13.2	Tipton
	44'	21.12	Weighted Average
	50' Est.	19. Est.	Tipton
Laney	93'	18.	(Estimated) X
Wilkins Peak	~~Not cored~~ Yes 414 ft cored but not analyzed		
Tipton	94'	20.	Partial

LANEY 125 ft @ 11.5 gal/T - Lower 1/2

Average Lower Laney and Tipton
Estimated 187' at 19 GPT

1814-22 8' @ 26 g/t
1826-31 5' @ 25 g/t
1834-47 13' @ 26 g/t

Table 6

CORE 41-23

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
825 - 875	50'	12.4	Lower Laney
875 - 890	15'	19.	Lower Laney
890 - 935	45'	13.5	Lower Laney
1951 - 1994	43'	~~20.18~~ 19.5 Bureau	Tipton
1951 - 1992	41'		
1996 - 2001	5'	17.	Tipton
2004 - 2013	9'	12.5	Tipton
2052 - 2095	43'	20.56 OK checks with Bureau	Tipton
	210'	17.7	Weighted Average

Average Lower Laney and Tipton only = 210' at 17.7 GPT

Tipton Average of beds more than 20 GPT = 70' at 27 GPT

1951-66 15' @ 28 3/4

1969-88 19' @ 28 3/4

2067-82 15' @ 27 3/4

1951-2013 = 62' @ 22.21

ERM

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Table 7

CORE 44-3

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
316 - 319	3'	17.03	Laney
363 - 367	4'	12.2	Laney
538 - 540	2'	12.65	Laney
727 - 757	30'	15.3	Upper Laney
758 - 760	2'	15.3	Upper Laney
883 - 890	7'	11.5	Laney
900 - 908	8'	11.1	Laney
909 - 911	2'	12.7	Laney
920 - 968	47'	16.8	Lower Laney
969 - 986	17'	18.4	Lower Laney
989 - 993	4'	12.6	Lower Laney
994 - 1009	15'	16.3	Lower Laney
1016 - 1018	2'	13.2	W. P.
1051 - 1055	4'	12.9	W. P.
1063 - 1065	2'	25.7	W. P.
1071 - 1076	5'	18.9	W. P.
1093 - 1096	3'	21.4	W. P.
1110 - 1112	2'	20.7	W. P.
1115 - 1118	3'	18.3	W. P.
1124 - 1127	3'	16.3	W. P.
1248 - 1250	2'	12.4	W. P.
1329 - 1331	2'	19.4	W. P.
1348 - 1350	2'	17.3	W. P.
1367 - 1371	4'	21.7	W. P.
1377 - 1380.8	4'	28.0	W. P.
1384 - 1386	2'	18.7	W. P.
1403 - 1405	2'	22.3 TRONA	W. P.
1410 - 1412	2'	17.8	W. P.
1419 - 1421	2'	13.7	W. P.
1429 - 1431	2'	14.7	W. P.
1488 - 1492	4'	15.6	W. P.
1495 - 1497	2'	20.8	W. P.
1510 - 1512	2'	15.8	W. P.
1552 - 1555	3'	17.1	W. P.
1561 - 1563	2'	13.95	W. P.
1578 - 1581	3'	21.8	W. P.
1600 - 1602	2'	13.2	W. P.
1627 - 1629	2'	20.1	W. P.
1640 - 1642	2'	17.	W. P.
2154 - 2157	3'	25.8 TRONA	W. P.
2178 - 2226	48'	25.6	Tipton
2229 - 2248	19'	14.7	Tipton
2255 - 2257	2'	13.7	Tipton
2259 - 2261	2'	10.5	Tipton
2270 - 2272	2'	11.7	Tipton
2273 - 2279	6'	14.1	Tipton
2284 - 2286	2'	11.	Tipton
2287 - 2332	45'	21.8	Tipton
	340'	18.7	Weighted Average

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CORE 44-3

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness		Average GPT	Member
	Overall	Net		
727 - 760	33'	32'	15.3	Upper Laney
920 - 1009	89'	83'	16.8	Lower Laney
2178 - 2332	[illegible]	126'	21.2	Tipton

Average of Lower Laney and Tipton only = 243' at 19.6 GPT

Average of beds with 20 GPT or more only = 84' at 25.6 GPT

-Tipton

(120' of this melded)

916-22 6' @ 27 g/T

971-76 5' @ 22 g/T

1361-71 4' @ 21

1377-81 4' @ 29 g/T

2178-83 5' @ 24 g/T

2188-96 6' @ 23 g/T

2199-2224 25' @ 30 g/T

2288-2312 25' @ 26 g/T

Tipton

Tipton 2313

2287

26 @

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Table 8

CORE 44-19

OIL SHALE BEDS WITH 10 GALLONS PER TON OR MORE

Depth	Thickness	Average GPT	Member
775 - 778	3'	11.0	Laney
1043 - 1045	2'	12.2	Laney
1049 - 1071	22'	17.6	Laney
1072 - 1077	5'	12.3	Wilkins Peak
1091 - 1099	8'	12.7	Wilkins Peak
1102 - 1107	5'	25.4	Wilkins Peak
1110 - 1123	13'	19.9	Wilkins Peak
1128 - 1130	2'	13.9	Wilkins Peak
1132 - 1136	4'	33.5	Wilkins Peak
1599 - 1602	3'	19.03	Wilkins Peak
1674 - 1676	2'	13.65	Wilkins Peak
1679 - 1681	2'	12.7	Wilkins Peak
1685 - 1687	2'	13.4	Wilkins Peak
1688 - 1690	2'	16.5	Wilkins Peak
1691 - 1704	13'	14.8	Wilkins Peak
	88'	17.81	Weighted Average

Incomplete - only partial Laney and partial Wilkins Peak
= 88' at 17.8 GPT

1065-69 4' @ 21 9/T
1073-76 3' @ 28 9/T
1102-07 5' @ 25 9/T
1111-1117 6' @ 26 9/T
1132-36 4' @ 33 9/T

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SUMMARY OF UNION PACIFIC CORE HOLE ASSAY DATA

Well	Location	Formation	Thickness	Avg. GPT	Bbls./Sq. Mile (Thousands)
2-19	19-17-110	Tipton	89 est.	23.0	94,340
4- 7	7-19-111	Wilkins Peak	60	14.9	44,400
22-15	15-18-108	Laney	93 est.	18.0	80,910
		Tipton	94	20.0	89,300
					170,210
41-23	23-17-109	Lower Laney	110	14.7	80,300
		Tipton	100	20.0	95,000
					175,300
44- 3	3-15-109	Upper Laney	32	15.3	24,000
		Lower Laney	83	16.8	68,000
		Tipton	126	21.2	126,000
					218,000
44-19	19-21-107	Laney	27	16.5	21,870
		Wilkins Peak	61	17.5	51,850
					73,720

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5-19-70

barrels per square mile. From the summarized data on Table 9 certain maps compiled for the Union Pacific Land Grant are as follows:

Figure Q. Isopachs of the entire Green River formation of oil shale beds containing 10 GPT or more. The best oil shales are those in the southeastern area, however, inasmuch as the well to the northwest did not core all of the oil shale, the partial assay results may be somewhat misleading.

Figure R, an isopachous map of the Green River formation for beds of oil shale containing 20 GPT or more proves the value of Wyoming oil shales when it is seen that there are 84' of oil shales at hole 44-3 with an average of nearly 26 GPT.

Figure S is an isopachous map of the Upper Laney oil shale which is present only in corehole 44-3. This oil shale is 55' thick and pinches out to the west within a few miles. To the east its presence is uncertain.

Figure T is also of the Upper Laney oil shale where it contains at least 15 GPT average beds. There may be a ring or lens of this bed with 15 GPT covering about 10 square miles.

Figures Q, R, S, T, U, V, W, X, and Y are in the Appendix.

Figure U. The map of the Lower Laney oil shale with beds averaging 10 GPT or more which shows a possible thickness of more than 110' in the vicinity of T17N, R108W and pinching out to the west and northwest within 10 miles.

Figure V - an isopachous map of the Lower Laney where the oil shale beds are 20 GPT or more in oil content. This portion of the section seems to be good only in the eastern part of the basin and here it attains only 20' in thickness.

Figure W. An isopach drawing of the beds in the Tipton which contain 20 GPT or more of shale oil. The increase in oil content is to the southeast from the northwest, but the 0 contour line may be incorrect as the Tipton was not cored at the Granger 4-7 well. It is likely that some Tipton exists near Granger, but until cored its value will be unknown.

Figure X is a map of shale oil in barrels per square mile in the portion of the Green River basin where the data is fairly reliable as a result of the drilling of the Union Pacific core holes. This Figure X includes oil shale beds containing 10 GPT or more of the Upper and Lower Laney and the Tipton but does not include those of the Wilkins Peak. The range is from 44 million barrels per square mile at the northwest to more than 200 million barrels per square mile at the southeast.

Figure Y is a map of an area of oil shale containing at least 20 GPT of oil from the Lower Laney and Tipton and indicates that there are rocks with as much as 125 million barrels per square mile in the southeastern Green River basin with an oil content considered by some scientists to be the minimum quality for commercial exploitation.

On Plate III, the map with colors indicating the extent of oil shales in the Green River basin, the Union Pacific Land Grant area encloses about 65 townships or 2340 square miles. Half of this land, or 1170 square miles, would come under Union Pacific mineral ownership. To estimate the amount of shale oil beneath Union Pacific lands at this stage of the study can only be a guess, but if we assume that the 1170 square miles contain an average of at least 10 GPT over an interval of 50' this would be a resource of 30 billion barrels. If, however, we assume an average from Figure X of 125 million barrels per square mile the resource becomes more than 146 billion barrels.

The area for which the information is more reliable is that of the cored region displayed on most of the Figures and this includes about 435 square miles of Union Pacific land so that the shale oil content in beds containing 10 GPT or more averages 125 million barrels per square mile for a total of about 55 billion barrels.

To consider only those beds of organic rock with 20 GPT or more underlying Union Pacific lands in the cored region we are looking at about 300 square miles with an average of about 100 million barrels per square mile for a total of

about 30 billion barrels. This shale oil content of 30 billion barrels is believed to be realistic, but the future total may be much higher.

FUTURE EXPLORATION FOR OIL SHALE IN THE GREEN RIVER BASIN

There is much to be done to make a final evaluation of the amount of oil from shale within the Green River basin and most of this study in the future will be in the form of core holes with some field investigations.

In all there are about 5800 square miles in the basin underlain by rocks containing some kerogen. There have been seven cores taken to evaluate the oil shales; six by Union Pacific and one by the U.S.B.M. at Eden in T23N, R107W, outside of the Union Pacific Land Grant.

Within the Land Grant area there are 2340 square miles underlain by oil shales, 1170 of which are Union Pacific lands. These lands include but six cores.

The area within the Land Grant investigated by coring involves 900 square miles, 450 of which are Union Pacific controlled. The core density of one hole for every 150 square miles is far below the minimum necessary to establish a meaningful resource quantity. The personnel at the U.S.B.M. who have spent many years studying cores of the world's oil shales believe that for a complete detailed evaluation three cores per township are required, but that one core per township would provide sufficiently accurate information for all practical purposes.

On Plate VIII locations are shown for proposed cores, proposed measured sections, the locations of cores already drilled and completed measured sections. There are eight sections to be measured and twelve cores proposed for some future date. Any core program should be made flexible so that locations and hole depths may be altered as information is progressively obtained.

The manner in which the shale oil is to be recovered will determine to a large extent the methods of exploratory work. Open pit mining will entail much careful surface study. Subsurface mining and in situ retorting will require a close pattern of drilling to outline the ore body.

Plate II is a map with a scale of 1" = 2 miles which shows surface geology in the form of formational and member contacts, measured sections, wells, cores, trona holes, main drainage features, and political boundaries. This map sums up how and where most of the data was obtained which has been presented in this most recent progress report. As additional facts are received that are applicable to the oil shale study they will be included on Plate VII.

It is estimated that in the Union Pacific portion of the Green River and Washakie basins there are at least 100 billion barrels of shale oil, a natural resource of tremendous importance, and for this reason it is strongly recommended that the investigation of these oil shales be continued to determine more exactly the oil content available for recovery when crude oil reserves have been depleted.

SUMMARY AND CONCLUSIONS

There have been several Union Pacific progress reports of the work evaluating the oil shales of the Green River basin, but this report includes most of the previously presented information and, in many cases, supercedes prior data. The oil shale study was begun in 1967 and field mapping and six cores were taken during that year. Additional work was done both in the field and in the office from time to time through the spring of 1970.

The Green River formation in the Green River basin in Wyoming includes about 5800 square miles, and the geographical and geological positions within the basin are indicated on various maps with this report. The Green River formation is present in southwestern Wyoming, northeastern Utah and northwestern Colorado, but the Wyoming portion is the only area that has been studied to date. The Green River formation is overlain by the Bridger formation and underlain by the Wasatch, and in order from youngest to oldest the members of the Green River consist of the Laney, Wilkins Peak, Tipton, and the Luman. The Niland and New Fork tongues of the Wasatch are within the Green River formation. The oil shales of interest occur in the basal portion of the Laney and throughout the Tipton.

Stratigraphically the members of the Green River thicken to the south and southeast and the oil shale beds also thicken and become higher in quality to the south and southeast. The New Fork tongue of the Wasatch was deposited at the north end of the lake and pinches out to the south, but where it is present within the Land Grant it divides the Tipton into an upper and lower member and replaces important oil shales.

The center of the Green River basin is a trough that runs northerly through T14N through T22N in Ranges 111W to 109W. The Church Buttes-Moxa arch and the Firehole anticline are prominent folds within the basin.

Many cuttings have been assayed by the Bureau of Mines from wells drilled in the Green River basin, but I have used almost none of this information believing that cuttings do not represent a true evaluation of the oil shales. Union Pacific drilled six cores in 1967 and the information from these cores has provided sufficient data to draw the maps included with this report. Economically the best oil shales of the Green River basin occur in the Tipton member and are located generally in the southeasterly part of the basin. Some of the beds will average well over 20 GPT with thicknesses of more than 125' and in particular at Hole 44-3, the most southeasterly of the cores, there are 84' of oil shales averaging nearly 26 GPT. The Lower Laney is also a good bed of oil shale though not as rich as the Tipton.

Oil shale beds of the Upper and Lower Laney and Tipton, with shale oil content of 10 GPT or more, range from 44 million barrels per square mile at the northwest to more than 200 million barrels per square mile at the southeast. For oil shale beds of the Lower Laney and Tipton, which contain at least 20 GPT, there are rocks in the southeastern portion of the basin containing as much as 125 million barrels per square mile.

Within the Land Grant area Union Pacific ownership includes about 1170 square miles underlain by oil shales of varying content. It is too soon, due to insufficient number of cores, to determine accurately the amount of shale oil present, but if it is assumed that there are at least 100' of oil shales averaging 10 GPT there would be 60 billion barrels of shale oil. Other data indicates that if we assume 125 million barrels per square mile there are more than 146

billion barrels.

The area cored includes about 435 square miles of Union Pacific mineral land and with an average content of 10 GPT the average of 125 million barrels per square mile indicates 55 billion barrels of shale oil. If 20 GPT or more is considered to be present in the Union Pacific lands, there are 300 square miles containing 30 billion barrels, and this figure is realistic, and the future total may be much higher.

The evaluation of the oil shales of the Green River basin is far from complete. Union Pacific has taken six cores and the Bureau of Mines has taken one core to cover an area of about 5800 square miles. Core density of one core per township would provide accurate information of the shale oil content. Within the Land Grant twelve cores have been proposed, and if drilled, would provide information of importance. Additional field work involving surface measured sections is planned.

It is estimated that the Union Pacific portion of both the Green River and Washakie basins contain at least 100 billion barrels of shale oil; and with the resource of this importance studies should be contained to further this oil shale evaluation.

During the week of May 11, 1970 it was announced that the Government was preparing to lease federal lands for oil shale development by the year 1972. However, on May 18, 1970 it was announced by the Department of the Interior Secretary, Walter Hickel, that the Government was going to cancel temporarily any consideration for leasing of Federal oil shale land. The reasons given were unclear but inferred that the department felt that at this time it was economically not feasible to undertake the leasing out of federal lands. Within a few weeks the real reason for this cancellation may be brought to light.

The position of the government now clearly offers to Union Pacific a very advantageous opportunity to accept consideration for the leasing or joint operation of their valuable oil shale properties by companies interested in developing a domestic supply of oil for the not too far distant future when crude reserves are seriously depleted by consumption in excess of the fields of the United States capability to produce.

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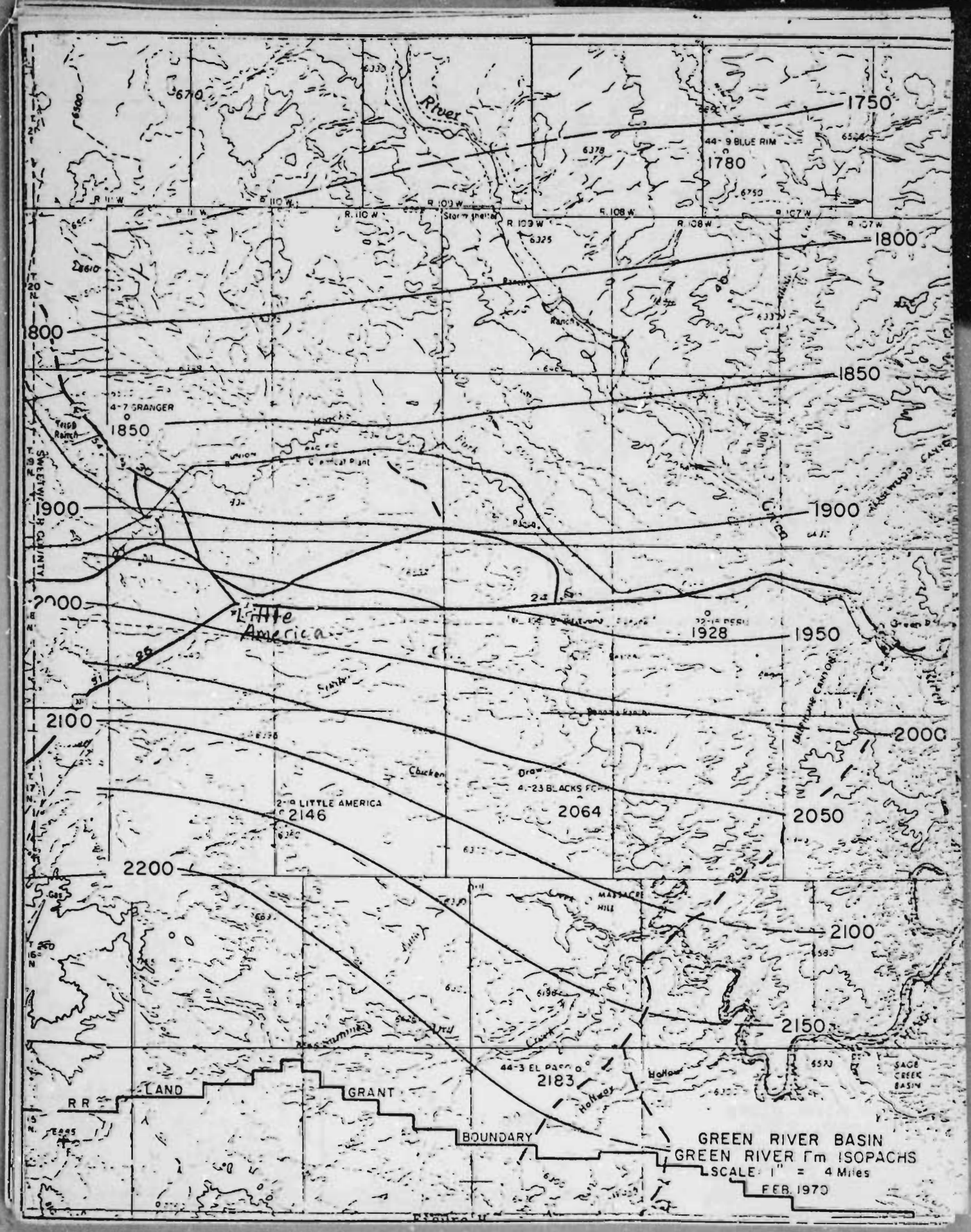
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1780
1800
1850
1900
1950
2000
2050
2100
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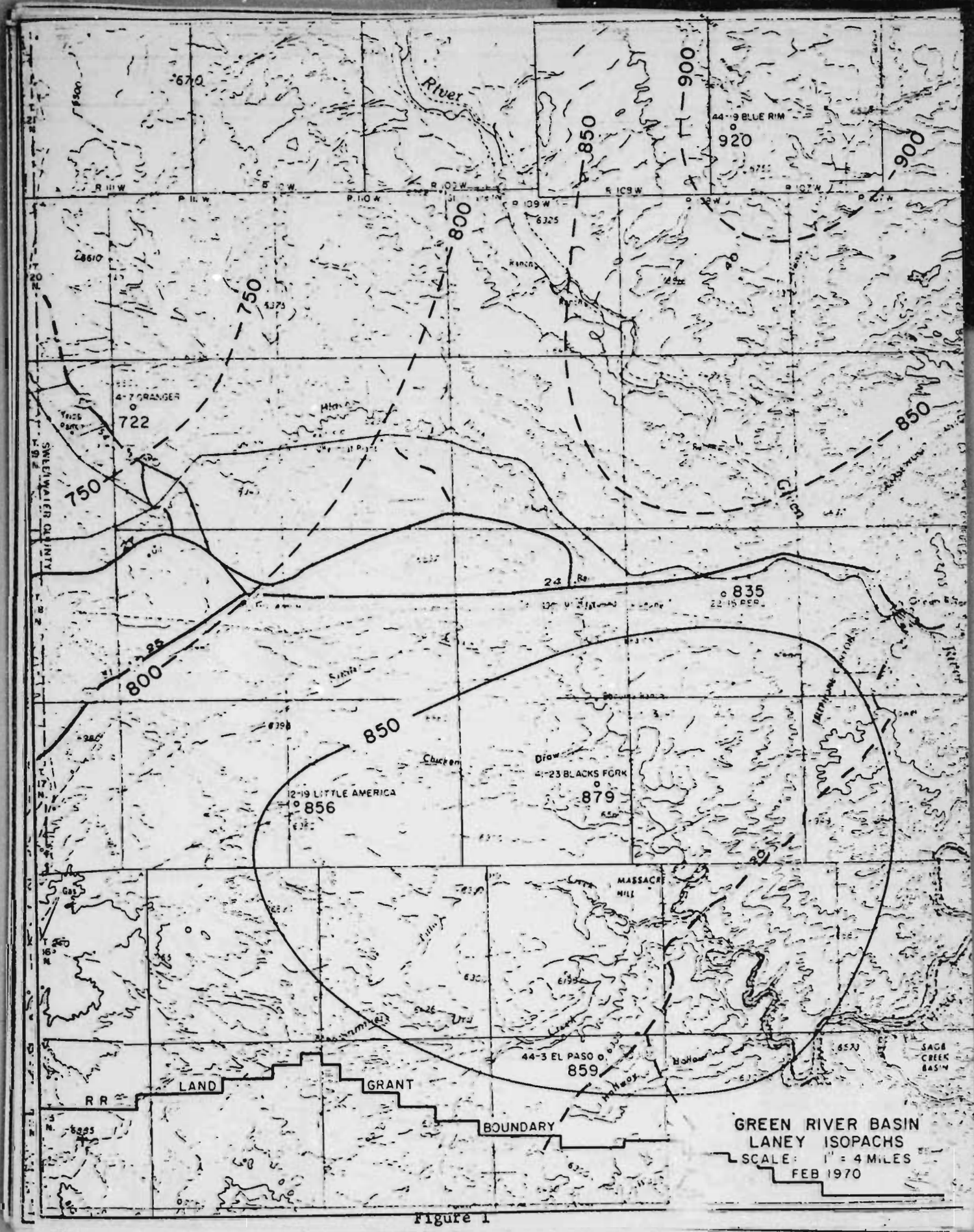
2183
Little America
GREEN RIVER BASIN
GREEN RIVER Fm ISOPACHS
SCALE 1" = 4 Miles
FEB. 1970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44-9 BLUE RIM
920
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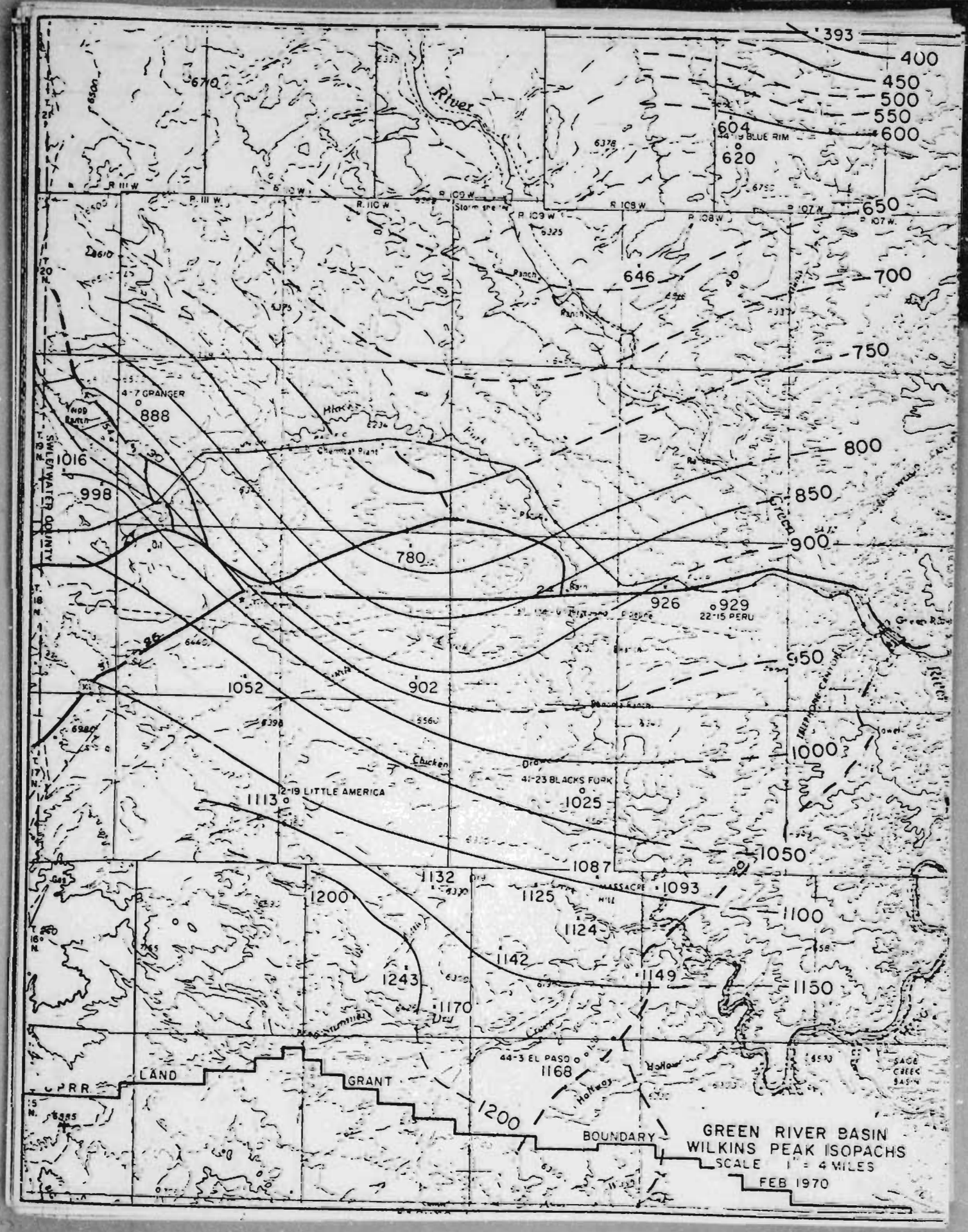
722
750
800
24
835
22-15 PER.
850
12-19 LITTLE AMERICA
856
4-23 BLACKS FORK
879
44-3 EL PASO
859
LAND
GRANT
BOUNDARY
RR
SAGE CREEK BASIN
GREEN RIVER BASIN
LANEY ISOPACHS
SCALE: 1" = 4 MILES
FEB 1970

Figure 1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902
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1016
998
888
4-7 GRANGER
1113
12-19 LITTLE AMERICA
1025
41-23 BLACKS FORK
1087
1093
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1149
1243
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1168
44-3 EL PASO
BLUE RIM
SWEETWATER COUNTY
Green River
Chicken Creek
Telephone Canyon
Sage Creek Basin
Chemical Plant
Ranch
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UPRR LAND GRANT
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WILKINS PEAK ISOPACHS
SCALE 1" = 4 MILES
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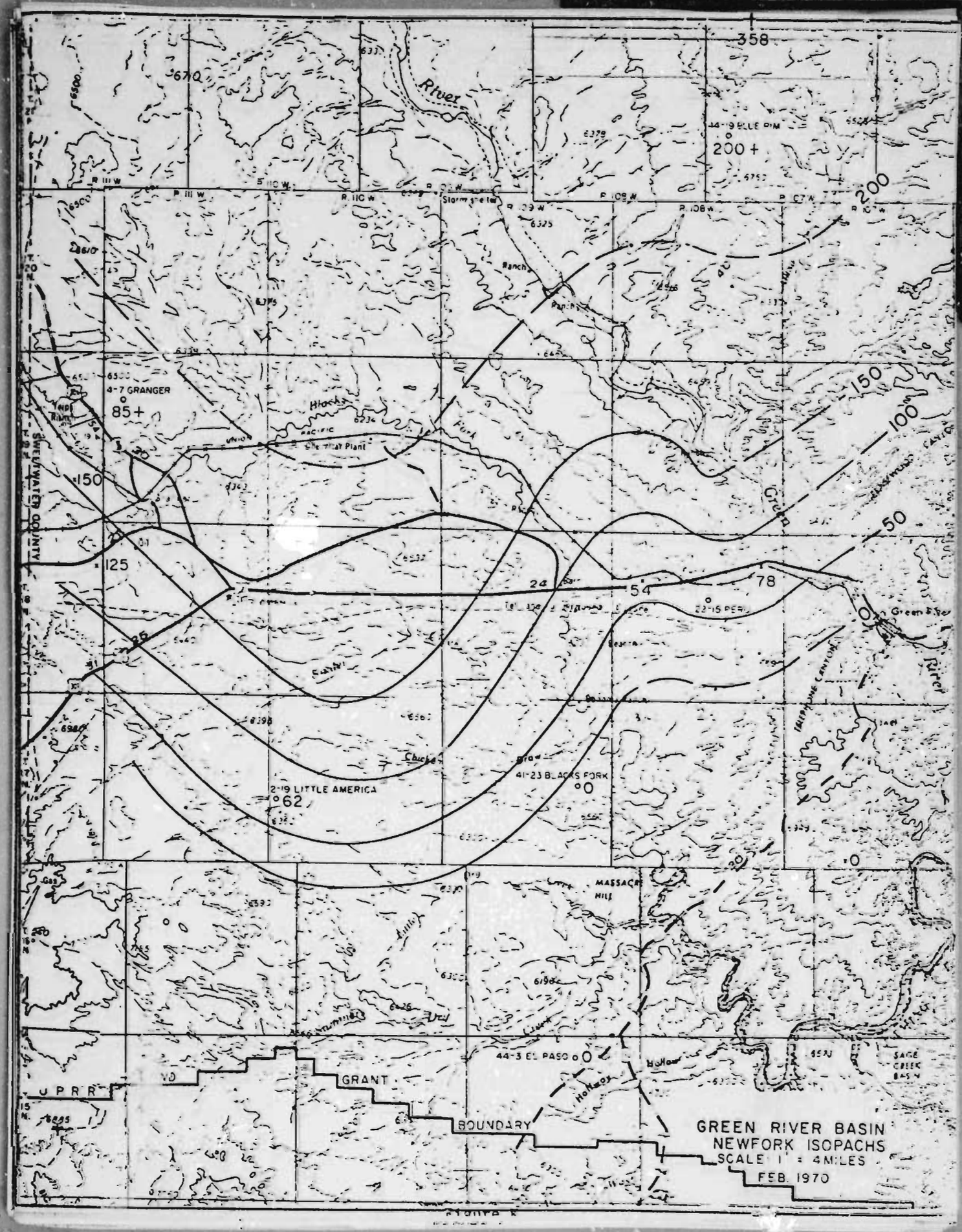
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River
200+
200
150
100
50
0
4-7 GRANGER
85+
125
24
54
78
2-19 LITTLE AMERICA
62
41-23 BLACKS FORK
44-3 EL PASO
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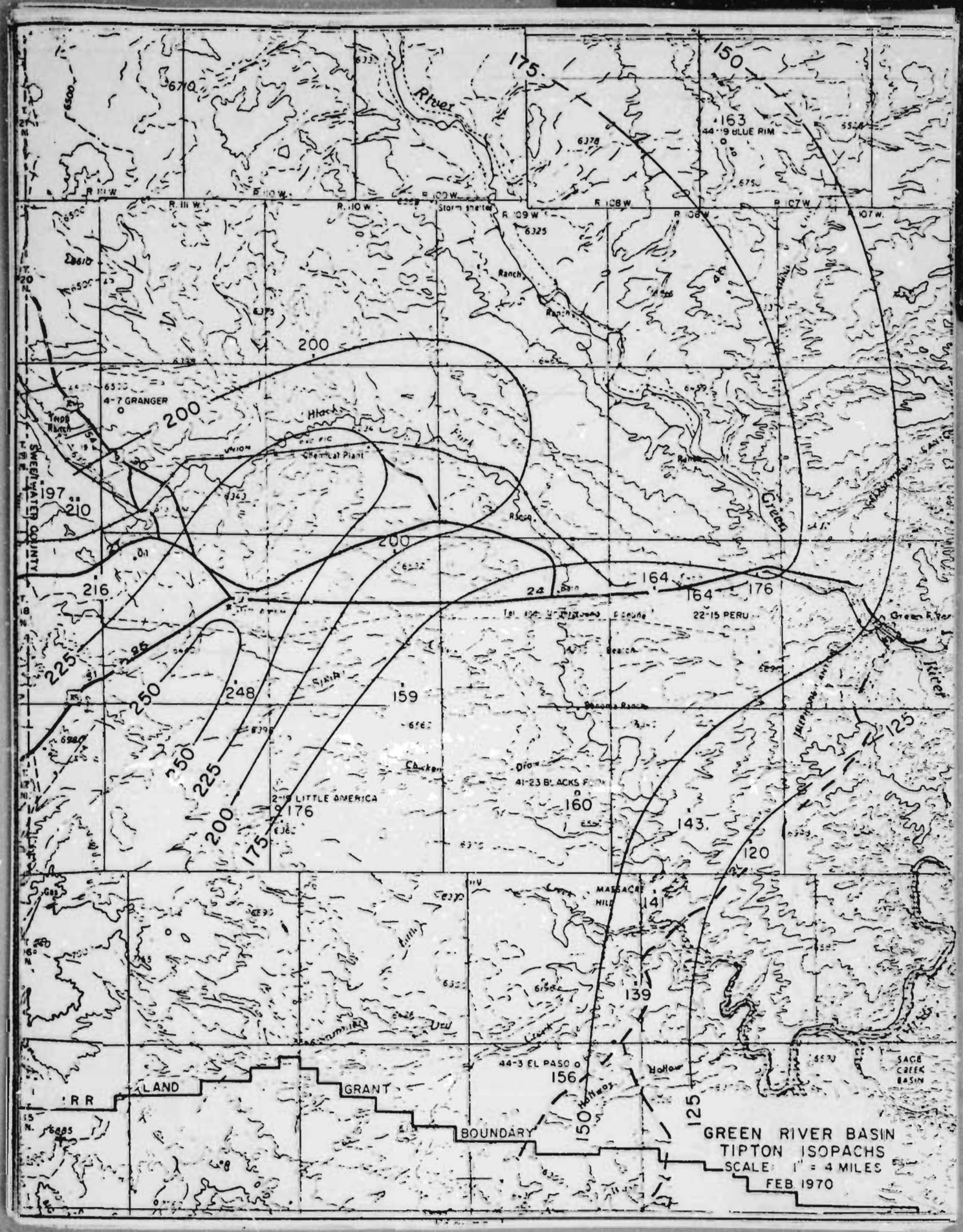
GREEN RIVER BASIN
NEWFORK ISOPACHS
SCALE 1" = 4 MILES
FEB. 1970


GREEN RIVER BASIN
TIPTON ISOPACHS
SCALE 1" = 4 MILES
FEB 1970
BOUNDARY
GRANT
LAND
RR
SWEETWATER COUNTY
Green River
Blue Rim
Granger
Little America
Peru
Chemical Plant
Massacre Hills
Sage Creek Basin
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125
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139
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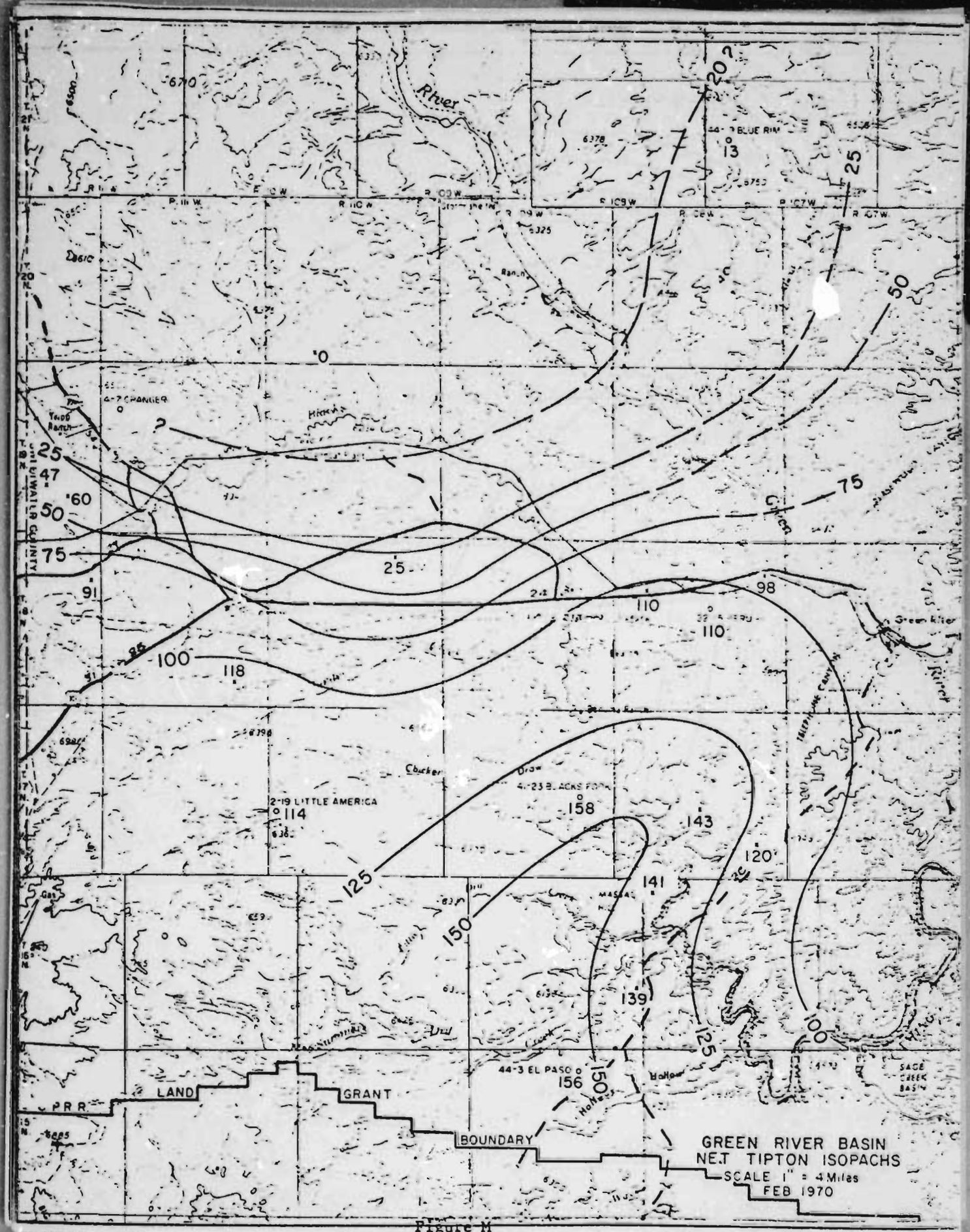
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NET TIPTON ISOPACHS
SCALE 1" = 4 Miles
FEB 1970
LAND GRANT BOUNDARY
44-3 EL PASO
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158
143
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114
118
110
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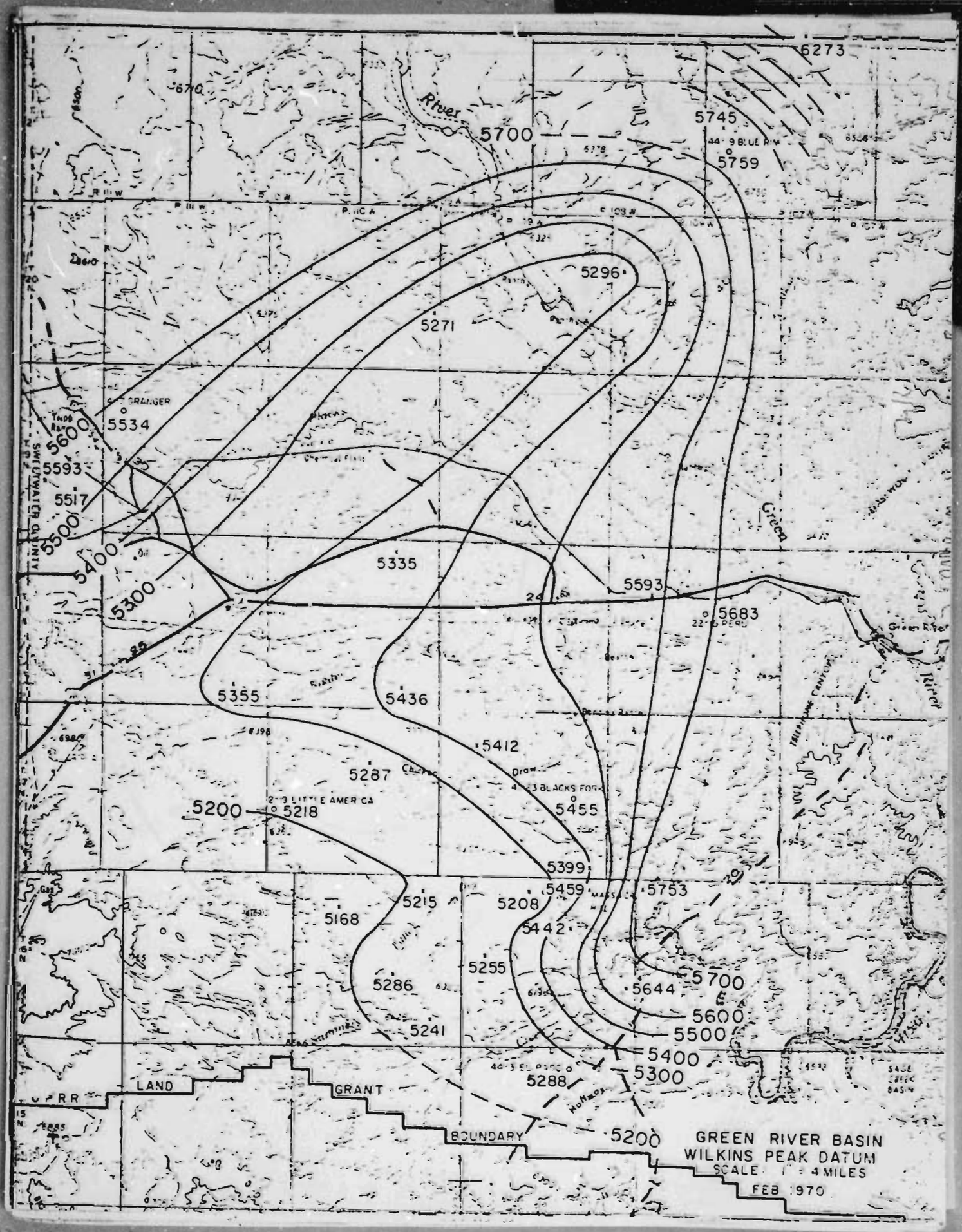
2-19 LITTLE AMERICA
4-23 BLACKS FORK
4-7 CHANLER
BLUE RIM
13
River
Green River
SAGE CREEK BASIN

Figure M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5700
5600
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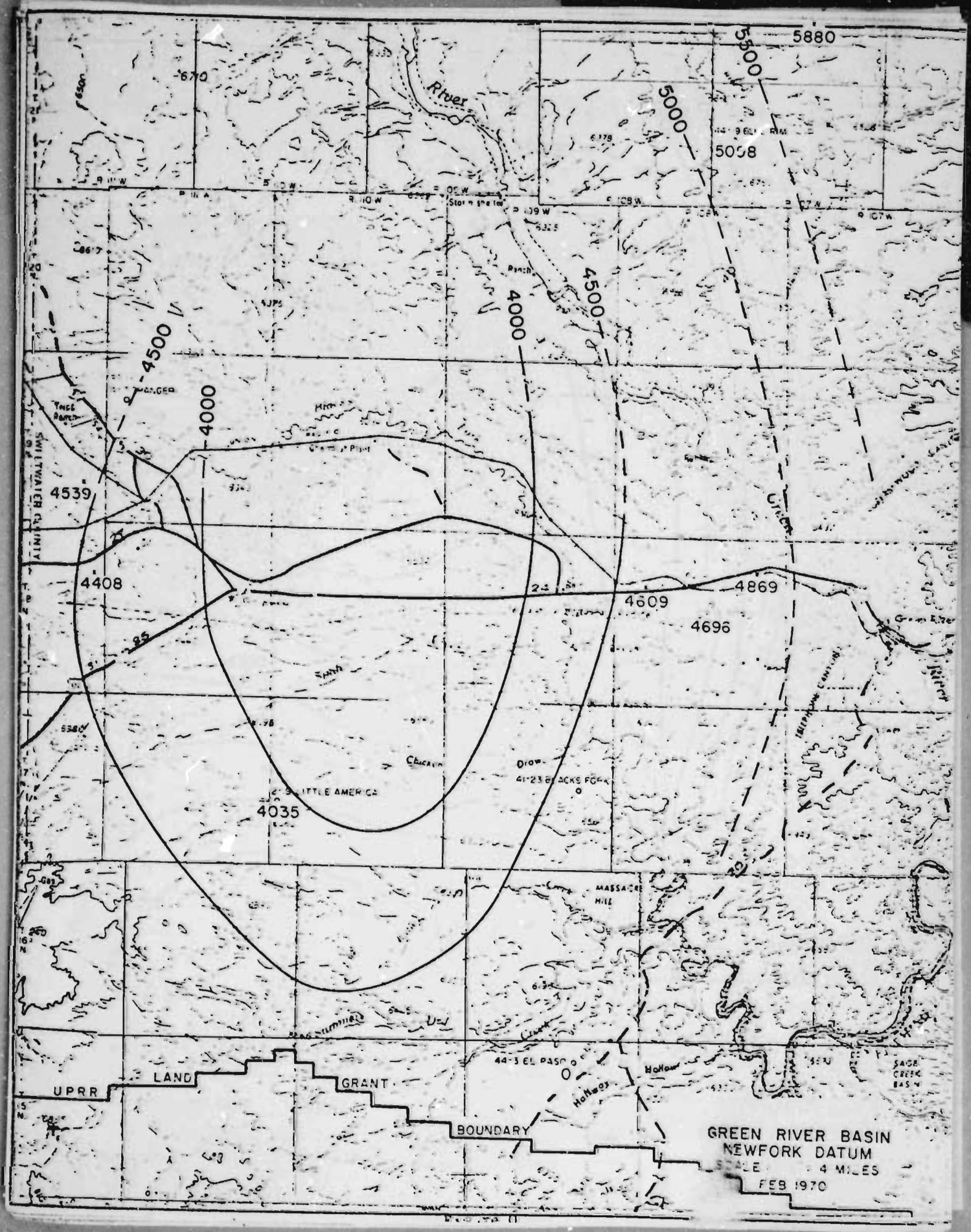
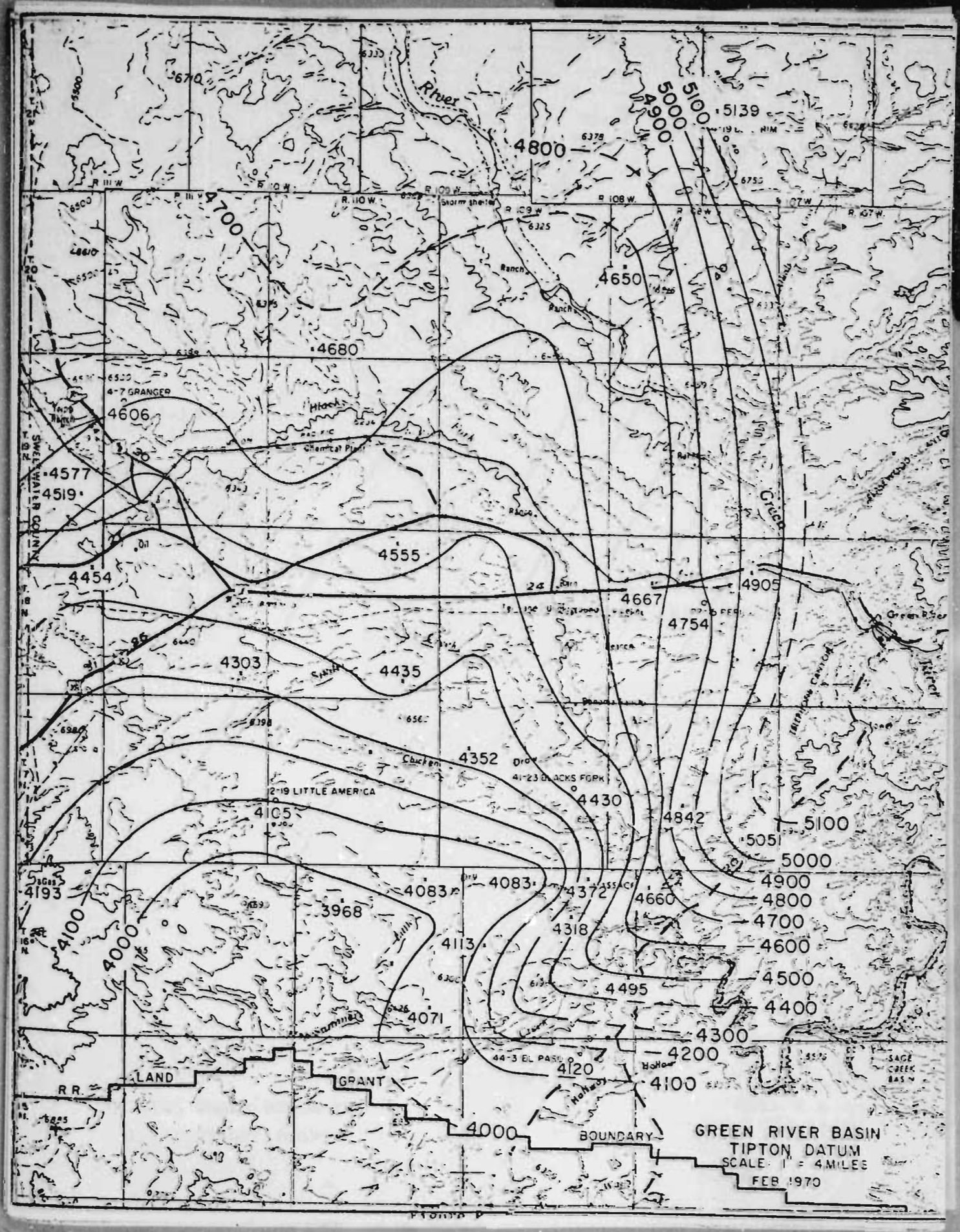
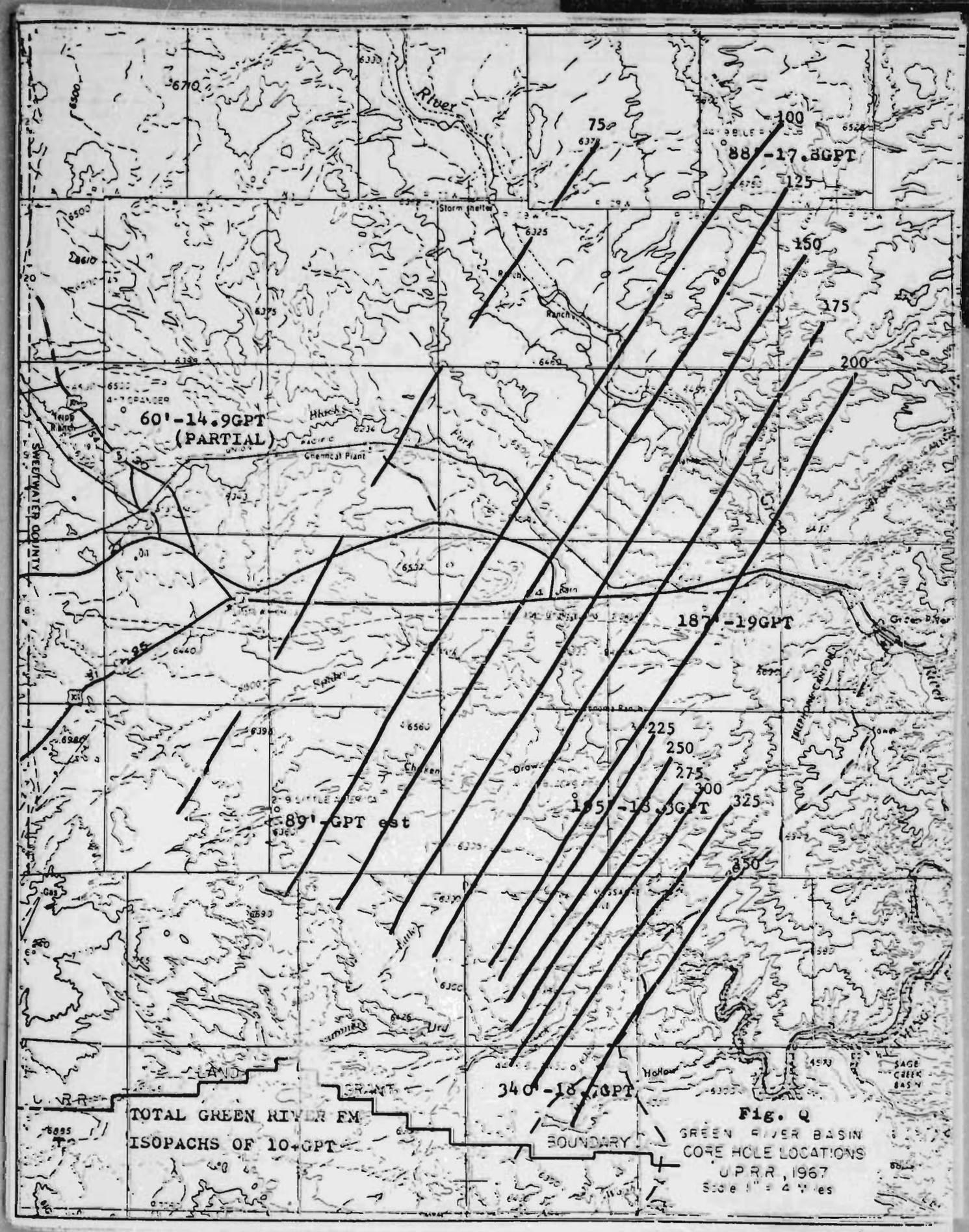
5300
5241
5288
5200
LAND
GRANT
BOUNDARY
GREEN RIVER BASIN
WILKINS PEAK DATUM
SCALE 1" = 4 MILES
FEB 1970


5880
5500
5000
4500
4000
4500
4000
River
5058
4539
4408
4609
4869
4696
4035
LITTLE AMERICA
MASSACRE HILL
UPRR LAND GRANT BOUNDARY
GREEN RIVER BASIN
NEWFORK DATUM
4 MILES
FEB 1970


River
4800
4900
5000
5100
5139
4700
4650
4680
4606
4577
4519
4454
4555
4905
4667
4754
4303
4435
4352
4430
4842
5100
5051
5000
4900
4800
4700
4600
4500
4400
4300
4200
4100
4000
4193
4083
4083
4372
4660
3968
4318
4113
4495
4071
4120
4105
LAND
GRANT
BOUNDARY
GREEN RIVER BASIN
TIPTON DATUM
SCALE 1" = 4 MILES
FEB 1970


75
100
125
150
175
200
225
250
275
300
325
350
88'-17.8GPT
60'-14.9GPT
(PARTIAL)
187'-19GPT
185'-18.3GPT
89'-GPT est
340'-18.7GPT
TOTAL GREEN RIVER FM
ISOPACHS OF 10+GPT
BOUNDARY
Fig. Q
GREEN RIVER BASIN
CORE HOLE LOCATIONS
UPRR, 1967
Scale 1" = 4 Miles

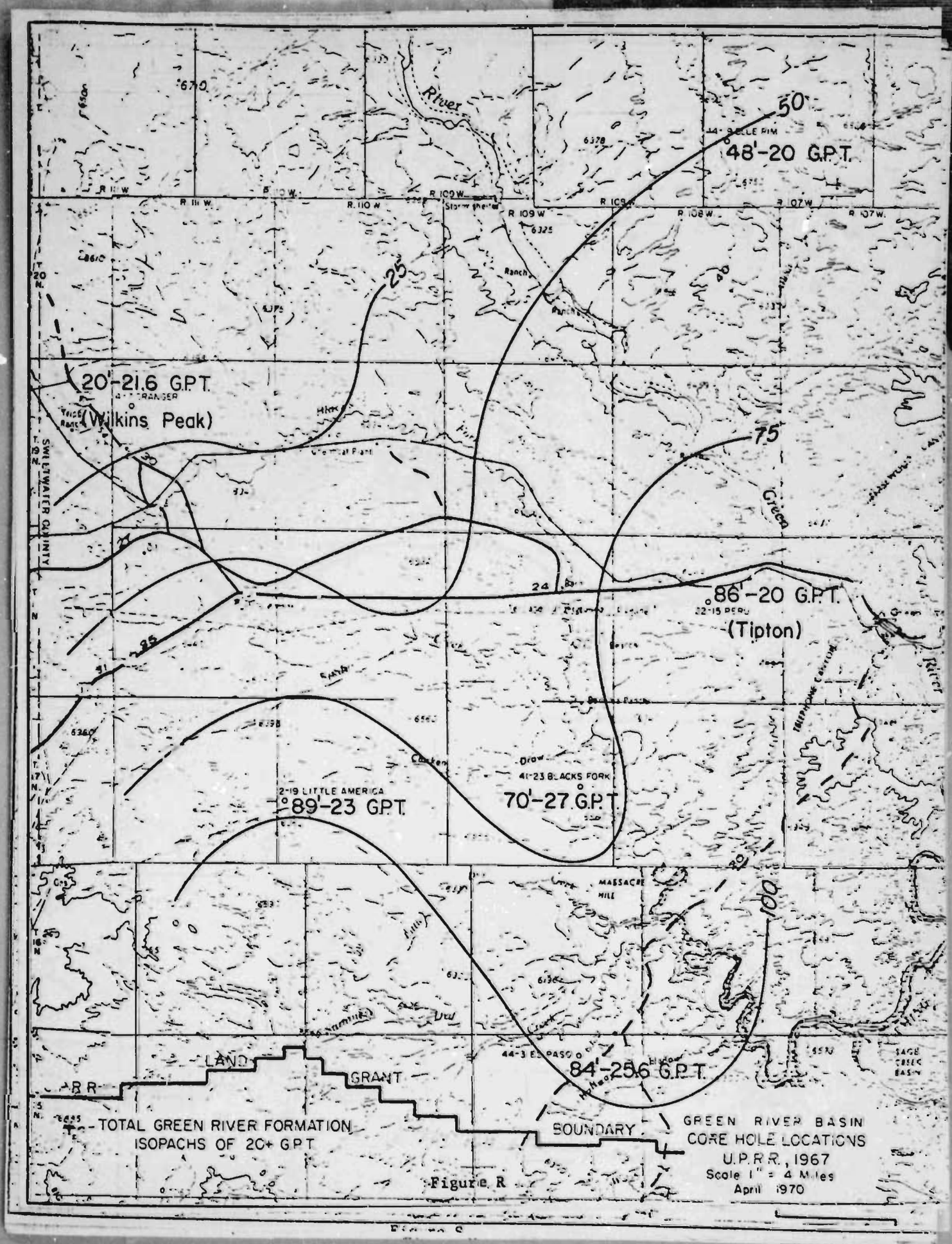
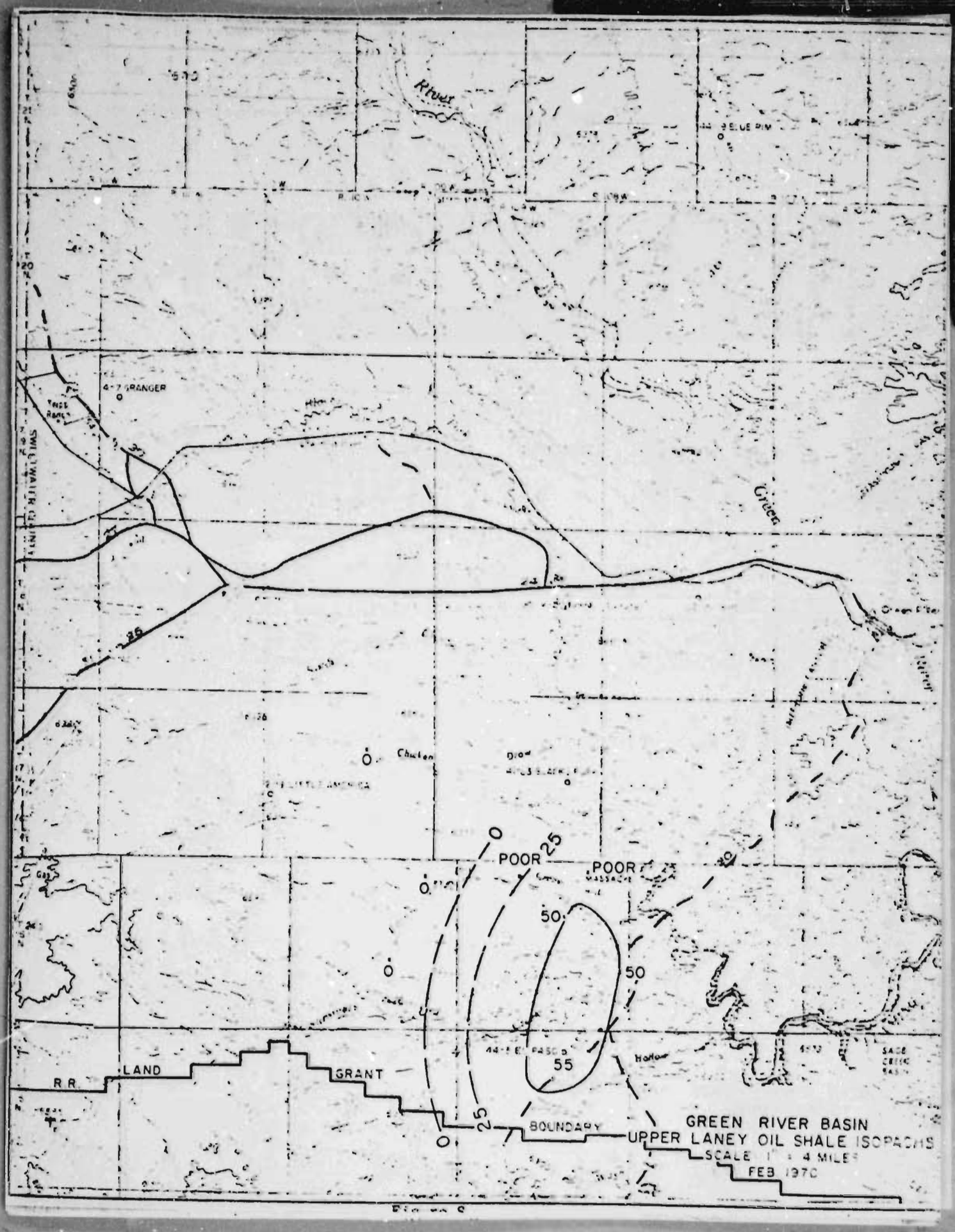
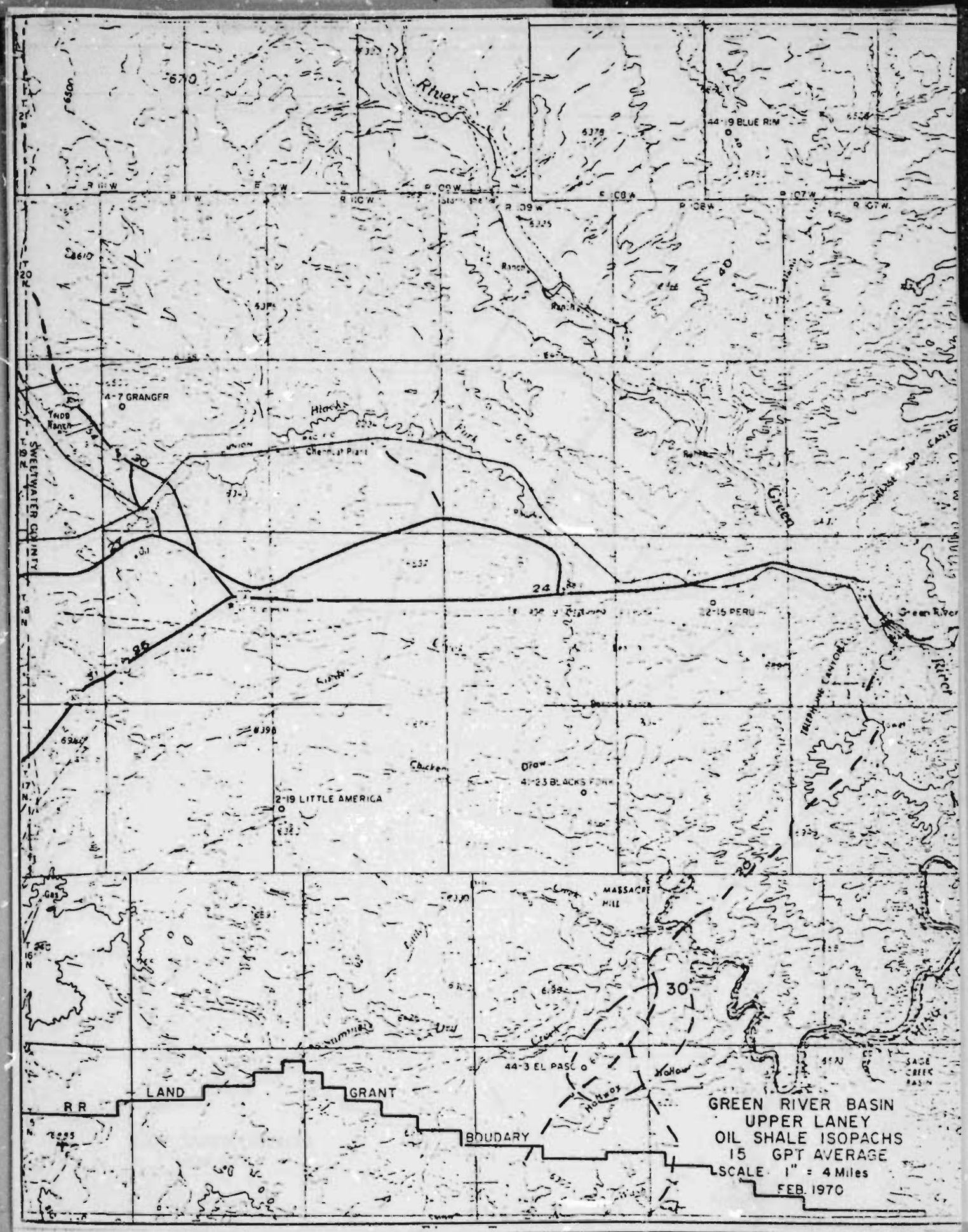
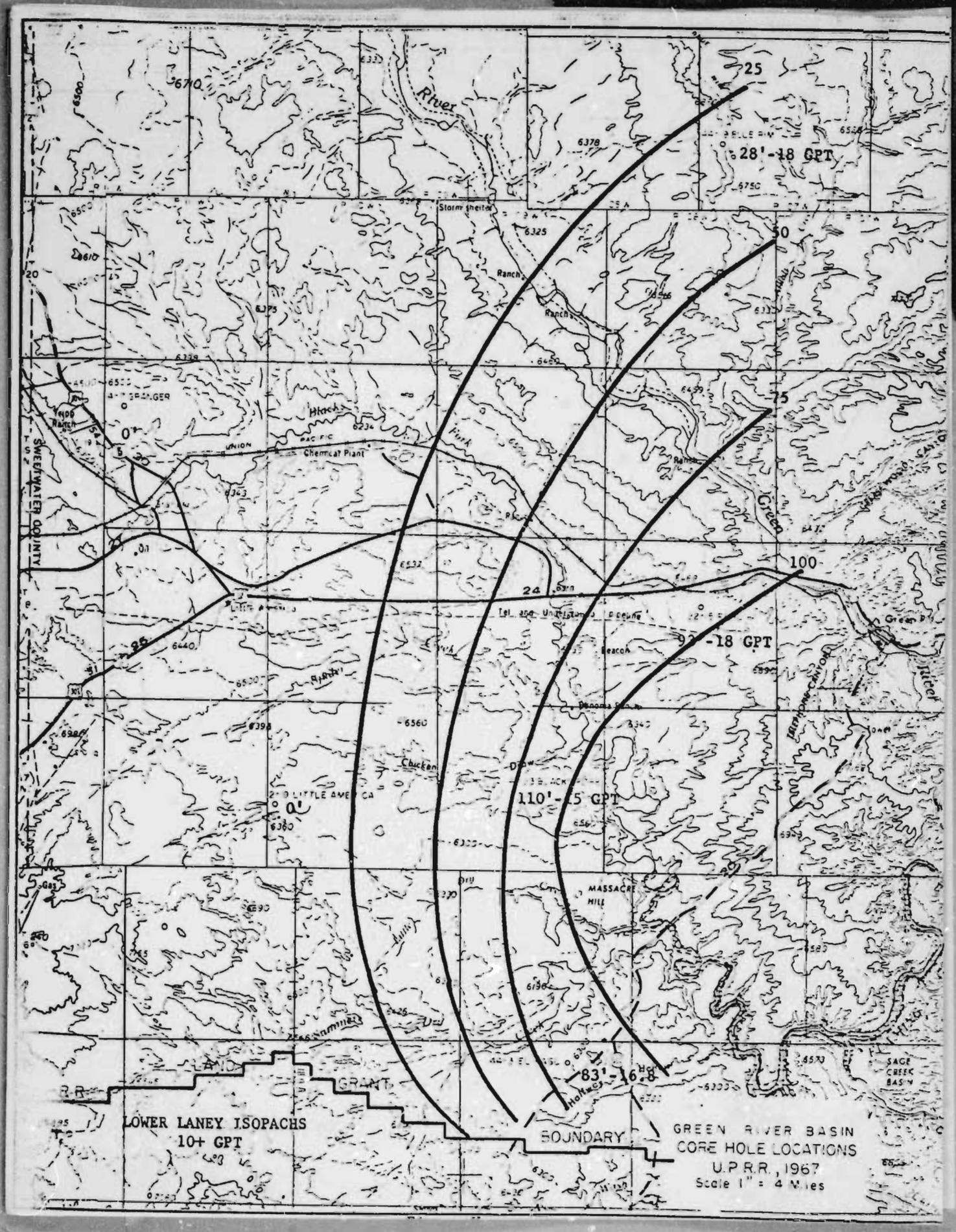
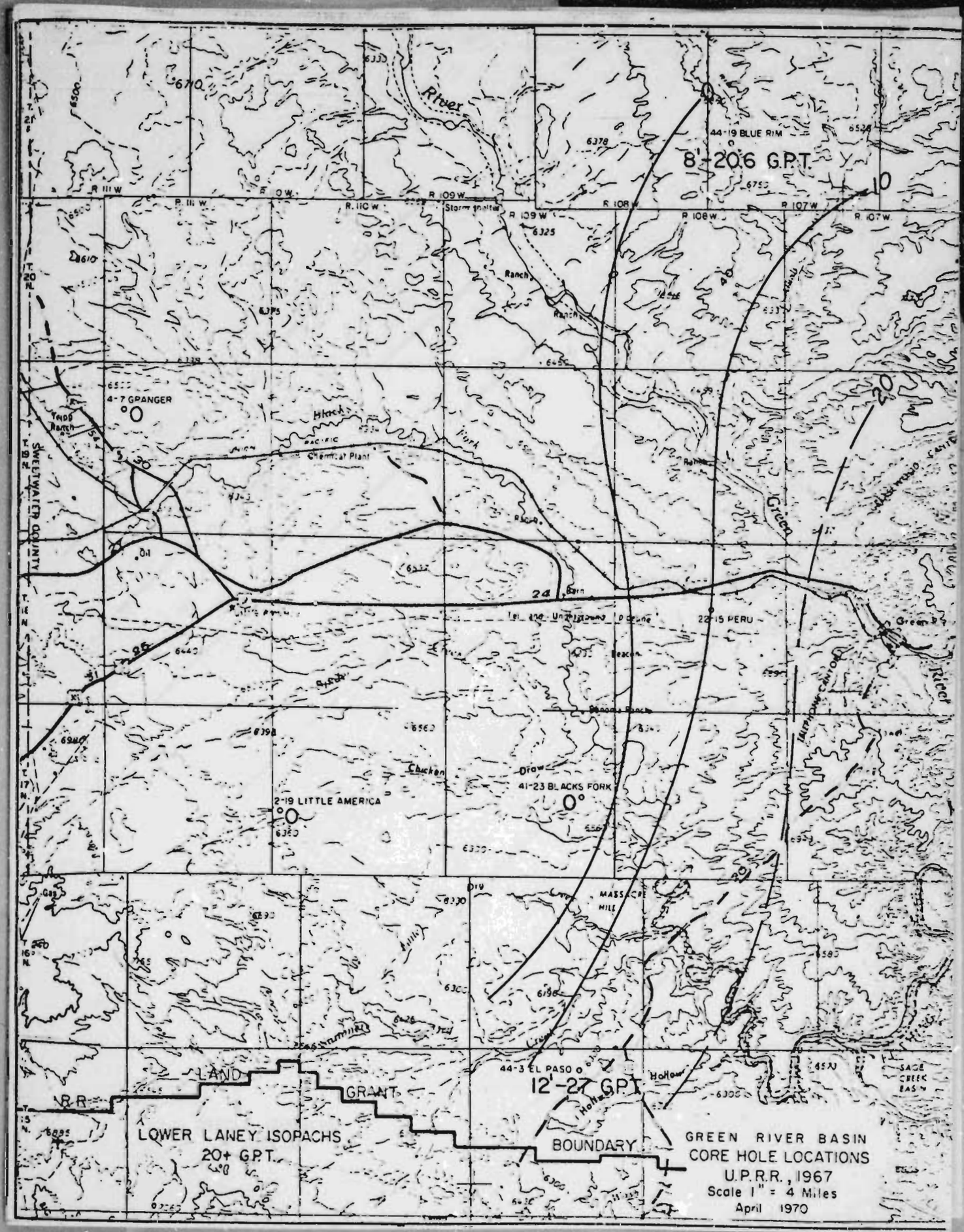

50
48'-20 G.P.T.
25
20'-21.6 G.P.T.
(Wilkins Peak)
75
86'-20 G.P.T.
(Tipton)
100
89'-23 G.P.T.
70'-27 G.P.T.
84'-25.6 G.P.T.
LAND GRANT
U.P.R.R.
SOUNDARY
TOTAL GREEN RIVER FORMATION
ISOPACHS OF 20+ G.P.T.
GREEN RIVER BASIN
CORE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles
April 1970

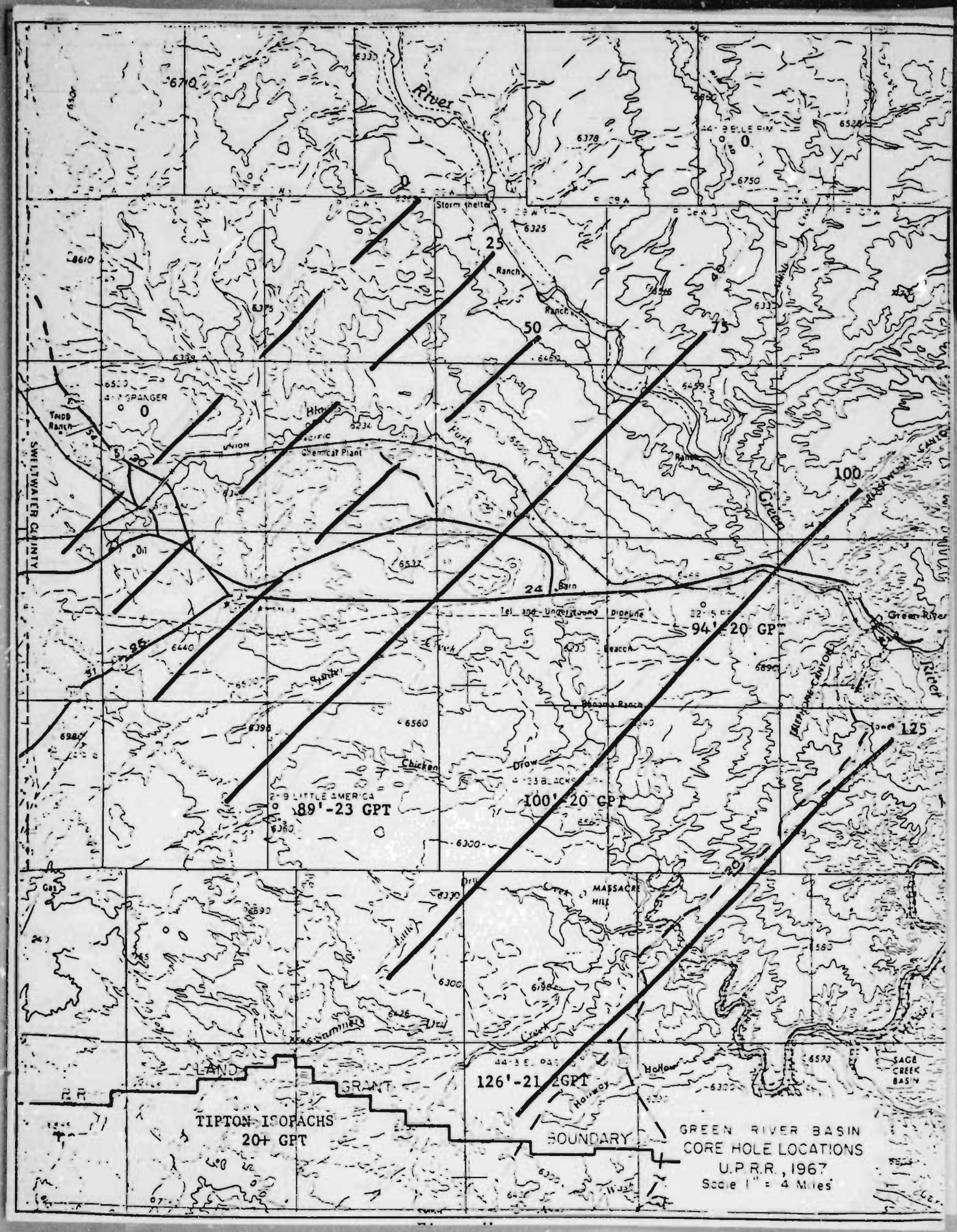
Figure R

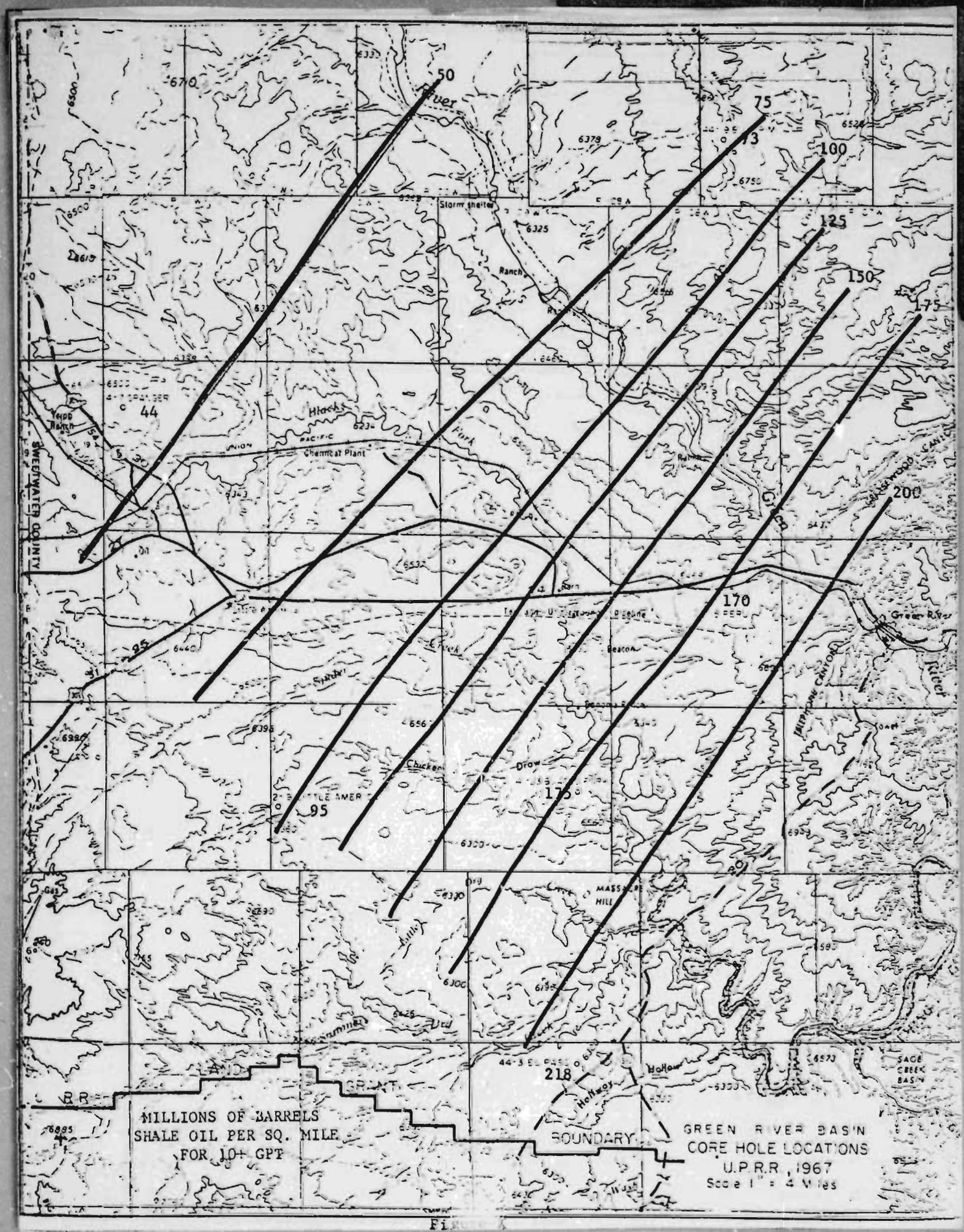

POOR
POOR
25
50
50
55
0
0
0
0
0
RR
LAND
GRANT
BOUNDARY
GREEN RIVER BASIN
UPPER LANEY OIL SHALE ISOPACHS
SCALE 1" = 4 MILES
FEB 1970


River
44-9 BLUE RIM
4-7 GRANGER
Chemical Plant
Green River
32-15 PERU
2-19 LITTLE AMERICA
4-23 BLACKS FORK
MASSACRE HILL
44-3 EL PASO
SWEETWATER COUNTY
LAND GRANT
BOUNDARY
R R
30
24
25
GREEN RIVER BASIN
UPPER LANEY
OIL SHALE ISOPACHS
15 GPT AVERAGE
SCALE 1" = 4 Miles
FEB. 1970

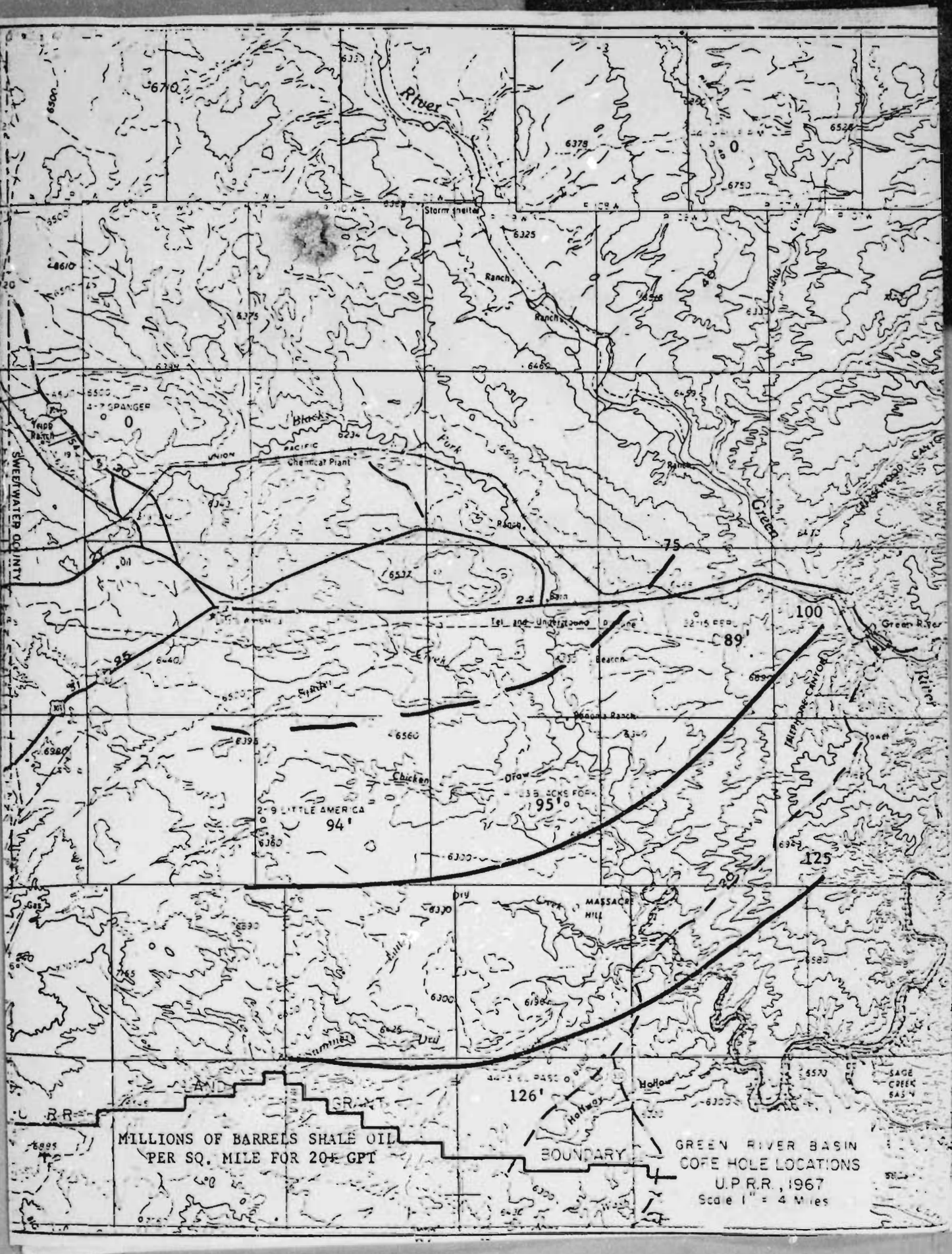

25
28'-18 GPT
50
75
100
110'-15 GPT
83'-16.8
LOWER LANEY ISOPACHS
10+ GPT
BOUNDARY
GREEN RIVER BASIN
CORE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles
SWEETWATER COUNTY
GRANT
Green River
Chemical Plant
LITTLE AMERICA
MASSACRE HILL
SAGE CREEK BASIN


44-19 BLUE RIM
8'-20 G.P.T.
4-7 GRANGER
2-19 LITTLE AMERICA
41-23 BLACKS FORK
44-3 EL PASO
12'-27 G.P.T.
22-15 PERU
LAND GRANT
R.R.
LOWER LANEY ISOPACHS
20+ G.P.T.
BOUNDARY
GREEN RIVER BASIN
CORE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles
April 1970


25
50
75
100
125
94'-20 GPT
89'-23 GPT
100'-20 GPT
126'-21 GPT
TIPTON ISOPACHS
20+ GPT
LAND GRANT
BOUNDARY
GREEN RIVER BASIN
CORE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles
SWEETWATER COUNTY
Storm shelter
Chemical Plant
Green River
SAGE CREEK BASIN
MASSACRE HILL


50
75
100
125
150
175
200
170
95
218
MILLIONS OF BARRELS
SHALE OIL PER SQ. MILE
FOR 10+ GPT
BOUNDARY
GREEN RIVER BASIN
CORE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles
SWEETWATER COUNTY
Storm shelter
Ranch
Chemical Plant
Green River
Beacon
Chicken Draw
MASSACRE HILL
Holloway
SAGE CREEK BASIN

Fi


River
Storm shelter
Ranch
Black
Fork
Union
Pacific
Chemical Plant
SWEETWATER COUNTY
Green River
Chicken
Creek
Dry
Summers
Hollow
MASSACRE
HILL
SAGE
CREEK
BASIN
75
100
125
89'
95'
94'
126'
2-9 LITTLE AMERICA
MILLIONS OF BARRELS SHALE OIL
PER SQ. MILE FOR 20+ GPT
BOUNDARY
GREEN RIVER BASIN
COPE HOLE LOCATIONS
U.P.R.R., 1967
Scale 1" = 4 Miles

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