WATERFLOOD EVALUATION

PROPOSED VIRDEN-ROSELEA UNIT NO. 3

VIRDEN-ROSELEA FIELD

MANITOBA

PRODUCING, CALGARY DIVISION

July, 1965

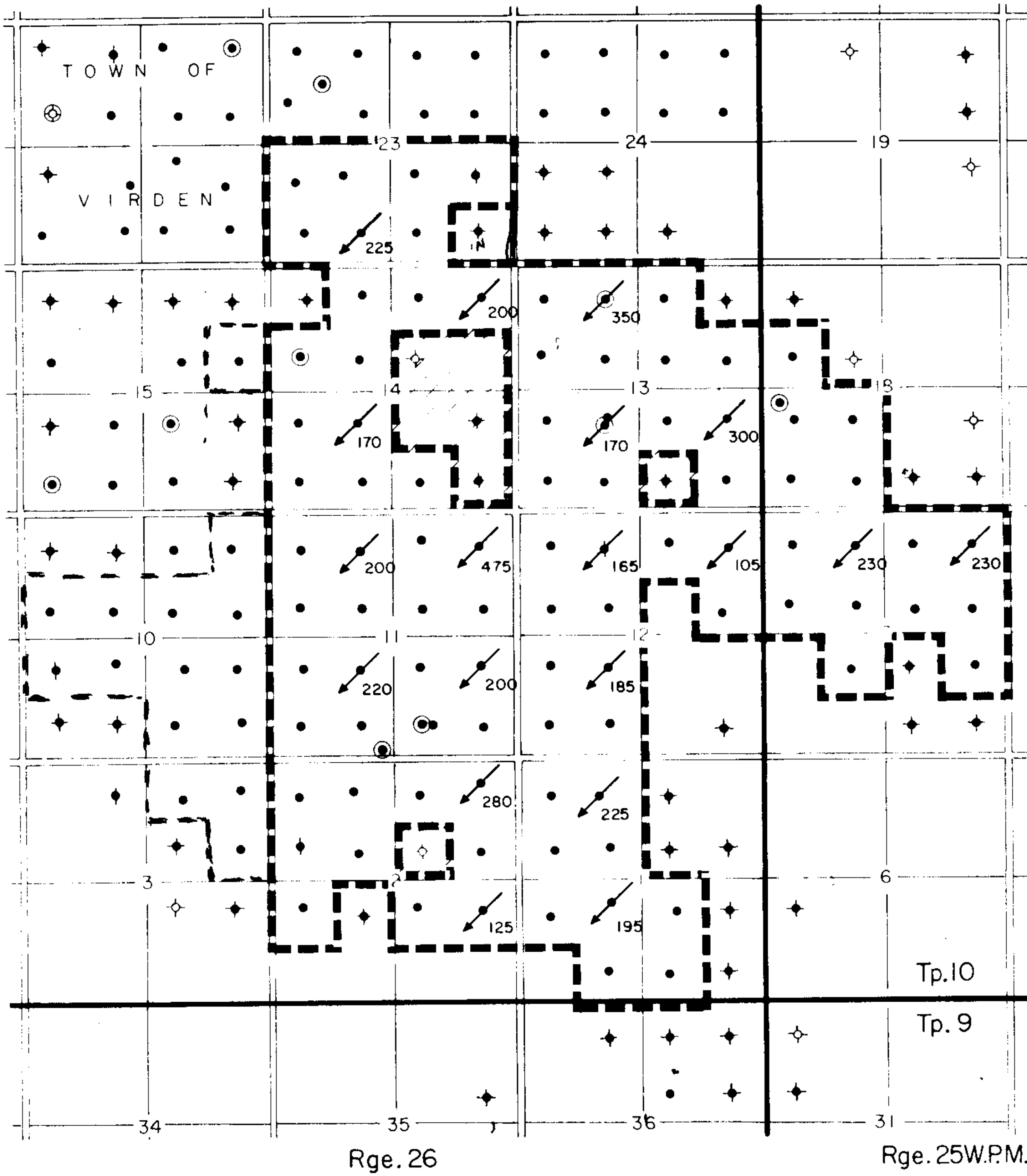


FIGURE 8

PROPOSED VIRDEN ROSELEA UNIT No. 3
WATERFLOOD INJECTION PATTERN

100 INJECTION WELL AND RATE

UNIT BOUNDARY

Scale : 1" = 3000'

PROPOSED VIRDEN-ROSELEA UNIT NO. 3

VIRDEN-ROSELEA FIELD, MANITOBA

SUMMARY:

I. INTRODUCTION

The purpose of this study was to investigate the feasibility of secondary recovery of oil by waterflooding the Mississippian limestone reservoir in a proposed portion of the Virden-Roselea Field. See Figure 1.

II. FINDINGS

1. The estimated original oil-in-place from volumetric calculations within the proposed waterflood area was 44,400,000 barrels.

2. Under primary depletion the indicated ultimate production from the proposed area would be 5,900,000 barrels or 13.3% of the original oil-in-place. The estimated cumulative production for the area to January 1, 1967 will be 4,900,000 barrels or 11.0% of the original oil-in-place.

3. The bottom hole pressure in the developed area has declined to an estimated average pressure of less than 300 psi.

4. Waterflood calculations indicate a total ultimate primary plus secondary recovery of 15,500,000 barrels or 35% of the original oil-in-place in the proposed waterflood area. This is an increase of 9,600,000 barrels over the ultimate primary recovery which represents 21.7% of the original oil-in-place.

III. CONCLUSION

The area outlined in Figure 1 should be waterflooded as increased ultimate recovery and increased production rates can be realized.

PROPOSED VIRDEN-ROSELEA UNIT NO. 3

WATERFLOOD EVALUATION

This report is a waterflood evaluation of the proposed Virden-Roselea Unit No. 3 area. The area of proposed water flooding is outlined on Figure 1. For greater detail in methods used, reference can be made to a report entitled "Waterflood Evaluation - Virden-Roselea Field - Manitoba" dated September 1963, which was prepared for the Virden-Roselea Unit No. 1.

1. GENERAL

There are 92 wells in the proposed waterflood area, the ownership being as follows:

COMPANY	WELLS
The British American Oil Co. Ltd.	3
The California Standard Company	53
Canadian Export Gas & Oil Ltd.	10
Imperial Oil Limited	6
Mineraloid Limited	8
Paradise Petroleums Limited	1
Rundle Petroleums Limited	7
Sun Oil Company	4
Total.......................................	92

The majority of the wells in the proposed waterflood area were drilled during 1955 and 1956. Completion techniques in this area varied; however, most of the wells have been cased through and selectively perforated. Initial stimulation usually consisted of an acid wash and squeeze. In some cases this was followed by some form of hydraulic fracturing.

Re-stimulation, other than scale removal, has in recent years generally proved ineffective due to the depleted reservoir condition.

2. ORIGINAL OIL-IN-PLACE DETERMINATION

Isopachs

The reservoir was treated as four separate zones for oil-in-place determination in this study. The four zones considered were the Crinoidal, Sandhill, Oolitic and Cherty zones. Core analyses are available for each zone in the number of wells indicated below:

ZONE	NUMBER OF WELLS WITH ANALYSES
Crinoidal	28
Sandhill	29
Oolitic	29
Cherty	17

In several cases, the analysis for the complete zone is not available.

Separate pay isopachs, based on core analyses, core descriptions, and log interpretations have been prepared for each of the four zones. These are presented in Figures 2, 3, 4 and 5 for the Crinoidal, Sandhill, Oolitic and Cherty zones respectively. Figure 6 represents a total pay isopach.

Original Oil-In-Place

The isopachs were planimetered to obtain the average pay thickness for each zone. An average footage weighted porosity was obtained for each zone from available core analyses in the area. The values used for the initial water saturation were those obtained for the Virden-Roselea Unit No. 1. A formation volume factor of 1.05 bbl./bbl. was also used.

The results are as follows:

ZONE	AVERAGE PAY THICKNESS	AVERAGE POROSITY	SUBSURFACE AREA (ACRES)	INITIAL WATER SATURATION
Crinoidal	8.13	9.6%	2570	52%
Sandhill	6.51	12.7	3320	48
Oolitic	7.69	11.5	3680	52
Cherty	9.45	12.6	3640	52
Total	31.78		3680	

Original Oil-In-Place - Cont'd

The original oil-in-place calculations for each of the three zones are as follows:

Crinoidal Zone

N = 7758 (.096) (20900) (0.48) (1/1.05)
= 7,100,000 barrels, or
N = 7758 (0.96) (40) (0.48) (1/1.05)
= 13,580 bbls./ft./40 acre lease, or
N = 7758 (0.96) (.48) (1/1.05)
= 340 bbls./acre - foot.

Sandhill Zone

N = 7758 (.127) (21600) (0.52) (1/1.05)
= 10,500,000 barrels, or
N = 7758 (.127) (40) (0.52) (1/1.05)
= 19,470 bbls./ft./40 acre lease, or
N = 7758 (.127) (.52) (1/1.05)
= 487 bbls./acre - foot.

Oolitic Zone

N = 7758 (.115) (28300) (0.48) (1/1.05)
= 11,500,000 barrels, or
N = 7758 (.115) (40) (0.48) (1/1.05)
= 16,270 bbls./ft./40 acre lease, or
N = 7758 (.115) (0.48) (1/1.05)
= 407 bbls./acre - foot.

Cherty Zone

N = 7758 (.126) (34400) (0.48) (1/1.05)
= 15,300,000 barrels, or
N = 7758 (.126) (40) (0.48) (1/1.05)
= 17,830 bbls./ft./40 acre lease, or
N = 7758 (.126) (0.48) (1/1.05)
= 446 bbls./acre - foot.

A summary of the original oil-in-place by zone and the relative amounts are as follows:

ZONE	OIL-IN-PLACE	PERCENT OF TOTAL
Crinoidal	7,100,000	16.0%
Sandhill	10,500,000	23.6
Oolitic	11,500,000	25.9
Cherty	15,300,000	34.5
Total....................	44,400,000	100.0

3. PRIMARY PERFORMANCE

An estimate of primary performance was made employing a rate versus time plot for the total proposed waterflood area (see Figure 7). The indicated ultimate primary recovery is 5,900,000 barrels or 13.3% of the original oil-in-place.

On January 1, 1967 which is the assumed date of waterflooding, it is estimated that the remaining primary recoverable reserves will be 1,000,000 barrels. The cumulative production for the area to January 1, 1965 was 4,400,000 barrels or 9.9% of the original oil-in-place. The estimated cumulative production for the area to January 1, 1967 will be 4,900,000 barrels or 11.0% of the estimated original oil-in-place.

4. WATERFLOOD RECOVERY PREDICTION

The waterflood recovery prediction was based on a combination of Welge's (1) displacement efficiency concept, Dykstra and Parsons (2) vertical sweep efficiency or permeability variation efficiency, and the concept of area sweep efficiency in pattern flood as explained by Caudle, Erickson and Slobod (3) and Dyes, Caudle and Erickson (4). The various efficiencies were found as functions of the water-oil ratios and were combined to yield the effective recovery of the waterflood.

Only one set of flooding efficiencies were applied to the total oil-in-place since the zones are similar in characteristics. The efficiencies used were based on the Cherty Zone. Any error incurred is believed to be within the accuracy of the prediction methods used.

Assumptions made in the prediction are that the economic limit will be 7 BOPD per well and that the area will be produced to a water-oil ratio of 10.5:1.

Assuming that waterflooding is initiated on January 1, 1967, the remaining oil-in-place at the start of the flood will be 39,500,000 barrels.

The predicted recovery to breakthrough is 5,300,000 barrels or 11.9% of the original oil-in-place or 13.5% of the oil-in-place at the beginning of the waterflood. The ultimate oil recovery under waterflood operations is estimated at 10,600,000 barrels or 24.0% of the original oil-in-place. The increase in oil recovery due to waterflooding is estimated to be 9,600,000 barrels or 21.7% of the original oil-in-place. The predicted total recovery would be composed of 4,900,000 barrels of primary oil production to January 1, 1967 and 10,600,000 barrels of oil recovered under waterflood operations for a total of 15,500,000 barrels or 35% of the original oil-in- place.

5. INJECTIVITY AND FLOOD PATTERN

Flood Pattern

The proposed flood pattern for the area is indicated on Figure 8. It consists of an inverted ninespot pattern with a total of nineteen proposed injection wells.

Injectivity Calculations

The formula employed in the calculation of the water injectivity rates is derived from Darcy's flow formula as indicated below:

$$Q = \frac{0.003541\ K_w h \Delta P}{\mu \beta (\ln d/r_w - 0.6190)}$$

where
- Q = injection rate in barrels per day
- K_w = reservoir permeability to water in millidarcies
- h = vertical thickness in feet
- ΔP = pressure differential (P surface + well bore - P reservoir)
- μ = viscosity of injection water at reservoir conditions in centipoise
- d = distance from injection well to producing well in flood pattern in feet
- r_w = effective well bore radius in feet

By assuming the following values, the formula reduces to the simplified form shown below:

Pwb = 0.433 psi/ft x 2100 ft. = 900 psi
Pinj = 1100 psi (not to exceed overburden pressure)
Pres = 500 psi (average over flood life)
$\therefore \Delta P$ = 1100 + 900 - 500 = 1500 psi
μ = 0.864 cp at reservoir conditions
d = 1320 feet between injector and nearest producer
r_w = 25 feet (radius of acidizing and fracturing assumed)

Then $Q = 1.84\ K_w h$

Where core analyses were available, they were employed in the injectivity determinations. Where core analyses were not available, the average values for the proposed waterflood area were used.

The following are the average parameters by zone for the area:

Zone	Kmax (air)	Kmax (water)	Injectivity (BWPD/FT)
Crinoidal	21.91	2.30	4.23
Sandhill	20.53	2.10	3.86
Oolitic	25.45	2.85	5.24
Cherty	43.96	6.60	12.14

Table 1 presents estimates of injectivities for the nineteen proposed injection wells. Satisfactory injectivity for waterflooding is indicated for the proposed waterflood area.

6. REFERENCES

1. Welge, H. J.
"A Simplified Method for Computing Oil Recovery by Gas or Water Drive." Journal of Petroleum Technology, April,1952,P.91

2. Dykstra, H. and Parsons, R.L.
"The Prediction of Oil Recovery by Water Flood." Secondary Recovery of Oil in the United States, American Petroleum Institute 1950, P.160.

3. Caudle, B.H. Erickson, R.A. and Slobod, R.L.
"The Encroachment of Injected Fluids Beyond the Normal Well Pattern." Journal of Petroleum Technology, May 1955, P. 79.

4. Dyes, A.B., Caudle, B.H. and Erickson, R.A.
"Oil Production after Breakthrough as Influenced by Mobility Ratio." Journal of Petroleum Technology, April 1954, P. 27.

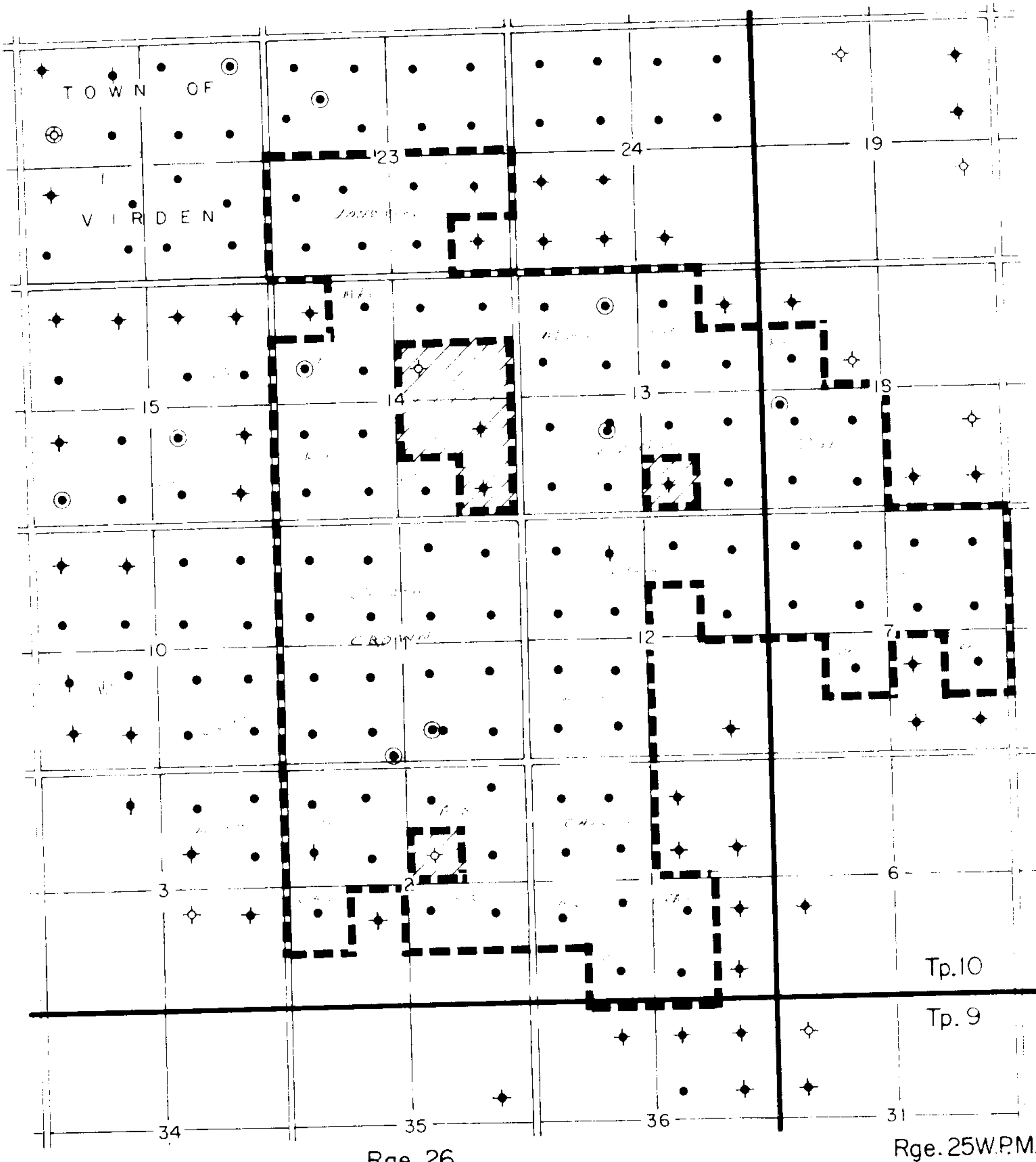


FIGURE 1

PROPOSED VIRDEN ROSELEA UNIT No. 3

Scale 1" = 3000'

UNIT BOUNDARY

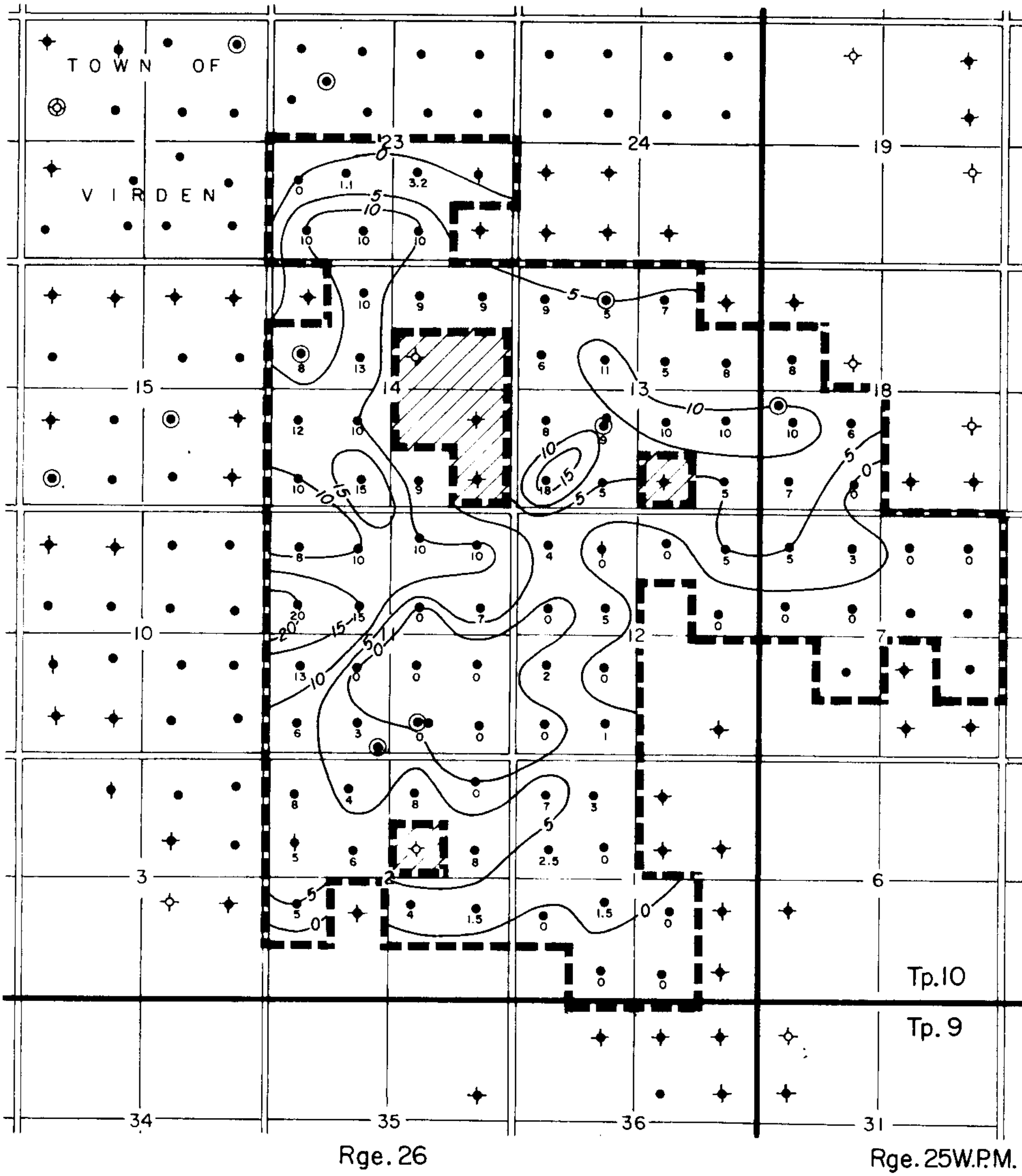


FIGURE 2

PROPOSED VIRDEN ROSELEA UNIT No. 3

CRINOIDAL ZONE PAY ISOPACH

C. I. = 5'

UNIT BOUNDARY

Scale : 1" = 3000'

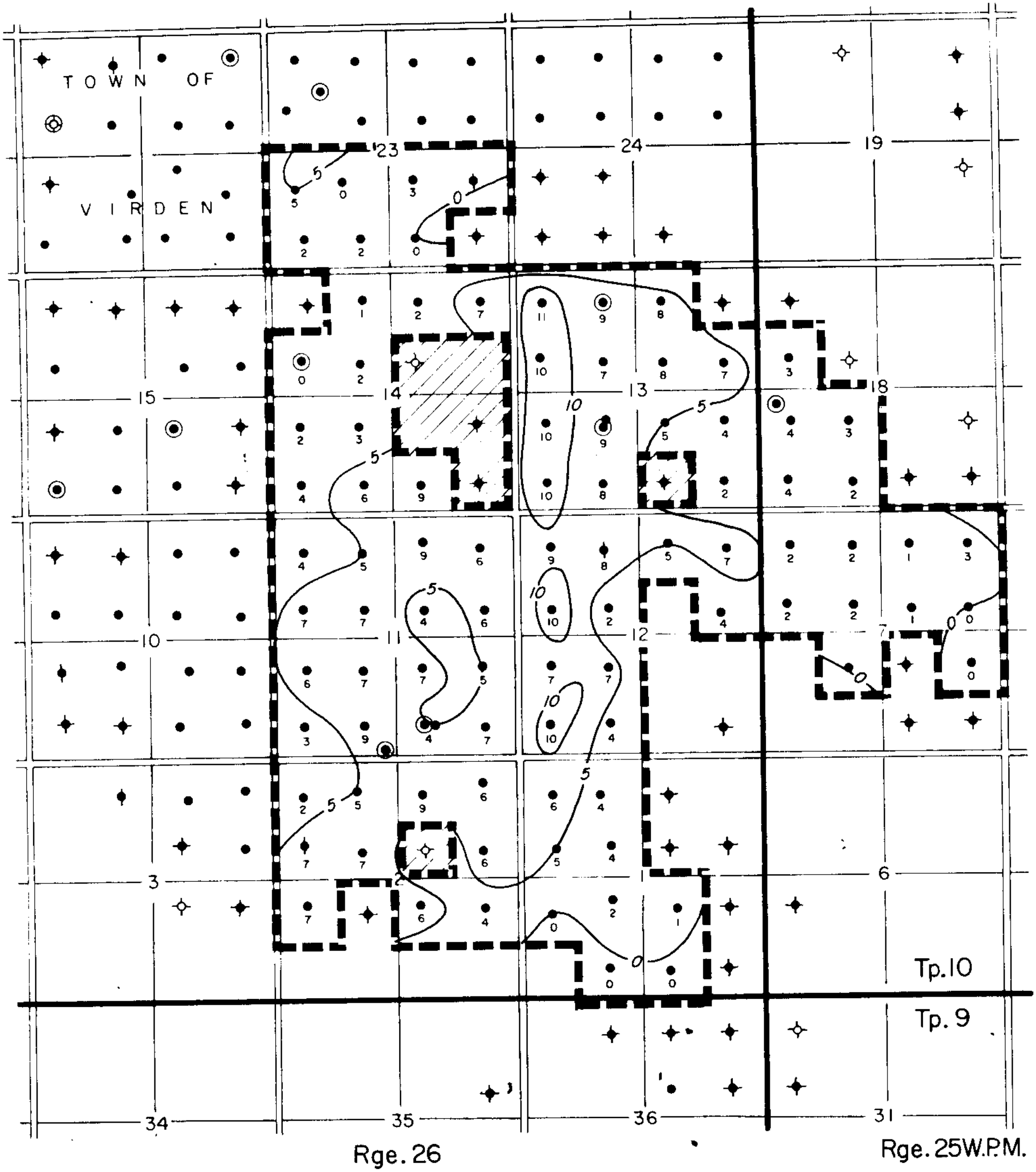


FIGURE 3

PROPOSED VIRDEN ROSELEA UNIT No. 3

SANDHILL ZONE PAY ISOPACH

C. I. = 5'

UNIT BOUNDARY

Scale: 1" = 3000'

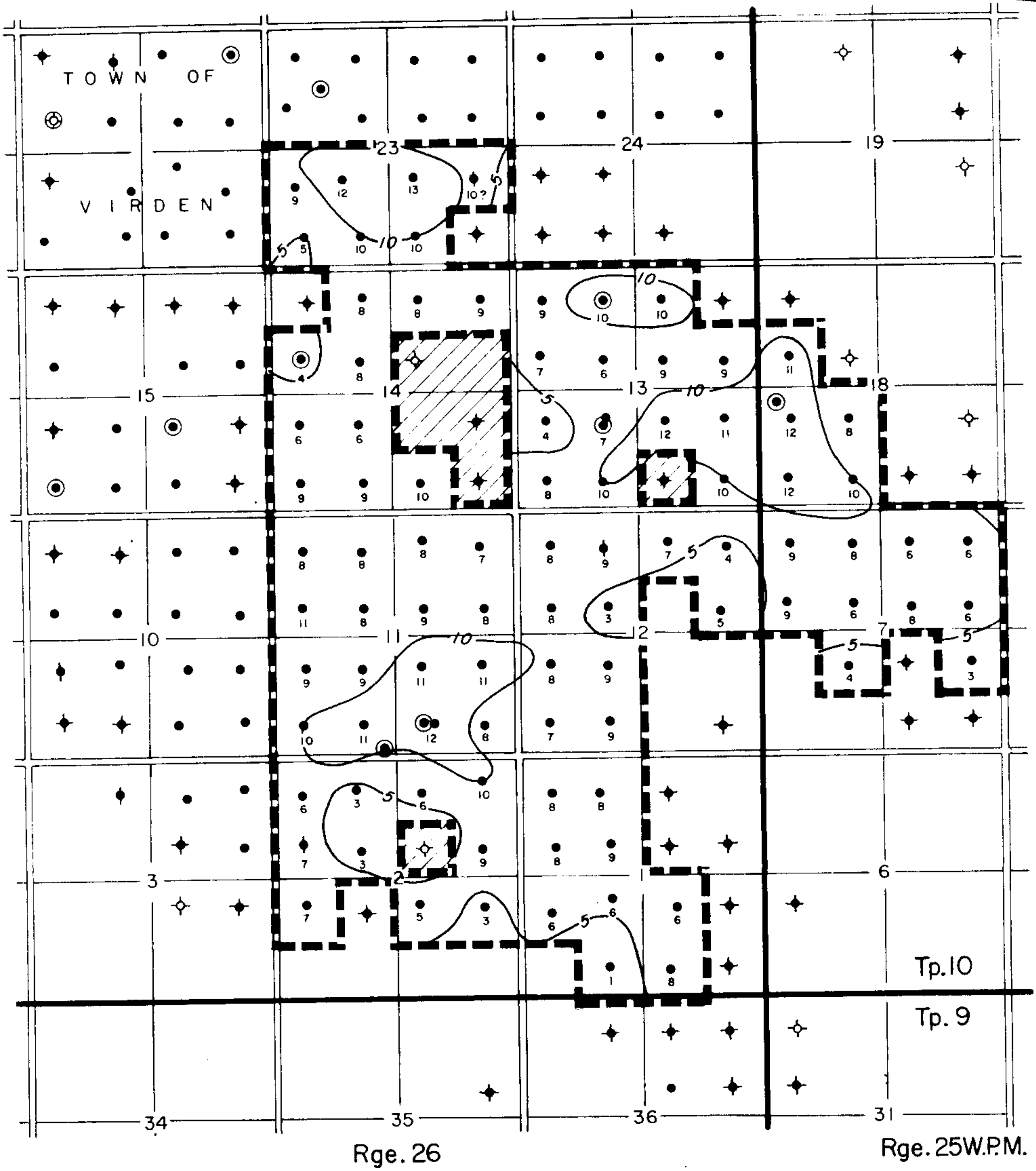


FIGURE 4

PROPOSED VIRDEN ROSELEA UNIT No. 3

OOLITIC ZONE PAY ISOPACH

C. I. = 5'

UNIT BOUNDARY

Scale : 1" = 3000'

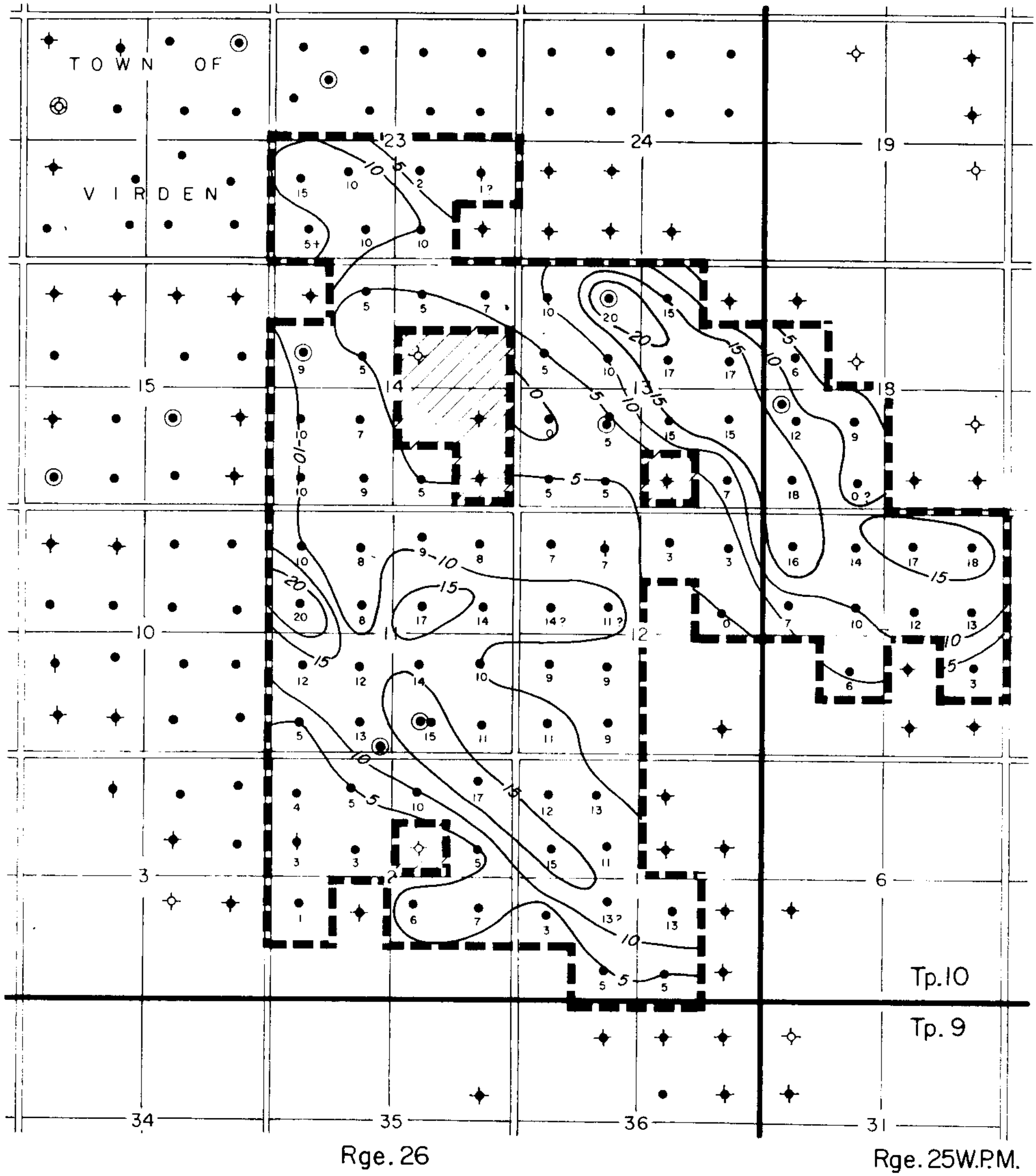


FIGURE 5

PROPOSED VIRDEN ROSELEA UNIT No. 3

CHERTY ZONE PAY ISOPACH

C. I. = 5'

▬ ▬ ▬ UNIT BOUNDARY

Scale : 1" = 3000'

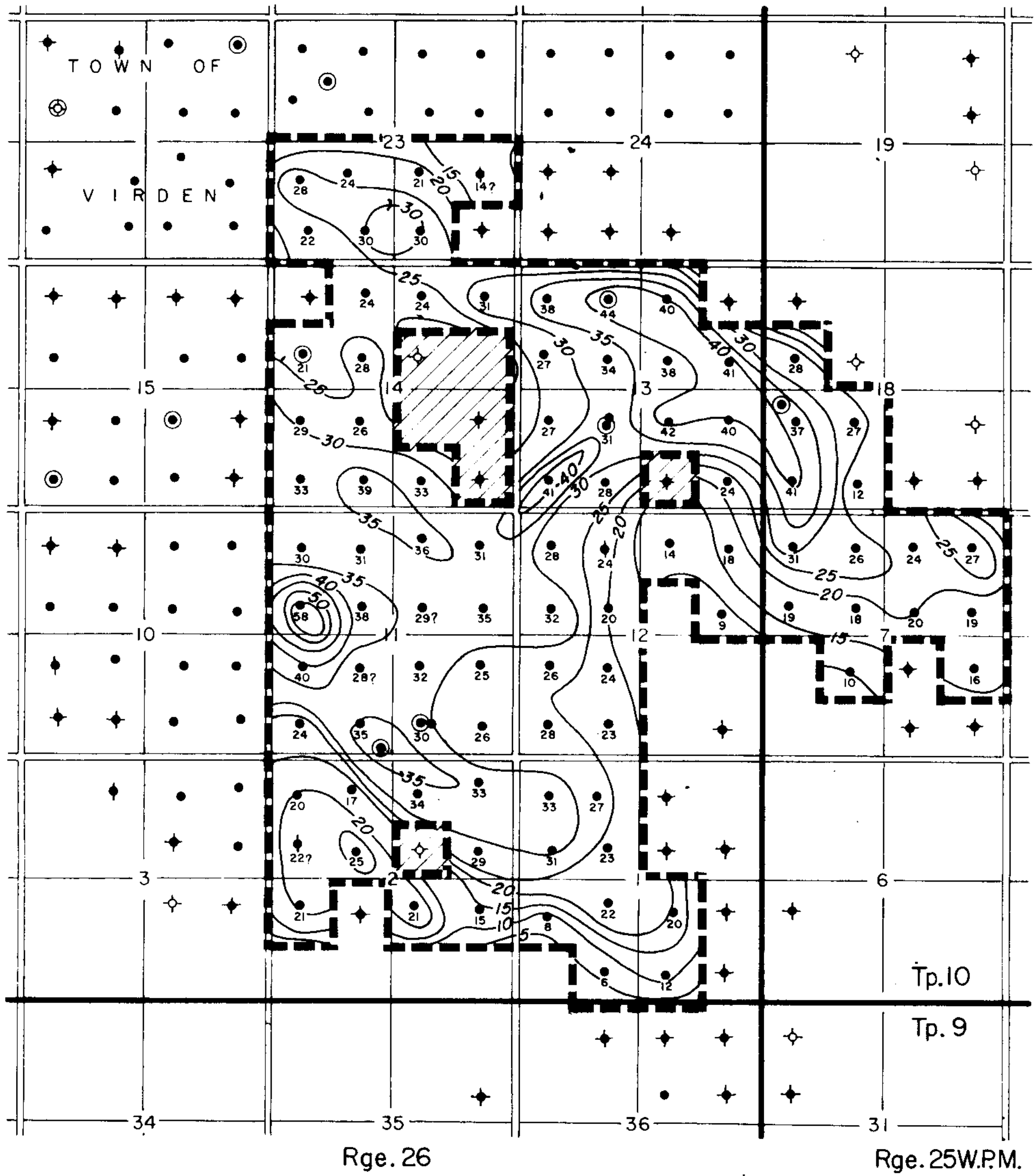


FIGURE 6

PROPOSED VIRDEN ROSELEA UNIT No. 3

TOTAL PAY ISOPACH

C. I. = 5'

▬ ▬ ▬ UNIT BOUNDARY

Scale: 1" = 3000'

FIGURE 7

PROPOSED VIRDEN ROSE

PREDICTED PRIMARY AND WAT

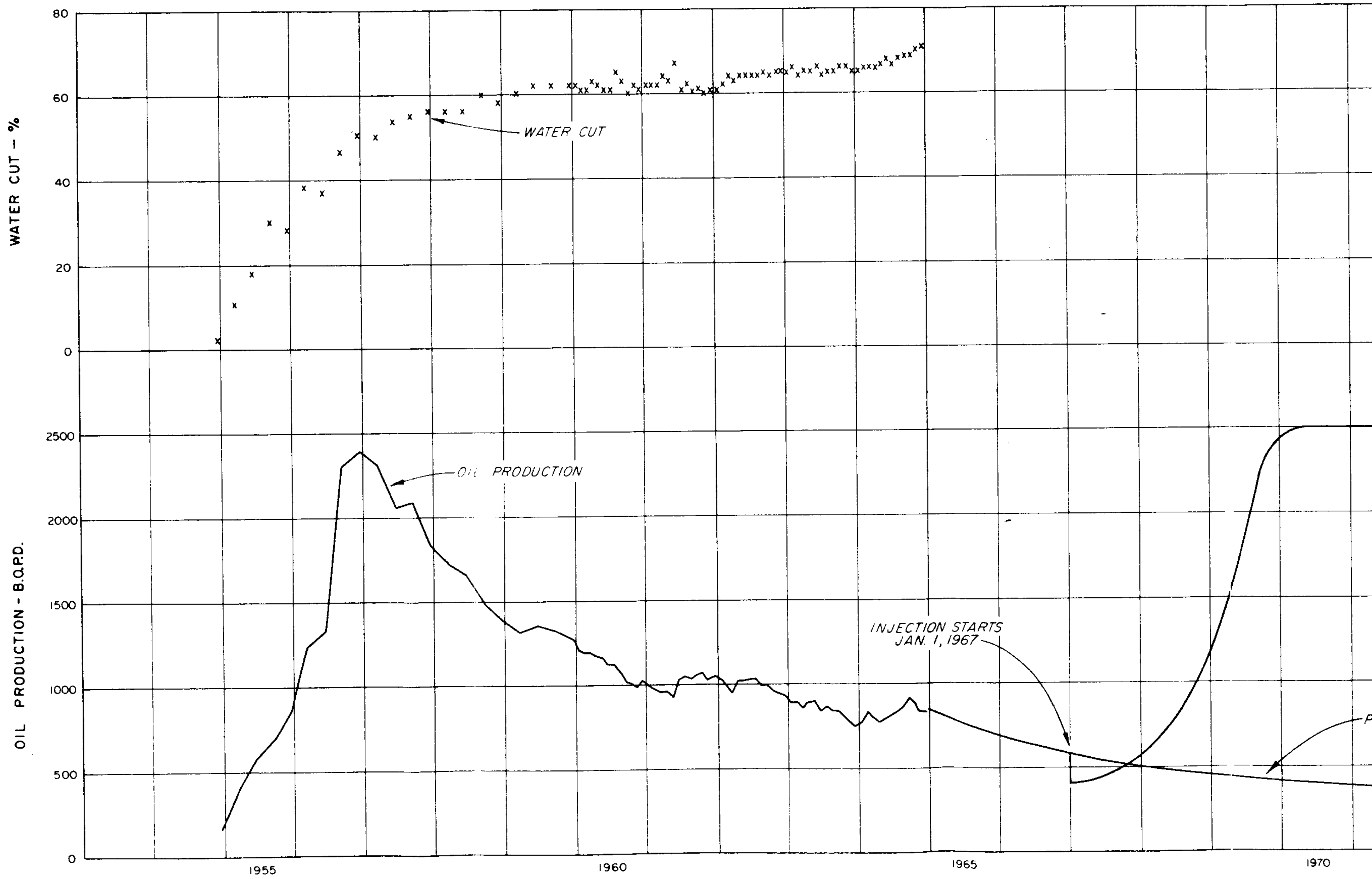
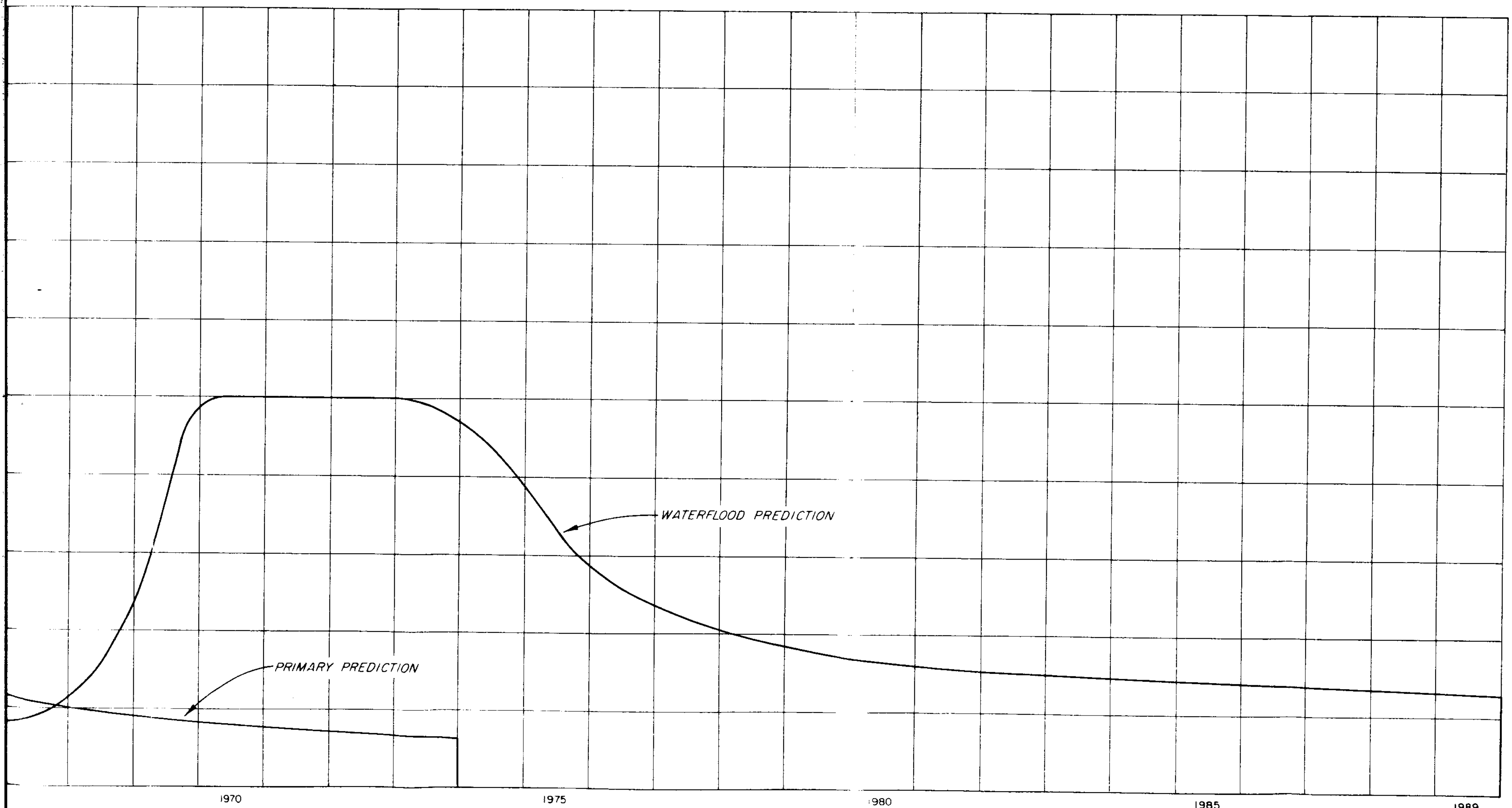


FIGURE 7

PROPOSED VIRDEN ROSELEA UNIT No. 3

EDICTED PRIMARY AND WATERFLOOD PRODUCTION



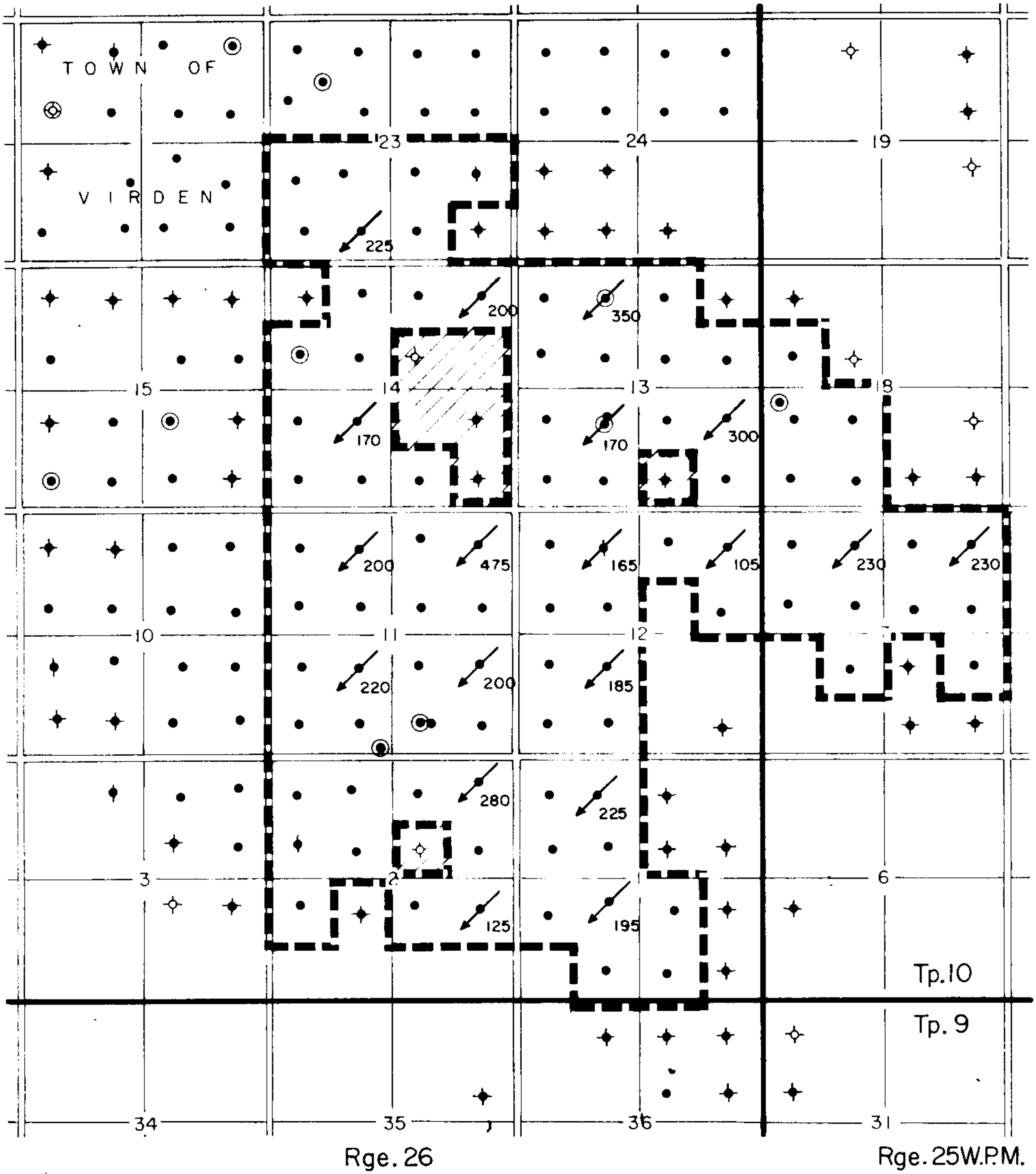


FIGURE 8

PROPOSED VIRDEN ROSELEA UNIT No. 3

WATERFLOOD INJECTION PATTERN

100 INJECTION WELL AND RATE

UNIT BOUNDARY

Scale: 1" = 3000'

TABLE 1

PROPOSED VIRDEN-ROSELEA UNIT NO. 3
SUMMARY OF
PROPOSED INJECTION WELL INJECTIVITIES

WELL	INJECTION RATE (BWPD)
14-7-10-25	230
16-7-10-25	230
6-1-10-26	195
14-1-10-26	225
8-2-10-26	125
16-2-10-26	280
6-11-10-26	220
8-11-10-26	200
14-11-10-26	200
16-11-10-26	475
6-12-10-26	185
14-12-10-26	165
16-12-10-26	105
6-13-10-26	170
8-13-10-26	300
14-13-10-26	350
6-14-10-26	170
16-14-10-26	200
3-23-10-26	225
TOTAL	4250