OUTLINE PROPOSAL

FOR EXTENDING

ELECTRIC RAILWAY OPERATION

OF THE

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

BY NEW POWER CONTRACTS

WITH

MONTANA POWER COMPANY

PUGET SOUND POWER & LIGHT COMPANY

WASHINGTON WATER POWER COMPANY

SEPTEMBER, 1971

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SUMMARY

A plan was laid out to electrify 212 miles of Milwaukee Road main line through Eastern Washington by constructing seven rectifier substations, and erecting 212 miles of catenary and feeder from Othello, Washington to Avery, Idaho. In addition to the new work proposed, a program to increase the feeder and substation capability in the presently electrified sections of the Coast and Rocky Mountain Divisions in three steps is proposed. Second and third step improvements to the power supply system are to be implemented when traffic increases 1,500,000 MGTM and 3,000,000 MGTM. The initial complement of 45 electric locomotives is increased by six electric locomotives for each 1,000,000 MGTM growth of traffic

CONCLUSIONS

1. The extension and expansion of the electrified sections of the Milwaukee Road will pay out. The first fifteen years of operation will yield a small profit whose present value in 1974 is estimated to be $194,562. In the sixteenth year when the second generation of diesel locomotives would come into service, if operation was with diesels, the savings will be very large - exceeding $2,000,000/year.

2. Extension of electric operation of the Milwaukee Road in Washington, Idaho and Montana would be an expression of the Railroad Management's faith in the future of the Northwest.

3. Costs and savings attributed to electric operation of the Milwaukee Road from Seattle-Tacoma, Washington to Harlowton, Montana are shown on Table A from 1974 through 1990. Costs are sensitive to: a) traffic density, b) fuel cost, c) labor cost, d) relative cost of electric to diesel locomotives, e) interest rates, f) locomotive availability ratio.

   a) A change of 100,000 MGTM annually after 1976 will make a $37,000 annual change in fuel and engine maintenance cost.

   b) An increase of 0.5¢/gal. of diesel fuel in 1977 will increase the annual savings from electric operation for 7,545,769 MGTM to $160,309, or by $2,125 per 100,000 MGTM/year.

c) A 1% increase in labor cost will increase the savings from electric operation by approximately $5,000/year in the early years and to $13,000/year after 15 years.

d) If the cost differential between diesel and electric locomotives were reduced 10% changing the ratio used in this report from 1.50 to 1 to 1.45 to 1 (a 3.3% price reduction per electric locomotive) there would be an increase of amortization savings of $22,500/year or 4.3% while the greater interest cost for electric locomotives would be reduced $54,000/year in 1974 and $46,800/year in 1978.

e) A one (1) percentage point change in interest rates would make an annual change in fixed cost and locomotive interest of approximately $140,000 divided between locomotive interest of $22,500 and fixed cost of $117,500.

f) If the availability ratio of diesel locomotives to electric locomotives was changed to 90% from 95%, the assumed 45 electric locomotives would displace 63 diesels rather than 60 diesels as assumed in this report. Such a change would increase amortization savings $60,000 and reduce interest cost charged to electrification by $72,000 in the first year of the project. For comparison with Table A, the charges for the first five years follow:

	AMORTIZATION SAVING	INTEREST COST	NET SAVINGS
1974	$ 585,000	$ 108,000	$ 302,428
1975	$ 585,000	$ 154,800	$ 140,200
1976	$ 585,000	$ 201,600	$ 8,207
1977	$ 585,000	$ 248,400	$ 237
1977	$ 585,000	$ 295,200	$ 27,800

4. The largest proportion of a capital outlay for electrification of the Milwaukee main line from Seattle-Tacoma to Harlowton will be for locomotives. Out of a total estimated investment of $32,000,000 by Milwaukee, $20,250,000 will be for locomotives and $11,750,000 for trolley, feeders and substations.

INTRODUCTION

Presently the Milwaukee Road operates 656 route miles of electrified track in two sections; one section of 220 miles extending from Seattle-Tacoma on Puget Sound east to Othello in Central Washington and the second section extending for 436 miles from Avery, Idaho east ot Harlowton, Montana.

To supply this 656 miles of 3000 V D.C. trolley, the Milwaukee Railroad owns 503 miles of 100 kV transmission and 22 motor-generator substations in Washington, Idaho and Montana.

This 656 miles of electrification is in working order and is worth far more today than its original cost or its book value, as means of supplying power to electric locomotives.

The addition of 212 miles of electrified route through Eastern Washington and Northern Idaho would provide a continuous electrified railroad for 868 miles from Seattle-Tacoma, Washington east through Washington and Northern Idaho to Harlowton, Montana. This electrification crosses five mountain ranges with grades as steep as 2.2%, and with some of the worst weather in North America.

Our studies have indicated that the choice between a D.C. catenary and power supply and an A.C. catenary and power supply will be influenced by factors other than power supply to the locomotive and the number of substations. These include, among others:

a) Availability of high voltage utility supply lines.
b) Strength of utility supply system.
c) Existing electrification facilities.
d) Tunnels and overhead obstructions.
e) Signal system changes.
f) Communication system changes.

Our investigation revealed that either Utility owned 115 kV lines or Railroad owned 100 kV lines were available along the 868 route miles for substation supply so that the maximum distance between substations supplied from existing high voltage lines would not need to exceed 30 miles, except in the one instance between St. Maries and Avery where the distance is 43 miles.

The existing electric facilities use motor generator sets to convert 2300 volt A.C. power to 3000 volt D.C. power. These machines are equipped to convert D.C. power generated by locomotives descending the mountains to A.C. power and return the energy to the serving utility.

Studies of the cost of changes to Signal and Communication Systems if the 3000 volt D.C. system were converted to single phase A.C. system, together with the minimizing of new investment by using existing conversion facilities to the best advantage by relocating some motor-generator sets, showed that the most economical way of expanding the Milwaukee Railroad's electrification would be at 3000 volts D.C.

After reviewing potential energy sales, it appeared to the utilities that the Railroad load would be desirable if some means could be found to finance the 212 mile "gap" in Eastern Washington, and to increase the capability of the presently electrified 656 route miles of electrification.

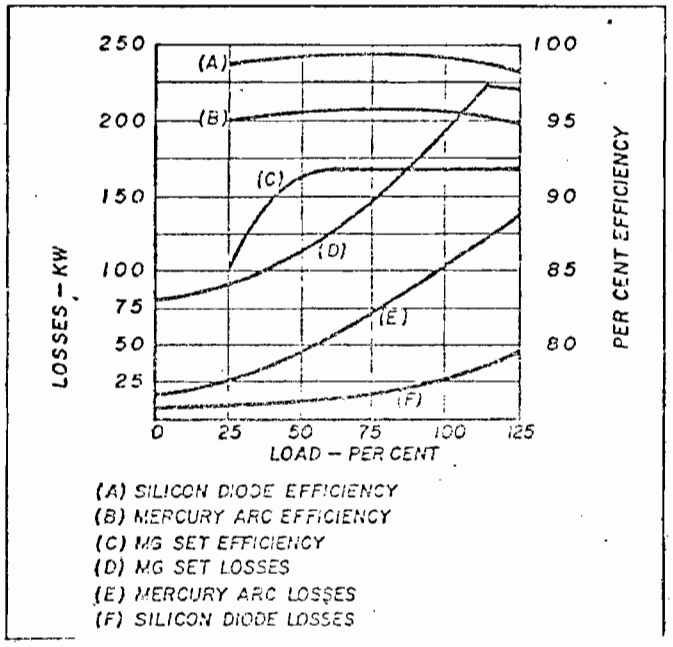
To this end, we have laid out an electrification scheme from the power utilities' engineers point of view. New substations in the area of the "gap" are supplied by rectifiers with silicon diodes. Increased substation capacity is made available on the Coast Division and the Rocky Mountain Division by installing five new rectifier substations to replace substations with motor generator sets. These displaced motor generator sets are proposed to be moved to 6 substations where increased power appears to be required.

Following the pattern established by the Railroad Company's electrical engineers, it is proposed to replace all copper feeders in the Coast and Rocky Mountain Divisions with aluminum feeders of approximately the same weight, thus doubling the equivalent copper cross section of all feeders replaced. This change will introduce a new size of wire to the Railroad; namely, 2250 MCM Al. "Sagebrush". This is equivalent to 1415 MCM copper. Second and third steps developing the Rocky Mountain Division to carry heavier traffic are proposed by installing five additional rectifiers and moving the displaced motor generator sets to areas where they may be required and may absorb regenerated power.

Losses from the 2400 volt utility delivery point to the locomotive were considered. Presently these losses approximate 30% on the Rocky Mountain Division and 25% on the Coast Division. These losses will be reduced substantially by this project.

The reductions are brought about in three ways:

1. Increasing feeder capacity by doubling feeder cross section.
2. Increasing maximum voltage to 3750 volts from 3300 volts.
3. By the use of silicon diode rectifiers with losses of less than 2% as compared with motor-generator set losses of 8%.



Comparison of efficiency and losses for power conversion equipment rated 2000 Kw, 1500 V D.C.

The sum of these improvements is estimated to reduce the electric losses over the completed 868 miles of electrified railroad to 10%.

Inflation has been considered only by increases in maintenance cost from 1970 to 1974, and by revising construction costs to estimated 1972 costs and by increasing locomotive cost 2.74%/per year from 1974. If this project is completed and in service by January 1974, any cost inflation for labor will increase the benefits to the Railroad from electrification. Fuel cost inflation should be greater for diesel fuel than for electric power because the utilities have large deposits of low cost coal available for development and oil supplies are increasingly more remote and more costly.

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PREFACE

This report has been prepared to update a presentation made to the Milwaukee Railroad executives at Chicago in November 1969. Since that time there have been major changes in costs and as a result of the Chicago Meeting, specific values for the cost of labor and fuel to the Railroad have been made available to the Utilities.

Principal changes in this report from the November 1969 report are: -

1) Increased cost of diesel fuel from 9¢/gal. to 10.5¢/gal.
2) Use of factor of 9% of diesel fuel cost for engine lube cost.
3) Use of Milwaukee actual substation and overhead maintenance cost for 1970 converted to a cost per route mile of electrified road and per substation.
4) Use of 90% efficiency for electric supply system applied to the ratio of 10 kwh to 1 gal. of diesel fuel.
5) Increasing the number of electric locomotives to 45 - 3600 hp and reducing the ratio of diesel to electric locomotives to 1.25 diesels to 1 electric.
6) Increase of some rectifier capacity from 4,400 Kw to 6,600 Kw.
7) Diesel maintenance cost of 31.4¢/MGTM in place of $15,741 per diesel unit.

The line maintenance cost has been stated in dollars per route mile of electrified railroad. This cost includes the maintenance cost of the Railroad's 100 kV transmission line. The overhead maintenance cost could be reduced if the Milwaukee could negotiate a sale of its 100 kV transmission line to the Power Utilities serving the Railroad's electrical facilities.

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The Ton Mile projections shown on Table I appeared to have a growth rate higher than could be maintained for more than a few years into the future.

The energy growth in megawatthours at a growth rate of 1/2 the historical rate from 1961 through 1970 is shown on Table II. Revenue estimates to the Utilities from traffic growth at half the historical rate are shown on Table V for the years 1974 through 1990.

With these potential energy sales in view, the various possible economies that could be realized from electric operation of the Railroad in the northwest were investigated in depth.

The electric power supply system and the electric locomotives were considered as one. The trolley system and substations are useless without electric locomotives to use the electric energy the trolley can supply. On the other hand, an electric locomotive is helpless without an electric trolley system to bring power to it.

A new modern electric supply system between Avery and Othello must be supported by the existing electrified sections of the Railroad in Montana and Washington.

Cost estimates have been prepared in three parts: the first for filling the "gap" from Othello to Avery, the second to reinforce the Coast Division and the third to reinforce the Rocky Mountain Division. To show the total cost of the proposed project, estimates of substation cost to serve the new and reinforced electrification included the AC portion of the substations to be paid for by the power supply companies. These costs have been deducted at the end to determine the cost of extending the electrification to the Railroad.

In addition to electrifying the "gap" from Othello to Avery and reinforcing the existing electrified Coast and Rocky Mountain Divisions to meet 1974 traffic, two additional improvement steps are proposed to meet projected traffic growth.

With the idea in mind of supplying an efficient, modern electric supply system for the Milwaukee Road from Harlowton to Seattle-Tacoma, a plan was prepared for a new electric catenary and feeder system to be supplied from seven rectifier substations between Othello, Washington and Avery, Idaho, together with a scheme to reinforce the present feeder system and substations at the Coast and Rocky Mountain Divisions in three steps to meet the requirements of traffic growth. These plans were based on the principal assumptions which follow.

PRINCIPAL ASSUMPTIONS

Financing of improvements to the Milwaukee's electrified sections and filling in the "gap" in Eastern Washington can only be done if the cost of fixed facilities of power lines and substations are considered, together with mobile equipment of motive power. Proposals contained in this report are based on the following assumptions:

1. Milwaukee will order locomotives for delivery in 1973 and thereafter in 1972 so that electric operation may be expanded over electrified sections of the Railroad as soon after January 1, 1973 as possible.

2. Milwaukee will order 45 locomotives at a cost of $450,000 each or a total cost of $20,250,000 from the General Electric Company.

3. Six additional electric locomotives will be purchased for each traffic increase of 1,000,000 MGTM.

4. Average cost of diesel locomotive - $300,000.

5. Copper of new 4/0 grooved trolley wire to be installed in the "gap" will be obtained by replacing 500 MCM and 700 MCM feeders between the Columbia River and Cedar Falls as follows:

   700 MCM Cu with 2,250 MCM Sagebrush Aluminum
   500 MCM Cu with 1,590 MCM Coreopsis Aluminum

   at no cost to the project. See conductor cost summary Avery-Othello and Coast Division.

6. Electrification cost estimates are those supplied by Washington updated to November 1971 with independent estimates for increased substation capacity in the existing electrified sections.

7. Proposed construction can be completed in two years.

8. Feeder and substation capacity will be increased to meet load growth in two steps. Step one for 1,500,000 MGTM increase, and step two when traffic has increased 3,000,000 MGTM.

10. Fixed charges are assumed to be 17%:
    8% Interest
    3% Depreciation
    3% Profit
    3% Taxes

11. For this study, electric power costs are assumed to be $0.007 per Kwh. The cost will be different for each utility and will be influenced by the impact of the Railroad's power demand on the Power Company's annual peak.

12. Diesel fuel cost - 10.5¢ per gal.

13. Diesel lube oil cost - 9% of diesel fuel cost.

14. Locomotive life: a. Diesel - 15 years
    b. Electric - 30 years

15. Locomotive maintenance cost: a. Diesel - 31.4¢/MGTM 1970
    b. Electric - 50% of Diesel

16. One 3600 hp electric locomotive is equivalent to 1.25 average diesels.

17. Locomotive availability of diesels equals 95% of electric.

18. Trolley maintenance cost 1970 - $571/route mile.

19. Substation operation and maintenance for motor-generator substations 1970 - $22,000/year/substation, rectifier substations $3,000/year/substation.

20. The three Power Companies will pay for and own the 115 kV facilities, transformers, regulators and 2400 volt secondary breaker in each of the new rectifier substations.

21. Wire cost and salvage value were estimated as follows:

Copper scrap	39¢/lb.
4/0 Cu Trolley	91¢/lb.
1.590 MCM Al	35.5¢/lb.
2.250 MCM Al	38.6¢/lb.

22. Labor inflation 1970 to 1974 - 142%.

23. Locomotive cost inflation 1974 to 1989 - 150% or 2.74%/year.

24. MGTM were converted to kilowatt hours by the following factors:

Coast Division	48 Kwh/MGTM
Avery-Othello	35 Kwh/MGTM
Rocky Mountain Div.	45 Kwh/MGTM

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ELECTRIFICATION
EXPANSION AND IMPROVEMENT
COST SUMMARY

AVERY - OTHELLO EXTENSION		
Poles, etc.		$ 1,680,000
Trolley and Feeders		3,120,000
Labor		3,000,000
	Trolley Total	$ 7,800,000
AC Substation Facilities		By Power Company
DC Substation Facilities		1,778,000
	Substation Total	$ 2,800,000
	Total Avery - Othello	$ 9,578,000
COAST DIVISION IMPROVEMENTS		
AC Substation Facilities		By Power Company
DC Substation Facilities		699,000
Feeder Increase		823,320
	Total Coast Division	$ 1,622,320
ROCKY MOUNTAIN DIVISION IMPROVEMENTS		
AC Substation Facilities		By Power Company
DC Substation Facilities		1,198,000
Feeder Increase		1,728,314
	Total Rocky Mountain Div.	$ 2,926,314
	Total Project	$14,135,634
COPPER CREDITS		
Coast Division	$ 928,744	
Rocky Mountain Division	1,451,365	$ 2,380,109
	Net Project	$11,755,525

Cost Summary - continued

STEP TWO

Coast Division Improvement

	By Power Company
A.C. Substation Facilities	
D.C. Substation Facilities	$ 252,000

Rocky Mountain Division Improvements

	By Power Company	
A.C. Substation Facilities		
D.C. Substation Facilities	$1,078,000	
Feeder Increase	340,000	
Total Rocky Mountain Division		1,606,000
Total Second Step		$1,518,000

STEP THREE

Rocky Mountain Division Improvements

	By Power Company
A.C. Substation Facilities	
D.C. Substation Facilities	$ 740,000
Feeder Increase	180,000
Total Third Step	$ 920,000

CONDUCTOR COST SUMMARY

AVERY-OTHELLO AND COAST DIVISION

COPPER TROLLEY WIRE REQUIRED

460 Miles @ 3,450#	=	1,587,000#
Copper Removed	=	1,699,345#
Copper Trolley Req.	=	1,587,000#
Net Excess of Cu		112,345#

Cost of 460 Mile 4/0 Trolley Wire from Estimated 91¢/lb - 3450#/Mile $ 1,440,400

Cost of Aluminum Feeder 90.8 Miles 2250 MCM @ 38.6¢/lb and 11,262#/Mile 394,719

77.4 Miles 1590 MCM @ 35.5¢/lb and 7,883#/Mile 216,590 611,309

* Credit for Feeder Wire Removed 1,699,345# @ 39¢/lb	662,744
Coast Division Feeder Labor	212,000
Cost of Feeder Replacement	263,435
Cost of Remanufacturing Cu Salvage to 4/0 Trolley Wire 1,587,000# @ 35¢/lb	555,450
Credit to Feeders for 1,587,000# Cu @ 39¢/lb	618,930
Net cost of Trolley Wire	1,174,380
Estimated Cost of New 4/0 Trolley Wire 460 Miles - 3,450#/Mile @ 91¢/lb	1,440,400
* Savings by using salvaged Cu	266,020
Cost of Feeder Replacement	263,435
Net Credit from Use of Salvaged Cu	2,585
Excess Cu Sold as Scrap 112,345# @ 39¢	43,795
Credit to Project from Salvaged Feeder Cu	46,380

* Coast Division Copper Credit

Credit for feeder wire removed 1,699,345# @ 39¢/lb.	662,744
Trolley savings from using salvaged Cu	266,020
NET CREDIT	$ 928,764

CONDUCTOR COST SUMMARY

ROCKY MOUNTAIN DIVISION

COPPER REMOVED

28 Miles 700 MCM @ 11,410#	=	319,480#
363 Miles 500 MCM @ 8,150#	=	2,960,368
128 Miles 4/0 @ 3,450#	=	441,600
Total Cu Removed		3,721,448#

ALUMINUM INSTALLED

28 Miles 2250 MCM @ 11,262#	=	315,336#
386 Miles 1590 MCM @ 7,883	=	3,041,100
Total Aluminum Required		3,356,444#

Salvage Value of Copper 3,721,448# @ 39¢/lb. $ 1,451,365

Cost of Aluminum

315,336# 2,250 MCM @ 38.6¢/lb	$ 121,720	
3,041,108# 1590 MCM @35.5¢/lb	$1,079,593	
Total Alumimum		1,201,313
Credit for Cu Conductors		250,052
Rocky Mountain Feeder Labor		527.000
Net Cost of Feeder Replacement		276,948

SAVINGS FROM ELECTRIC OPERATION

The savings from electric operations are found in three areas, 1) lower cost of energy, 2) lower cost of locomotive maintenance, and 3) lower capital cost for locomotives. These savings from operating 868 miles of electrified railroad will pay the fixed charges on the extension and improvements to Milwaukee's electrified operations when the three serving utilities take over the responsibility for power supply to the 2400 volt bus in the Railroad Company's substations.

COST OF ENERGY SAVING

The growth of energy use has been determined from a projection of gross ton miles at one half (1/2) the historical growth rate for a 10 year base from 1961 through 1970. The rates used are:

2.12%/Year for Coast Division
2.96%/Year for Avery-Othello
2.72%/Year for Rocky Mountain Division

These projections as shown in Table II assuming an energy ratio of 10 kwh to one gallon of diesel oil; the price of diesel oil at 10.5¢/gal. and a price for electricity of 0.7¢/kwh, with an electric system efficiency of 90%, there is an energy cost saving of 0.245¢/kwh. Diesel lubricants cost 9% of diesel fuel cost or the equivalent of 0.085¢/kwh. The total savings from fuel and lube oil per kwh of power purchased is 0.33¢/kwh after the expiration of existing power contracts.

LOCOMOTIVE MAINTENANCE SAVINGS

Experience has shown that electric locomotive maintenance cost vary from 1/3 to 1/2 the maintenance cost of diesel locomotives. For this study, electric locomotive maintenance cost has been taken as 50% of diesel locomotive maintenance cost. The maintenance cost in 1970 was 31.4¢/MGTM. Maintenance cost is directly related to labor cost. The Railroad industry has recently agreed on a new labor contract providing for a 42% pay increase for union employees over a three year period. A two year construction period has been assumed for this project beginning in January 1972, for completing in January 1974. Maintenance cost per MGTM has been increased to 142% of the 1970 figure for 1974 estimates to 44.4¢/MGTM. The saving for electric locomotive operation is 22.2¢/MGTM as shown in Table A from 1974 through 1990.

LOCOMOTIVE CAPITAL SAVINGS

One 3600 horse power electric locomotive is equivalent to 1.25 average diesel locomotives in tractive effort. Diesel locomotives have 95% of the availability of electric locomotives. From these figures it appears that 1.32 diesel locomotives will equal one electric locomotive in freight service. If the Milwaukee Road requires 45 electric locomotives for freight operation from Harlowton to Puget Sound, the Railroad will require 60 diesel locomotives for the same tractive effort and availability. For this study, an average life of 15 years for diesel locomotives and 30 years for electric locomotives has been used.

45 Electric Locomotives @ $450,000	$20,250,000
60 Diesel Locomotives @ 300,000	18,000,000
Annual Amortization on 15 year Life of Diesel Locomotives	1,200,000
Annual Amortiziation on 30 year Life on Electric Locomotives	675,000
Annual Amortization Savings	$ 525,000

The foregoing savings are shown on Table A for the years 1974 through 1990. It was assumed that full electric operation would begin in 1974 and that all new locomotives would be delivered and in operation by that year.

ELECTRIC MAINTENANCE COST

Electrical maintenance cost for the Coast Division and the Rocky Mountain Division in 1970 was

$571/route mile for trolley and OH lines

$22,000/substation for 22 rotary substations

These costs were increased to 142% of 1970 costs for 1974, based on a recent labor contract giving the following 1974 costs:

$810/route mile for trolley and OH lines

$31,240/substation for rotary substations

Two new figures were estimated for 1974:

$540/route mile for Avery-Othello trolley

$3,000/substation for rectifier substations

The lower trolley maintenance figure for Avery-Othello is based on the fact that there will be no 100 kV transmission line maintenance in the "Gap". Maintenance cost for 1974:

656 miles route @ $810/mile	$ 531,360
212 miles route @ $540/mile	114,480
	$ 645,840
17 Rotary substations @ $31,240	$ 531,080
12 Rectifier substations @ $3,000	36,000
	$ 567,080
1974 Total Electric Maintenance	$1,112,920

MILWAUKEE ELECTRIFICATION

FINANCING

Estimated Cost of Project	$ 13,571,525
Annual Fixed Charges @ 17%	$ 1,998,439

Referring to Table A, it may be seen that these estimated fixed charges are exceeded by savings from electric operation most years after 1972. The present value of the savings from electric operation in 1974 for the years 1974 through 1990 is $194,562. Projections are not extended beyond 1990 because in the years 1989 and thereafter when all original diesels would be replaced, the savings from electric operation are very large. By taking advantage of the existing power contracts that have much lower rates, large savings are possible in 1974 and 1975.

The contract for power supply to the Rocky Mountain Division with the Montana Power Company expires June 30, 1975. Power has been purchased for 0.536¢/kwh under this contract.

The contract for power supply to the Coast Division with Puget Sound Power & Light Co. and Washington Water Power Co. expires April 30, 1976. Power has been purchased for 0.585¢/kwh under this contract.

It should be remembered that the fixed charge of 17% is made up as follows:

8% Interest
3% Depreciation
3% Profit
3% Taxes

Considering only interest and depreciation as necessary expenses, the cost of ownership is per year, $1,293,108.

Referring again to Table A, it may be seen that by exploiting existing power contracts, Milwaukee will make a small saving on its electrification investment as soon as total electric operation begins.

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AVERY - OTHELLO
SCOPE OF EXTENSION

To provide facilities for electric operation of trains will require a complete new trolley and feeder system, together with seven (7) new 115 kV AC to 3300 DC - 4400 kw substations. The following are the major items required.

RECTIFIER SUBSTATIONS

1. Roxboro
2. Ralston
3. Revere
4. Malden
5. Tekoa
6. Plummer
7. St. Maries

The trolley will consist of 2 - 4/0 grooved trolley wires over the main track for 212 miles and one (1) 4/0 grooved trolley wire over side tracks and in yards.

Feeders parallel to the main line will consist of 170 miles of 1,590 Mcm Al from Othello to St. Maries and 45 miles of 2,250 Mcm Al from St. Maries to Avery. The feeders will be run on the trolley poles. An estimated cost detail of this construction is shown on the following pages.

AVERY - OTHELLO

212 ROUTE MILES

CATENARY AND FEEDER COST

POLES, GUYS AND ANCHORS	
11,000 35' Poles @ $55 ea.	$ 605,000
20,000 Mast Arms @ $14 ea.	280,000
10,000 Anchors @ $12 ea.	120,000
16,000 Pulloffs @ $10 ea.	160,000
11,000 Guy Wires @ $15 ea.	165,000
1,250 Span Wires @ $30 ea.	37,500
Miscellaneous Material	147,500
Stores Expense	165,000
Total Poles, etc.	$1,680,000

TROLLEY AND FEEDERS	
265 Miles 1/2" Messenger @ $600/mile	$ 159,000
460 Miles 4/0 Cu Trolley @ $3140/mile	1,440,400
172 Miles 1590 Mcm Al @ $2800/mile	461,600
43 Miles of 2 - 2250 Mcm Al @ $8700/mile	374,100
460 Miles Catenary Hangers @ $240/ea.	110,400
25 Switches @ $175/ea.	4,375
Miscellaneous Material	295,125
Stores Expense	275,000
Total Trolley	$3,120,000

Engr. & Supt.	$ 120,000
Labor 212 Miles @ $11,000/mile	2,332,000
Equipment	185,000
Contingencies	363,000
Total Labor, etc.	$3,000,000
Total Overhead	$7,800,000

AVERY - OTHELLO

SUBSTATION COST

7 - 115 kV Substation Facilities		By Power Company
Fence and Grading		
Steel Structures		
115 kV Disc. Sw.		
115 kV Fuses & Mtg.		
Lightning Arresters		
Foundation		
Buswork & Insulators		
Ground Mat		
Miscellaneous Material		
Labor and Overhead		
7 - Rectifier Transformers @	$ 100,000	By Power Company
7 - Secondary Breakers @	10,000	By Power Company
7 - Rectifiers & DC Switchgear @	210,000	$ 1,470,000
7 - DC Terminals & Cables @	4,000	28,000
7 - Supervisory Remote Stations @	10,000	70,000
7 - Labor and Overhead @	25,000	175,000
	TOTAL SEVEN SUBSTATIONS	$ 1,743,000
MASTER SUPERVISORY FOR SEVEN STATIONS		21,000
SPARE RECTIFIER DIODES & FUSES		14,000
	TOTAL SEVEN SUBSTATION	$ 1,778,000
AVERY - OTHELLO TOTAL PROJECT		$ 9,578,000

WASHINGTON WATER POWER COMPANY

SUPPLY FACILITIES

FOR

RAILROAD SUBSTATIONS

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1. ROXBORO - WEST
   1¼ Mile of 115 kV Line
   2 - 115 kV Switches

2. RALSTON - WEST
   No 115 kV Line
   2 - 115 kV Switches

3. REVERE
   ½ Mile of 115 kV Line
   2 - 115 kV Switches

4. MALDEN
   1¼ Mile of 115 kV Line
   1 - 115 kV Switch

5. TEKOA
   1 Mile of 115 kV Line
   1 - 115 kV Switch

6. PLUMMER
   ½ Mile of 115 kV Line
   1 - 115 kV Switch

7. ST. MARIES
   1½ Mile of 115 kV Line
   1 - 115 kV Switch

TOTAL SUPPLY FACILITIES

TELEMETERING

From eight (8) Railroad substations
to Spokane and to Malden

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COAST DIVISION

IMPROVEMENTS

To bring the existing Coast Division electrification up to the standards of the proposed Avery - Othello electrification, the following improvements are proposed:

Two (2) new 115 kV AC to 3300 V DC Rectifier Substations at:

Black River Junction
Taunton

Motor-generator sets from the substations replaced by these rectifier substations will permit increase of M-G capacity at locations where it is desirable to absorb regenerated power from trains descending the mountains.

The changes in motor-generator capacity and the additional rectifiers proposed are given below:

Substation	Existing Capacity	Proposed Capacity
Tacoma Junction	2,000 Kw	2,000 Kw M-G
Renton	4,000 Kw	6,600 Kw R
Cedar Falls	4,000 Kw	6,000 Kw M-G
Hyak	4,000 Kw	6,000 Kw M-G
Cle Elum	3,000 Kw	3,000 Kw M-G
Kittitas	4,000 Kw	6,000 Kw M-G
Doris	6,000 Kw	6,000 Kw M-G
Taunton	4,000 Kw	4,400 Kw R

Feeder capacity will be increased by replacing:

500 Mcm Cu with 1,590 Mcm Al.
700 Mcm Cu with 2,250 Mcm Al.

as shown in the following table:

CEDAR FALLS - HYAK 21.8 MILES

Remove 2 - 700 Mcm Cu 497,476# Install 2 - 2250 Mcm Al. 491,023#

HYAK - KITTITAS 60.0 Miles

Remove 1 - 500 Mcm Cu 489,060# Install 1 - 1590 Mcm Al. 472,980#

KITTITAS - DORIS 23.6 MILES

Remove 2 - 700 Mcm Cu 538,552# Install 2 - 2250 Mcm Al. 531,566#

DORIS - COLUMBIA RIVER 4 MILES

Remove 2 - 500 Mcm Cu 65,208# Install 2 - 1590 Mcm Al. 63,064#

TAUNTON - OTHELLO 9.4 MILES

Remove 1 - 500 Mcm Cu 76,619# Install 1 - 1590 Mcm Al. 74,100#

Remove 1 - 4/0 Cu 32,430#

The copper replaced on the Coast Division will be reprocessed into 4/0 grooved trolley wire for use between Avery and Othello. This will provide a saving of almost $900,000 over purchasing new 4/0 grooved trolley wire.

Estimated costs for these improvements are shown on the following pages.

COAST DIVISION

IMPROVEMENTS

SUBSTATION INCREASE CAPACITY

BLACK RIVER JUNCTION NEW SUBSTATION 6,600 Kw		
Fence & Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 2000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals & Cables	8,000	
3rd DC Feeder Breaker	10,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	$ 345,000
TAUNTON SUBSTATION RECTIFIER 4,400 Kw		
Fence & Grading	3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 2000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	$ 210,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	25,000	252,000
TACOMA JUNCTION SUBSTATION		
Supervisory Control		10,000
DORIS REPLACE M-G SET		
Replace 1 - 2000 Kw G.E. M-G Sets with 2000 Kw West, M-G Set from Taunton	40,000	
Supervisory Control	10,000	50,000
CLE ELUM SUBSTATION		
Supervisory Control		10,000

KITTITAS ADD M-G SET

Install 3rd 2000 Kw West. M-G Set from Taunton on Existing Foundation	$ 26,000	
Supervisory Control	10,000	$ 36,000

HYAK M-G SETS

Install 3rd 2000 Kw G.E. M-G from Renton	26,000	
Supervisory Control	10,000	36,000

CEDAR FALLS ADD M-G SET

Install 3rd 2000 Kw G.E. M-G Set from Renton	26,000	
Supervisory Control	10,000	36,000

MASTER SUPERVISORY FOR EIGHT STATIONS	24,000
TOTAL SUBSTATION	$ 699,000

FEEDER CONDUCTOR INCREASE

DORIS TO THE COLUMBIA RIVER		
Replace 4 Miles of 2 - 500 Mcm Cu Feeders		
with 2 - 1590 Mcm Al. 63,064# Al @ 35.5¢/lb.	$ 22,388	
Labor	10,000	$ 32,388
KITTITAS TO DORIS		
Replace 23.6 Miles of 2 - 700 Mcm Cu Feeders		
with 2 - 2250 Mcm Al. 531,566# Al @ 38.6¢/lb.	205,184	
Labor	60,000	265,184
HYAK TO KITTITAS		
Replace 60 Miles of 1 - 500 Mcm Cu Feeders		
with 1 - 1590 Mcm Al. 472,980# Al @ 35.5¢/lb.	167,908	
Labor	75,000	242,908
CEDAR FALLS TO HYAK		
Replace 21.8 Miles of 2 - 700 Mcm Cu Feeders		
with 2 - 2250 Mcm Al. 491,023# Al @ 38.6¢/lb.	189,535	
Labor	55,000	244,535
TAUNTON TO OTHELLO		
Replace 9.4 Miles of 1 - 500 Mcm Cu and 1 - 4/0		
Cu Feeders with 1 - 1590 Mcm Al. 74,100# Al @ 35.5¢/lb.	26,305	
Labor	12,000	38,305
TOTAL FEEDER COST		$ 823,320
TOTAL COAST DIVISION		$1,622,320

PUGET SOUND POWER & LIGHT COMPANY

ADDED FACILITIES REQUIRED

FOR

COAST DIVISION IMPROVEMENTS

115 KV LINE TO BLACK RIVER JUNCTION

2 Miles of 115 kV line from Milwaukee's Renton Substation west to Black River Junction

TELEMETERING

Telemeter Railroad load from six (6) Railroad substations to Redmond and from Redmond to Tacoma

TOTAL PUGET

ROCKY MOUNTAIN DIVISION

IMPROVEMENTS

To bring the existing Rocky Mountain Division electrification up to the standards of the proposed Avery - Othello electrification, the following improvements are proposed:

Three (3) new 115 kV AC to 3300 V DC Rectifier Substations at:

Tarkio

Eustis

Francis

Motor-generator sets from the substations replaced by these rectifier substations will permit increase of M-G capacity at locations where it is desirable to absorb regenerated power from trains descending the mountains.

The changes in motor-generator capacity and the additional rectifiers proposed are given below:

Substation	Existing Capacity	Proposed Capacity
Avery	4,500 Kw	6,000 Kw M-G
East Portal	6,000 Kw	6,000 Kw M-G
Drexel	4,000 Kw	4,000 Kw M-G
Tarkio	4,000 Kw	6,600 Kw R
Primrose	4,000 Kw	4,000 Kw M-G
Ravenna	4,000 Kw	4,000 Kw M-G
Gold Creek	4,000 Kw	4,000 Kw M-G
Morel	4,000 Kw	4,000 Kw M-G
Janney	7,500 Kw	7,500 Kw M-G
Piedmont	4,500 Kw	6,000 Kw M-G
Eustis	4,000 Kw	4,400 Kw R
Francis	4,000 Kw	6,600 Kw R
Loweth	4,000 Kw	4,000 Kw M-G
Two Dot	4,000 Kw	4,000 Kw M-G

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Feeder capacity will be increased by replacing:

500 Mcm Cu with 1,590 Mcm Al.

700 Mcm Cu with 2,250 Mcm Al.

as shown in the following table:

AVERY - EAST PORTAL 23.8 Miles

Remove 2 - 500 Mcm Cu 387,988# Install 2 - 1590 Mcm Al. 375,231#

EAST PORTAL - DREXEL 23.7 Miles

Install 2 - 1590 Mcm Al. 373,654#

Remove 1 - 500 Mcm Cu 14.7 Miles 119,820#

Remove 2 - 500 Mcm Cu 9.0 Miles 146,718

Remove 1 - 4/0 Cu 9.0 Miles 31,050

DREXEL - TARKIO 38.0 Miles

Remove 1 - 500 Mcm Cu 309,738# Install 1 - 1590 Mcm Al. 299,554#

Remove 1 - 4/0 Cu 24.0 Miles 82,800#

TARKIO - PRIMROSE 36.7 Miles

Remove 1 - 500 Mcm Cu 299,142#

Remove 4/0 Cu 24 Miles 82,800 Install 1 - 1590 Mcm Al. 289,306#

PRIMROSE - RAVENNA 37.0 Miles

Remove 1 - 500 Mcm Cu 301,587# Install 1 - 1590 Mcm Al. 291,671#

Remove 1 - 4/0 Cu 8 Miles 27,600#

RAVENNA - GOLD CREEK 33.3 Miles

Remove 1 - 500 Mcm Cu 271,428# Install 1 - 1590 Mcm Al. 265,504#

GOLD CREEK - MOREL 35.5 Miles

Existing 1 - 1590 Al. Feeder

MOREL - JANNEY 33.5 Miles

Remove 1 - 500 Mcm Cu 23.4 Miles 190,733# Install 1 - 1590 Mcm Al. 184,462#

JANNEY - PIEDMONT 28.4 Miles

Remove 2 - 700 Mcm Cu 14 Miles 319,480 Install 2 - 2250 Mcm Al. 315,336#

PIEDMONT - EUSTIS 41.6 Miles

Remove 1 - 500 Mcm Cu 339,082#

Remove 1 - 4/0 Cu 13 Miles 44,850# Install 1 - 1590 Mcm Al. 327,933#

EUSTIS - FRANCIS 30 Miles

Remove 1 - 500 Mcm Cu 244,530# Install 1 - 1590 Mcm Al. 236,490#

Remove 1 - 4/0 Cu 13 Miles 44,850#

FRANCIS - LOWETH 30.4 Miles

Remove 1 - 500 Mcm Cu 247,790# Install 1 - 1590 Mcm Al. 239,643#

Remove 1 - 4/0 Cu 25 Miles 86,250#

LOWETH - TWO DOT 33.2 Miles

Existing 1 - 1590 Al. Feeder

East from Loweth 8 Miles Install 1 - 1590 Mcm Al. 63,064#

TWO DOT - HARLOWTON 12.0 Miles

Remove 1 - 500 Mcm Cu 97,812# Install 1 - 1590 Mcm Al. 94,596#

Remove 1 - 4/0 Cu 41,400#

Two additional steps at power supply improvement are proposed for the Rocky Mountain Division for future years when traffic increases 1,500,000 MGTM and when the traffic increase from 1974 is 3,000,000 MGTM. The second step provides for a rectifier substation in the Coast Division to secure a large Motor-Generator set for use in the Rocky Mountain Division. Estimated costs for these improvements are shown on the following pages.

ROCKY MOUNTAIN DIVISION

IMPROVEMENTS

SUBSTATION INCREASE CAPACITY

FIRST STEP

TARKIO SUBSTATION RECTIFIER 6,600 Kw		
Fence and Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 3000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals and Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	$ 333,000
EUSTIS SUBSTATION RECTIFIER 4,400 Kw		
Fence and Grading	3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 2000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	210,000	
DC Terminals and Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	25,000	252,000
FRANCIS SUBSTATION RECTIFIER 6,600 Kw		
Fence and Grading	3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 3000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals and Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	333,000

PIEDMONT REPLACE M-G SETS

Replace 3 - 1500 Kw G.E. M-G Sets with 3 - 2000 Kw		
G.E. M-G Sets @ $25,000	$ 75,000	
Supervisory Control	10,000	$ 85,000

AVERY REPLACE M-G SETS

Replace 3 - 1500 Kw G.E. M-G Sets with 3 - 2000 Kw		
G.E. M-G Sets from East Portal @ $25,000	75,000	
Supervisory Control	10,000	85,000

SUPERVISORY CONTROL AT SUBSTATIONS

Install Supervisory Control at the Following Substations:		
Drexel	10,000	
Janney	10,000	
Primrose	10,000	
Ravenna	10,000	
Gold Creek	10,000	
Morel	10,000	
Loweth	10,000	
Two Dot	10,000	80,000

DEER LODGE SUPERVISORY MASTER

Install Supervisory Control Master at Deer Lodge Dispatchers Office	30,000
TOTAL SUBSTATIONS	$1,198,000

FEEDER CONDUCTOR INCREASE

AVERY TO EAST PORTAL		
Replace 23.8 Miles of 2 - 500 Mcm Cu with		
2 - 1590 Mcm Al. 375,231# Al @ 35.5¢/lb.	$ 133,207	
Labor	62,000	$ 195,207
EAST PORTAL TO DREXEL		
Replace 14.7 Miles of 2 - 500 Mcm Cu and		
9 Miles of 1 - 500 Mcm and 1-4/0 Cu with 23.7		
Miles of 2 - 1590 Mcm Al. 373,654# Al @ 35.5¢/lb.	132,647	
Labor	55,000	187,647
DREXEL TO TARKIO		
Replace 38.1 Miles of 1 - 500 Mcm Cu and		
24 Miles of 1-4/0 Cu with 38.1 Miles of		
1 - 1590 Mcm Al. 299,554# Al @ 35.5¢/lb.	106,342	
Labor	48,000	154,342
TARKIO TO PRIMROSE		
Replace 36.7 Miles of 1 - 500 Mcm Cu and		
24 Miles of 1-4/0 Cu with 36.7 Miles of		
1590 Mcm Al. 289,306# Al @ 35.5¢/lb.	102,704	
Labor	46,000	148,704
PRIMROSE TO RAVENNA		
Replace 37.0 Miles of 1 - 500 Mcm Cu and		
8 Miles of 1-4/0 Cu with 1 - 1590 Mcm Al.		
291,671# Al @ 35.5¢/lb.	103,543	
Labor	45,000	148,543
RAVENNA TO GOLD CREEK		
Replace 33.3 Miles of 1 - 500 Mcm Cu with		
1 - 1590 Mcm Al. 265,504# Al @ 35.5¢/lb.	94,254	
Labor	42,000	136,254

MOREL TO JANNEY

Replace 23.4 Miles of 1 - 500 Mcm Cu with 1 - 1590 Mcm Al. 184,462# Al @ 35.5¢/lb.	$ 65,484	
Labor	30,000	$ 95,484

JANNEY TO PIEDMONT

Replace 14 Miles of 2 - 700 Mcm Cu with 14 Miles of 2 - 2250 Mcm Al. 315,336# Al @ 38.6¢/lb.	121,720	
Labor	42,000	163,720

PIEDMONT TO EUSTIS

Replace 41.6 Miles of 1 - 500 Mcm Cu and 26 Miles of 1-4/0 Cu with 41.6 Miles of 1 - 1590 Mcm Al. 327,933# Al @ 35.5¢/lb.	116,416	
Labor	52,000	168,416

EUSTIS TO FRANCIS

Replace 29.9 Miles of 1 - 500 Mcm Cu and 13 Miles of 1-4/0 Cu with 29.9 Miles of 1 - 1590 Mcm Al. 236,490# Al @ 35.5¢/lb.	83,954	
Labor	38,000	121,954

FRANCIS TO LOWETH

Replace 30.4 Miles of 1 - 500 Mcm Cu and 25 Miles of 1-4/0 Cu with 30.4 Miles of 1 - 1590 Mcm Al. 239,643# Al @ 35.5¢/lb.	85,073	
Labor	40,000	125,073

LOWETH TOWARD TWO DOT

Add second 1590 Mcm Al. Feeder East from Loweth for 8 Miles. 63,064# Al @ 35.5¢/lb.	22,388	
Labor	12,000	34,388

TWO DOT TO HARLOWTON

Replace 12.0 Miles of 1 - 500 Mcm Cu and 1-4/0 Cu with 1 - 1590 Mcm Al.			
94,596# Al @ 35.5¢/lb.		$ 33,582	
Labor		15,000	$ 48,582
	TOTAL FEEDERS		$1,728,314
	TOTAL FIRST STEP		$2,926,314

SECOND STEP

COAST DIVISION

CLE ELUM SUBSTATION RECTIFIER 4,400 Kw

Fence & Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 2000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	210,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	25,000	$ 252,000

ROCKY MOUNTAIN DIVISION

TWO DOT SUBSTATION RECTIFIER 6,600 Kw

Fence & Grading	3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 2000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals & Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	333,000

JANNEY REPLACE M-G SETS

Replace 3 - 1500 Kw G.E. and 1 - 3,000 Kw G.E. M-G Set with

2 - 2000 Kw G.E. M-G Sets from Two Dot

2 - 2000 Kw G.E. M-G Sets from Loweth

4 - M-G Sets @ $25,000 $ 100,000

RAVENNA SUBSTATION RECTIFIER 6,600 Kw

Fence & Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 3000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals & Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	$ 333,000

LOWETH REPLACE M-G SETS

Replace 2 - 2000 Kw G.E. M-G Sets with 1 - 3000 Kw G.E. M-G Set from Janney and 1 - 3000 Kw G.E. M-G Set from Cle Elum		
2 - M-G Sets @ $35,000	70,000	
Rewind 1 Transformer	15,000	85,000

MOREL ADD M-G SET

Add 1 - 2000 Kw G.E. M-G Set from Ravenna to 2 - 2000 Kw G.E. M-G Sets		
Building Expansion	35,000	
Install M-G Set	$ 40,000	$ 75,000

TOTAL SUBSTATIONS	$1,660,000

FEEDER INCREASE
(Labor and Material)

FRANCIS TO LOWETH

Run second 1590 Mcm Al. Feeder 30.4 Miles Parallel to Existing 1590 Mcm Al. Feeder	150,000

FRANCIS TOWARD EUSTIS

Run second 1590 Mcm Al. Feeder 15 Miles West Toward Eustis, Paralleling Existing 1590 Mcm Al. Feeder	75,000

MOREL TO JANNEY

Run second 1590 Mcm Al. Feeder 24 Miles East from Morel, Paralleling Existing Feeder	115,000
TOTAL FEEDERS	$ 340,000
TOTAL SECOND STEP	$1,518,000

THIRD STEP

PRIMROSE SUBSTATION RECTIFIER

Fence and Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 3000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals & Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	$ 333,000

DREXEL ADD M-G SET

Add 1 - 2000 kW G.E. M-G Set from Primrose to
2 - 2000 kW G.E. M-G Sets

Building Expansion	$ 34,000	
Install M-G Set	40,000	$ 74,000

GOLD CREEK SUBSTATION RECTIFIER 6,600 kW

Fence and Grading	$ 3,000	
115 kV Facilities	By Power Company	
Rectifier Transformer	By Power Company	
Secondary Breaker 3000 A, 5 kV	By Power Company	
Rectifier & DC Switchgear	280,000	
DC Terminals and Cables	6,000	
Supervisory Control	10,000	
Labor and Overhead	34,000	333,000
	TOTAL SUBSTATIONS	$ 740,000

FEEDER INCREASE

(Labor and Material)

DREXEL TOWARD TARKIO

Run second 1590 Mcm Al. Feeder 10 Miles East Toward Tarkio, Paralleling Existing 1590 Mcm Al. Feeder	50,000

TWO DOT TO LOWETH

Run second 1590 Mcm Al. Feeder 25.2 Miles West Toward Loweth, Paralleling Existing 1590 Mcm Al. Feeder	130,000
TOTAL FEEDERS	$ 180,000
TOTAL THIRD STEP	$ 920,000

MONTANA POWER COMPANY

ADDED FACILITIES REQUIRED

FOR

ROCKY MOUNTAIN DIVISION IMPROVEMENTS

TELEMETERING

Telemeter Railroad load from thirteen (13) Railroad substations to Butte and from Butte to Deer Lodge

CONTRACTS

Presently the Milwaukee Road has two contracts with the three power companies that supply electric energy to the electrified sections of the railroad.

The Rocky Mountain Division is served by the Montana Power Company under a contract that expires June 30, 1975.

The Coast Division is served by the Washington Water Power Company and The Puget Sound Power and Light Company under a contract that expires April 30, 1976.

The contract with the Montana Power Company does not presently have a demand charge and the Milwaukee is paying 0.536¢/kWH.

The contract with The Washington Water Power Company and the Puget Sound Power and Light Company has a seasonal demand charge. The application of this seasonal demand charge has resulted in a yearly average cost per kilowatt hour, ranging from a low of 0.548¢/kWH in 1958 to a high of 0.606¢/kWH in 1968. The average yearly rate over the last few years has been 0.585¢/kWH.

If this proposed extension of the Milwaukee electrified operation is completed, it is anticipated that after the present contracts expire, each of the three serving power companies will have a separate contract with the railroad covering service to railroad substations in each utility's service area.

Cost of power to the Milwaukee under these new contracts may be more or less than 0.7¢/kWH assumed in this report. The cost will be different for each utility and will be influenced by the impact of the Railroad's Power demand on each power company's annual peak. All power cost to the Railroad will increase as the cost of generation to the utilities increases.

Year	Annual MGTM	Fuel	terest	Total	Net Savings (-Cost)
1974	6,972,399	1,388,915	00	3,294,359	170,428
1975	7,158,458	1,271,472	00	3,333,359	52,290
1976	7,349,536	1,096,570	00	3,375,359	(-114,193)
1977	7,545,769	1,099,836	00	3,417,359	(-117,363)
1978	7,747,299	1,128,955	00	3,459,359	(-85,504)
1979	7,974,269	1,158,855	20(3)	3,528,879	5,530
1980	8,166,828	1,189,555	41	3,577,300	30,557
1981	8,385,129	1,221,078	62	3,625,721	62,112
1982	8,609,327	1,253,445	84	3,847,483	(-77,501)
1983	8,838,583	1,286,680	05	3,895,904	(-41,570)
1984	9,076,063	1,320,805	46(4)	3,975,845	57,045
1985	9,318,936	1,355,846	22	4,031,621	90,228
1986	9,568,377	1,391,827	94	4,087,393	125,813
1987	9,824,554	1,428,774	73	4,143,172	163,852
1988	10,087,683	1,466,515	89(5)	4,333,908	169,472
1989	10,357,922	1,505,665	59)(6)	2,238,460	2,963,663
1990	10,635,476	1,545,666	07)	2,349,812	2,954,329

(1) Rocky Mountain Division Power ubstations.
(2) Coast Division Power Contract ubstations.
(3) Purchase 6 Electric Locomotive ubstations.
(4) Purchase 6 Electric Locomotive 000 MGTM Increase Over 1974.
(5) Purchase 6 Electric Locomotive 0,000 MGTM Increase Over 1974.
(6) Replace 60 Diesel Locomotives

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MILWAUKEE ELECTRIFICATION
TABLE I
TON MILES (000's) TRAFFIC ACTUAL & PROJECTED

	COAST DIVISION		ROCKY MOUNTAIN DIVISION
	TACOMA-OTHELLO	OTHELLO-AVERY	AVERY-HARLOWTON
Year	Actual	Actual	Actual
1961	784,493.	883,720.	2,087,745.
1962	866.118.	978,401.	2,304.023.
1963	875.482.	1,047,463.	2,423,801.
1964	921,143.	1,130,185.	2,605,801.
1965	973,695.	1,194,212.	2,856,038.
1966	1,010,489.	1,249,689.	3,082,349.
1967	1,020,759.	1,272,838.	3,084,730.
1968	1,092,196.	1,350,332.	3,306.969.
1969	1,137,192.	1,390,413.	3,291,913.
1970	1,157,000.	1,603,263.	3,292,000.
	4.24 PROJECTED	5.92 PROJECTED	5.43 PROJECTED
1971	1,227,525.	1,637,419.	3,745,360.
1972	1,279,590.	1,734,386.	3,948,914.
1973	1,333,863.	1,837,096.	4,163,531.
1974	1,390,438.	1,945,888.	4,389,811.
1975	1,449,412.	2,061,123.	4,628,390.
1976	1,510,888.	2,183,183.	4,879,935.
1977	1,574,971.	2,312,470.	5,145,152.
1978	1,641,772.	2,449,414.	5,424,782.
1979	1,711,407.	2,594,468.	5,719,610.
1980	1,783,995.	2,748,111.	6,030,461.
1981	1,859,662.	2,910,854.	6,358,206.
1982	1,938,539.	3,083,234.	6,703,764.
1983	2,020,760.	3,265,822.	7,068,102.
1984	2,104,469.	3,459,223.	7,452,241.
1985	2,195,814.	3,664,078.	7,857,258.
1986	2,288,948.	3,881.063.	8,284,286.
1987	2,386,032	4,110,899.	8,734,523.
1988	2,487,234.	4,354,345.	9,209,230.
1989	2,592,728	4,612,208.	9,709,736.
1990	2,702,530	4,885,342.	10,347,443.

MILWAUKEE ET TRIFICATION

TABLE II

TON MILE TRAFFIC (000's) ACTUAL & PROJECTED AT ONE HALF HISTORICAL RATE

	COAST DIVISION		ROCKY MOUNTAIN DIVISION	
	TACOMA-OTHELLO	OTHELLO-AVERY	AVERY-HARLOWTON	TACOMA-HARLOWTON
YEAR	ACTUAL	ACTUAL	ACTUAL	PROJECTED
1961	784,493	883,720	2,087,745	
1962	866,118	978,401	2,034,023	
1963	875,482	1,047,463	2,423,801	
1964	921,143	1,130,185	2,605,801	
1965	973,695	1,194,212	2,856,038	
1966	1,010,489	1,249,689	3,082,349	
1967	1,020,759	1,272,838	3,084,730	
1968	1,092,196	1,350,332	3,306,969	
1969	1,137,192	1,390,413	3,291,913	
1970	1,157,000	1,603,263	3,292,000	
	2.12% Projected	2.96% Projected	2.71% Projected	
1971	1,202,562	1,591,646	3,648,829	6,443,027
1972	1,228,055	1,638,774	3,747,983	6,614,812
1973	1,254,098	1,687,298	3,849,831	6,791.227
1974	1,280,694	1,737,258	3,954,447	6,972,399
1975	1,307,854	1,788,698	4,061,906	7,158,458
1976	1,335,590	1,841,661	4,172,285	7,349,536
1977	1,363,914	1,896,192	4,285,663	7,545,769
1978	1,392,839	1,952,338	4,402,122	7,747,299
1979	1,442,377	2,010,146	4,521,746	7,974,269
1980	1,452,541	2,069,666	4,644,621	8,166,828
1981	1,483,346	2,130,949	4,770,834	8,385,129
1982	1,514,803	2,194,046	4,900,478	8,609,327
1983	1,546,928	2,259,011	5,033,644	8,839,583
1984	1,579,734	2,325,900	5,170,429	9,076,063
1985	1,613,236	2,394,769	5,310,931	9,318,936
1986	1,647,448	2,465,678	5,455,251	9,568,377
1987	1,682,385	2,538,676	5,603,493	9,824,554
1988	1,718,064	2,613,856	5,755,763	10,087,683
1989	1,754,499	2,691,252	5,912,171	10,357,922
1990	1,791,707	2,770,940	6,072,829	10,635,476

MILWAUKEE ELECTRIFICATION

TABLE III

KILOWATT HOURS ACTUAL & PROJECTED

	COAST DIVISION				ROCKY MOUNTAIN DIVISION	
	TACOMA-OTHELLO		OTHELLO-AVERY		AVERY-HARLOWTON	
Year	Actual	Estimated Total Electric	Actual	Estimated Total Electric	Actual	Estimated Total Electric
1961	37,655,654	40,542,316	30,930,200	34,147,060	93,948,525	104,675,505
1962	41,573,664	42,261,890	34,244,035	30,169,235	103,681,035	110,365,495
1963	42,023,136	44,054,399	36,661,205	38,311,162	109,071,045	116,363,671
1964	44,214,864	45,922,936	39,614,750	40,579,934	117,261,045	122,687,839
1965	46,737,456	47,870,725	41,797,421	42,983,061	128,523,735	129,355,714
1966	48,503,472	49,901,128	43,739,115	45,528,500	138,705,705	136,385,976
1967	48,988,272	52,017,650	44,549,330	48,224,679	138,812,850	143,798,322
1968	52,425,408	54,223,942	47,261,620	51,080,525	148,813,605	151,613,516
1969	54,585,216	56,523,813	48,664,455	54,105,492	148,136,085	159,853,452
1970	55,536,000	58,921,231	56,114,205	57,309,598	148,140,000	168,541,215
	4.24% GROWTH	PROJECTED	5.92% GROWTH	PROJECTED	5.43% GROWTH	PROJECTED
1971		61,420,334		60,703,448		177,701,143
1972		64,025,434		64,298,282		187,358,897
1973		66,741,029		68,106,000		197,541,534
1974		69,571,803		72,139,209		208,277,580
1975		72,522,642		76,411,264		219,597,111
1976		75,598,640		80,936,307		231,531,840
1977		78,805,103		85,729,322		244,115,201
1978		82,147,567		90,806,378		257,382,447
1979		85,631,798		96,183,682		271,370,744
1980		89,263,811		101,879,641		286,119,282
1981		93,649,874		107,912,911		301,669,377
1982		96,996,519		114,303,470		318,064,594
1983		101,110,559		121,072,474		335,350,863
1984		105,399,093		128,242,336		353,576,611
1985		109,869,522		135,836,795		372,792,898
1986		114,529,561		143,880,994		393,053,557
1987		119,387,252		152,401,568		414,415,348
1988		124,450,979		161,426,726		436,938,116
1989		129,729,481		170,986,351		460,648,958
1990		135,231,866		181,112,351		485,722,401

MILWAUKEE ELEC' 'IFICATION

TABLE IV

KILOWATT HOURS PROJECTED AT 1/2 HISTORICAL GROWTH RATE

	COAST DIVISION				ROCKY MOUNTAIN DIVISION		
	TACOMA-OTHELLO		OTHELLO-AVERY		AVERY-HARLOWTON		
YEAR	ACTUAL	ESTIMATED	ACTUAL	ESTIMATED	ACTUAL	ESTIMATED	PROJECTED TOTAL
1961	37,655,654	40,542,316	30,930,200	34,147,060	93,948,525	104,675,505	
1962	41,573,664	42,261,890	34,244,035	36,169,235	103,681,035	110,365,495	
1963	42,023,136	44,054,399	36,661,205	38,311,162	109,071,045	116,363,671	
1964	44,214,864	45,922,936	39,614,750	40,519,934	117,261,045	122,637,839	
1965	46,737,456	47,870,725	41,797,421	42,983,061	128,523,735	129,355,714	
1966	48,503,472	49,901,128	43,739,115	45,528,500	138,705,705	136,385,976	
1967	48,988,272	52,017,650	44,549,330	48,224,679	138,812,850	143,798,322	
1968	52,425,408	54,223,942	47,261,620	51,089,525	148,813,605	151,613,516	
1969	54,585,216	56,563,813	48,664,455	54,105,492	148,136,085	159,853,457	
1970	55,536,000	58,921,231	56,114,205	57,309,598	148,140,000	168,541,215	
	2.12% Projected		2.96% Projected		2.71% Projected		
1971	58,946,652		57,357,101		168,659,258		284,963,011
1972	60,196,743		59,055,433		173,242,429		292,494,605
1973	61,473,344		60,804,062		177,905,145		300,227,541
1974	62,777,019		62,604,447		182,785,788		308,167,254
1975	64,108,341		64,458,152		187,752,836		316,309,329
1976	65,467,896		66,366,674		192,854,860		324,689,430
1977	66,856,284		68,331,851		198,095,526		333,283,661
1978	68,274,115		70,355,143		203,478,604		342,107,862
1979	69,722,014		72,438,344		209,007,961		351,168,319
1980	71,200,620		74,583,229		214,687,574		360,471,423
1981	72,710,582		76,781,623		220,521,526		370,023,731
1982	74,065,407		79,065,407		226,514,011		379,831,984
1983	75,827,252		81,406,517		232,669,336		389,903,105
1984	77,435,332		83,816,948		238,991,927		400,244,207
1985	79,077,514		86,298,750		245,486,329		410,862,539
1986	80,754,523		88,854,039		252,157,211		421,765,773
1987	82,467,709		91,484,989		259,009,369		432,962,067
1988	84,215,989		94,193,840		266,047,728		444,398,557
1989	86,001,970		96,982,901		273,277,348		456,262,219
1990	87,825,827		99,854,545		280,703,427		468,383,799

MILWAUKEE ELECTRIFICATION

TABLE V

ESTIMATED POWER COST FOR COMPLETE ELECTRIC OPERATION 1974 THROUGH 1990

	COAST DIVISION		ROCKY MOUNTAIN DIVISION
	TACOMA-OTHELLO	OTHELLO-AVERY	AVERY-HARLOWTON
YEAR	ESTIMATED	ESTIMATED	ESTIMATED
1974	367,724	438,231	968,764
1975	375,033	451,207	1,206,311
1976	433,135	464,566	1,349,984
1977	467,993	478,322	1,386,668
1978	435,918	492,486	1,424,350
1979	488,054	507,068	1,463,055
1980	498,404	522,082	1,502,813
1981	508,974	537,471	1,893,650
1982	518,457	553,478	1,585,598
1983	530,790	569,845	1,628,685
1984	542,043	586,718	1,672,943
1985	553,542	604,091	1,718,404
1986	565,281	621,978	1,765,100
1987	579,374	640,394	1,813,065
1988	589,511	659,356	1,862,334
1989	602,013	678,880	1,912,941
1990	614,780	698,981	1,964,923

The Milwaukee Road Collection
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VOLTAGE REQUIREMENTS AND CONTROL

To operate electric locomotives efficiently, the voltage supplied to the trolley must be as near constant as possible. Railroads using DC to operate trains, use one of three means to control DC voltage depending on the type of conversion equipment employed.

1. Motor-generator sets control voltage by changing the field current of the DC generator

2. Rectifier DC voltage may be controlled by phase control

3. Rectifier DC voltage may be controlled by changing the AC voltage supplied to the rectifier

Voltage supplied to the nominal 3300 volt trolley of the electrified divisions of the Milwaukee should be under control at the Railroad's dispatcher. The voltage range required is from a maximum of 3600 volts to a minimum of 2,000 volt at the DC terminals of the conversion equipment.

This range of voltage can be delivered by the motor-generator sets now in use by the Railroad Company. Extension of the electrified sections of Milwaukee through eastern Washington and northern Idaho contemplates the use of solid state rectifiers to supply 3300 volt DC current to the trolley. Voltage output of these rectifiers could be controlled by phase control but this control has two undesirable features.

1. At reduced voltage with phase control, a great many harmonics of large magnitude are introduced into the AC supply system.

2. At reduced voltage, the power factor of the AC load is reduced.

Considering the voltage characteristics of the heavy traction type rectifiers proposed for use by Milwaukee, a rectifier with load top changing on its supply transformer appears to be the most effective way to control voltage.

Heavy traction type rectifiers have about a 6% droop in voltage as load is applied.

To supply 3300 volts of rated load, a rectifier will have the following voltage variation:

Percent Load	DC Voltage
0	3500
100	3300
150	3200
200	3100
300	2900
450	2600

To control this voltage from a maximum of 3600 volts to a minimum of 2,000 volts, load tap changing equipment on the rectifier transformer should use the standard 32 step tap changing equipment with 50 volts change on each step. With neutral voltage at 3300 volts, the voltage range with this combination of LTC equipment and a 6% rectifier droop are listed below.

Percent Load	Maximum Voltage	Minimum Voltage
0	4100	2500
100	3900	2300
150	3800	2200
200	3700	2100
300	3500	1900
450	3200	1600

Although the no load voltage can only be reduced to 2500 volts, as soon as locomotives begin drawing current from the rectifier, the voltage will droop to the desired level.

A similar range of voltage control may be secured by using standard range 32-5/8% step LTC equipment and an Amplistat. This combination of equipment will cost approximately the same as extended range load tap changing equipment. The voltage range possible with these facilities and 3700 volts no load output from the rectifier are listed below.

Percent Load	Maximum Voltage	Minimum Voltage
0	4070	2630
100	3870	2430
150	3770	2330
200	3670	2230
300	3470	2030
450	3170	1730

SUBSTATION EQUIPMENT

Milwaukee Road electrical engineers have determined that rectifier ratings should have a continuous rating of 4400 Kw with standard heavy traction rating as follows:

Load Duration	Percent Load	Output Kilowatts	Amperes
Continuous	100	4400	1333
2 hours	150	6600	2000
1 minute	450	19800	6000

Rectifiers operating with six (6) phases should satisfy the Railroad's requirements. This can be done by using a three phase bridge rectifier connection in conjunction with a 115 Kv delta to 2520 V wye LTC secondary with 36 volt taps on the secondary which will supply a 50 volt charge to the rectifier output.

RECTIFIER TRANSFORMER

5000 Kva outdoor, 55 Kv rise continuous with fan rating of 6250 Kva delta, 115 Kv primary with rated Kva taps arranged

2 - 2½% taps above rated voltage

2 - 2½% taps below rated voltage

wye secondary with 32 steps load tap changing to provide 50 volt step changes of DC output

RECTIFIER

4400 Kw 3300 volt continuous silicon rectifier, inherent regulation from no load to full load of approximately 6%. Power factor at rated load 95%.

The rectifier transformers included under these specifications are designed to carry the equivalent of two 2-hour overloads in a 24 hour period, subject to the following conditions:

(A) Subsequent to each 2 hour overload, the load is reduced to 100% or less for a sufficient time to allow the liquid temperature to drop to at least the 100% level.

(B) The RMS load over the entire 24 hour period does not exceed 100%.

DC overloads and short circuits will be cleared by the d-c breaker without operation of cell isolating fuses or failure of silicone cells.

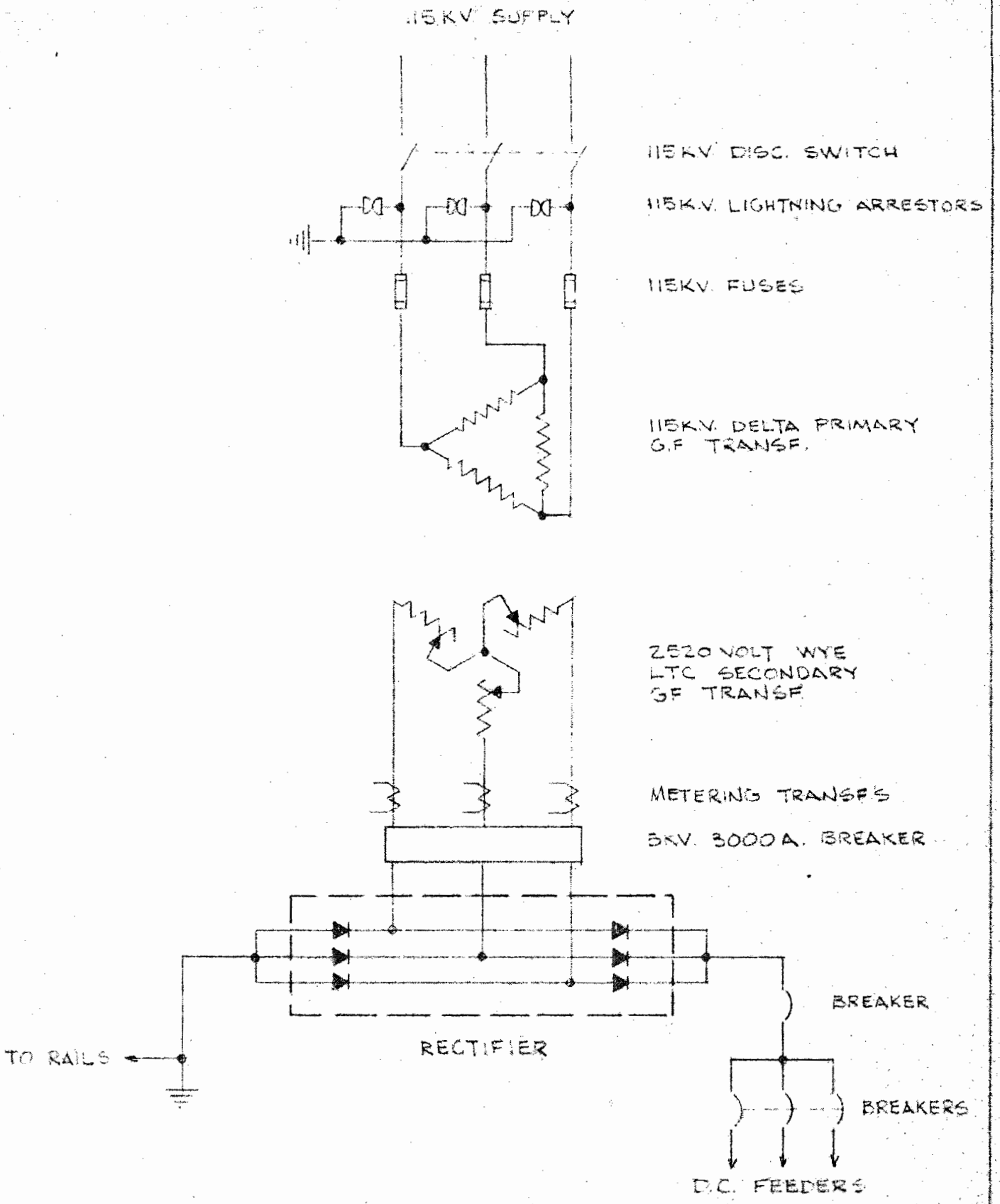
A failed silicone cell will be disconnected by its isolating fuse without damage to other cells or isolating fuses, and without operation of the d-c breakers.

Possible substation arrangements are shown on the following three drawings.

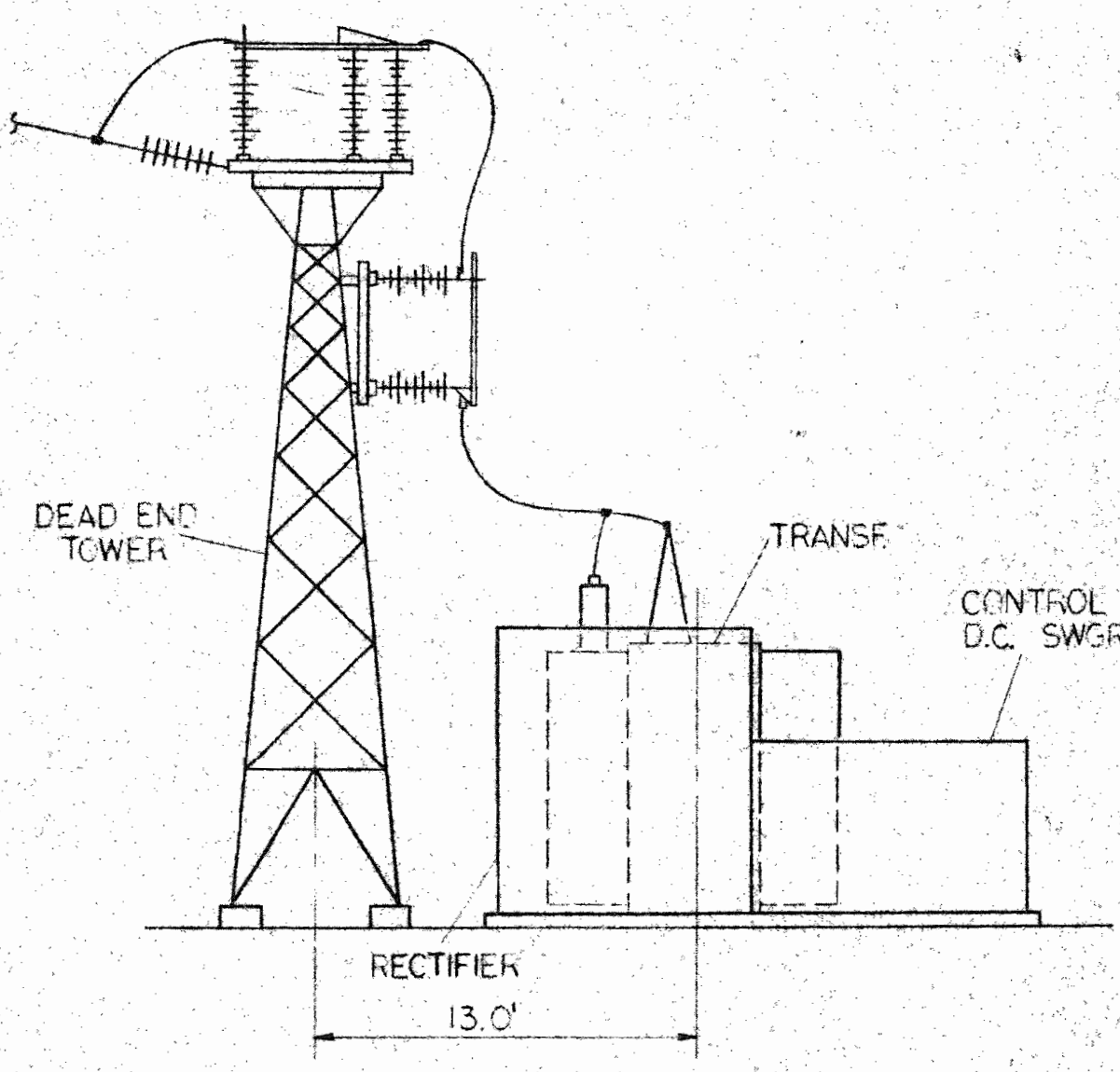
M - 2847 Rectifier Substation - Simplified Diagram

M - 2845 Rectifier Substation - Elevation

M - 2844 Rectifier Substation - Plan



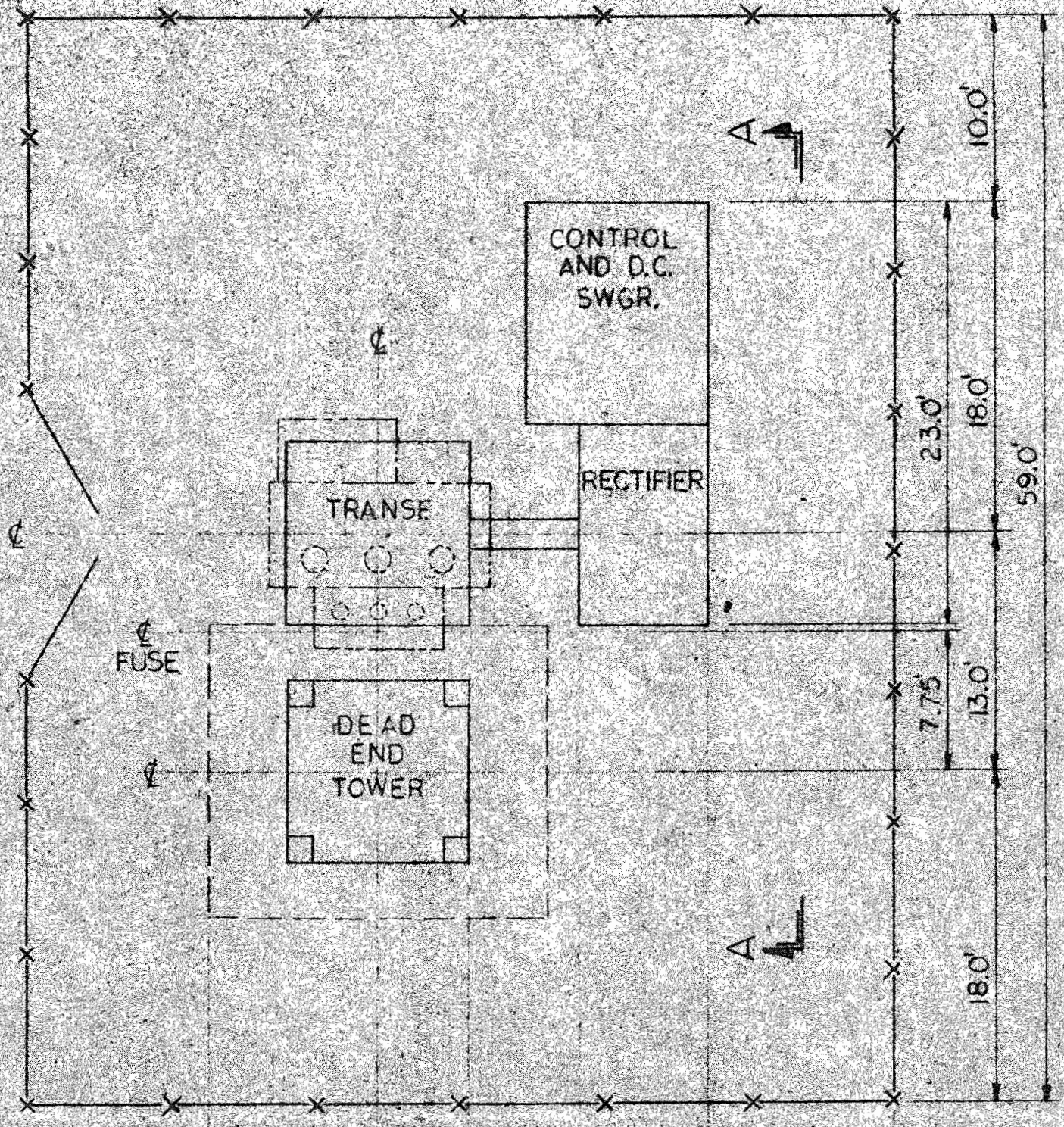
MILWAUKEE ELECTRIFICATION RECTIFIER SUBSTATION SIMPLIFIED DIAGRAM				
PUGET SOUND POWER & LIGHT COMPANY GENERAL ENGINEERING DEPT. BELLEVUE, WASH.				
SCALE NONE	DRAWN	CHECK'D	APPROV'D	M-2847
DATE 11-14-69	R.L.K.			
TR.				



ELEVATION A-A

TYPICAL RECTIFIER SUBSTATION FOR MILWAUKEE RAILROAD ELECTRIFICATION				
PUGET SOUND POWER & LIGHT COMPANY GENERAL ENGINEERING DEPARTMENT BELLEVUE				
SCALE: 1/8"=1'-0"	DRAWN	CHK'D.	APP'D.	
DATE: 11-14-68	T.D.A.			M-2845
IR				

File No. 6625-11



PLAN

TYPICAL RECTIFIER SUBSTATION FOR MILWAUKEE RAILROAD ELECTRIFICATION

PUGET SOUND POWER & LIGHT COMPANY
GENERAL ENGINEERING DEPARTMENT BELLEVUE

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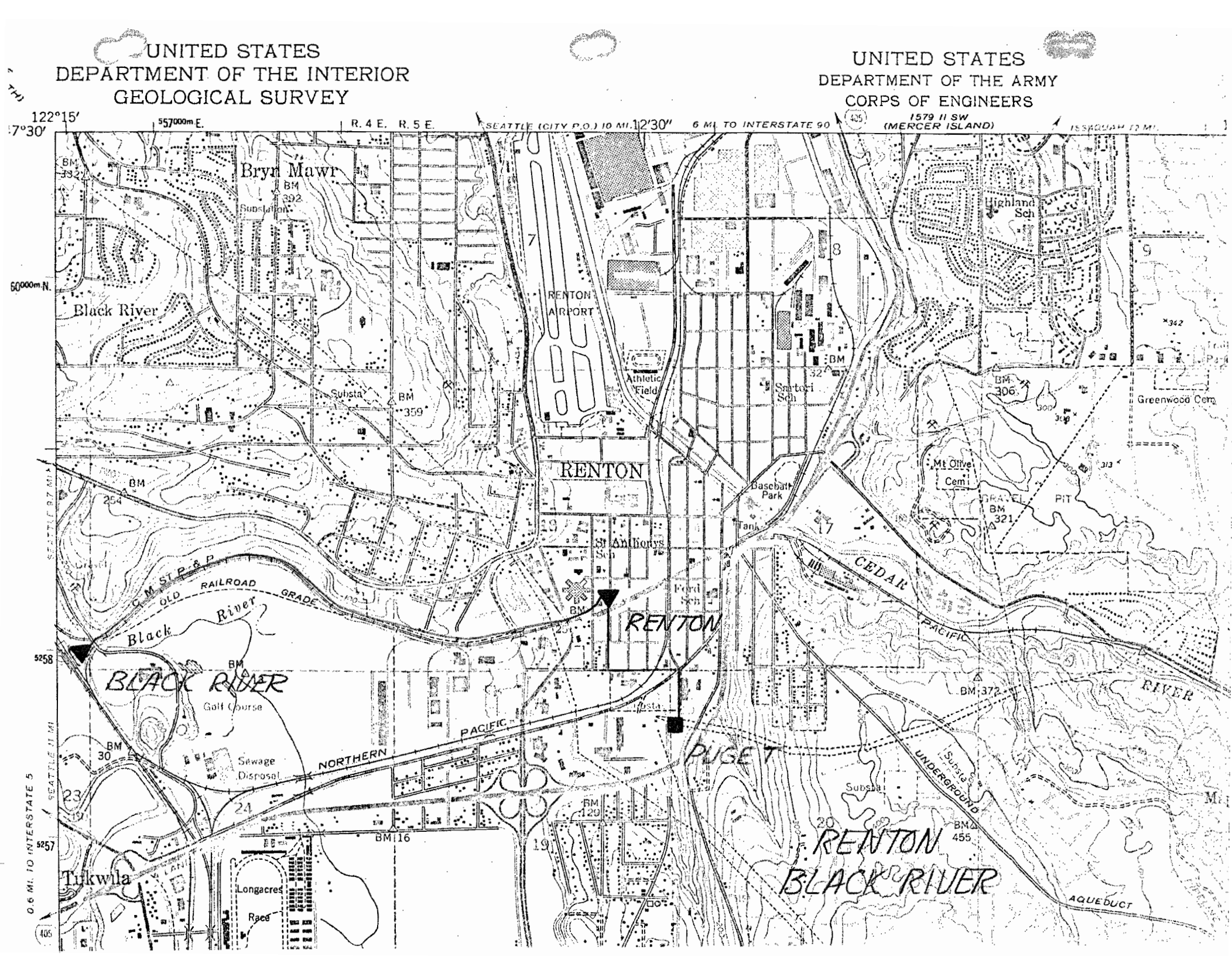
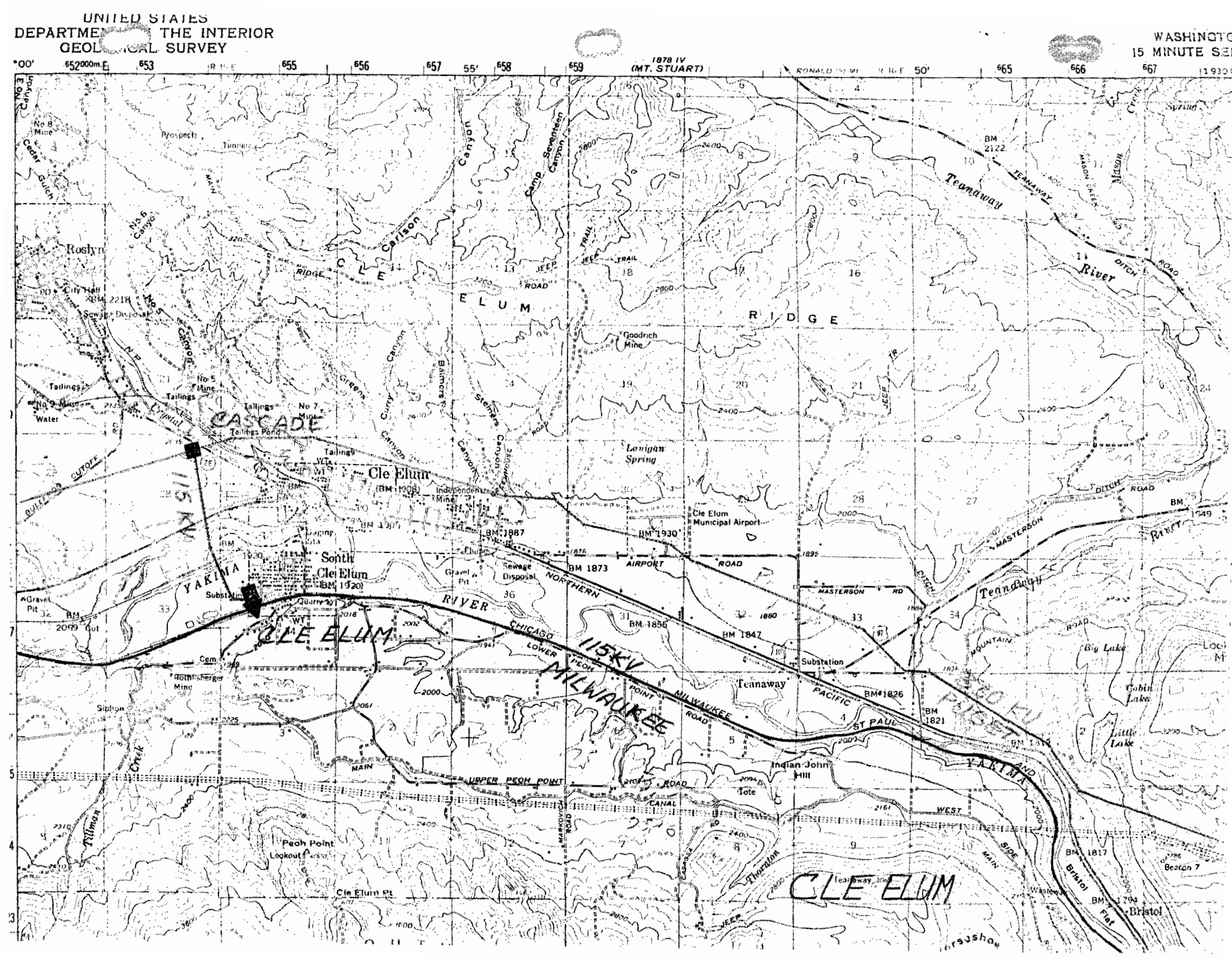
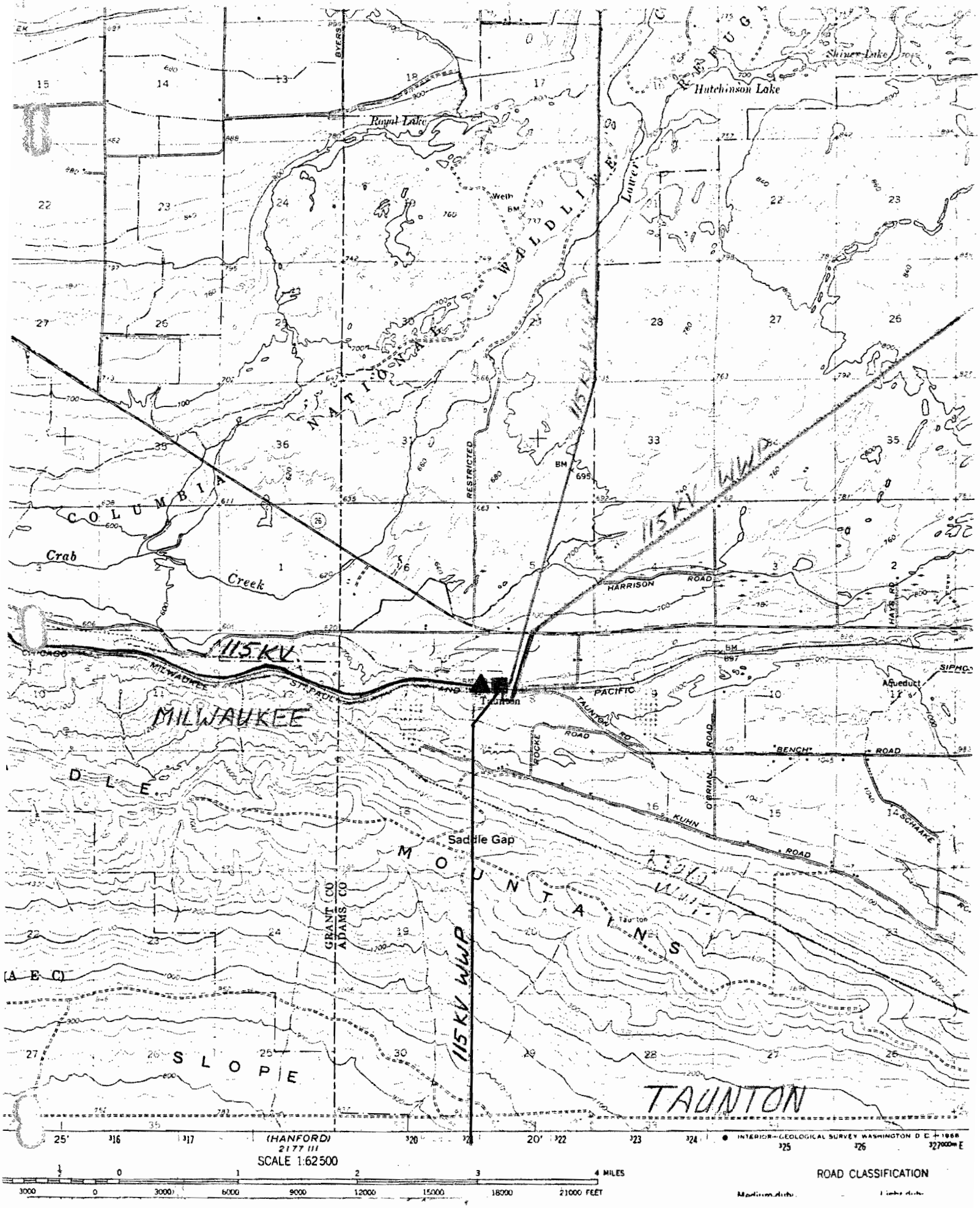
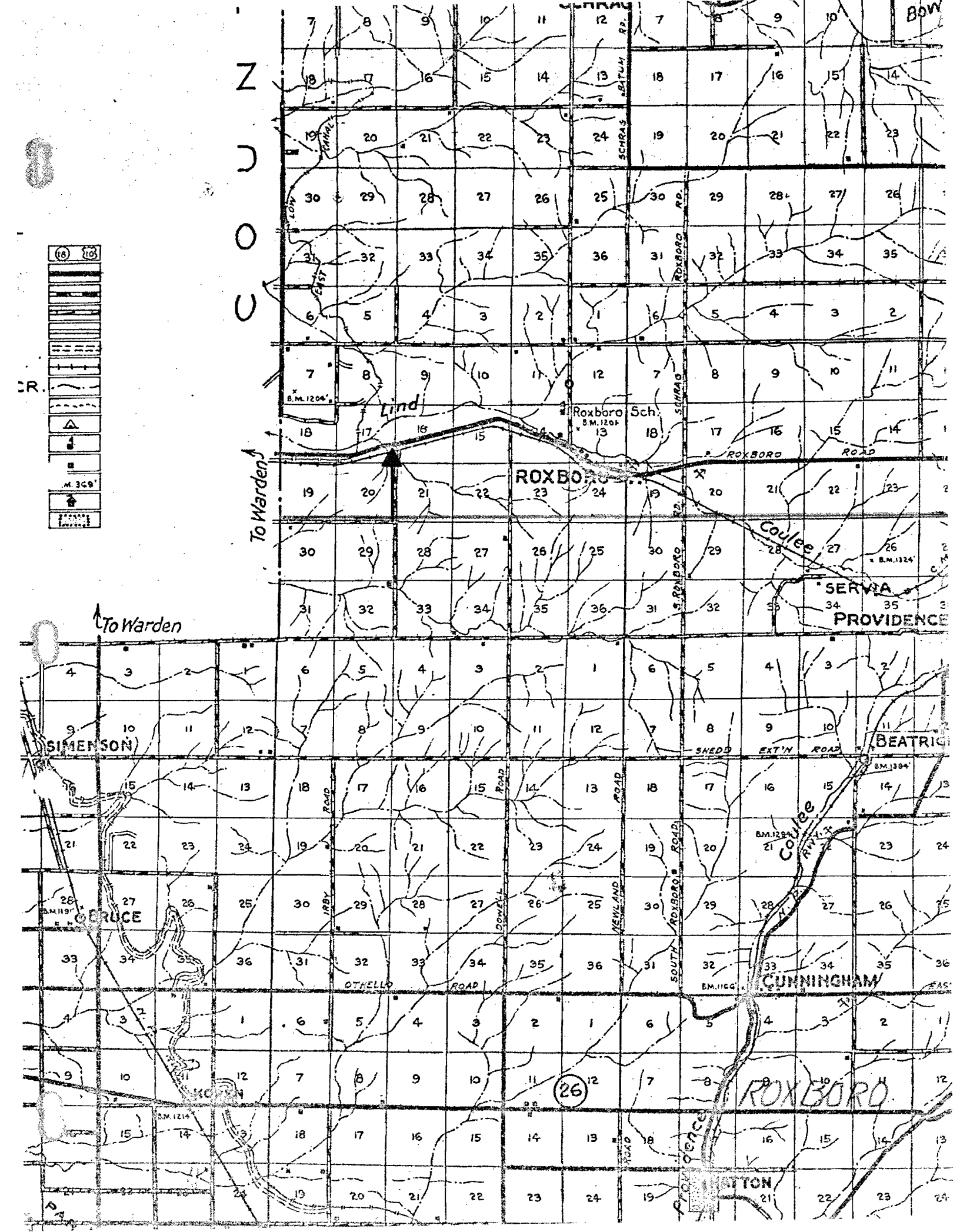
DATE: 11-W-43	T.D.A.		
IR			

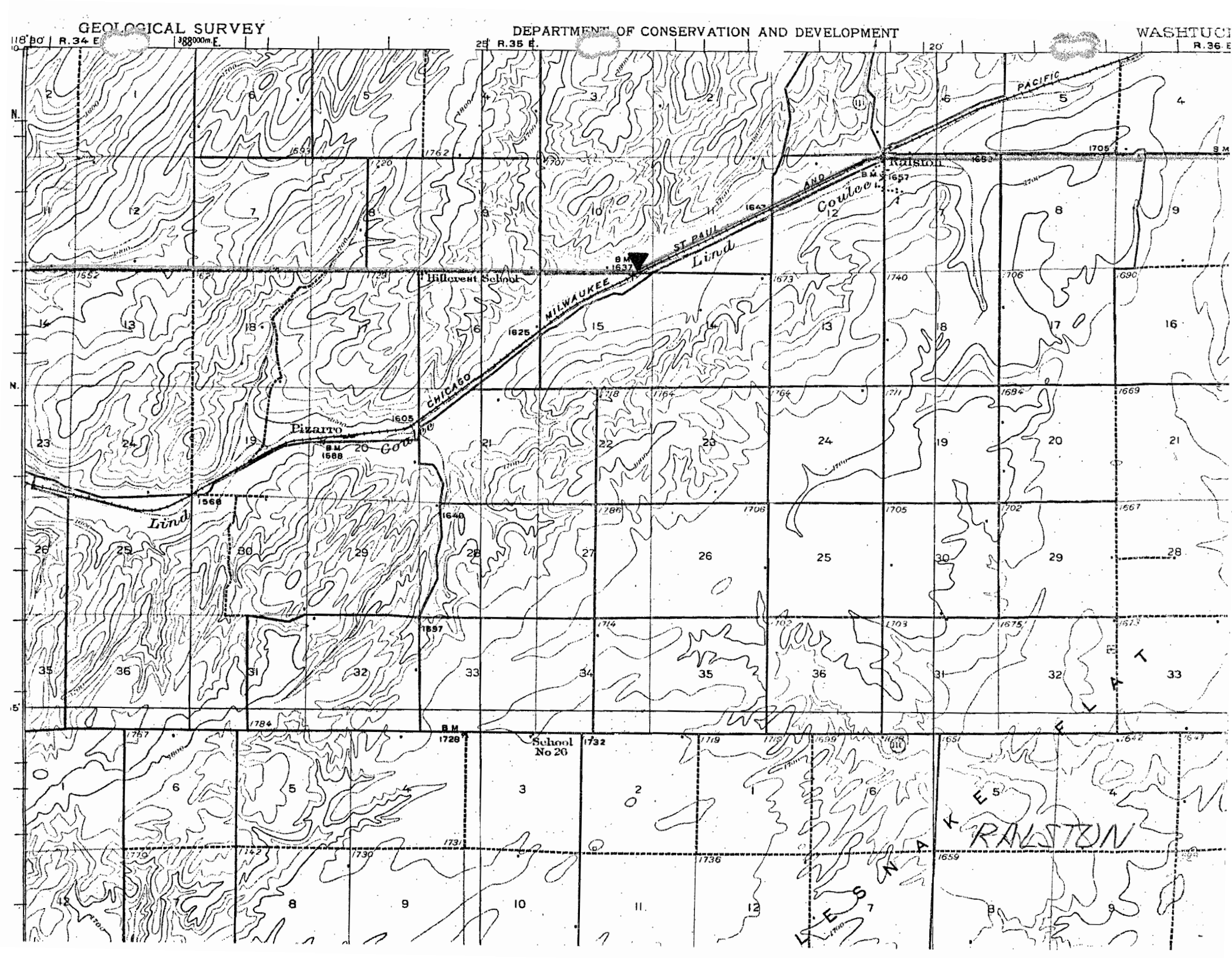
M-2844

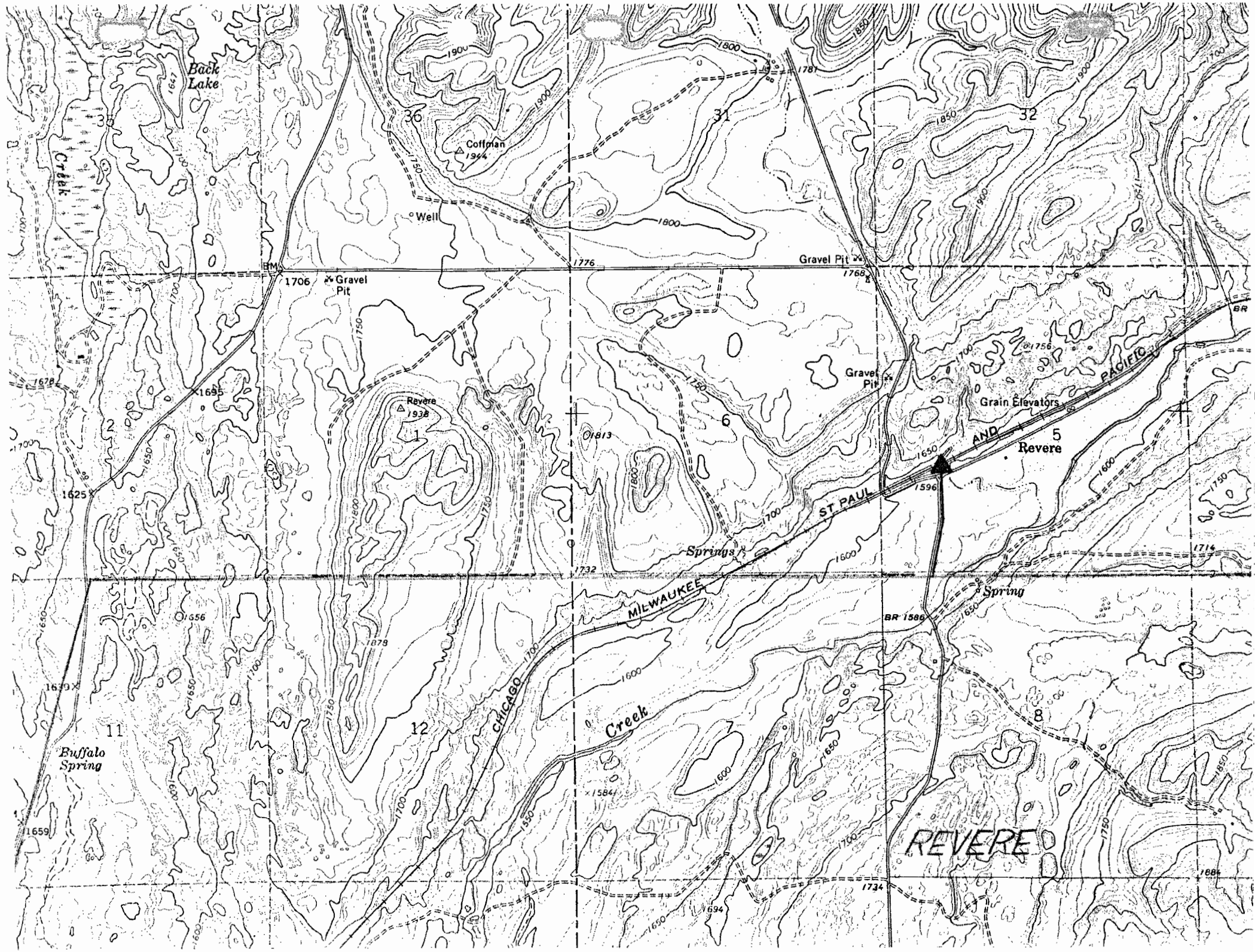

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
UNITED STATES
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
122°15'
47°30'
557000m E.
R. 4 E.
R. 5 E.
SEATTLE (CITY P.O.) 10 MI.
12'30"
6 MI. TO INTERSTATE 90
1579 II SW
(MERCER ISLAND)
ISSAQUAH 12 MI.
60000m N.
Bryn Mawr
Substation
Black River
RENTON AIRPORT
Athletic Field
Sartori Sch
Highland Sch
Greenwood Cem
Mt Olive Cem
RENTON
Baseball Park
St Anthonys Sch
Ford Sch
GRAVEL PIT
CEDAR
OLD RAILROAD GRADE
Black River
BLACK RIVER
Golf Course
Sewage Disposal
NORTHERN PACIFIC
PUGET
UNDERGROUND
AQUEDUCT
Tukwila
Longacres Race
RENTON
BLACK RIVER
5258
5257
SEATTLE 8.7 MI
SEATTLE 11 MI
0.6 MI. TO INTERSTATE 5


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON
15 MINUTE SERIES
1878 IV
(MT. STUART)
RONALD RIDGE
Roslyn
No 8 Mine
Prospects
Tunnels
Cedar Gulch
No 6 Canyon
No 5 Canyon
No 4 Canyon
Carlson Canyon
Camp Seventeen Canyon
Cle Elum Ridge
Trail
Jeep Trail
Ridge
Road
Teanaway River
Ditch
Mason Creek
City Hall
BM 2218
Sewage Disposal
No 5 Mine
No 4 Mine
Tailings
Tailings Pond
Water
Crystal
Cascade
Goodrich Mine
Green Canyon
Bamers Canyon
Steiners Canyon
Lanigan Spring
Railroad Cutoff
Cle Elum
(BM 1908)
Independent Mine
Cle Elum Municipal Airport
BM 1930
BM 1887
BM 1873
Airport
Road
Masterson
Ditch
BM 1949
South Cle Elum
(BM 1920)
Substation
Gravel Pit
Sewage Disposal
Yakima River
Northern Pacific
Chicago Lower Peoh Point Milwaukee Road
115 KV
Milwaukee
BM 2009 Cut
Quarry
BM 1856
BM 1847
Substation
Masterson Rd
Teanaway Road
Mountain
Big Lake
Cemetery
Rothsberger Mine
Siphon
Teanaway
BM 1826
BM 1821
St Paul and Yakima
Cabin Lake
Little Lake
Indian John Hill
Tote
Upper Peoh Point Road
Canal
West Side Main
Tillman Creek
Peoh Point Lookout
Cle Elum Pit
Markovich Road
Thornton
Cle Elum
Teanaway
Wastewa
Bristol Flat
BM 1817
Beacon 7
BM 1794
Bristol


Hutchinson Lake
Shiner Lake
Royal Lake
Weth BM
BM 695
BM 897
NATIONAL WILDLIFE REFUGE
RESTRICTED
Lower
COLUMBIA
Crab Creek
115 KV WWP
HARRISON ROAD
HAYES RD
CHICAGO MILWAUKEE ST PAUL AND PACIFIC
115 KV
Taunton
Aqueduct
SIPHON
MILWAUKEE
DALE
TAUNTON ROAD
ROCKE ROAD
"BENCH" ROAD
O'BRIAN ROAD
KUHN ROAD
SCHRAMM ROAD
Saddle Gap
MOUNTAINS
GRANT CO
ADAMS CO
115 KV WWP
(A E C)
SLOPE
TAUNTON
(HANFORD)
2177 III
INTERIOR—GEOLOGICAL SURVEY WASHINGTON D C 1968
SCALE 1:62500
4 MILES
21000 FEET
ROAD CLASSIFICATION


COUNTY
To Warden
Lind
ROXBORO
Roxboro Sch.
B.M. 1204'
B.M. 1208'
ROXBORO ROAD
Coulee
B.M. 1324'
SERVIA
PROVIDENCE
To Warden
SIMENSON
SHEDD EXT'N ROAD
BEATRICE
B.M. 1394'
B.M. 1284'
BRUCE
B.M. 1191'
OTHELLO ROAD
B.M. 1166'
CUNNINGHAM
B.M. 1214'
ROXBORO
26
SCHRAG
BATUM RD.
CANAL
MOT
EAST
ROXBORO RD.
SOUTH ROXBORO ROAD
NEWLAND ROAD
IRBY ROAD
DOWELL ROAD
CR.


GEOLOGICAL SURVEY
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
WASHTUCNA
118°30'
R. 34 E.
388000m. E.
25
R. 35 E.
20
R. 36 E.
N.
PACIFIC
Ralston
AND
Coulee
ST PAUL
Lind
MILWAUKEE
Hillcrest School
CHICAGO
Pizarro
Coulee
Lind
School No 20
RALSTON
FLAT
LAKE
WASHTUCNA


Back Lake
Creek
Coffman 1944
Well
Gravel Pit
Gravel Pit
Gravel Pit
Revere 1938
Grain Elevators
Revere
Springs
Spring
Buffalo Spring
Creek
REVERE
ST PAUL
MILWAUKEE
CHICAGO
PACIFIC
AND
BR
BR 1586
BM 1706
1776
1768
1781
1813
1732
1734
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1625
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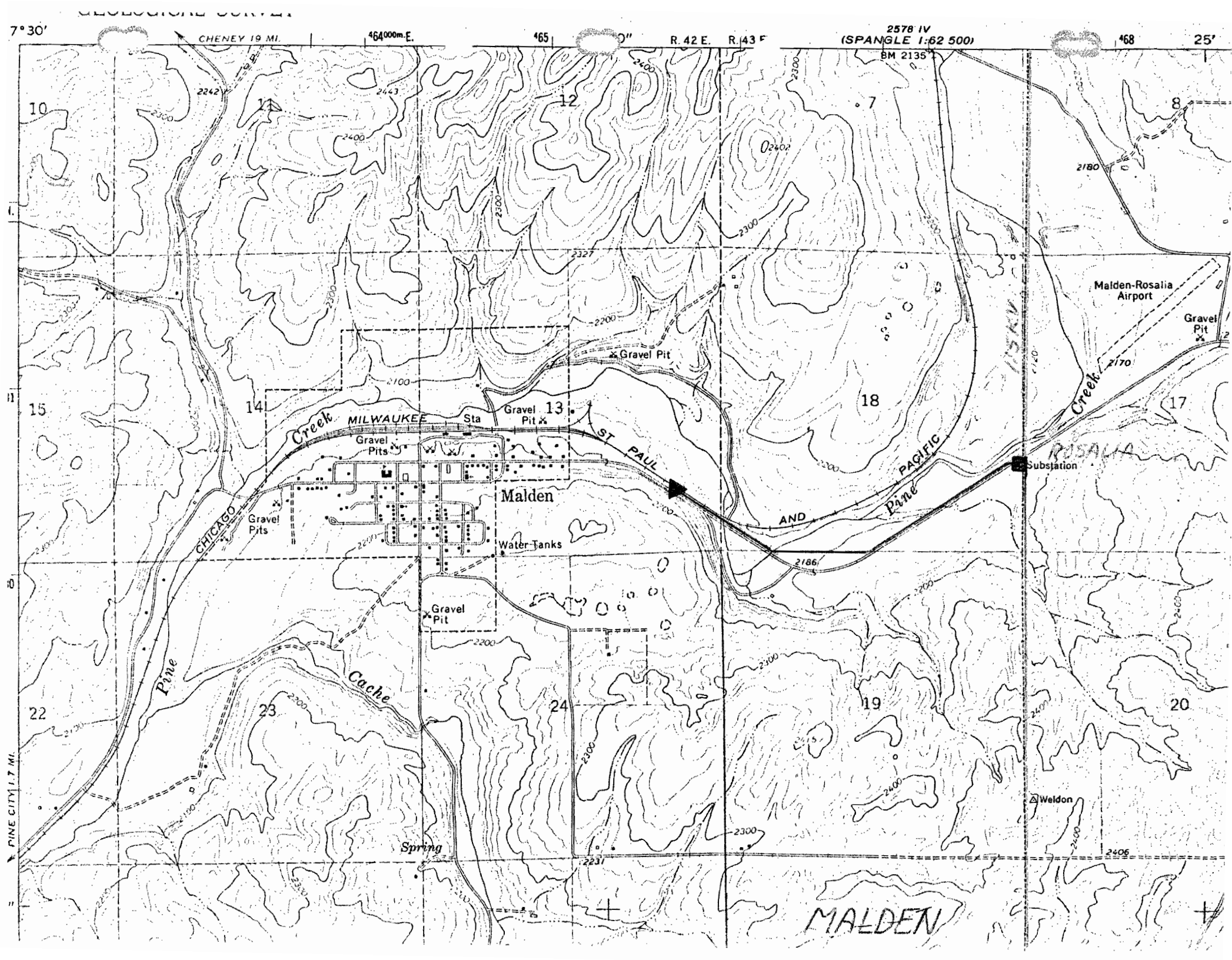
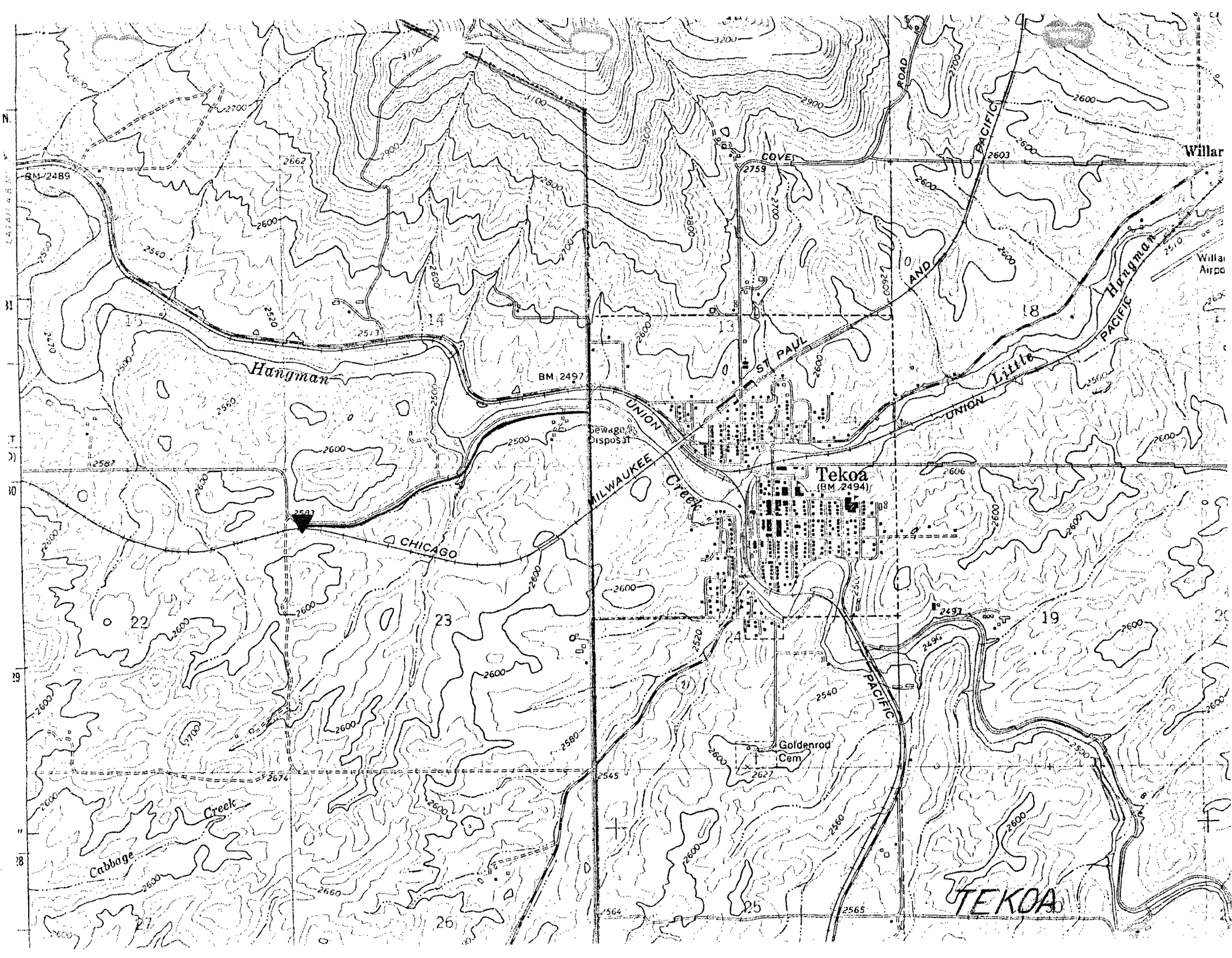
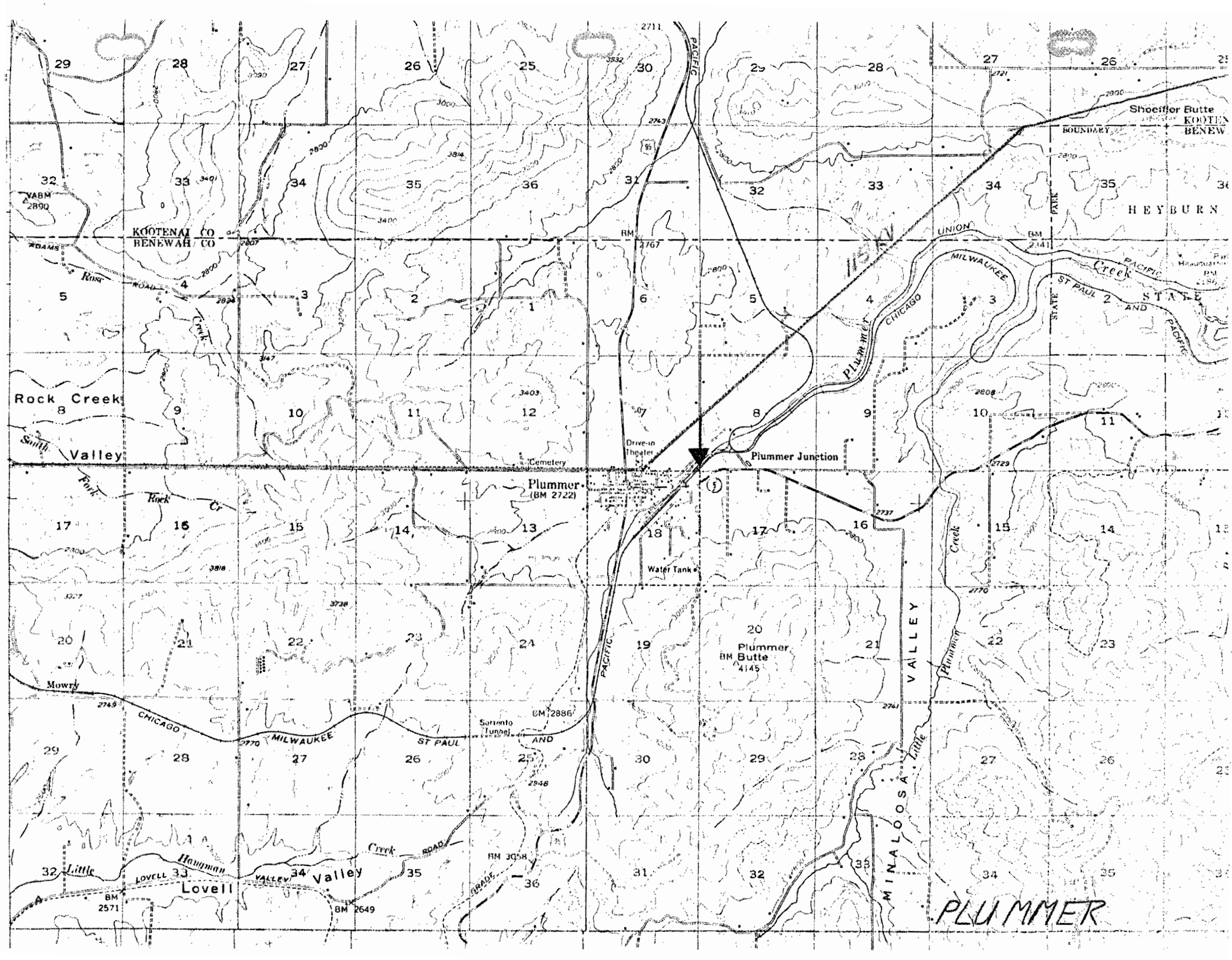
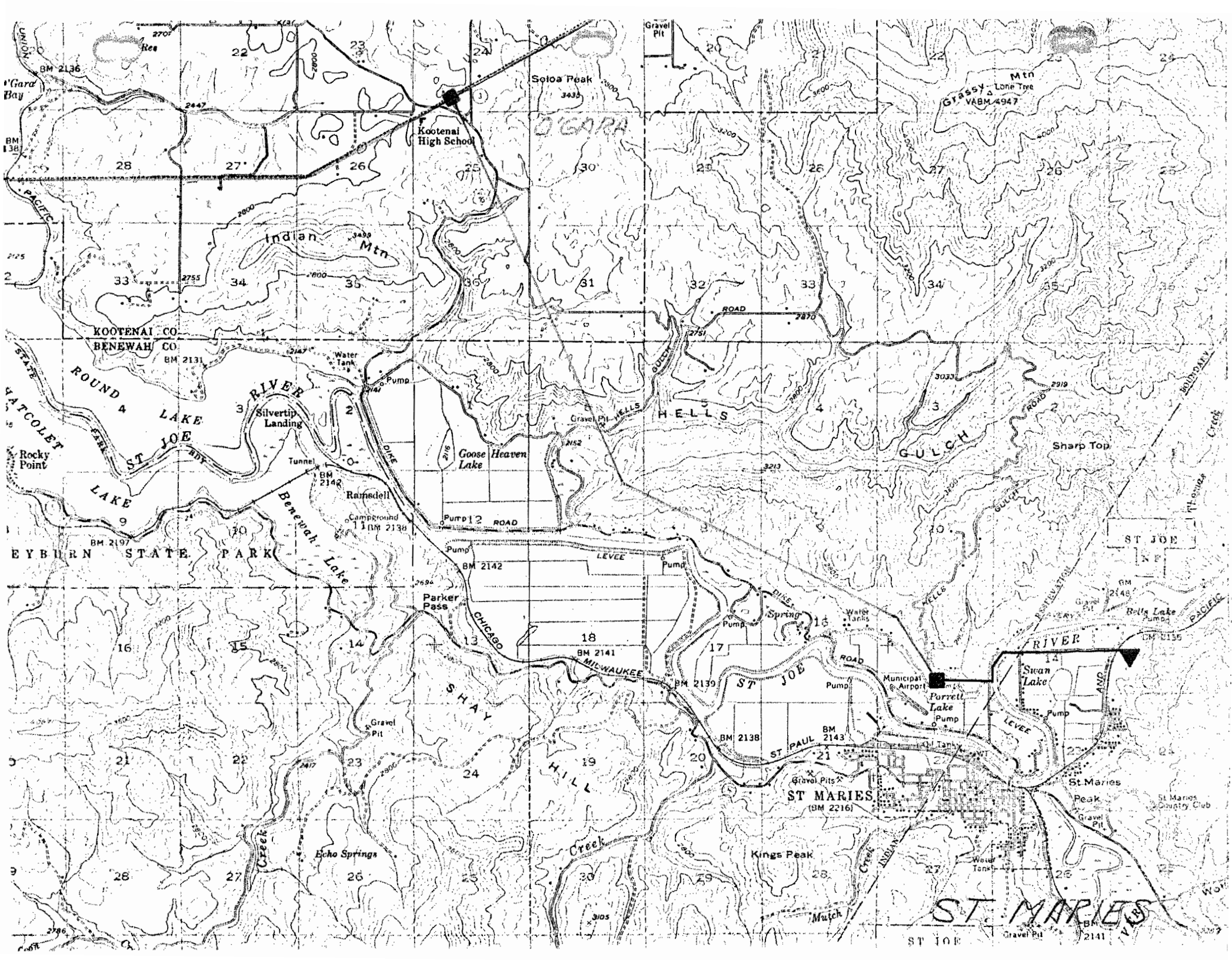
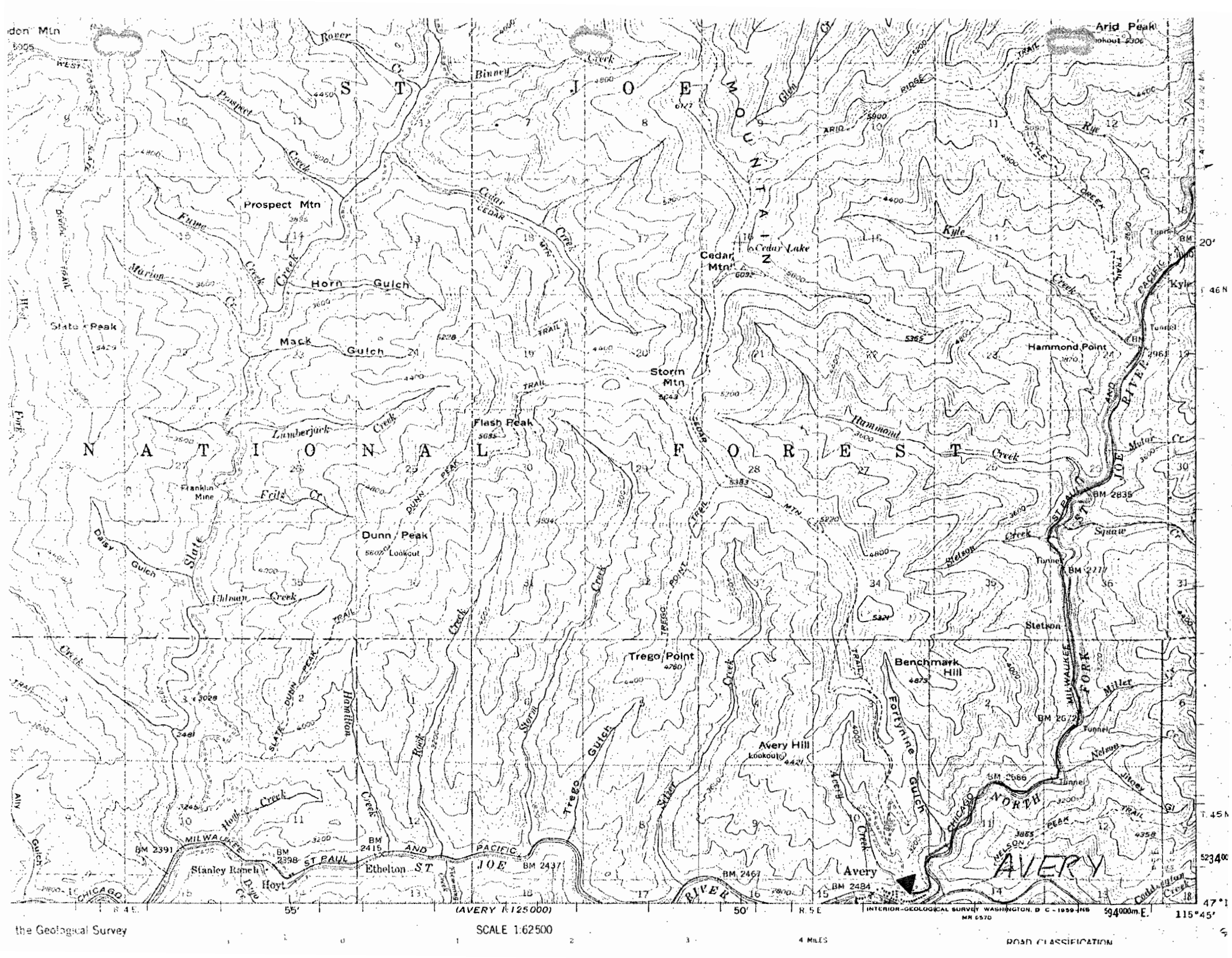
11
12


7°30'
CHENEY 19 MI.
464000m.E.
465
R. 42 E.
R. 43 E.
2578 IV
(SPANGLE 1:62 500)
BM 2135
468
25'
Malden-Rosalia Airport
Gravel Pit
Gravel Pit
Gravel Pit
Gravel Pits
Gravel Pits
Gravel Pit
Malden
Water Tanks
Substation
MILWAUKEE
Sta
ST PAUL
AND
PACIFIC
CHICAGO
Creek
Pine
Cache
Spring
Weldon
MALDEN
PINE CITY 1.7 MI.


Tekoa
(BM 2494)
BM 2489
BM 2497
Hangman
Little Hangman
Creek
Cabbage Creek
CHICAGO
MILWAUKEE
UNION PACIFIC
ST PAUL AND PACIFIC
COVE ROAD
Sewage Disposal
Goldenrod Cem
Willar
Airpo
TEKOA


KOOTENAI CO
BENEWAH CO
Rock Creek
South Fork Rock Cr
Valley
Plummer
(BM 2722)
Plummer Junction
Drive-in Theater
Cemetery
Water Tank
Plummer Butte
4145
Shoeffler Butte
HEYBURN
STATE PARK
BOUNDARY
KOOTEN
BENEW
ADAMS
ROAD
UNION
PACIFIC
MILWAUKEE
CHICAGO
ST PAUL
AND
PACIFIC
PLUM MER
Creek
MINALOOSA
VALLEY
Little
Plummer
Creek
Mowry
CHICAGO
MILWAUKEE
ST PAUL
AND
PACIFIC
Sunnto
Tunnel
BM 2886
BM 3058
Hangman
Creek
ROAD
Little
LOVELL
VALLEY
Valley
Lovell
BM
2571
BM 2649
GRADE
VABM
2890
BM
2767
BM
2441
PLUMMER


Soloa Peak
Kootenai High School
Grassy Mtn
Lone Tree
VABM 4947
Indian Mtn
KOOTENAI CO
BENEWAH CO
ROUND LAKE
ST JOE RIVER
Silvertip Landing
Water Tank
Pump
Gravel Pit
HELLS GULCH
Sharp Top
Goose Heaven Lake
Tunnel
Ramsdell
Campground
Rocky Point
EYBURN STATE PARK
Benewah Lake
Parker Pass
CHICAGO MILWAUKEE
ROAD
LEVEE
DIKE
Spring
Water Tanks
Municipal Airport
Porrett Lake
Swan Lake
Bells Lake
ST JOE
SHAY HILL
Gravel Pits
ST MARIES
St Maries Peak
St Maries Country Club
Kings Peak
Echo Springs
Mutch
ST MARIES
BM 2136
BM 2131
BM 2142
BM 2141
BM 2139
BM 2138
BM 2143
BM 2148
BM 2135
BM 2141


Arid Peak
Prospect Mtn
Cedar Mtn
Cedar Lake
Horn Gulch
Mack Gulch
Slate Peak
Storm Mtn
Flash Peak
Hammond Point
Dunn Peak
Lookout
Trego Point
Benchmark Hill
Avery Hill
Lookout
Stetson
Avery
NATIONAL FOREST
ST JOE
Prospect Creek
Cedar Creek
Marion Creek
Lumberjack Creek
Eells Cr
Slate Creek
Daisy Gulch
Ohman Creek
Hoyt Creek
Trego Creek
Fortymile Gulch
Avery Creek
Kyle Creek
Hammond Creek
Squaw Creek
Nelson Creek
Miller Creek
Caddy Creek
Franklin Mine
Stanley Ranch
Ethelton
MILWAUKEE ST PAUL AND PACIFIC
CHICAGO NORTH SHORE
ST JOE RIVER
BM 2391
BM 2398
BM 2415
BM 2437
BM 2467
BM 2484
BM 2835
BM 2777
BM 2672
BM 2686
AVERY
INTERIOR-GEOLOGICAL SURVEY, WASHINGTON, D. C.-1959-NS
MR 0570
(AVERY 1:125000)
SCALE 1:62500
4 MILES
ROAD CLASSIFICATION
R.4E.
R.5E.
55'
50'
T.46N.
T.45N.
47°15'
115°45'
594000m.E.
5234000m.N.
the Geological Survey