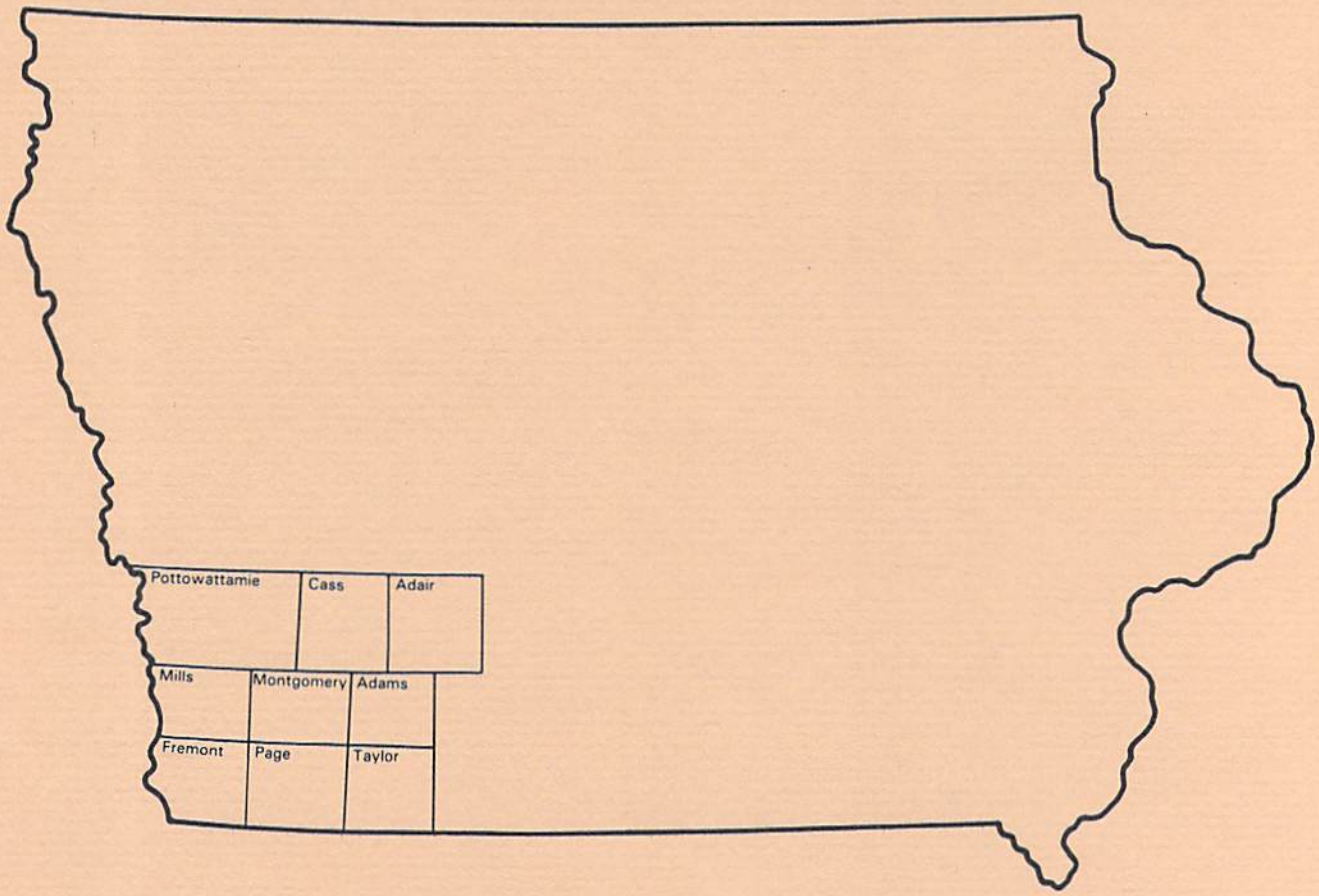
WATER-SUPPLY BULLETIN
Number 14
1984

POTENTIAL WATER-SUPPLY IMPOUNDMENT SITES IN SOUTHWEST IOWA

by Patricia M. Witinok



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FOREWORD

Water Supply Bulletin Number 14 offers an important contribution to the potential development of water supplies in nine southwestern Iowa counties. Except for the floodplain along the Missouri River, many municipalities and private landforms in these counties have long experienced difficulties in locating, developing, and maintaining adequate, high quality water sources. For municipalities, increasing per capita consumption and other competing demands have imposed pumping stress on many shallow wells completed within sand and gravel deposits associated with the larger rivers of the region. Instances of nitrate contamination in excess of drinking-water quality standards aggravate the problem. For private landowners, upland wells completed within areally restricted sands and gravels are subject to lowered yields during dry periods. Additionally, they often possess high concentrations of iron or other dissolved minerals that affect water quality.

Other reports have considered impoundments as sources for water supplies, including sites within southwestern Iowa. However, they did not include, as does this report, design criteria based upon impoundment life, sediment yield to the impoundment, and the amount of water withdrawal to be sustained. Hopefully, this publication will stimulate a closer look at impoundments for serving the long-term needs for reliable water supplies in southwestern Iowa.

Donald L. Koch
State Geologist and Director
Iowa Geological Survey

TABLE OF CONTENTS

TABLE OF CONTENTS Continued

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

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INTRODUCTION

The nine counties that are the subject of this report (Pottawattamie, Cass, Adair, Mills, Montgomery, Adams, Fremont, Page, and Taylor) are among a group of southern and western Iowa counties that have experienced chronic, sometimes acute, water supply problems. In most of the region, adequate supplies of good quality groundwater are not available, except for those counties that border the Missouri River (Pottawattamie, Mills, and Fremont). And, even in these counties, the available resource is confined to the narrow corridor of the Missouri River floodplain. Away from this corridor, dependable groundwater supplies can often be drawn from alluvial materials associated with the larger rivers and streams. Alluvial aquifers, however, are prone to pumping stress as new demands are placed on them, and, in several instances, are yielding water of increasing inferior quality.

Faced with the problems of a deficient groundwater supply, generally poor groundwater quality, and a trend toward degradation of the better supplies available, the residents of the region must begin to look at other alternatives for meeting their future water demands. In addition to conserving and protecting those resources that are currently available, there are three primary alternatives which may be worthy of evaluation: the desalinization of poor-quality groundwater (Laverentz, 1974); importation of water from the Missouri River groundwater system; and/or the development of surfacewater sources. Possibly the simplest and most economically favorable alternative is the latter. This report addresses the potential for development of surfacewater impoundments.

In considering whether or not the storage of surfacewater is feasible to meet water supply demands, there are many questions that must be answered.

First, are there stream valleys available where water can be impounded in areas of water demand? Second, is there sufficient streamflow during dry, low-flow periods to provide water to sustain specific water demands? Third, how large must the stream basin be to provide a particular sustained demand? Fourth, how large must an impoundment be to sufficiently store both water and sediment for a realistic design period? And, fifth, are the engineering properties of soils at a specific site amenable to the construction of a dam and reservoir? Reconnaissance-level information can be used to rapidly determine preliminary site feasibility, but is by no means adequate for final design and construction. The final design plan for any impoundment requires a thorough and detailed site evaluation.

SCOPE OF STUDY

The objectives of this study are to evaluate the characteristics of small watersheds in nine southwestern Iowa counties (Fremont, Page, Taylor, Mills, Montgomery, Adams, Pottawattamie, Cass, and Adair) and to determine which offer potential impoundment sites for public water supply.

To assess the preliminary feasibility of an impoundment site, several fundamental watershed and site criteria are considered, they include:

1. The availability of stream valleys that can be dammed to impound water in adequate volumes to meet water-supply design specifications.
2. Definition of contributing watersheds that have sufficient yield to provide the necessary water to meet design withdrawal rates and anticipated losses.
3. Site locations that correspond favorably with the geographic centers of water demand and do not present problems related to existing structural or cultural features.
4. General soil and geologic characteristics that are compatible with the construction and operation of a water storage/supply reservoir.

The sites indexed in this report have been evaluated on the basis of these criteria. In addition, to bring the study more into perspective with the scale of economics and the anticipated water demands of the study region, some preliminary assumptions were made. They are as follows:

- No site would be considered wherein a dam exceeding one-half mile in length would be required.
- No site was considered where the maximum depth of water behind the dam would be less than 20 feet.
- No site was considered where the required dam would be less than 30 feet or exceed 90 feet in height.
- For the purpose of water supply, water requirements were based on an average daily per capita demand of 100 gallons.
- Annual demands were calculated on the basis of 100 gallons per capita per day for 365 days per year.

PROCEDURE AND METHODOLOGY

In each of the nine counties studied, several steps were followed to locate and determine the feasibility of potential impoundment sites. The procedures and assumptions used are outlined in the following sections.

Determination of Water Demand

Design criteria for a water supply reservoir can be quite variable. Thus, for this study, arbitrary limits were placed on the impoundment size. Basically, two categories of water supply were considered, small municipal systems and county-wide rural water distribution systems. Respectively, populations of 5,000 and 12,000 were set as reasonable numbers for the present study's purpose. Potential reservoirs were screened in terms of their adequacy to sustain water supplies at these population levels. The daily per capita demand, as given earlier, was set at 100 gallons per day per capita.

At this value, the required sustained withdrawal rate for a community of 5,000 people is 500,000 gallons per day (gpd) or nearly one cubic foot per second (cfs), and a county-wide distribution system for 12,000 people requires 1,200,000 gpd or approximately 2 cfs.

Considerations of Drainage Area

One of the most important factors in reservoir siting is determining whether its contributing watershed is adequate to provide enough water to meet the design demand plus compensate for losses from various causes. Because most smaller impoundments, such as considered in this investigation, are located on ungaged streams, adequate records are not usually available to make yield determinations directly. Therefore, regional mathematical methods have been developed to derive watershed yield from available runoff and rainfall data. Such a method, developed by the U.S. Geological Survey (Heinitz, 1970), and modified by the Iowa Department of Environmental Quality (1980), was used to estimate watershed yield for each of the nine counties studied. Basically, a minimum watershed area was determined for each county which could supply 100 (gpd per capita) for populations of 5,000 and 12,000. Details of the method are discussed in Appendix A. Based on these analyses, it was concluded that watersheds greater than 25 square miles in area were much larger than required to meet the design demands of the study. Consequently, sites with drainage areas exceeding 25 square miles were excluded.

Preliminary Site Selection

The next step was to locate points along the various rivers and streams of the study region where drainage areas were adequate with respect to the preliminary established yield requirements. In the process, points along

streams with sufficient drainage area were located on a drainage area base map. The base map was derived from tables and maps presented in Larimer (1957).

Site Evaluation

Sites located during the preliminary site selection process were transferred to seven and one-half or fifteen minute series U.S. Geological Survey topographic quadrangle maps. In this step, the potential for locating an impoundment was visually examined relative to the criteria established for dam length, dam height, and minimum impoundment depth. If the site met these criteria, a line was drawn to represent the location of a dam, and the contour representing the maximum level of impoundment was outlined. The outlined area, maximum impoundment surface area, was planimetered and the total surface area calculated. The total storage volume for each site was calculated by multiplying the maximum impoundment depth (in feet) by the surface area (in acres), and dividing by three. The method used in this calculation is given in Appendix B. To this point, no consideration was given to design storage requirements for sustained withdrawal or for the storage of sediment.

Required Storage Capacities

Three important factors determine the total storage requirement of a water impoundment; the impoundment's projected design life, sediment yield to the impoundment, and the amount of water withdrawal (and losses) that must be sustained. To reasonably estimate these parameters, regional equations were derived to determine the relationship between sustained water supply (draft) and water storage, and sediment loss and sediment storage. The methods for deriving these relations are discussed in Appendices C and D.

In addition to these criteria, two other factors (related to variability in watershed yield) were considered. During drier periods, a watershed may not yield the water necessary to sustain a required withdrawal. To compensate for this, an impoundment must be designed to store enough water to meet such contingencies. This is defined as carry-over storage. Alternatively, a reservoir can be designed to meet a specific, sustained level of withdrawal corresponding to a watershed's lowest annual yield. This is defined as within-year storage. In either case the frequency and magnitude of low-watershed yield events must be characterized.

In this investigation calculations for draft-rate/storage were based on the concept of within-year storage. For this purpose, regional draft-rate/storage equations were derived through an analysis of the relationship between watershed areas and observed low streamflows that have recurred statistically, once in ten and once in twenty years. Using this method, required water storage volumes and sustainable withdrawal rates are based on projected minimum annual watershed yields.

The total design storage capacity of an impoundment includes; storage required to meet the design water draft-rate, and the storage needed for the sediment the watershed contributes to the reservoir. To calculate sediment storage volumes, an areal relation for sediment loss was derived for the study region, (the method is discussed in Appendix D). Sediment storage volumes were calculated for reservoir design-life periods of 20 and 50 years.

After the draft and sediment storage volume requirements were determined several preliminary sites were eliminated on the basis of inadequate storage capacity. Many preliminary sites in both design population categories were found to be much larger than required. Therefore, for comparative purposes, and to bring the net storage requirements more into scale with the selected

population design demand, additional calculations were made. This involved determining the actual storage requirements for the two selected demand levels and the two design periods chosen at each selected site. This procedure is discussed in Appendix E.

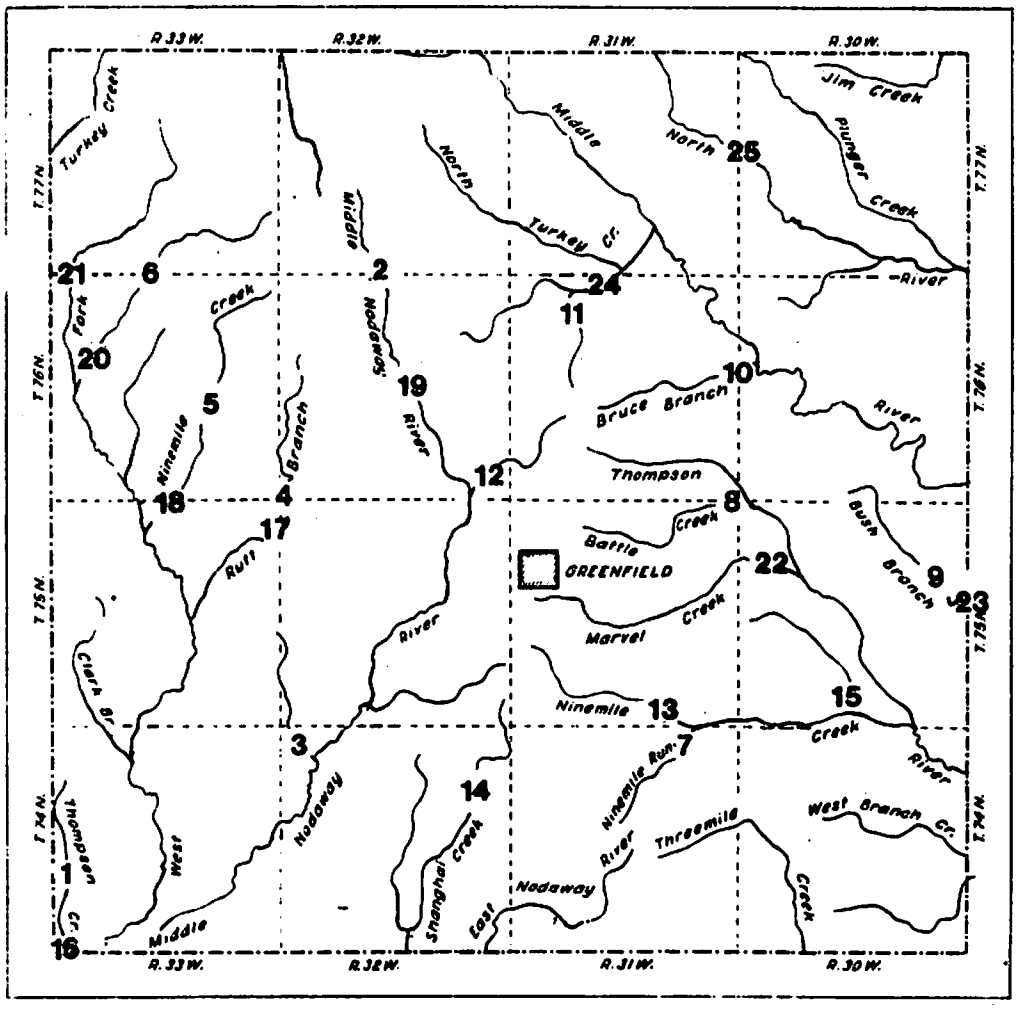
Existing Structural and Cultural Features

In the final step, each site was evaluated for existing structural and cultural features that would probably obviate the construction of a storage reservoir at selected sites. No on-site investigations were conducted; reliance was placed on details given on the topographic quadrangle maps used for the study. Particular attention was paid to areas in which an impoundment would encroach upon community developments; cemeteries, parks, railroads, primary highways, and related features. Additionally, impoundment sites crossed by power transmission lines and petroleum and gas pipelines were excluded.

RESULTS

In the pages that follow, information is presented on 164 potential reservoir sites for the nine counties in the study region. For each county there is a reservoir site location map and a table which summarizes, for each site, the general and design storage characteristics, and sustainable draft rates for specified population categories. Most of the available sites selected had capacities two to five times greater than the calculated required storage and thus they were scaled down to impoundment dimensions relative to the calculated required capacity (methodology examined in Appendix E). The tables are accompanied by a set of maps which give the location, topographic, and cultural details for each site. The site numbers in the tables correspond to the site numbers on the maps. The topographic maps on which sites are

identified have been reduced in size from the original. Seven and one-half minute maps have been reduced by 73 percent and 15 minute maps have been reduced by 50 percent.



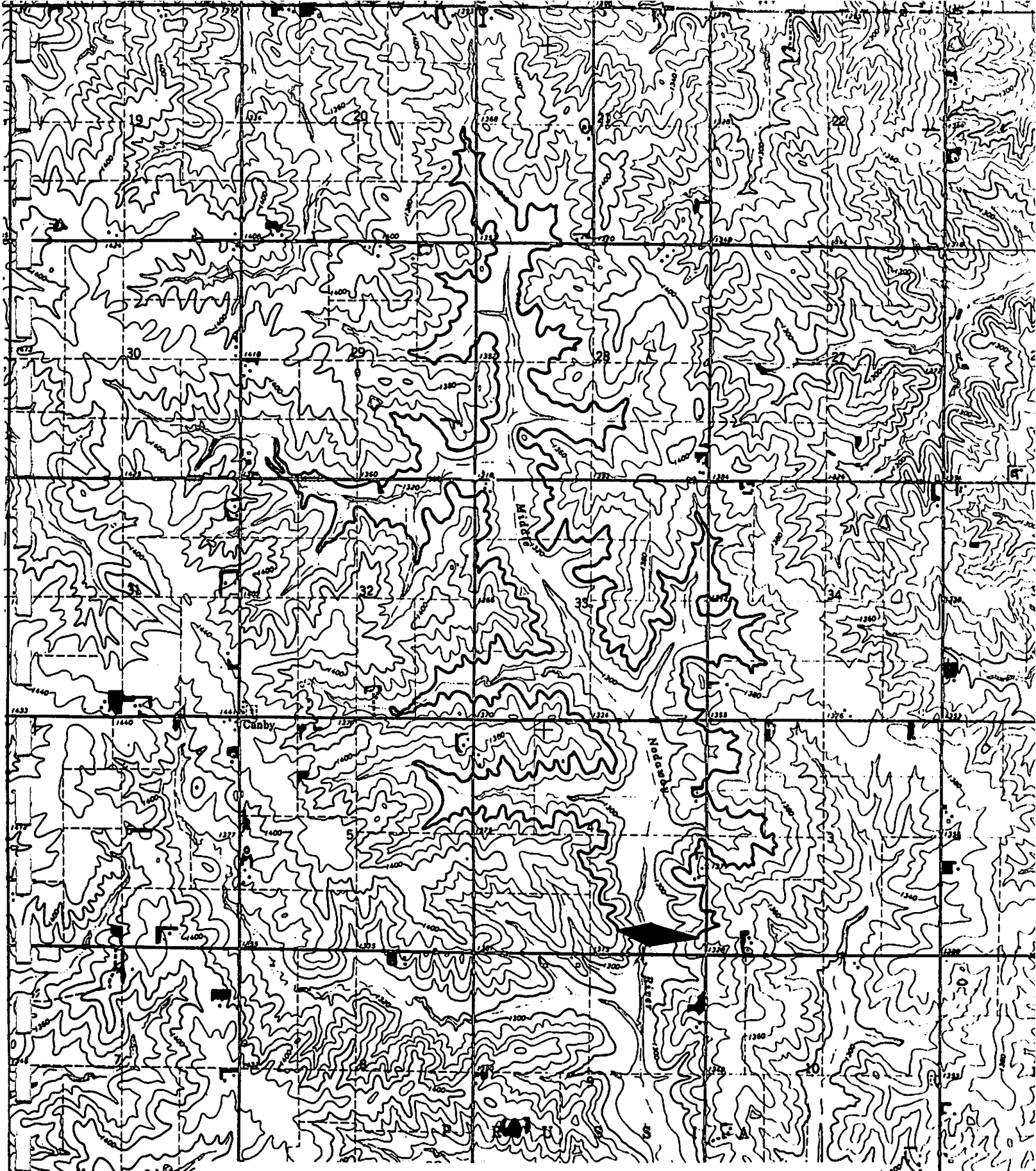
Index map for impoundment sites in Adair County.

ADAIR COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles^2)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet^3/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	19	74	33	7.04	60	696	13918	5	1	10	377	377	234	585	31	48	15	24	626	985
										20	1072	1072	234	585	65	83	33	41	1339	1698
2	4	76	32	9.00	60	796	15919	5	1	10	349	349	289	722	32	54	16	27	653	1097
										20	968	968	289	722	63	85	31	42	1288	1732
3	6	74	34	8.12	40	407	5421	5	1	10	361	361	264	661	47	77	24	38	649	1060
										20	1014	1014	264	661	96	126	48	63	1326	1737
4	6	75	32	10.60	40	387	5160	5	1	10	328	328	332	830	50	87	25	43	685	1201
										20	891	891	332	830	92	129	46	65	1269	1786
5	22, 23	76	33	8.94	60	745	14907	5	1	10	350	350	287	717	32	53	16	27	653	1094
										20	972	972	287	717	63	84	32	42	1290	1731
6	4	76	33	9.16	60	715	14305	5	1	10	347	347	293	733	32	54	16	27	656	1106
										20	960	960	293	733	63	85	31	42	1285	1693
7	2	74	31	7.78	55	528	9677	5	1	10	366	366	255	637	34	55	17	27	638	1030
										20	1032	1032	255	637	70	91	35	46	1322	1714
8	31	76	30	7.90	60	729	14587	5	1	10	364	364	258	645	31	50	16	25	638	1010
										20	1025	1025	258	645	64	84	32	42	1316	1713
9	12, 13	75	30	7.76	60	330	6607	5	1	10	366	366	254	636	31	50	16	25	636	1027
										20	1033	1033	254	636	64	83	32	42	1319	1710
10	13	76	31	6.27	60	435	8589	5	1	10	388	388	212	531	30	46	15	23	615	942
										20	1115	1115	212	531	66	82	33	41	1361	1687
11	8	76	31	7.61	40	269	3584	5	1	10	368	368	250	625	46	75	23	37	642	1031
										20	1041	1041	250	625	97	125	48	63	1339	1729
12	36	76	32	5.76	40	284	3790	5	1	10	396	396	197	492	45	67	22	33	615	922
										20	1146	1146	197	492	101	123	50	61	1394	1700
13	34	75	31	8.21	40	292	3898	5	1	10	360	360	267	667	47	77	24	39	650	1065
										20	1009	1009	267	667	96	126	48	63	1324	1739
14	11, 12	74	32	6.10	55	637	11675	5	1	10	390	390	207	517	33	50	16	25	613	932
										20	1126	1126	207	517	72	90	36	45	1333	1688
15	33, 34	75	30	6.14	60	660	13190	5	1	10	390	390	208	520	30	46	15	23	613	932
										20	1124	1124	208	520	67	82	33	41	1365	1685
16	6, 31	73, 74	33	11.70	60	639	12787	5	1	10	314	314	361	903	34	61	17	30	692	1247
										20	842	842	361	903	60	87	30	44	1233	1788
17	5	75	32	16.30	60	893	17866	12	2	10	831	831	480	1200	66	102	33	51	1344	2082
										20	1147	1147	480	1200	81	117	41	59	1668	2406
18	4, 33	75, 76	33	15.80	40	734	9786	12	2	10	843	843	467	1168	98	151	49	75	1359	2086
										20	1165	1165	467	1168	122	175	61	88	1693	2420
19	15	76	32	14.70	40	617	8222	12	2	10	868	868	439	1098	98	148	49	73	1356	2040
										20	1204	1204	439	1098	123	173	61	86	1705	2388
20	18	76	33	15.00	40	575	7662	12	2	10	861	861	447	1117	98	148	49	74	1357	2052
										20	1193	1193	447	1117	123	173	62	87	1702	2397
21	31	77	33	14.40	40	651	8686	12	2	10	875	875	432	1079	98	147	49	73	1356	2027
										20	1215	1215	432	1079	124	172	62	86	1709	2380
22	7, 8	75	30	14.50	40	484	6455	12	2	10	873	873	434	1085	98	147	49	73	1356	2031
										20	1211	1211	434	1085	123	172	62	86	1797	2383
23	13	75	30	14.10	60	399	7977	12	2	10	882	822	423	1060	65	97	33	49	1339	1990
										20	1226	1226	423	1050	82	114	41	57	1691	2342
24	4, 33	76, 77	31	17.40	40	591	7878	12	2	10	807	807	507	1269	99	156	49	78	1364	2153
										20	1110	1110	507	1269	121	178	62	89	1678	2458
25	13	77	31	17.50	40	752	10023	12	2	10	805	805	510	1275	99	156	49	78	1364	2158
										20	1107	1107	510	1275	121	179	61	89	1677	2471

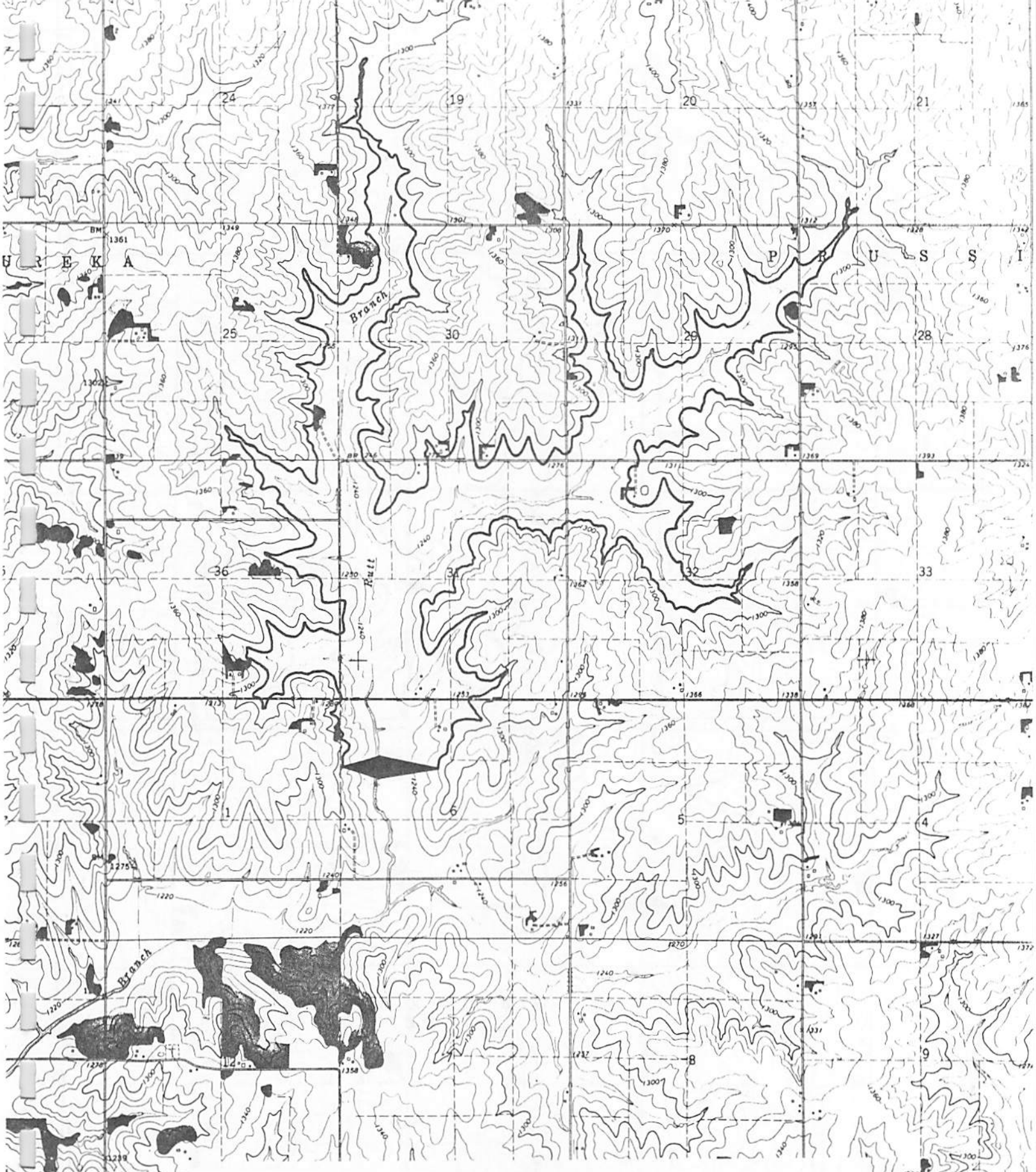
* Column 1 20 year design, Column 2 50 year design periods.

SITE NO.: 1 COUNTY: Adair
LOCATION: SECTION: 19 T 74N, R 33W
QUADRANGLE: Bridgewater
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

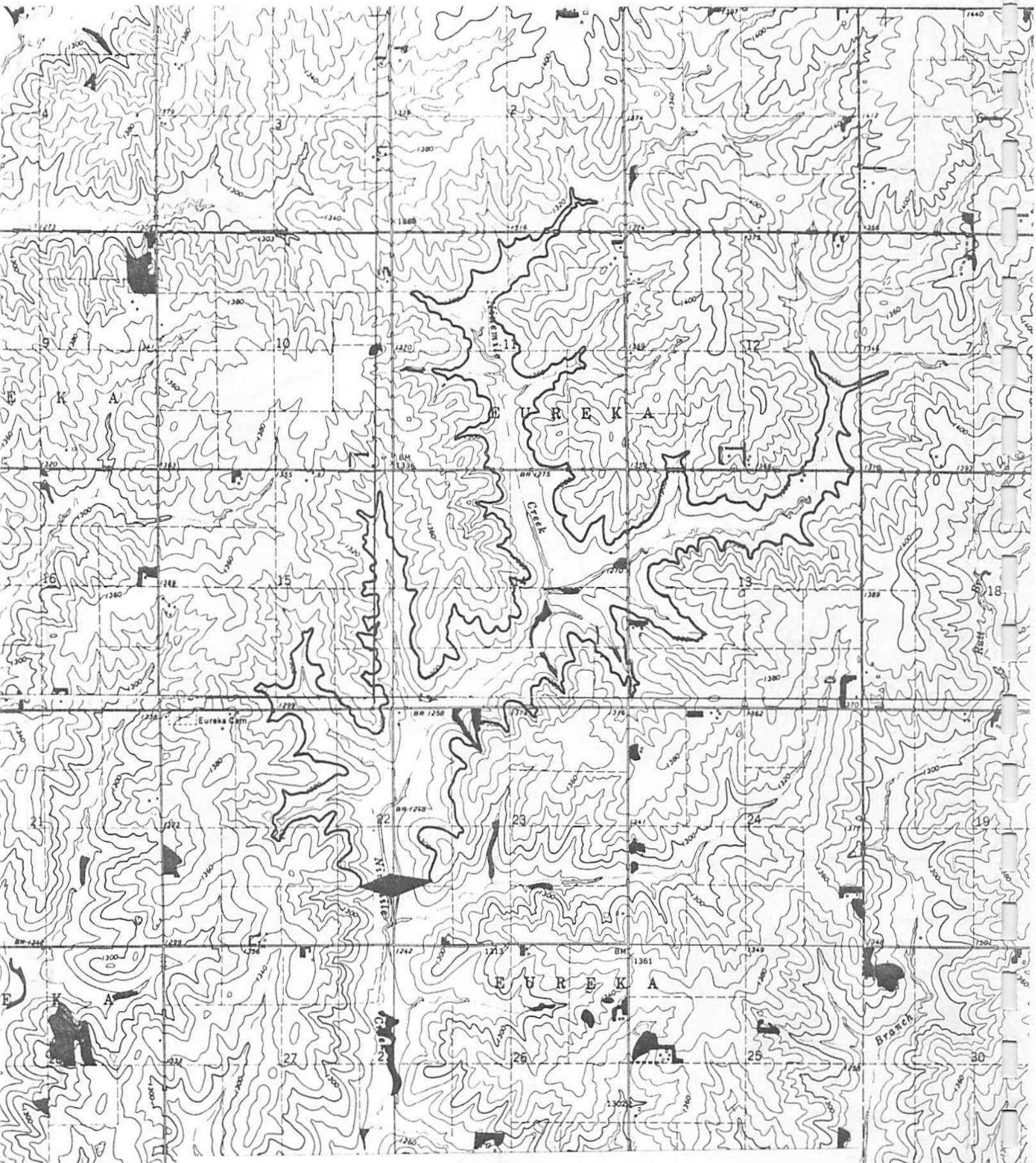


SITE NO.: 2 COUNTY: Adair
LOCATION: SECTION: 4 T 76N, R 32W
QUADRANGLE: Canby
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 3 COUNTY: Adair
LOCATION: SECTION: 6 T 74N, R 34W
QUADRANGLE: Fontanelle, Nevinville
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 4 COUNTY: Adair
LOCATION: SECTION: 6 T 75N, R 32W
QUADRANGLE: Fontanelle
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

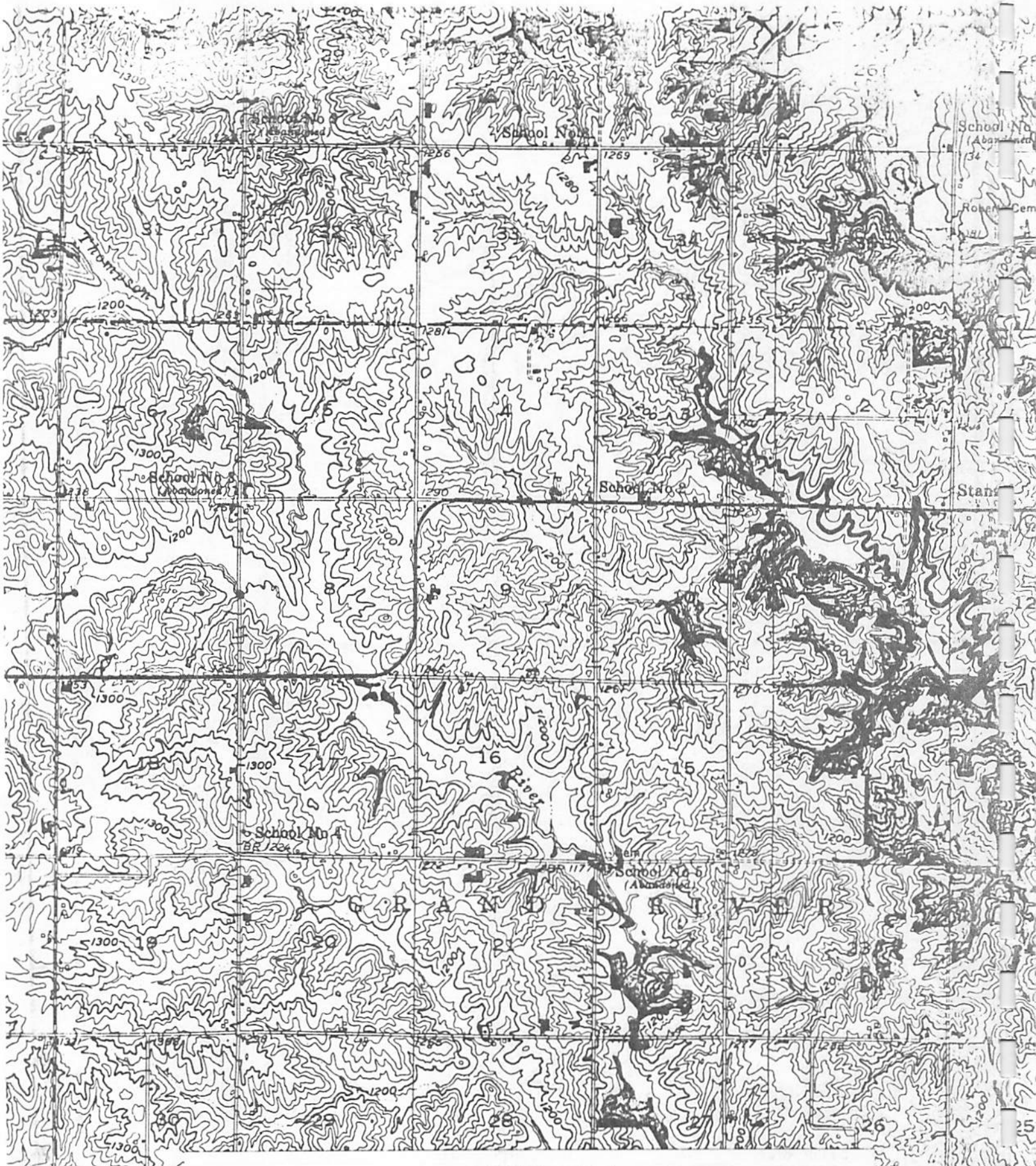


SITE NO.: 5 COUNTY: Adair
LOCATION: SECTION: 22, 23 T 76N, R 33W
QUADRANGLE: Adair South, Canby, Fontanelle, Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 6 COUNTY: Adair
LOCATION: SECTION: 4 T 76N, R 33W
QUADRANGLE: Adair South, Canby
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 7 COUNTY: Adair
LOCATION: SECTION: 2 T 74N, R 31W
QUADRANGLE: Orient, Zion
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20, 10 FT.

SITE NO.: 8 COUNTY: Adair
LOCATION: SECTION: 31 T 76N, R 30W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.



SITE NO.: 9 COUNTY: Adair
LOCATION: SECTION: 12, 13 T 75N, R 30W
QUADRANGLE: Greenfield
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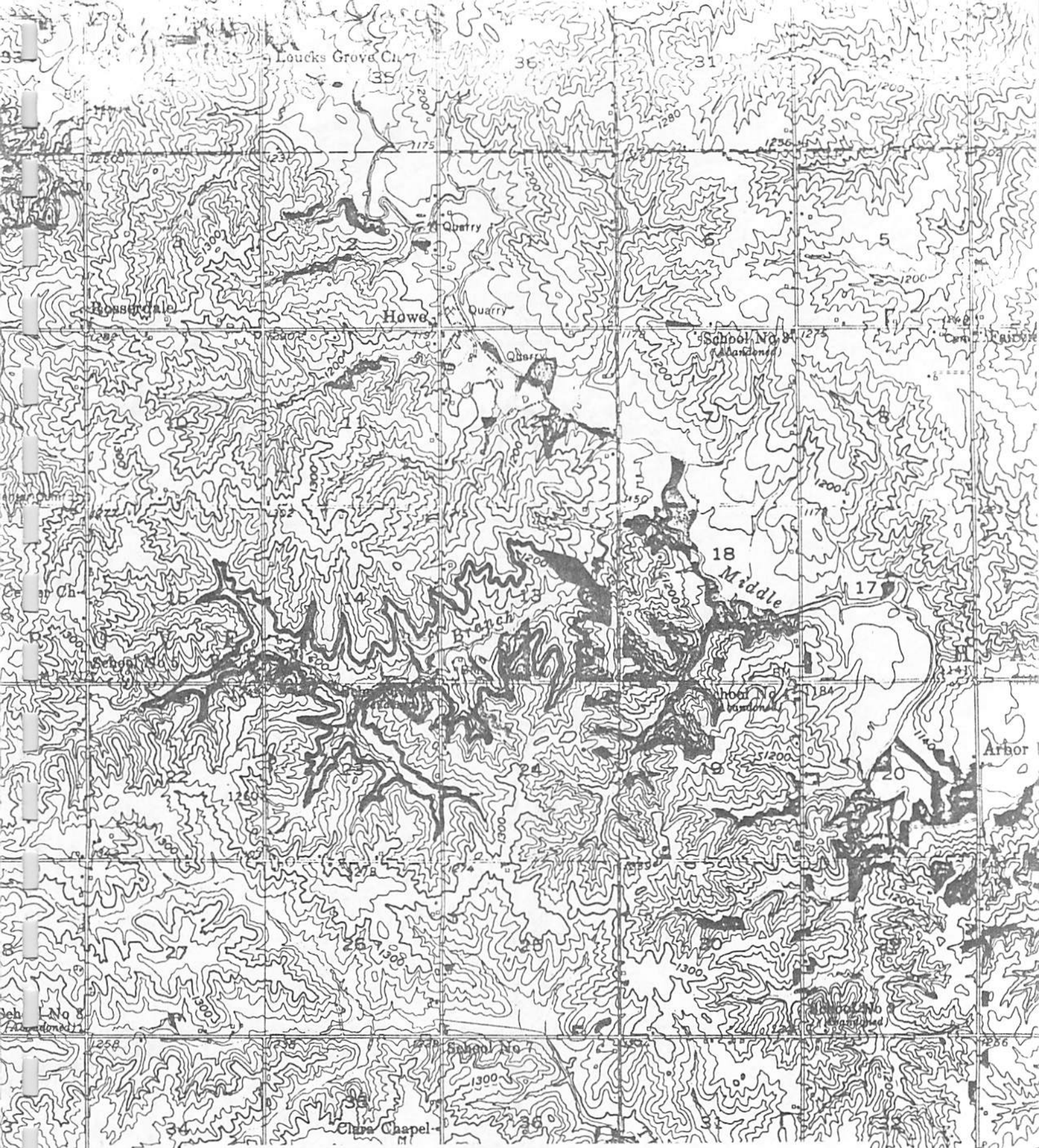

SITE NO.: 10 COUNTY: Adair

LOCATION: SECTION: 13 T 76N, R 31W

QUADRANGLE: Greenfield

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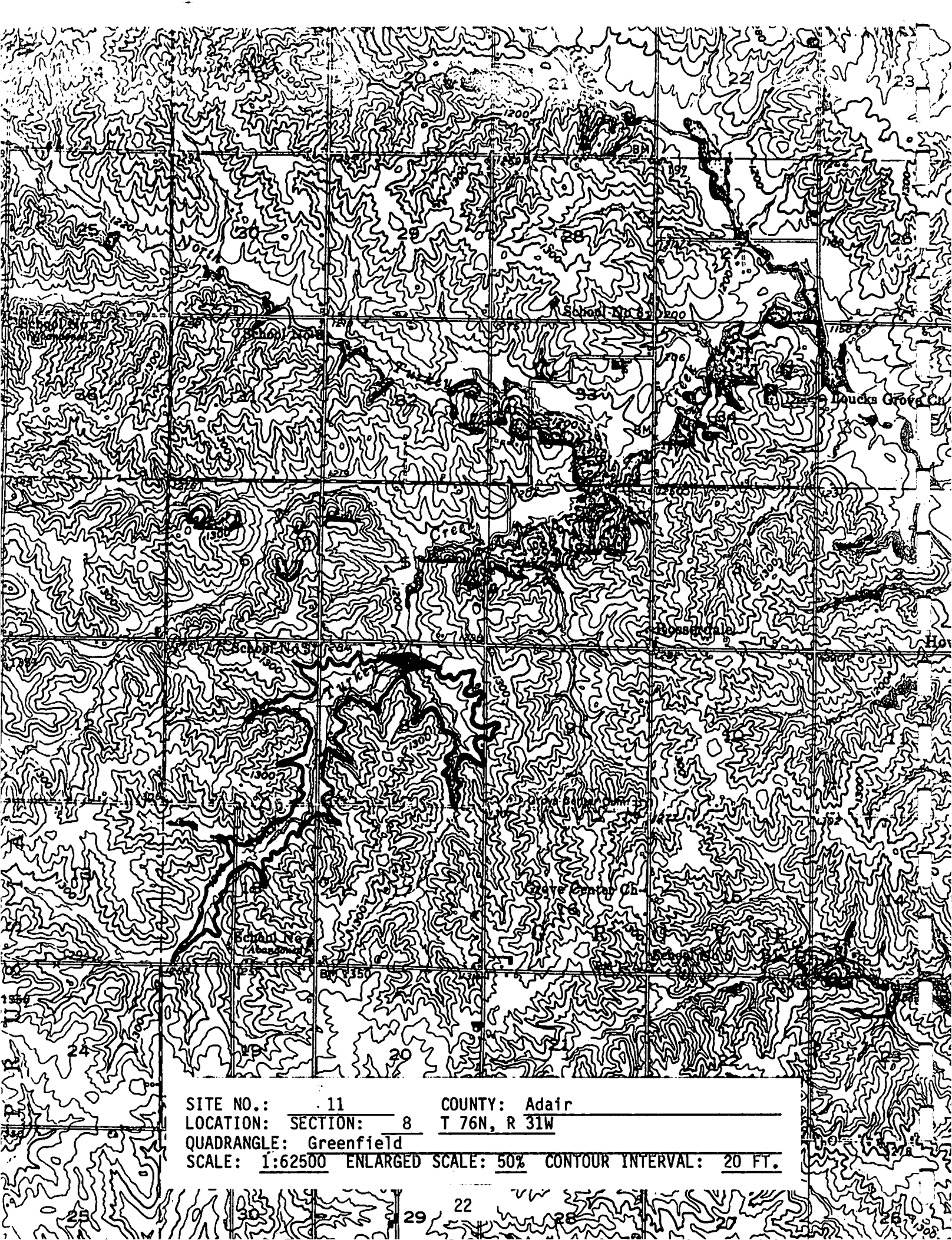

SITE NO.: 11 COUNTY: Adair
LOCATION: SECTION: 8 T 76N, R 31W
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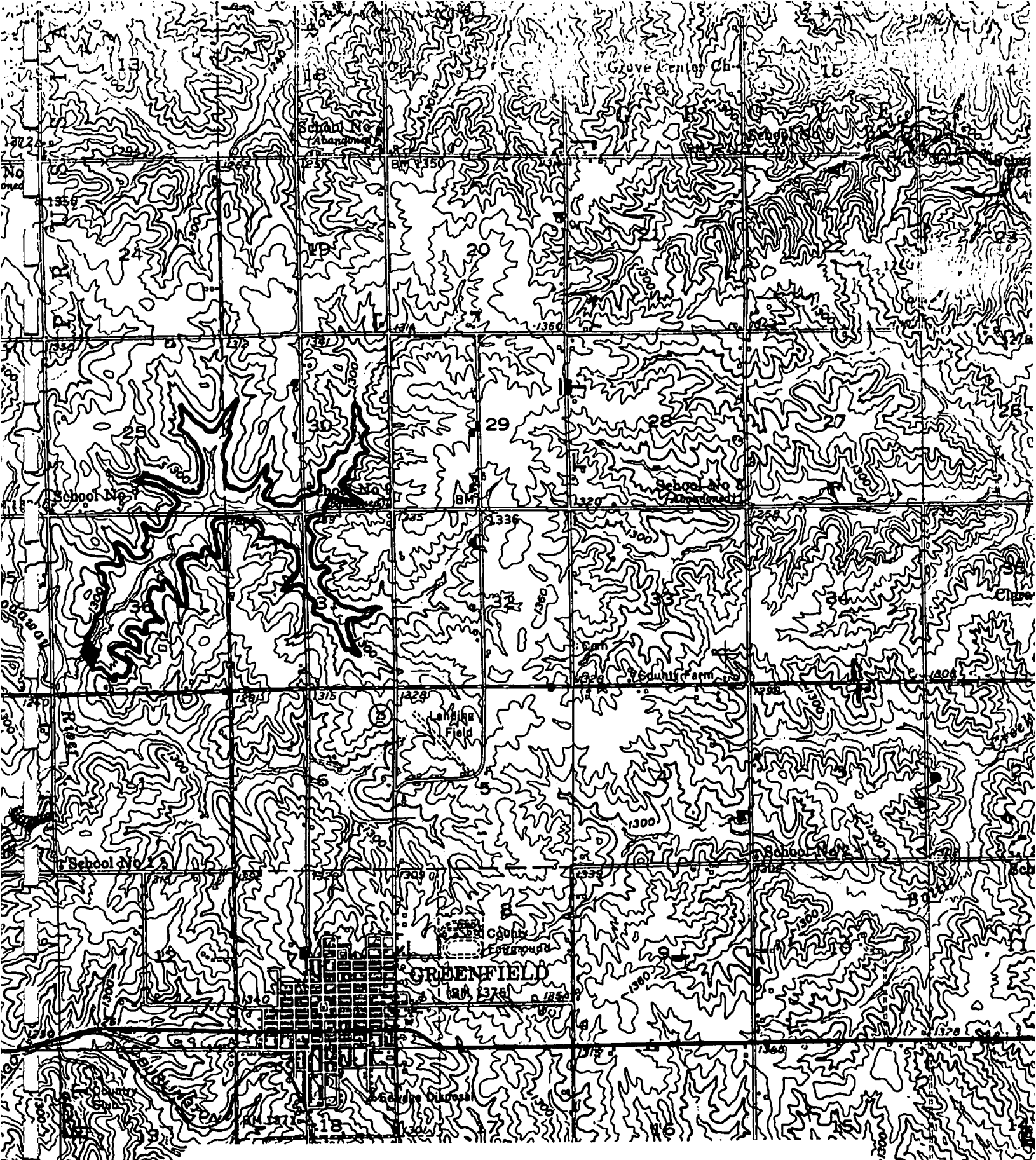
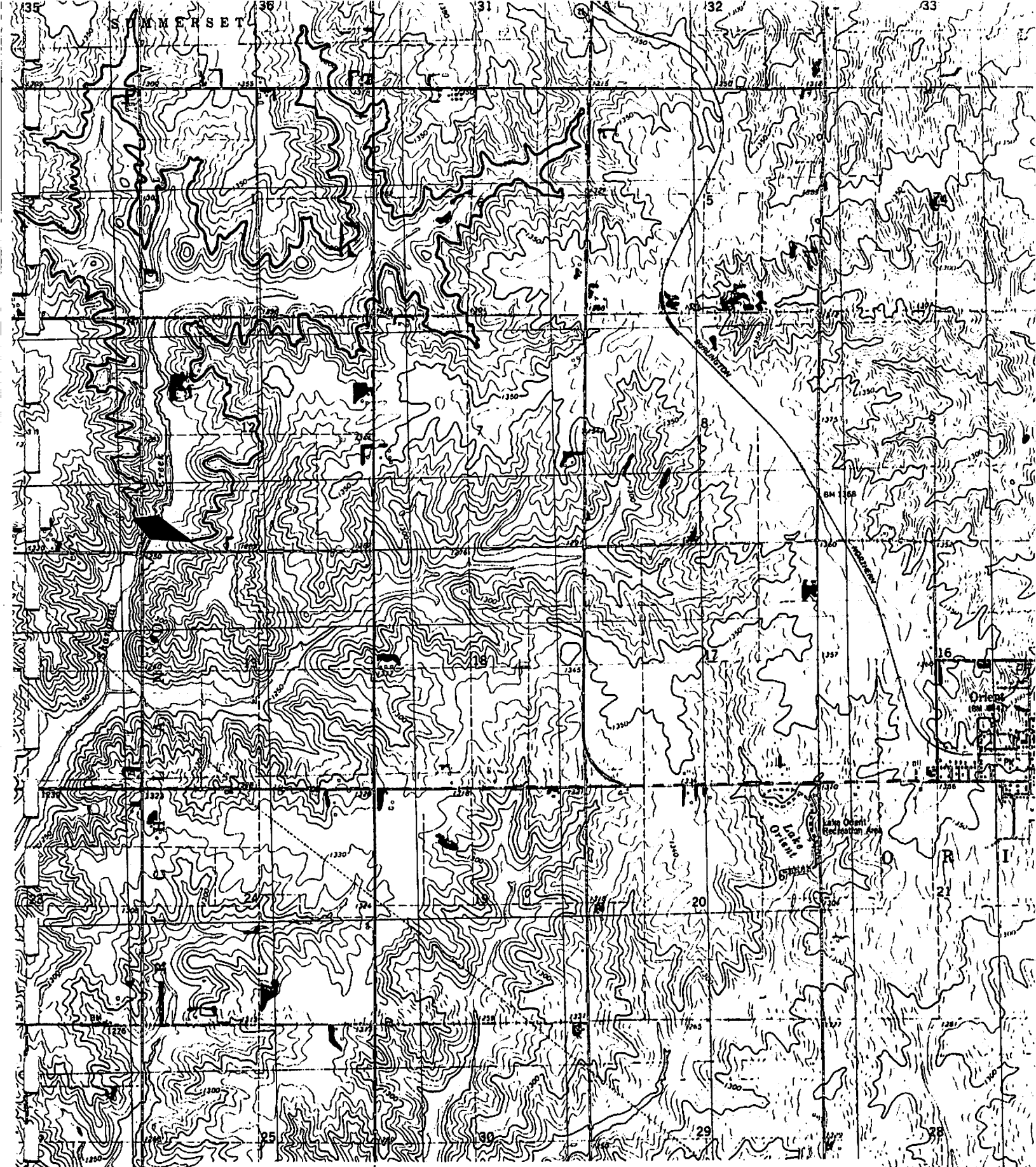


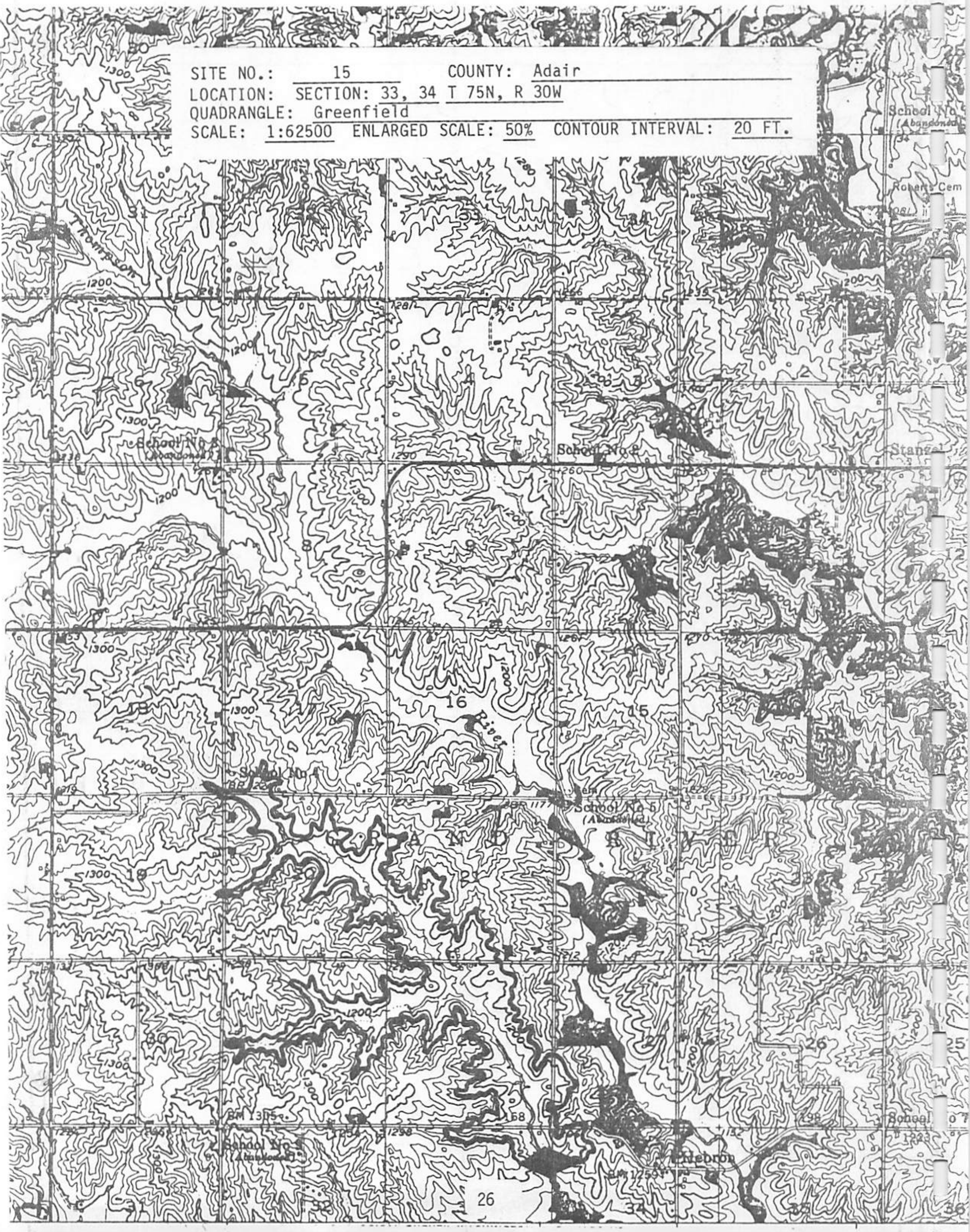
SITE NO.: 12 COUNTY: Adair
LOCATION: SECTION: 36 T 76N, R 32W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.


SITE NO.: 13 COUNTY: Adair
LOCATION: SECTION: 34 T 75N, R 31W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.
GREENFIELD
Clara Chapel
School No 1
School No 2
School No 7
Landing Field
County Farm
Sewage Disposal
Greenfield Cem
Marvel
Creek

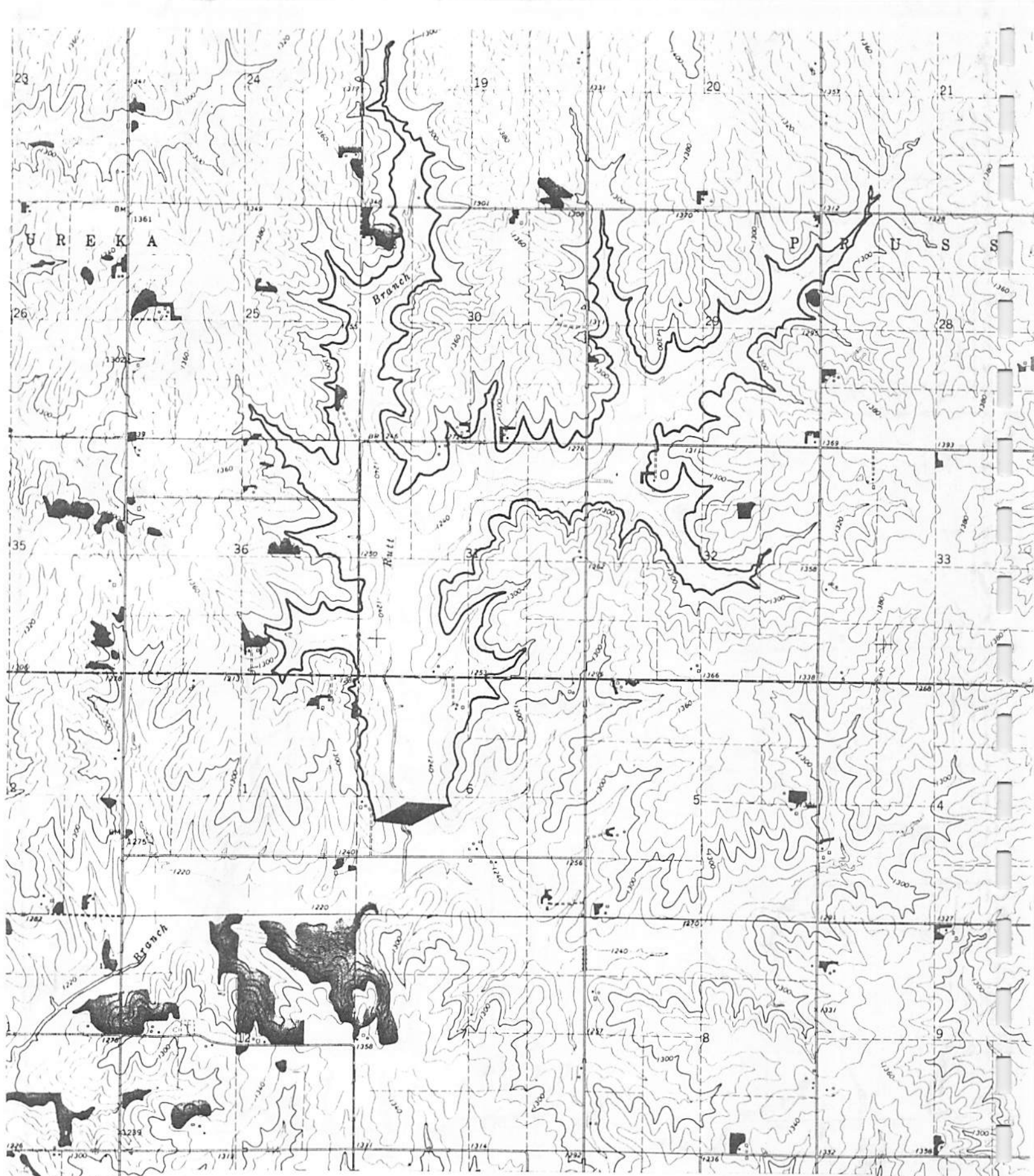


SITE NO.: 14 COUNTY: Adair
LOCATION: SECTION: 11, 12 T 74N, R 32W
QUADRANGLE: Orient
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

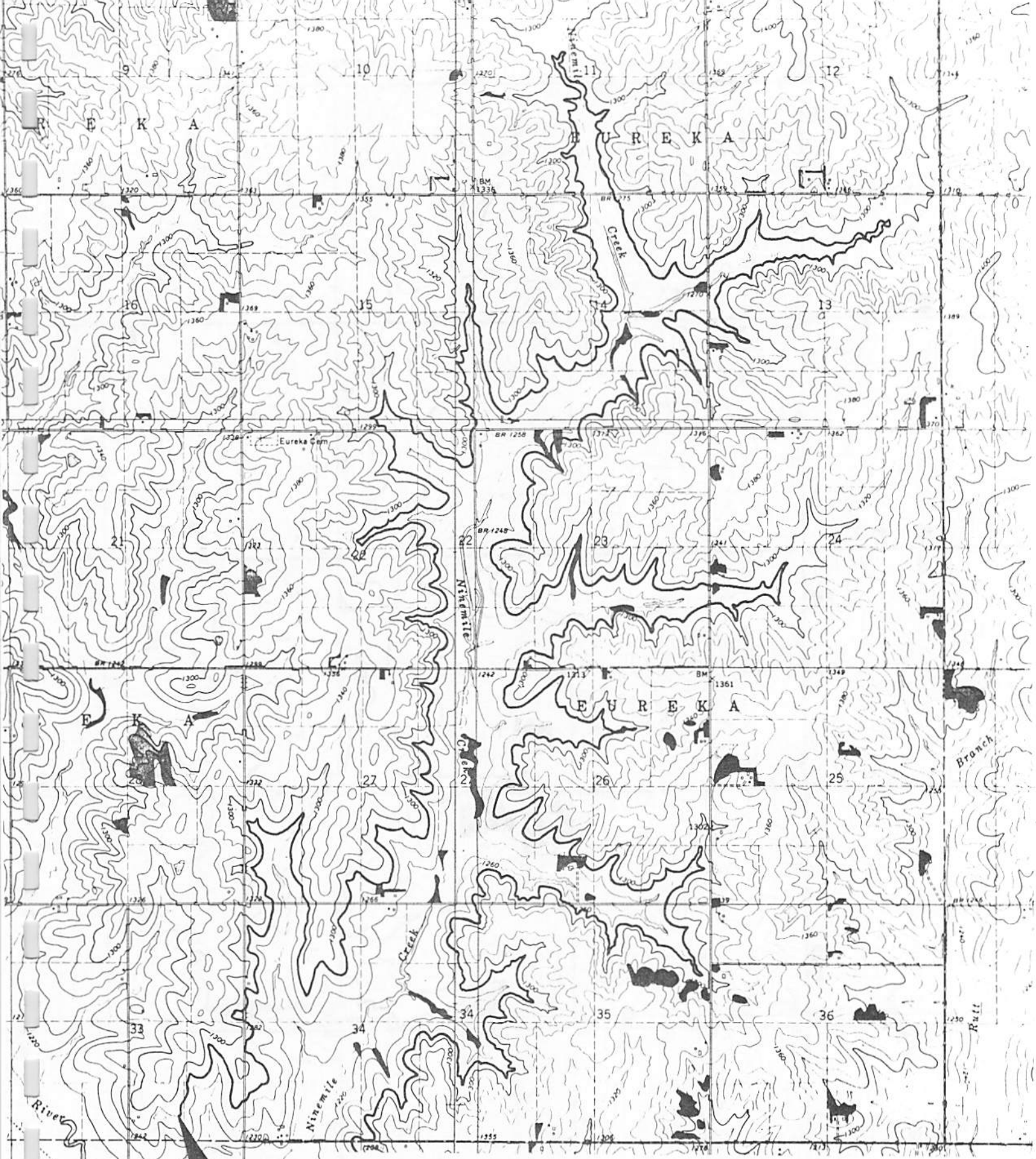
SITE NO.: 15 COUNTY: Adair
LOCATION: SECTION: 33, 34 T 75N, R 30W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.



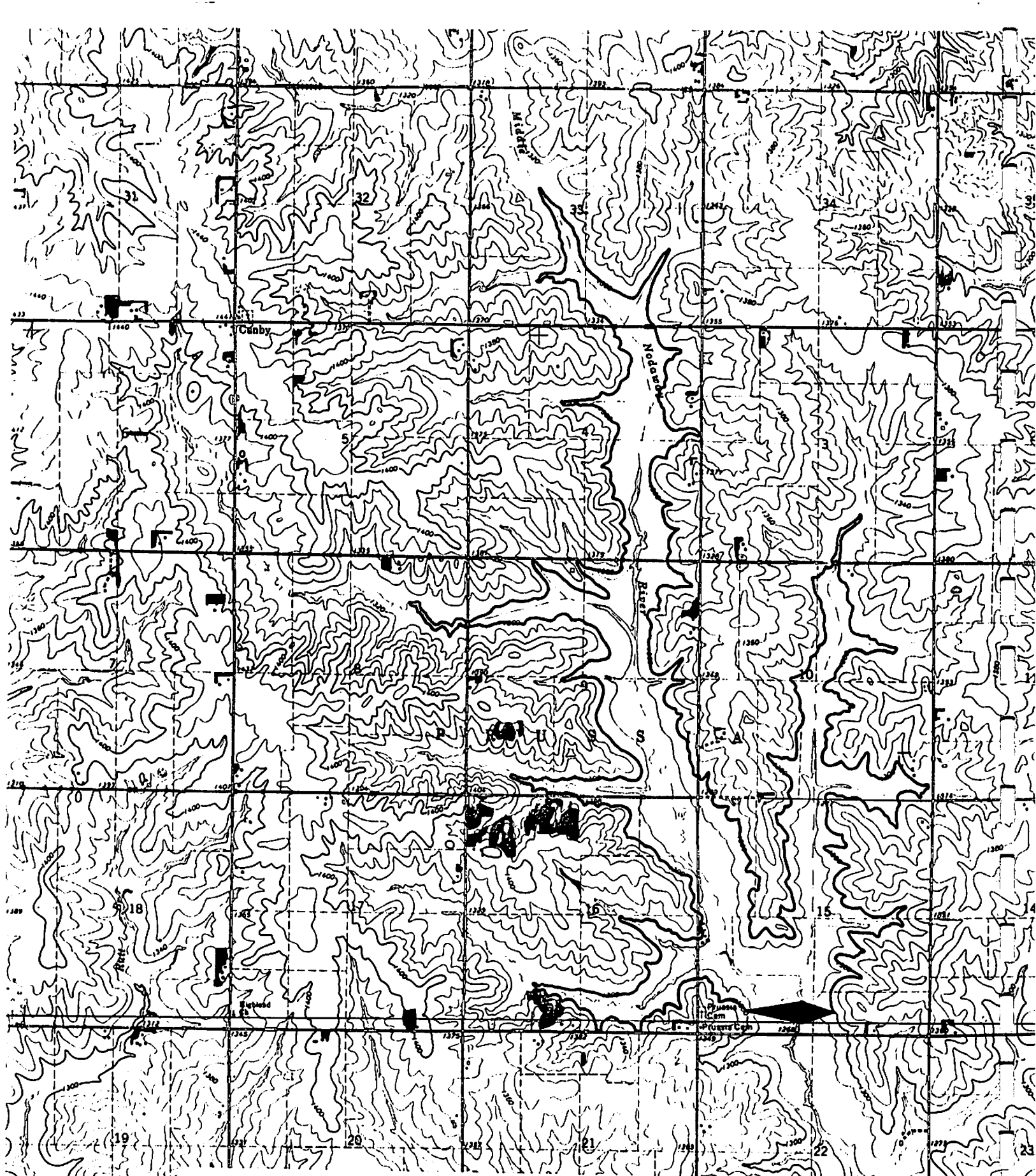
SITE NO.: 16 COUNTY: Adair
LOCATION: SECTION: 6, 13 T 74, 73N, R 33W
QUADRANGLE: Bridgewater
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



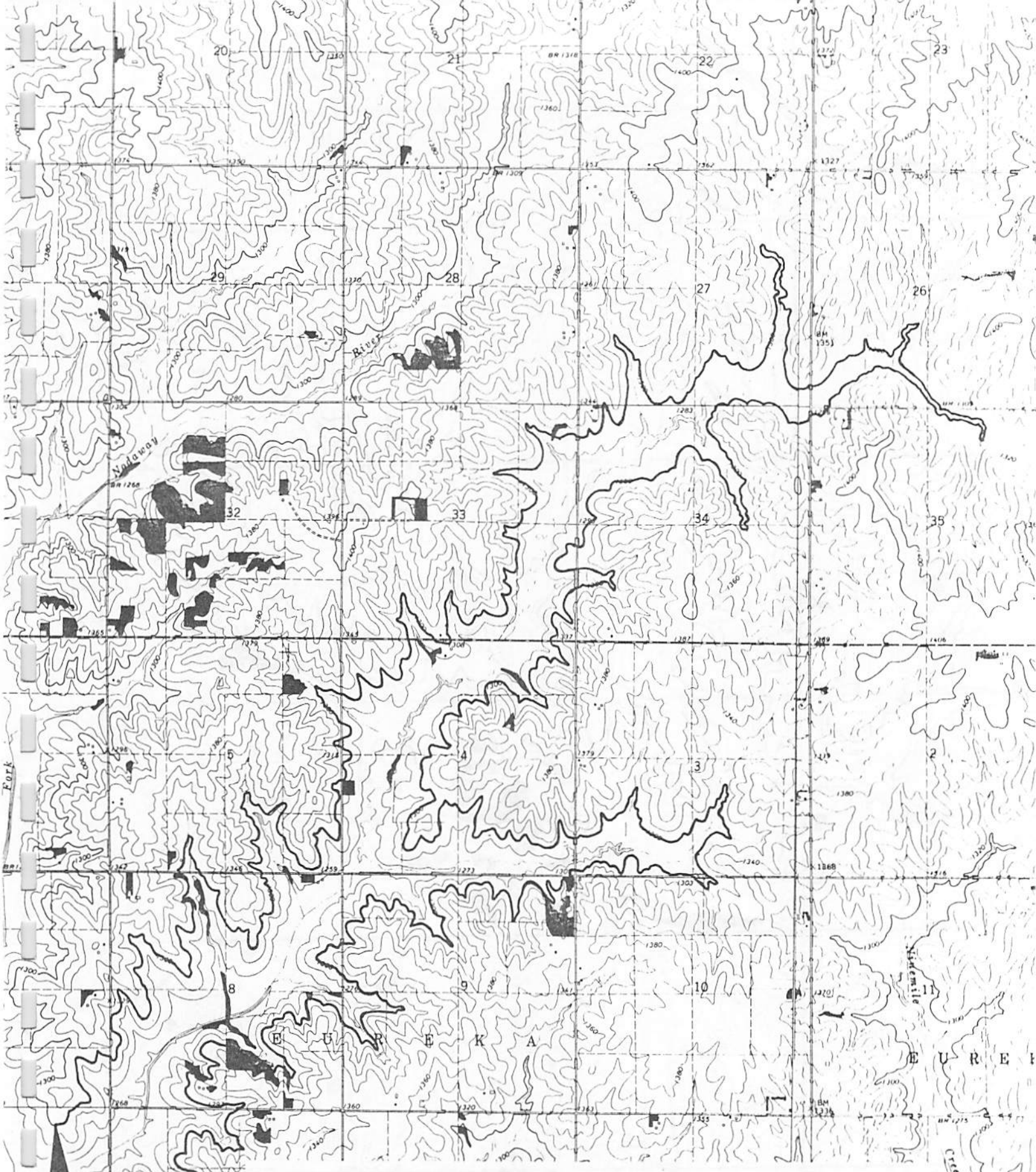
SITE NO.: 17 COUNTY: Adair
LOCATION: SECTION: 6 T 75N, R 32W
QUADRANGLE: Fontanelle
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



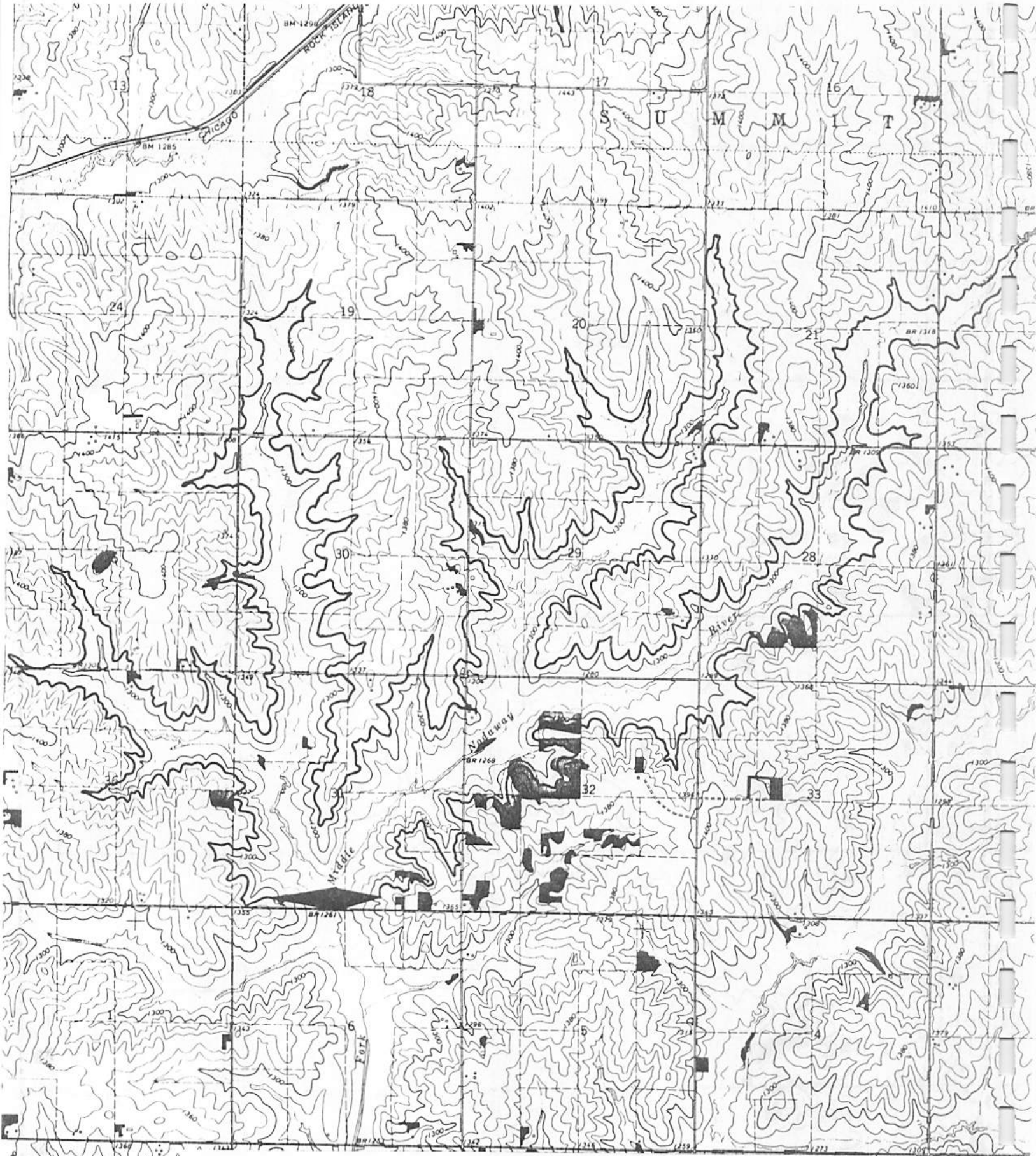
SITE NO.: 18 COUNTY: Adair
LOCATION: SECTION: 4, 33 T 75, 76N, R 33W
QUADRANGLE: Adair South, Canby, Fontanelle SW, Fontanelle
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



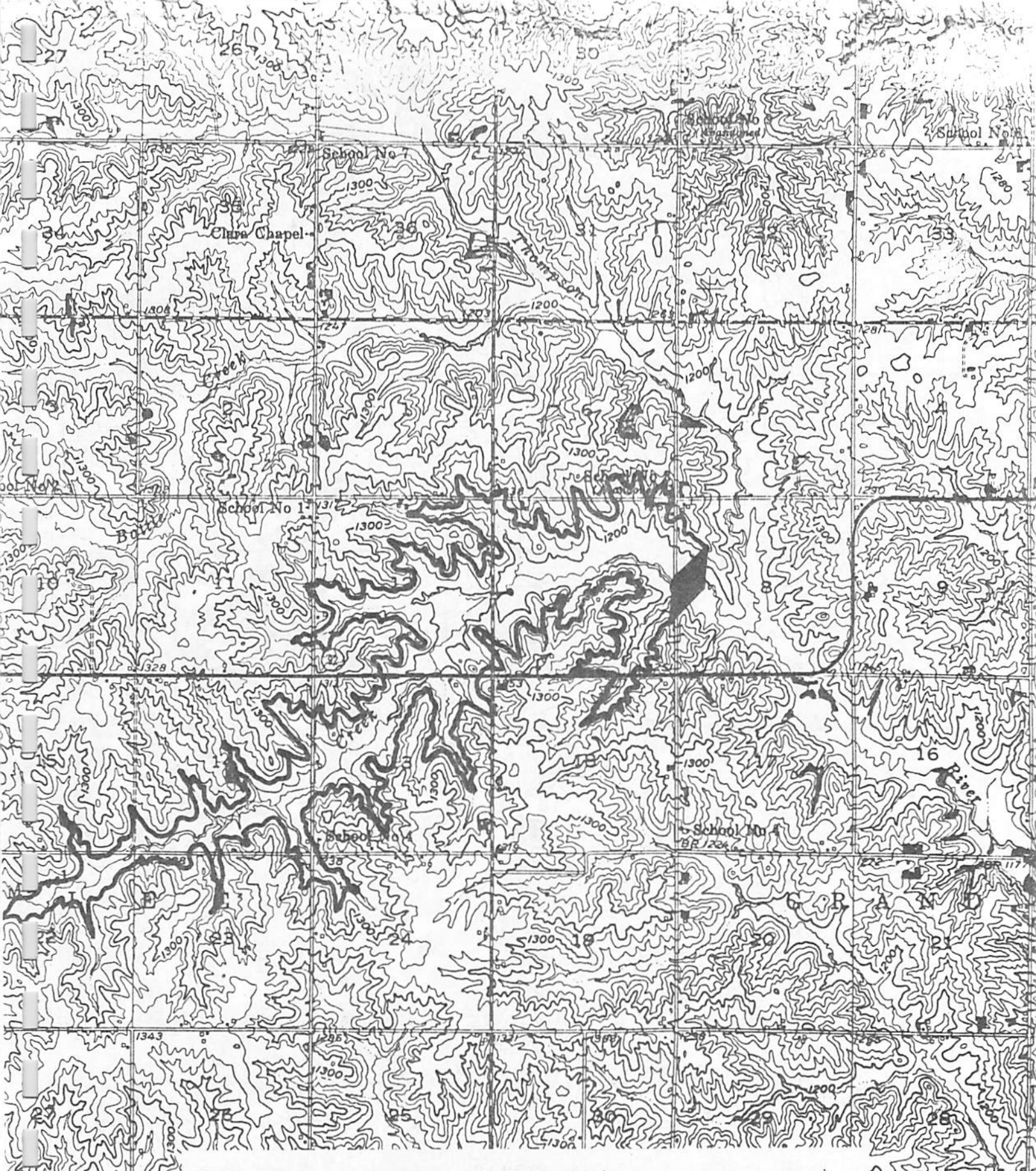
SITE NO.: 19 COUNTY: Adair
LOCATION: SECTION: 15 T 76N, R 32W
QUADRANGLE: Canby, Fontanelle
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



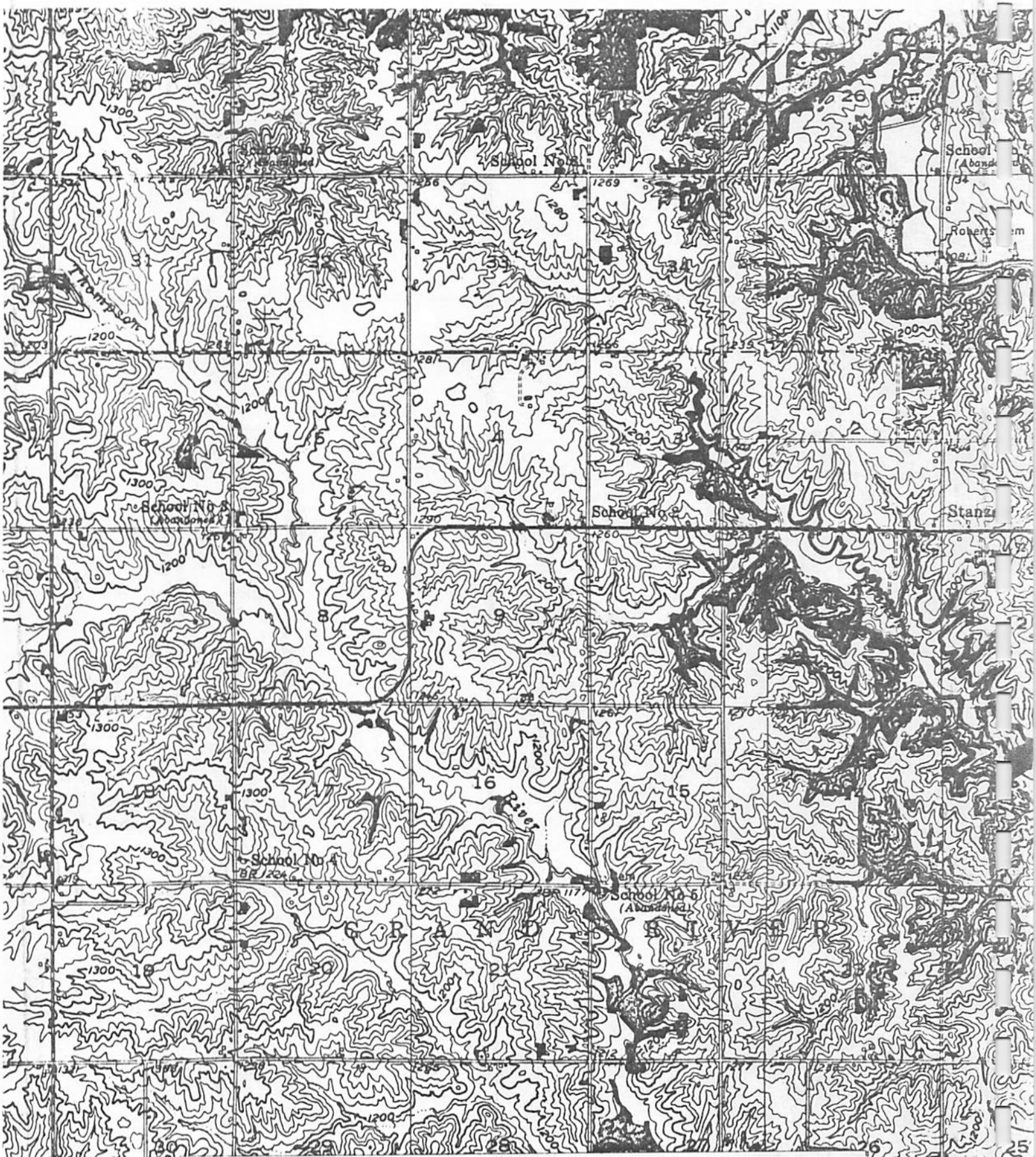
SITE NO.: 20 COUNTY: Adair
LOCATION: SECTION: 18 T 76N, R 33W
QUADRANGLE: Adair South, Canby
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



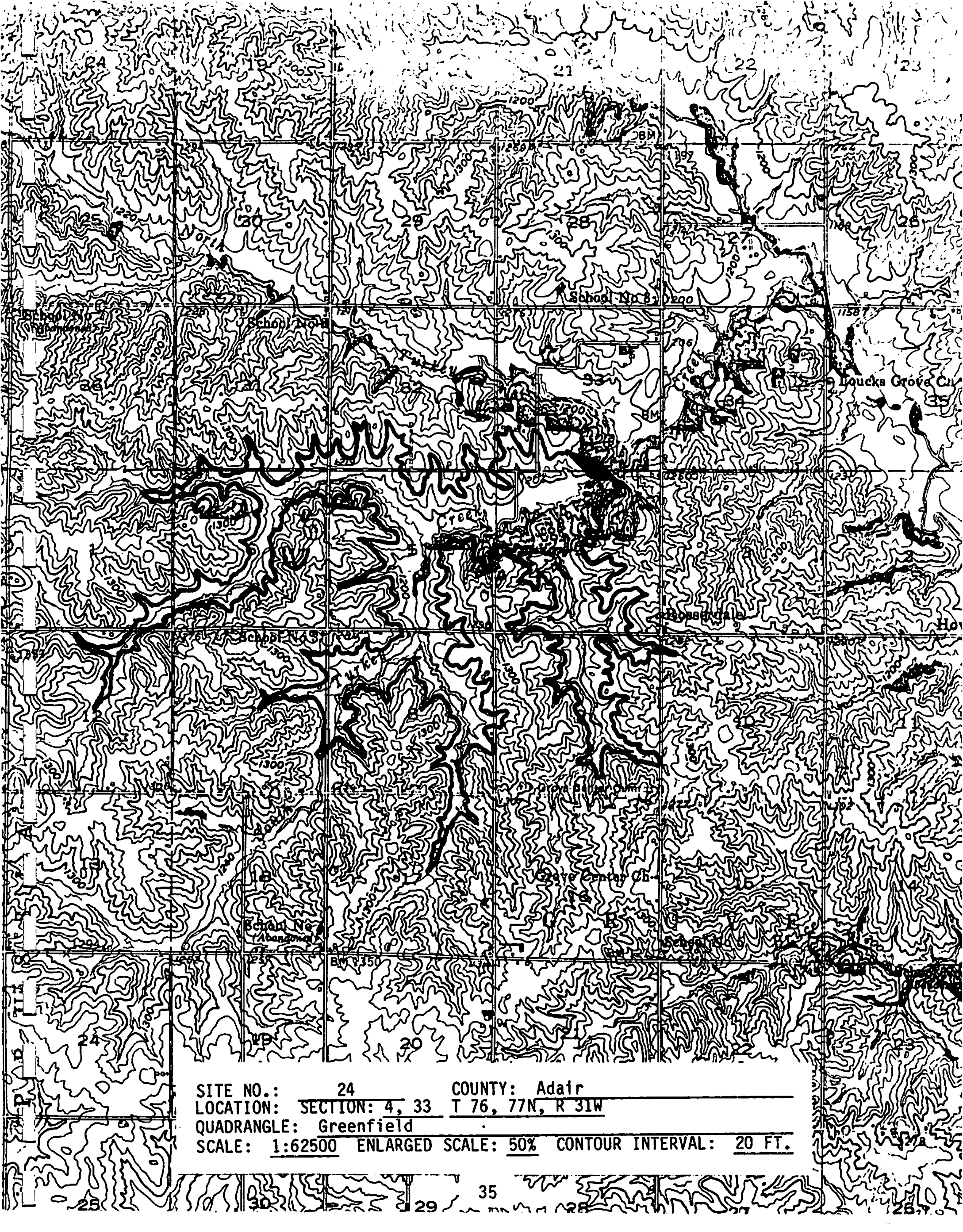
SITE NO.: 21 COUNTY: Adair
LOCATION: SECTION: 31 T 77N, R 33W
QUADRANGLE: Adair South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



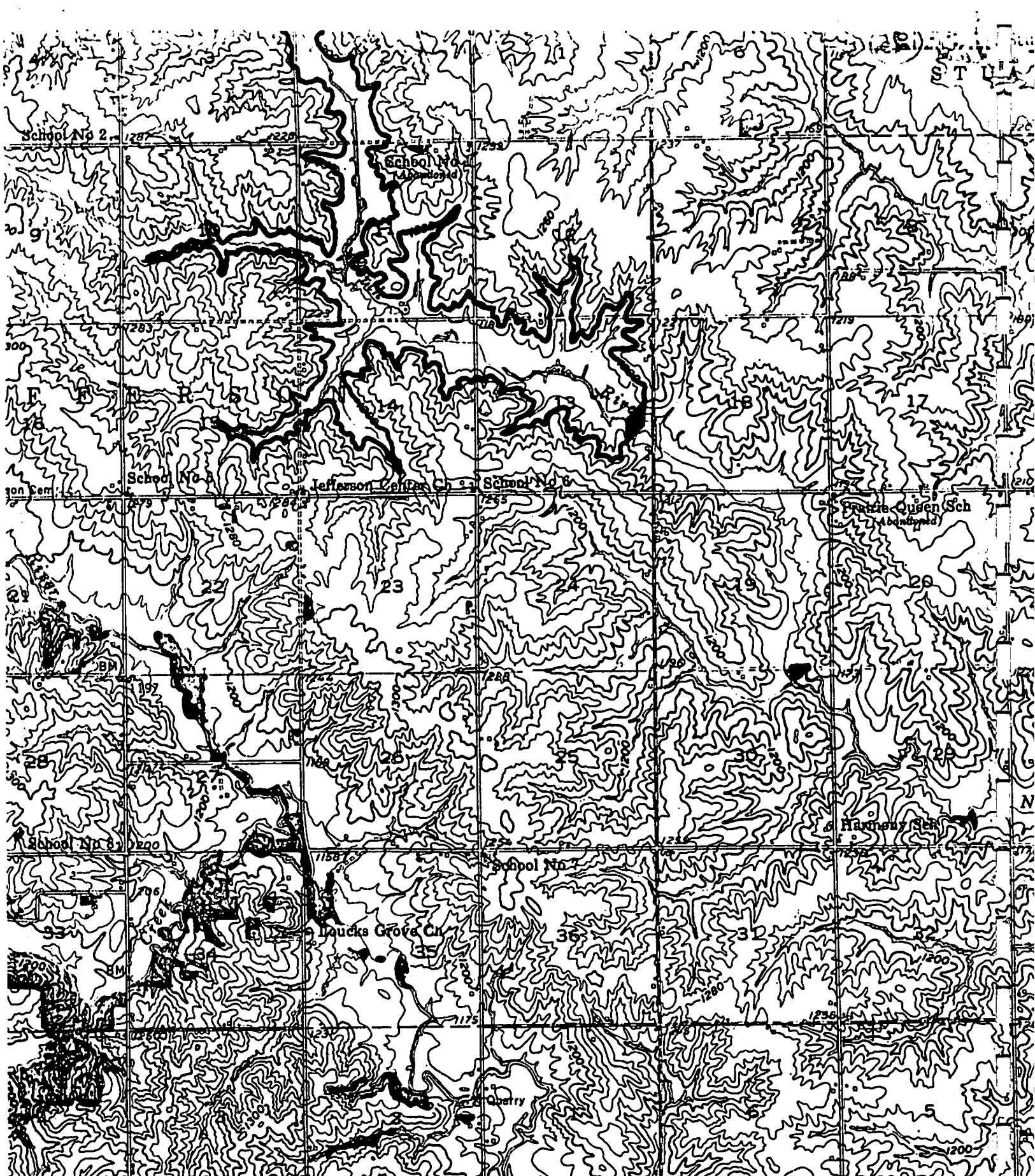
SITE NO.: 22 COUNTY: Adair
LOCATION: SECTION: 7, 8 T 75N, R 30W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.



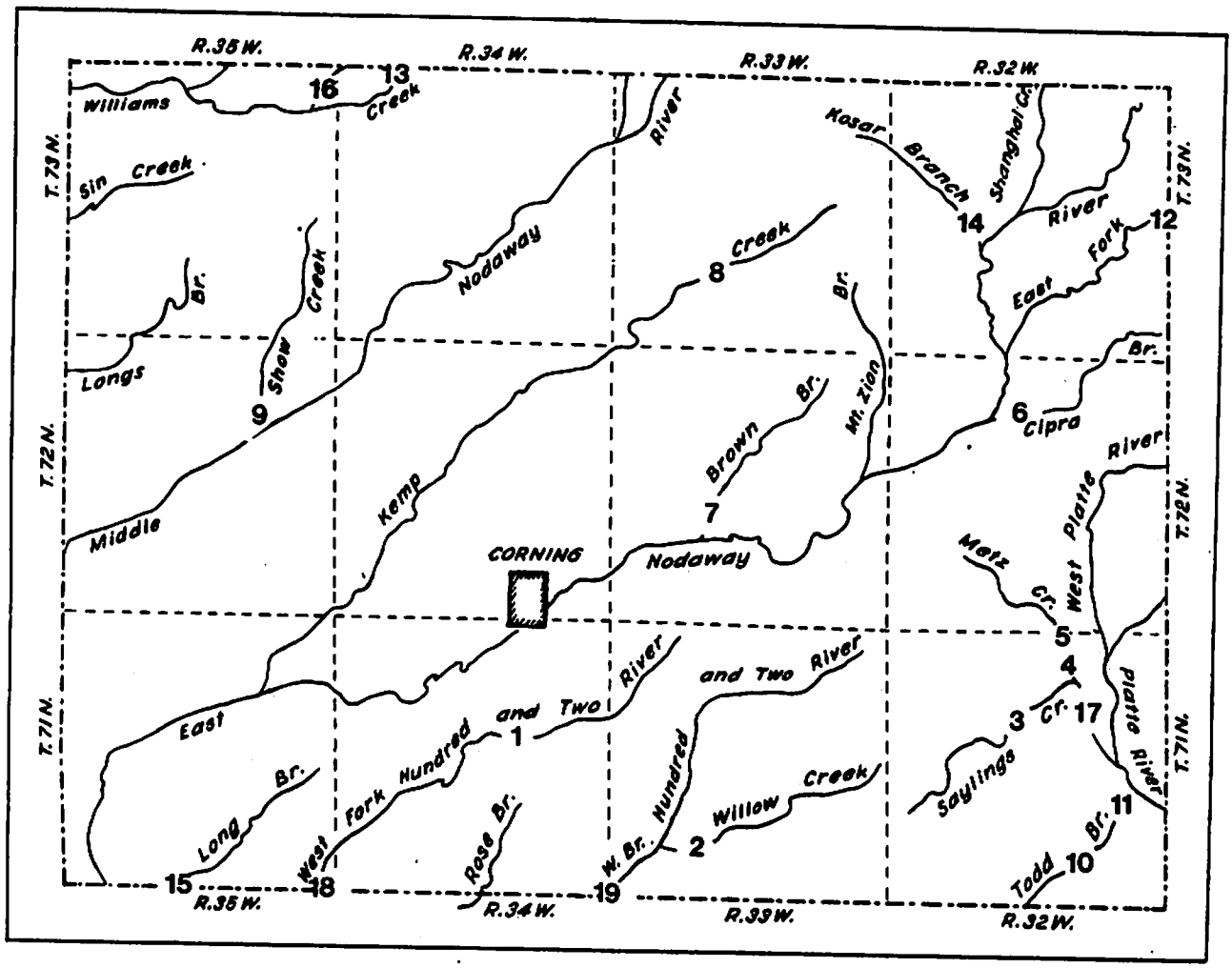
SITE NO.: 23 COUNTY: Adair
LOCATION: SECTION: 13 T 75N, R 30W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.



SITE NO.: 24 COUNTY: Adair
LOCATION: SECTION: 4, 33 T 76, 77N, R 31W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.



SITE NO.: 25 COUNTY: Adair
LOCATION: SECTION: 13 T 77N, R 31W
QUADRANGLE: Greenfield
SCALE: 1:62500 ENLARGED SCALE: 50% CONTOUR INTERVAL: 20 FT.

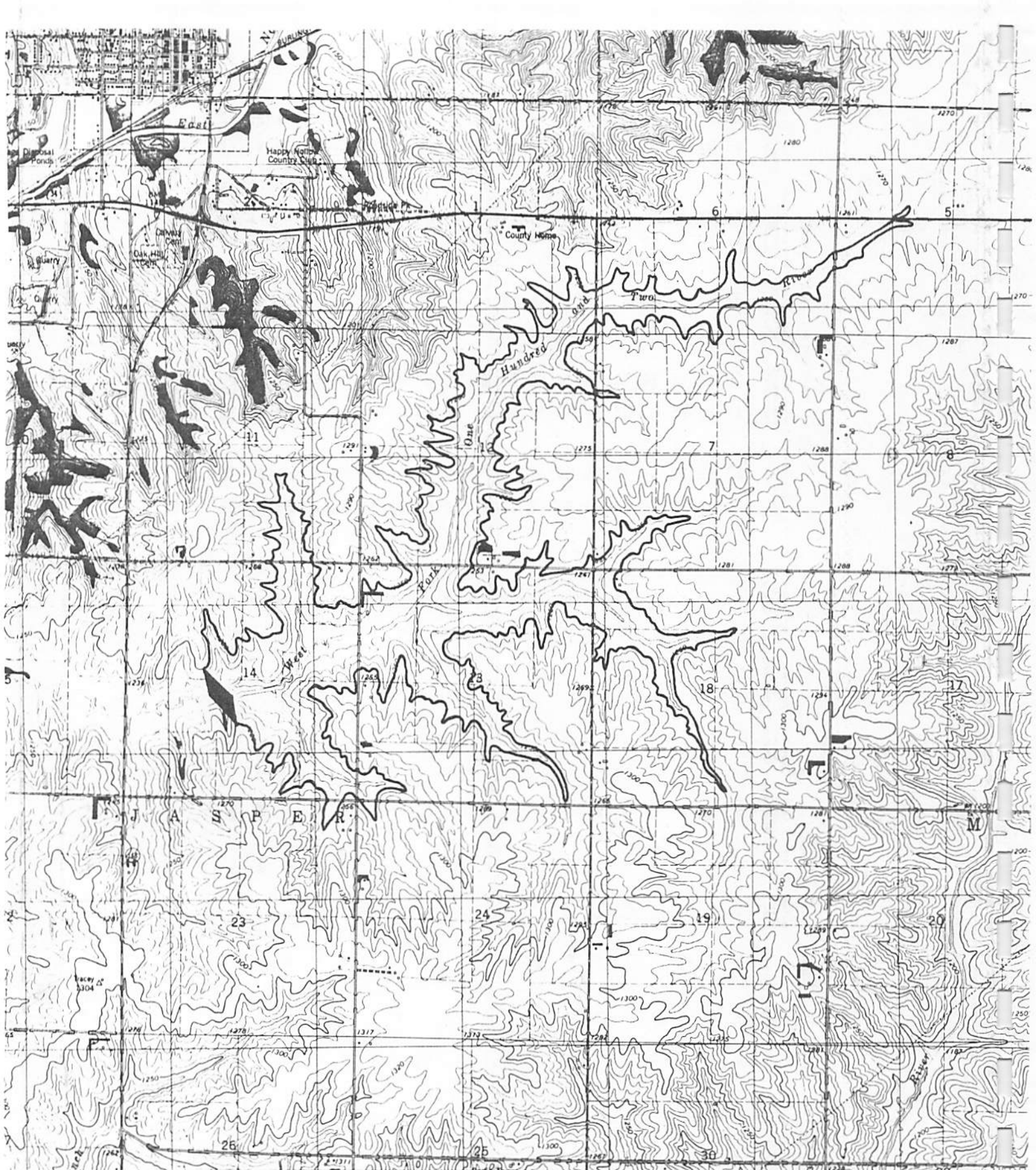


Index map for impoundment sites in Adams County.

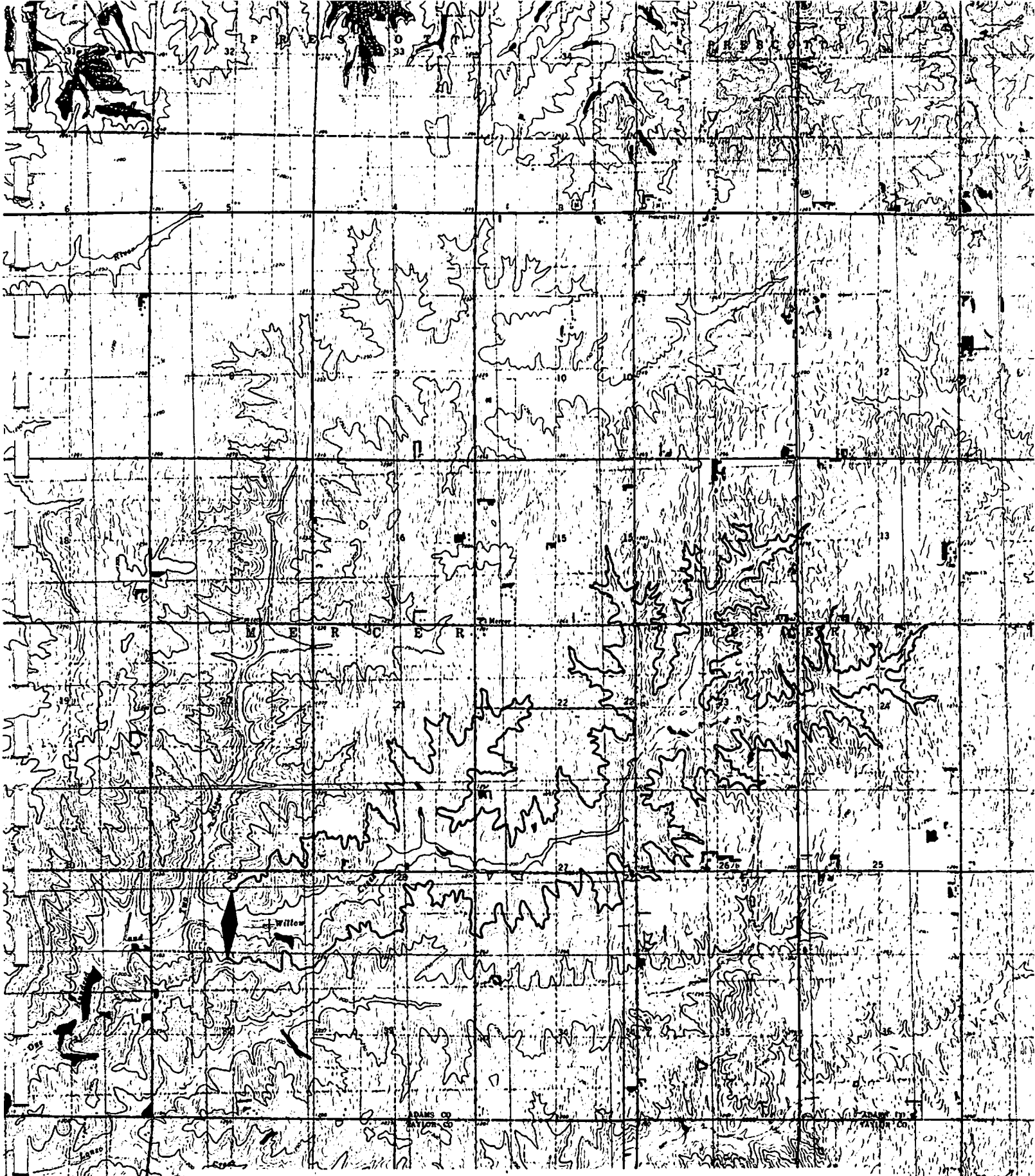
ADAMS COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS			Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	SCALED DRAFT RATE/STORAGE REQUIREMENTS							
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)				Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	14	71	34	8.91	35	499	5821	5	1	10	350	350	286	715	55	91	27	46	664	1111
										20	973	973	286	715	108	145	54	72	1313	1761
2	29, 32	71	33	8.93	55	1015	18611	5	1	10	349	349	287	717	35	58	17	29	653	1095
										20	972	972	287	717	69	92	34	46	1293	1735
3	16	71	32	10.50	45	993	14896	5	1	10	329	329	329	823	44	77	22	38	680	1190
										20	896	896	329	823	82	115	41	57	1266	1776
4	3, 10	71	32	6.47	35	186	2170	5	1	10	385	385	218	544	52	80	26	40	629	969
										20	1105	1105	218	544	113	141	57	71	1379	1719
5	3	71	32	6.40	45	606	9096	5	1	10	386	386	216	539	40	62	20	31	621	955
										20	1109	1109	216	539	88	110	44	55	1358	1702
6	9	72	32	8.78	45	601	9019	5	1	10	352	352	283	706	42	71	21	35	656	1094
										20	980	980	283	706	84	112	42	56	1304	1318
7	21	72	33	10.10	40	410	5470	5	1	10	334	334	319	796	49	85	25	42	677	1173
										20	915	915	319	796	93	128	46	64	1279	1775
8	21, 28	73	33	11.50	40	756	10077	5	1	10	317	317	356	890	50	91	25	45	698	1252
										20	850	850	356	890	91	131	45	65	1252	1806
9	2	72	35	10.80	60	590	11792	5	1	10	325	325	337	843	33	58	17	29	679	1199
										20	882	882	337	843	61	86	31	43	1250	1768
10	26, 27	71	32	8.56	45	769	11527	5	1	10	355	355	277	691	42	70	21	35	652	1081
										20	991	991	277	691	85	112	42	56	1310	1738
11	23, 24, 25	71	32	11.60	45	846	12692	5	1	10	315	315	359	897	45	81	23	40	696	1252
										20	846	846	359	897	80	116	40	58	1245	1801
12	13, 24	73	32	12.90	35	871	10165	5	1	10	299	299	393	982	59	110	30	55	722	1336
										20	791	791	393	982	101	152	51	76	1234	1849
13	5	73	34	9.12	40	570	7597	5	1	10	347	347	292	730	48	81	24	40	663	1117
										20	962	962	292	730	94	127	47	64	1301	1756
14	17, 20	73	32	9.97	40	1053	14044	5	1	10	336	336	315	788	49	84	24	42	675	1166
										20	921	921	315	788	93	128	46	64	1282	1772
15	33	71	35	7.03	55	387	7103	5	1	10	350	350	286	715	55	91	27	46	664	1111
										20	973	973	286	715	108	145	54	72	1313	1761
16	1	73	35	18.50	60	533	10663	12	2	10	783	783	535	1337	66	106	33	53	1351	2173
										20	1074	1074	535	1337	81	121	40	60	1439	2471
17	10, 11	71	32	21.10	35	745	8696	12	2	10	730	730	599	1496	114	191	57	95	1386	2322
										20	994	994	599	1496	137	213	68	107	1660	2594
18	30	71	34	17.90	45	958	14364	12	2	10	796	796	520	1300	88	140	44	70	1340	2166
										20	1094	1094	520	1300	108	160	54	80	1657	2173
19	31	71	33	24.50	45	1120	16800	12	2	10	666	666	680	1700	90	158	45	79	1391	2145
										20	897	897	680	1700	150	173	75	86	1452	2443

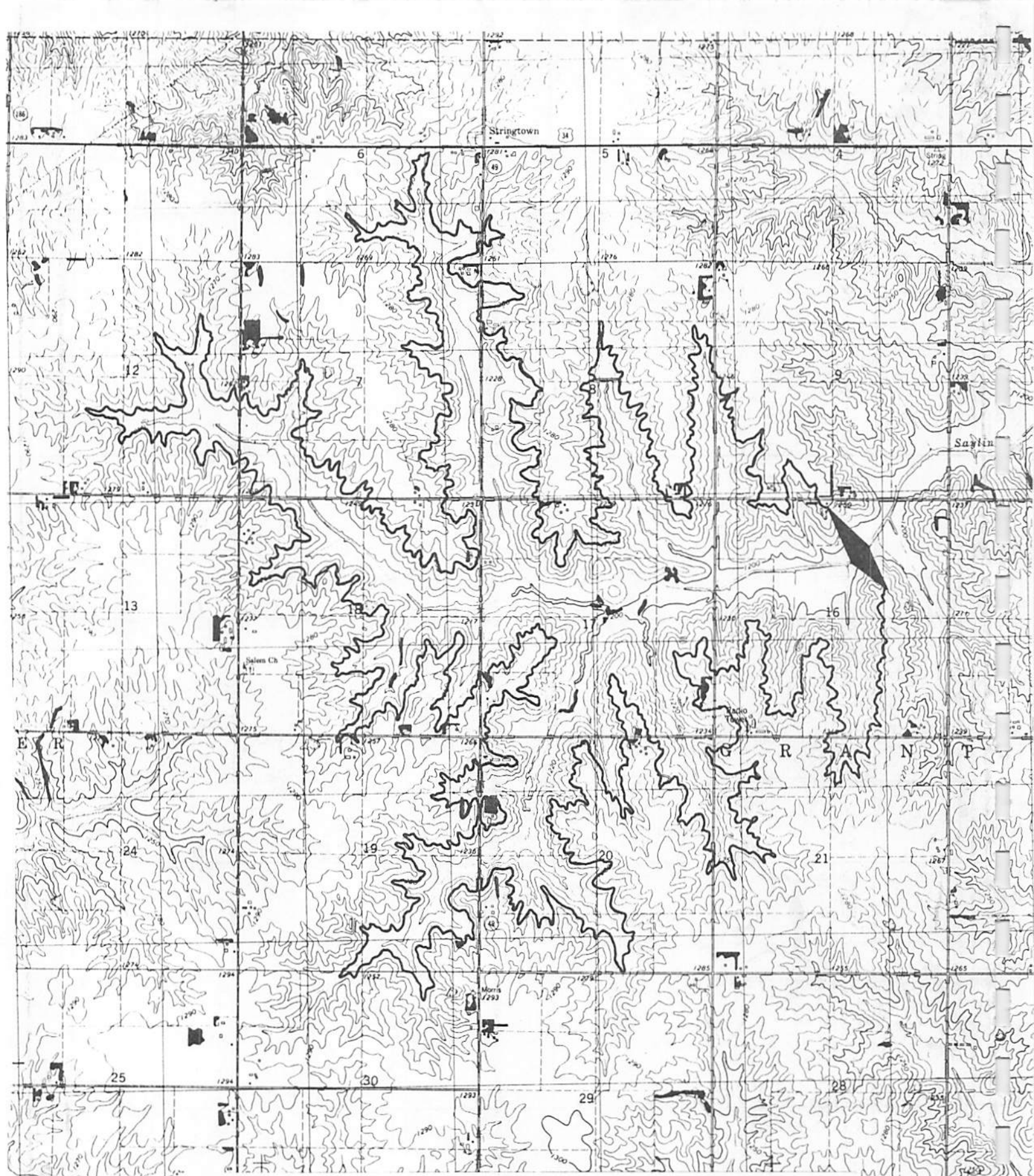
* Column 1 20 year design, Column 2 50 year design periods.



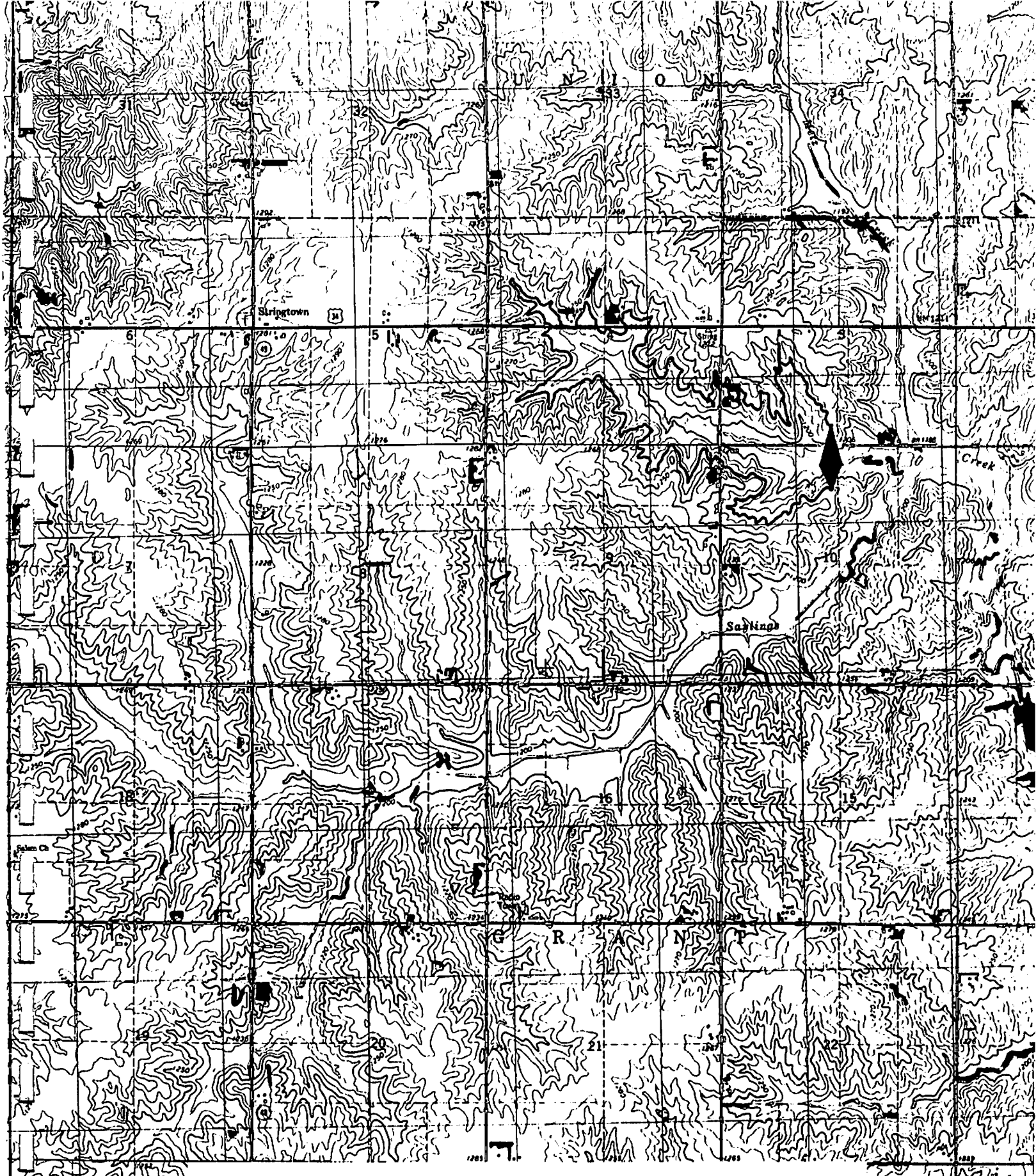
SITE NO.: 1 COUNTY: Adams
LOCATION: SECTION: 14 T 71N, R 34W
QUADRANGLE: Corning South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



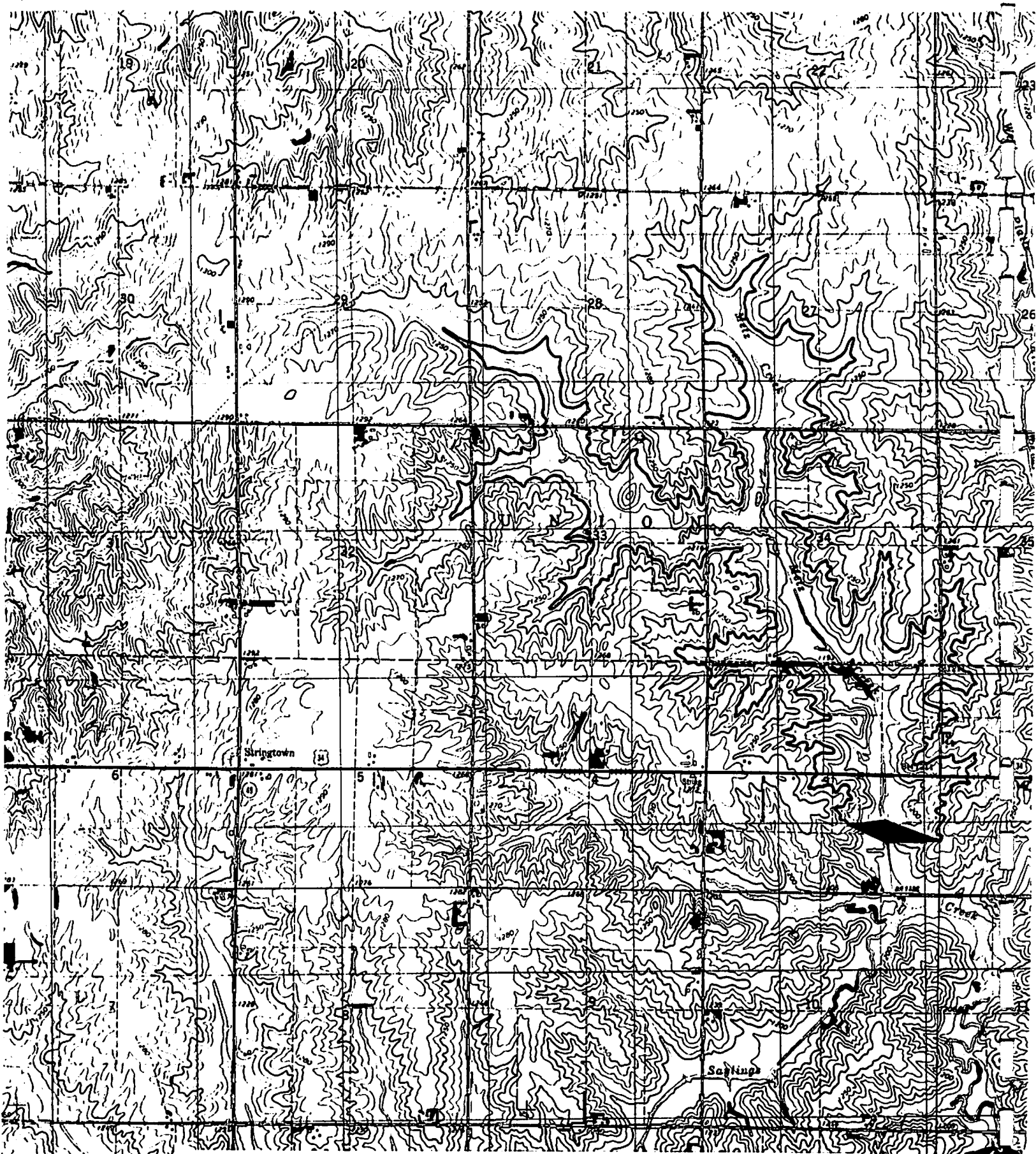
SITE NO.: 2 COUNTY: Adams
LOCATION: SECTION: 29, 32 T 71N, R 33W
QUADRANGLE: Corning South, Lenox
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.



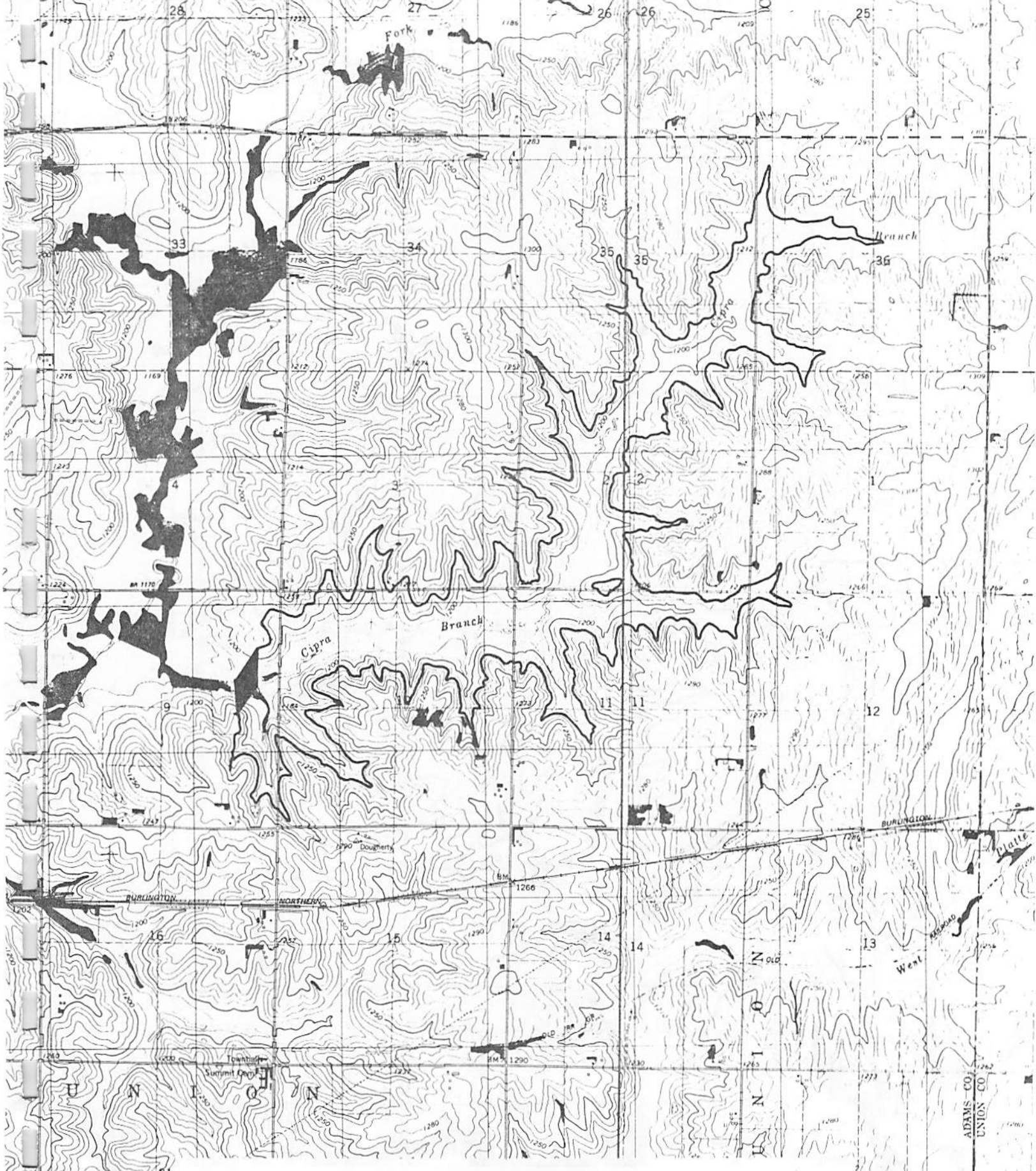
SITE NO.: 3 COUNTY: Adams
LOCATION: SECTION: 16 T 71N, R 32W
QUADRANGLE: Lenox
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



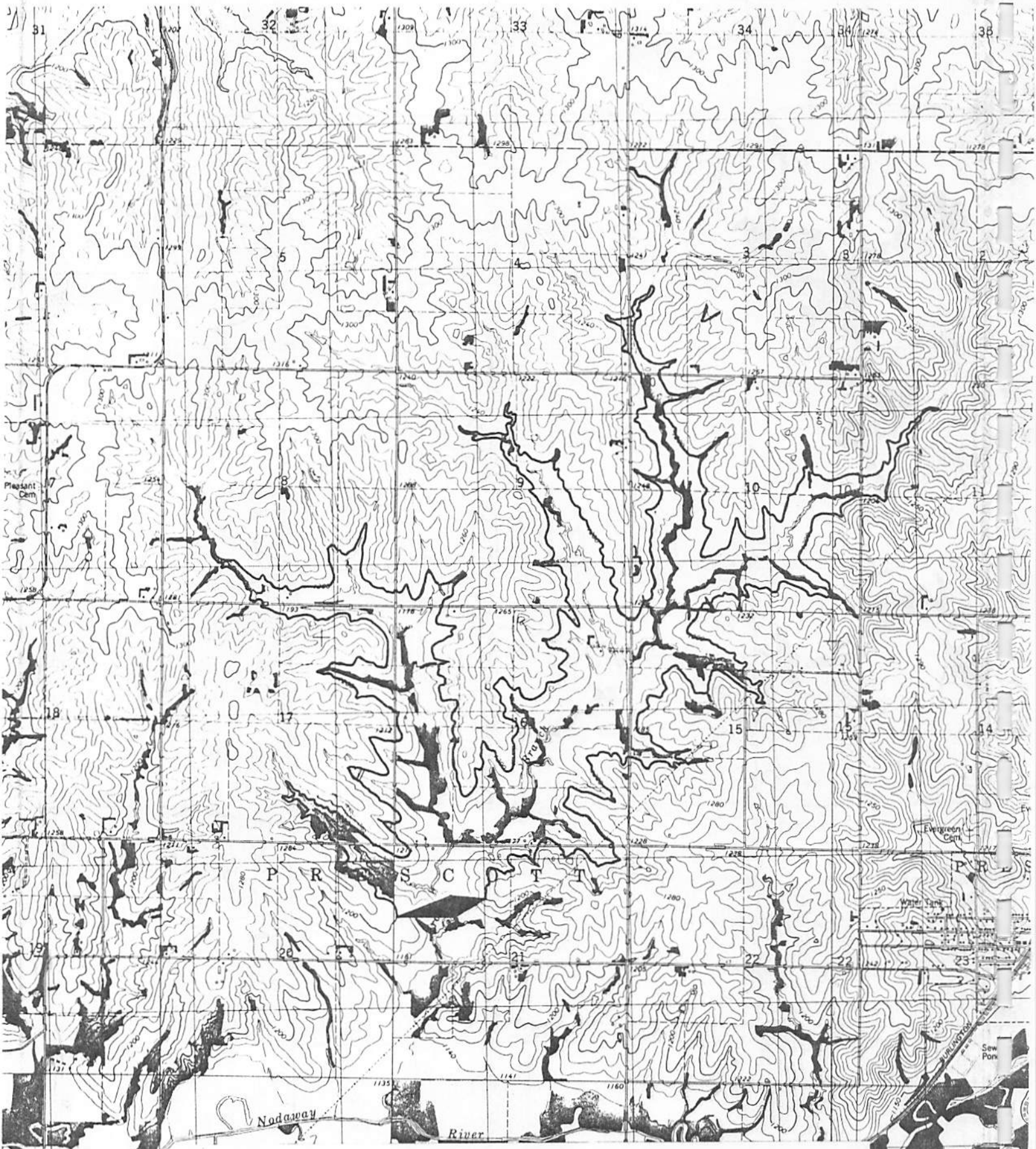
SITE NO.: 4 COUNTY: Adams
LOCATION: SECTION: 3, 10 T 71N, R 32W
QUADRANGLE: Lenox
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 5 COUNTY: Adams
LOCATION: SECTION: 3 T 71N, R 32W
QUADRANGLE: Prescott, Lenox
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



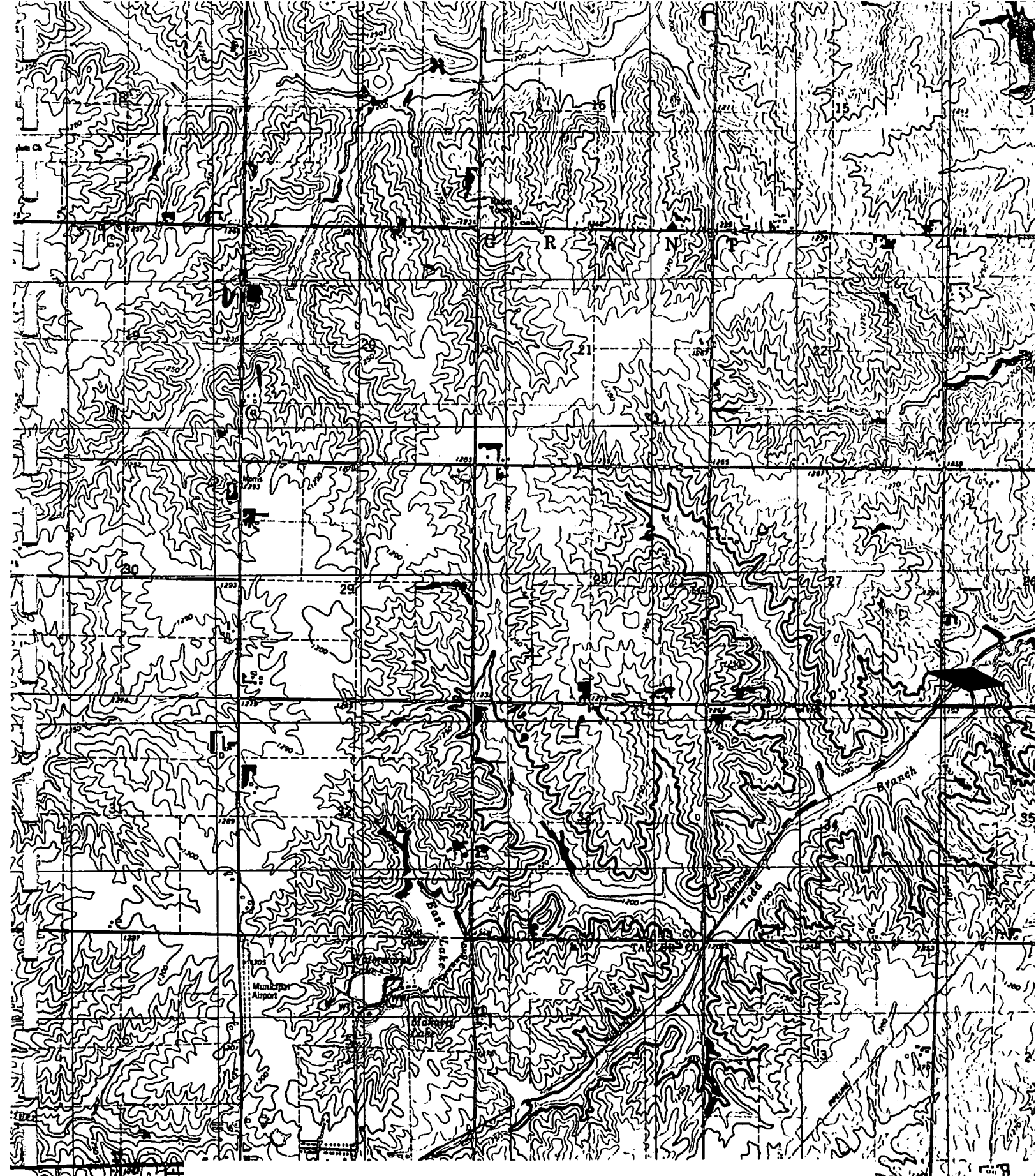
SITE NO.: 6 COUNTY: Adams
LOCATION: SECTION: 9 T 72N, R 32W
QUADRANGLE: Prescott, Creston West
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



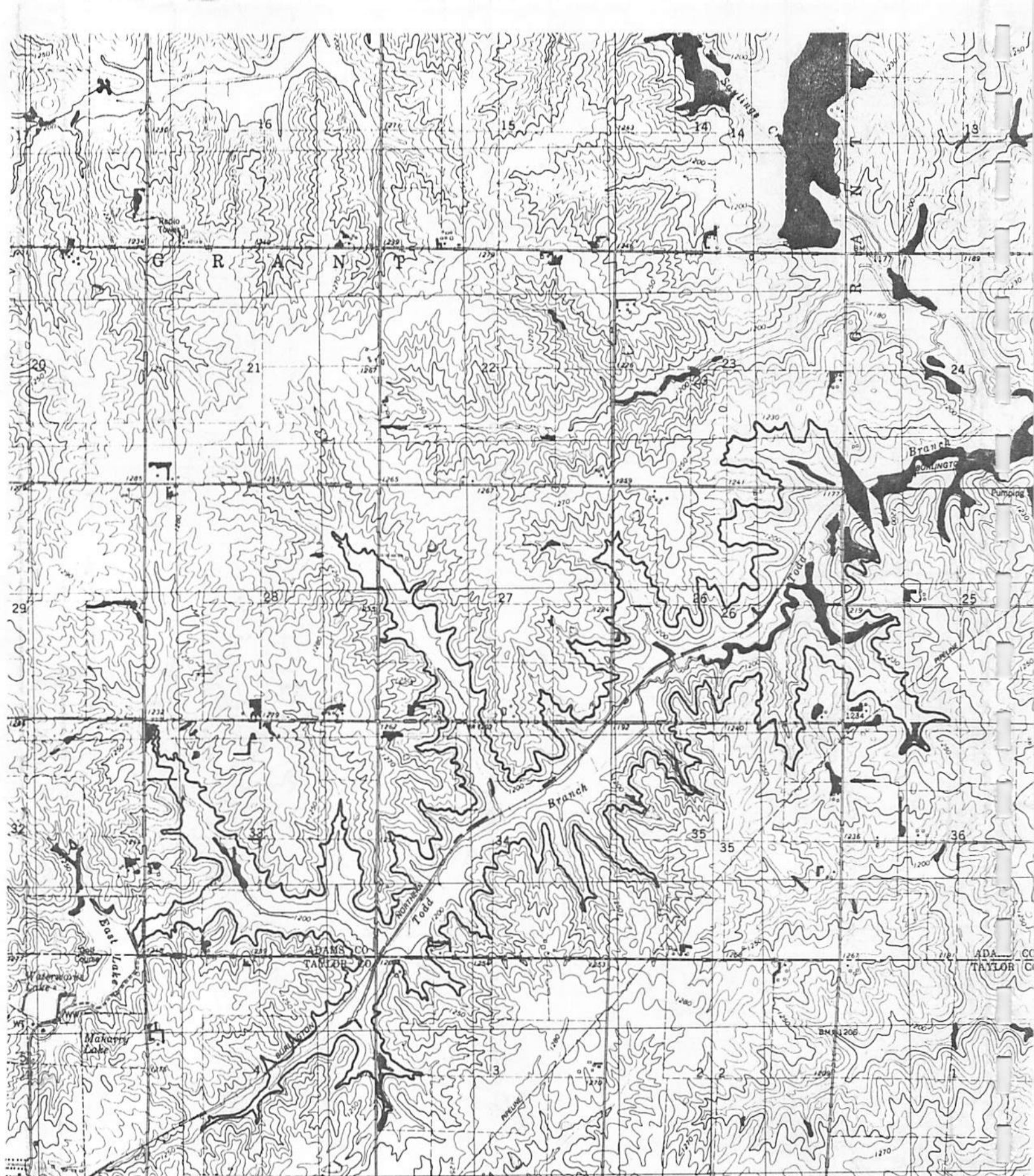
SITE NO.: 7 COUNTY: Adams
LOCATION: SECTION: 21 T 72N, R 33W
QUADRANGLE: Corning North, Prescott
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20, 10 FT.

SITE NO.: 8 COUNTY: Adams
LOCATION: SECTION: 21, 28 T 73N, R 33W
QUADRANGLE: Bridgewater, Nevinville, Corning North, Prescott
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20, 10 FT.

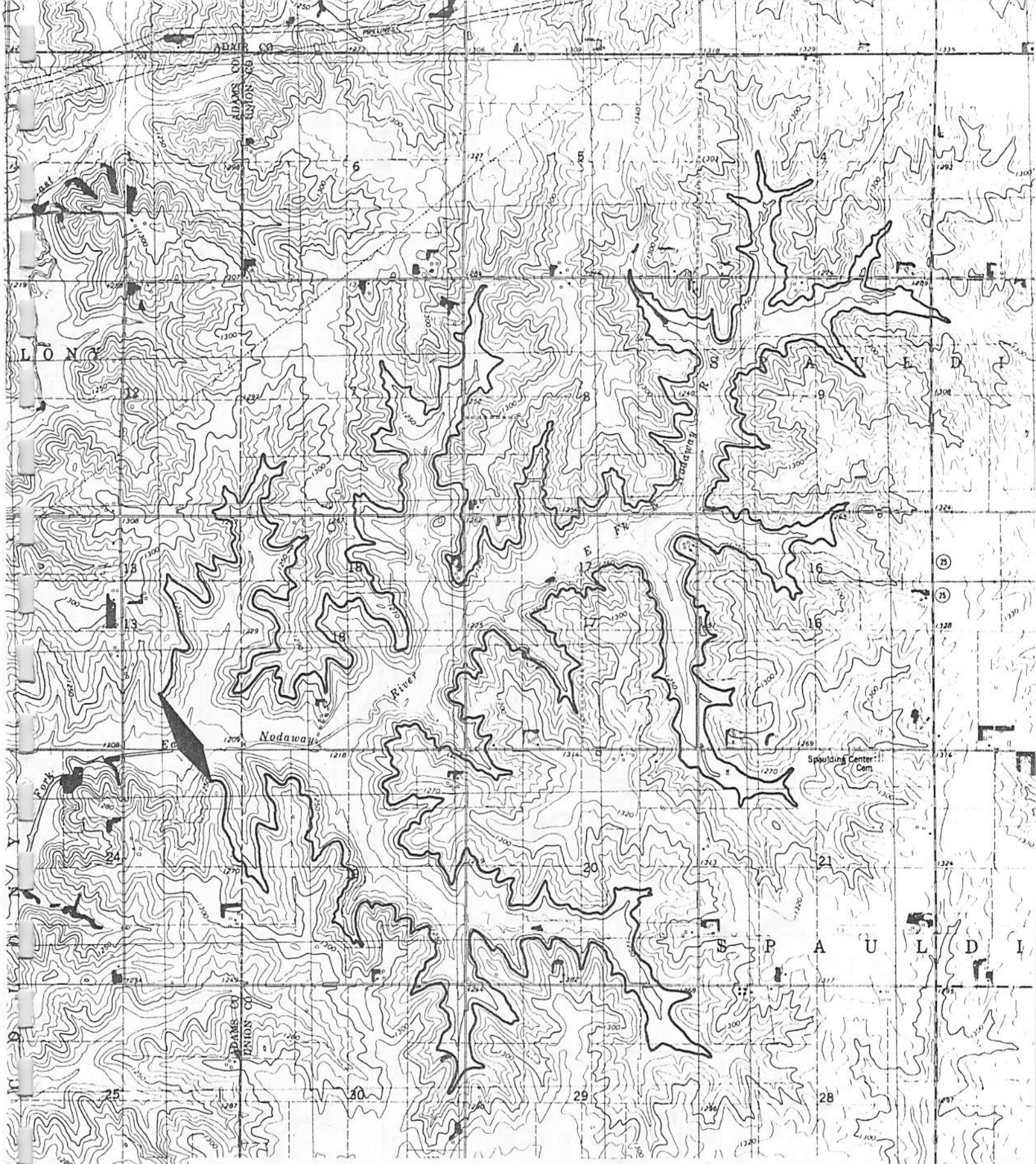
SITE NO.: 9 COUNTY: Adams
LOCATION: SECTION: 2 T 72N, R 35W
QUADRANGLE: Carbon
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



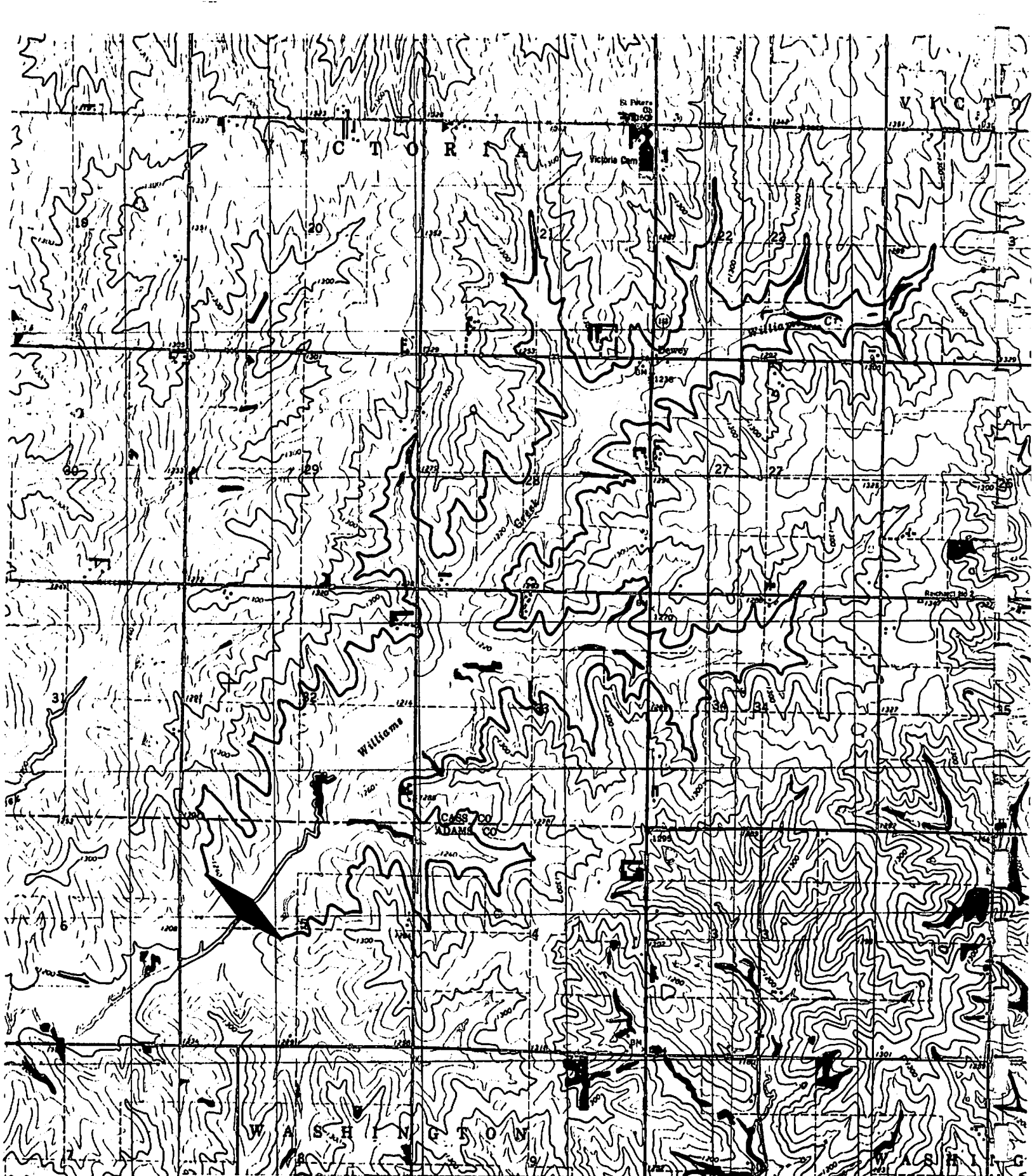
SITE NO.: 10 COUNTY: Adams
LOCATION: SECTION: 26, 27 T 71N, R 32W
QUADRANGLE: Lenox
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



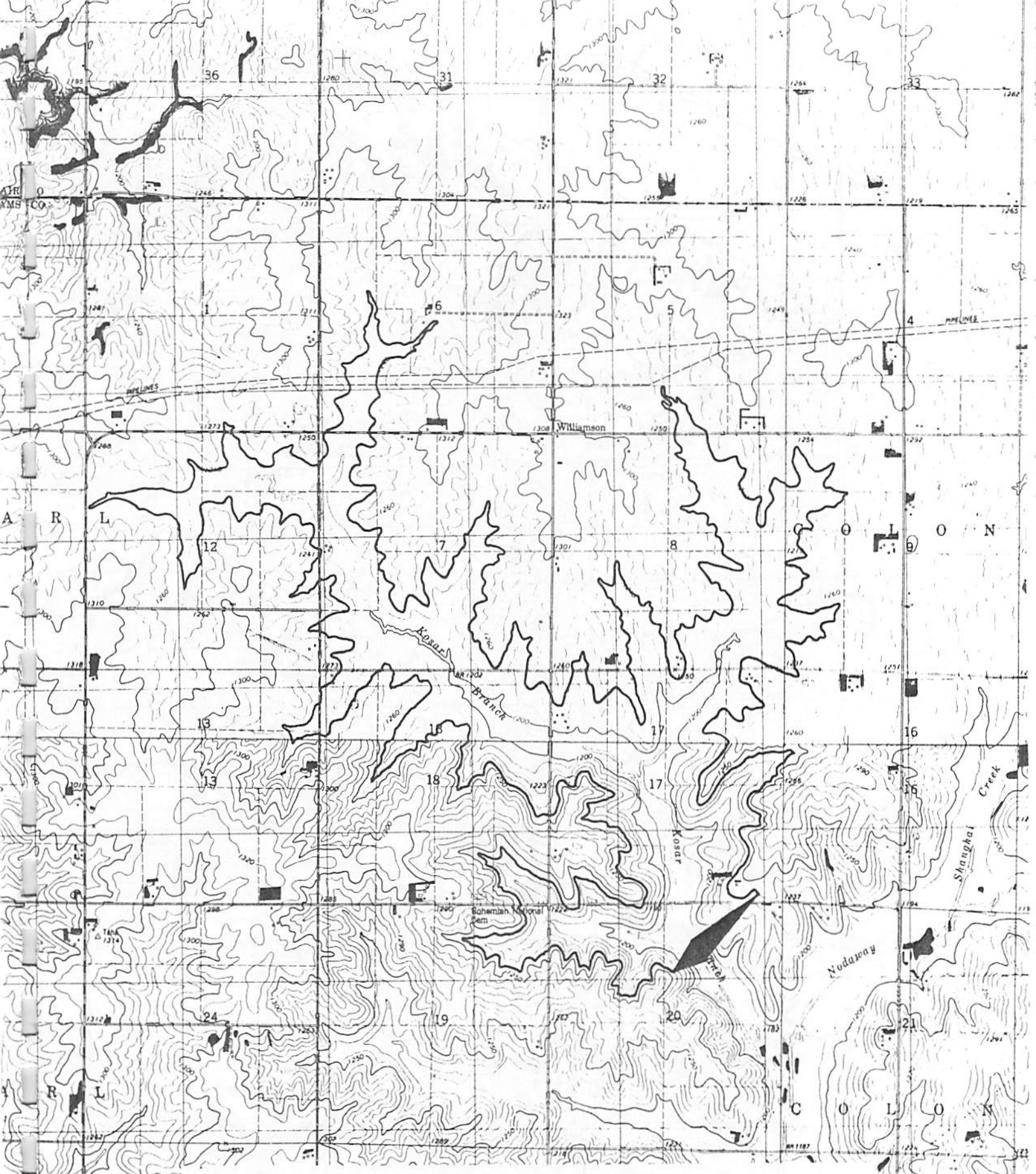
SITE NO.: 11 COUNTY: Adams
LOCATION: SECTION: 23, 24, 25 T 71N, R 32W
QUADRANGLE: Lenox, Kent
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



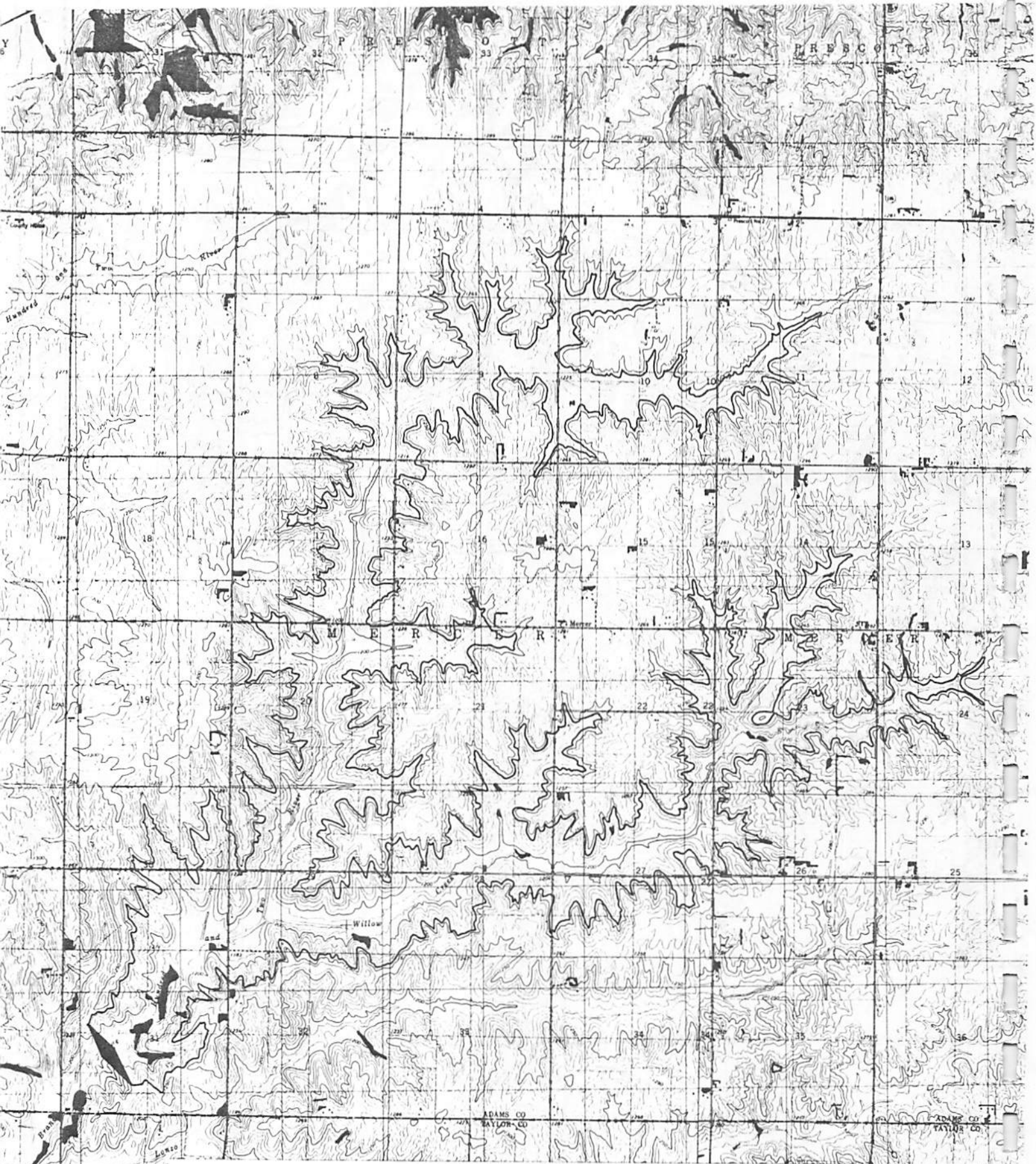
SITE NO.: 12 COUNTY: Adams
LOCATION: SECTION: 13, 24 T 73N, R 32W
QUADRANGLE: Orient, Creston West
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



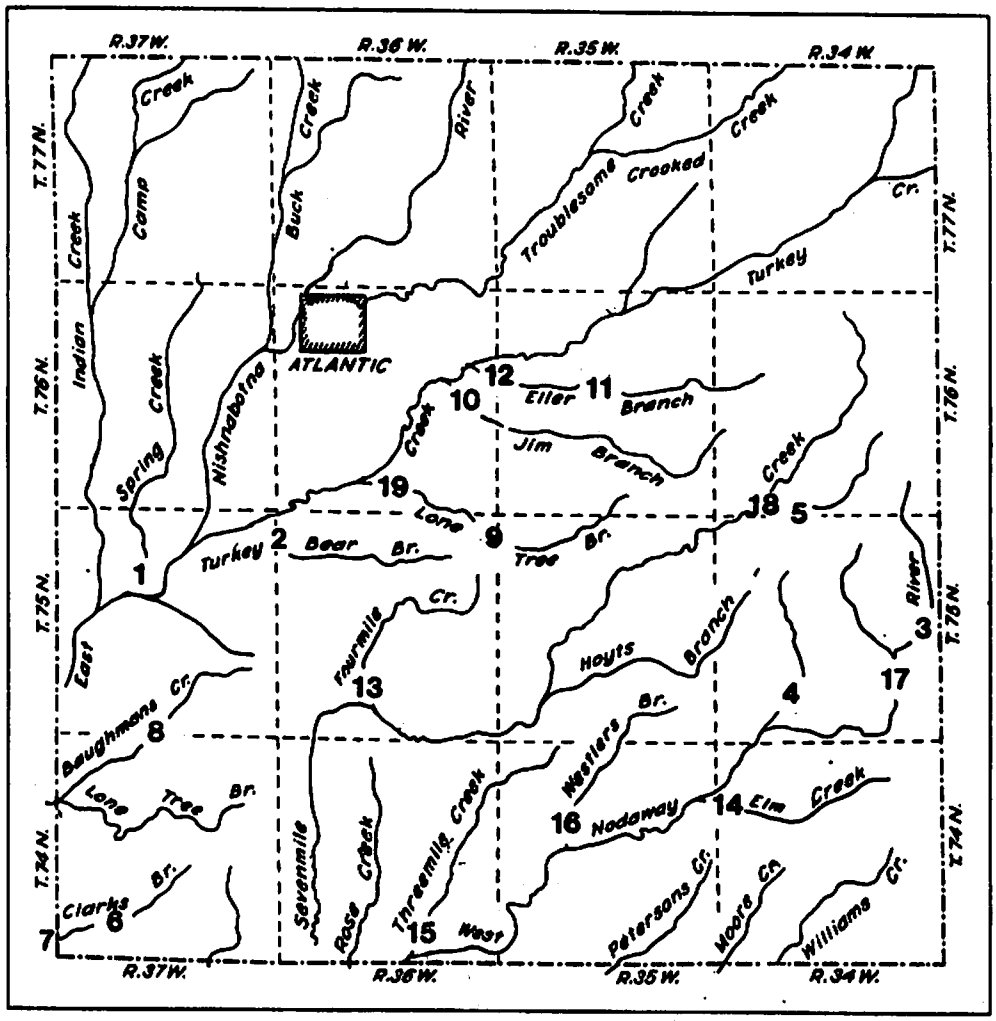
SITE NO.: 13 COUNTY: Adams
LOCATION: SECTION: 5 T 73N, R 34W
QUADRANGLE: Dewey, Bridgewater
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 14 COUNTY: Adams
LOCATION: SECTION: 17, 20 T 73N, R 32W
QUADRANGLE: Nevinville, Prescott
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 19 COUNTY: Adams
LOCATION: SECTION: 31 T 71N, R 33W
QUADRANGLE: Corning South, Lenox
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.

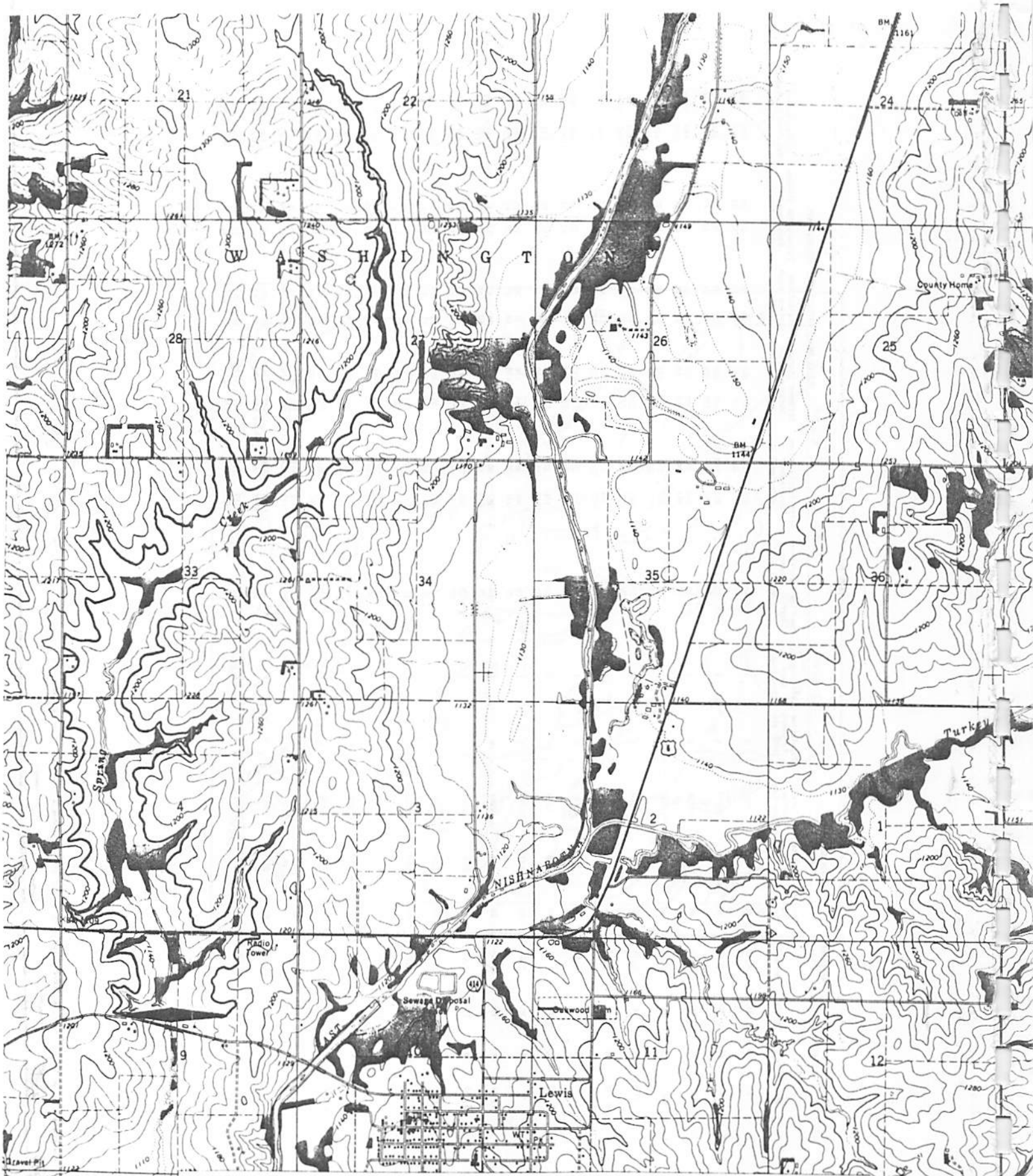


Index map for impoundment sites in Cass County.

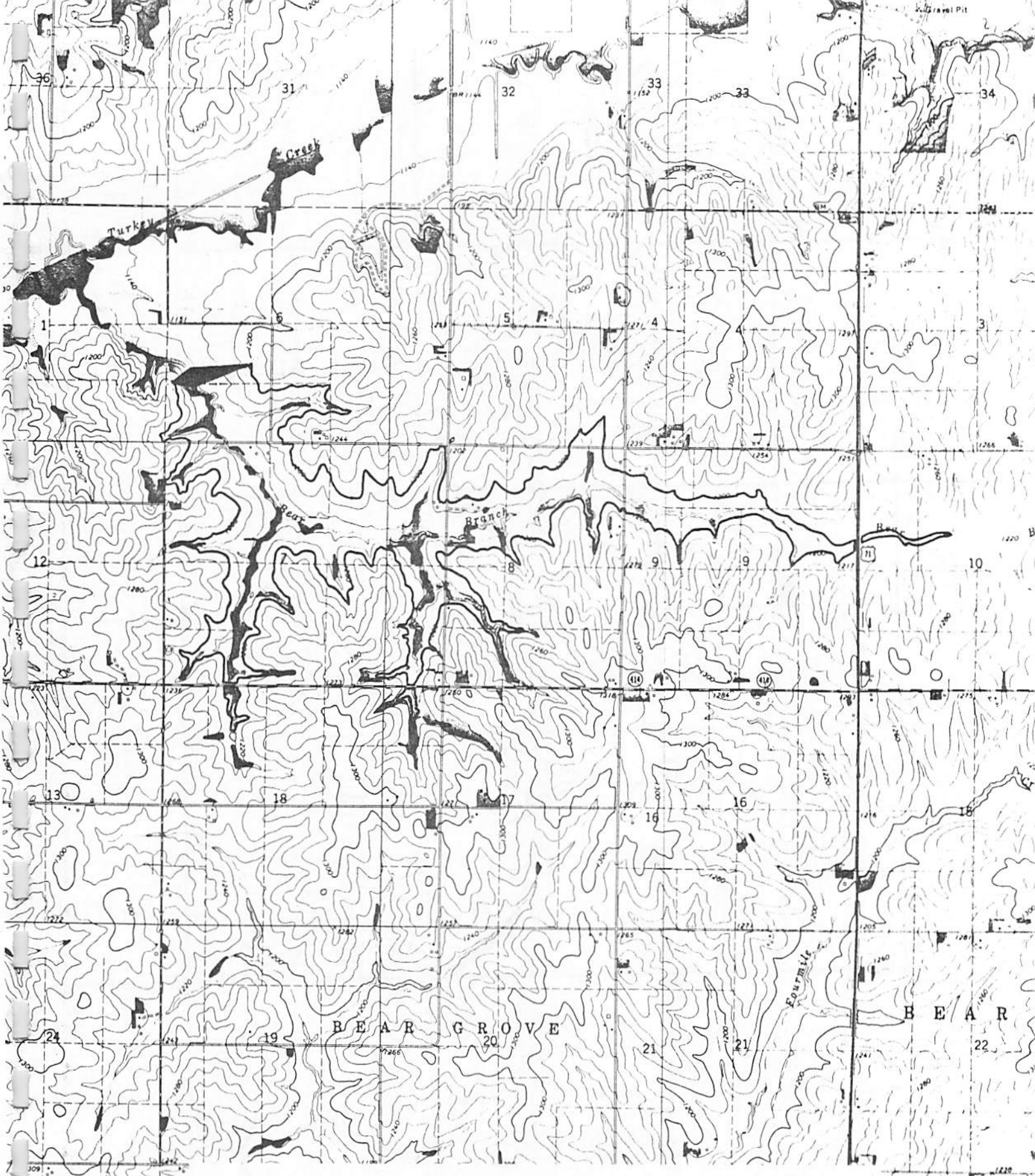
CASS COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	9	75	37	10.80	60	493	9869	5	1	10	325	325	337	843	33	58	17	29	679	1198
										20	882	882	337	843	61	85	31	43	1250	1768
2	6	75	36	8.67	60	509	10172	5	1	10	353	353	280	699	32	53	16	26	649	1079
										20	985	985	280	699	63	84	32	42	1296	1726
3	13	75	34	9.53	40	845	11270	5	1	10	342	342	303	758	48	82	24	41	669	1141
										20	942	942	303	758	93	128	47	64	1292	1764
4	28	75	34	7.00	60	692	13845	5	1	10	377	377	233	582	31	48	15	24	625	983
										20	1075	1075	233	582	65	83	33	41	1340	1698
5	33	76	34	6.78	40	796	10608	5	1	10	381	381	226	566	46	71	23	36	630	982
										20	1087	1087	226	566	99	124	49	62	1363	1715
6	29, 32	74	37	6.97	45	267	4001	5	1	10	378	378	232	580	41	64	20	32	630	990
										20	1076	1076	232	580	87	110	44	55	1352	1711
7	29, 32	74	37	10.70	45	315	4728	5	1	10	327	327	335	837	44	78	22	39	683	1707
										20	887	887	335	837	81	115	41	57	1262	1781
8	4, 33	74, 75	37	7.10	45	328	4919	5	1	10	376	376	236	589	64	87	32	44	632	997
										20	1069	1069	236	589	87	111	44	55	1348	1713
9	6	75	35	7.80	60	852	17036	5	1	10	366	366	255	638	31	50	16	25	636	1029
										20	1031	1031	255	638	64	83	32	42	1318	1711
10	13, 14	76	36	12.30	60	949	18988	5	1	10	307	307	377	943	34	63	17	31	701	1281
										20	816	816	377	943	60	88	30	44	1223	1802
11	15, 16	76	35	7.61	60	709	14173	5	1	10	368	368	250	625	31	50	16	25	634	1018
										20	1041	1041	250	625	65	83	32	42	1323	1708
12	13, 18	76	35, 36	11.10	60	703	14051	5	1	10	322	322	345	863	33	59	17	30	684	1214
										20	868	868	345	863	61	87	30	43	1244	1775
13	28	75	35	6.89	60	498	9958	5	1	10	378	378	230	574	30	48	15	24	623	976
										20	1081	1081	230	574	66	83	33	41	1343	1696
14	7	74	34	8.67	60	619	12380	5	1	10	353	353	280	699	32	53	16	26	649	1079
										20	985	935	280	699	63	84	32	42	1296	1726
15	34, 35	74	36	11.30	60	700	13998	5	1	10	319	319	351	877	34	60	17	30	686	1226
										20	859	859	351	877	61	87	30	43	1240	1779
16	16, 17	74	35	8.45	60	.790	15805	5	1	10	357	357	273	684	32	52	16	26	646	1066
										20	997	997	273	684	64	84	32	42	1302	1722
17	25, 26	75	34	17.20	40	1083	14434	12	2	10	811	811	502	1256	99	155	49	78	1363	2145
										20	1117	1117	502	1256	122	178	61	89	1680	2373
18	32	76	34	19.00	40	877	11687	12	2	10	778	778	547	1368	99	161	50	81	1375	2226
										20	1058	1058	547	1368	120	142	60	91	1666	2517
19	34	76	35	15.97	60	1142	22832	12	2	10	839	839	472	1179	66	101	33	50	1343	2368
										20	1159	1159	472	1179	82	117	41	59	1671	2396

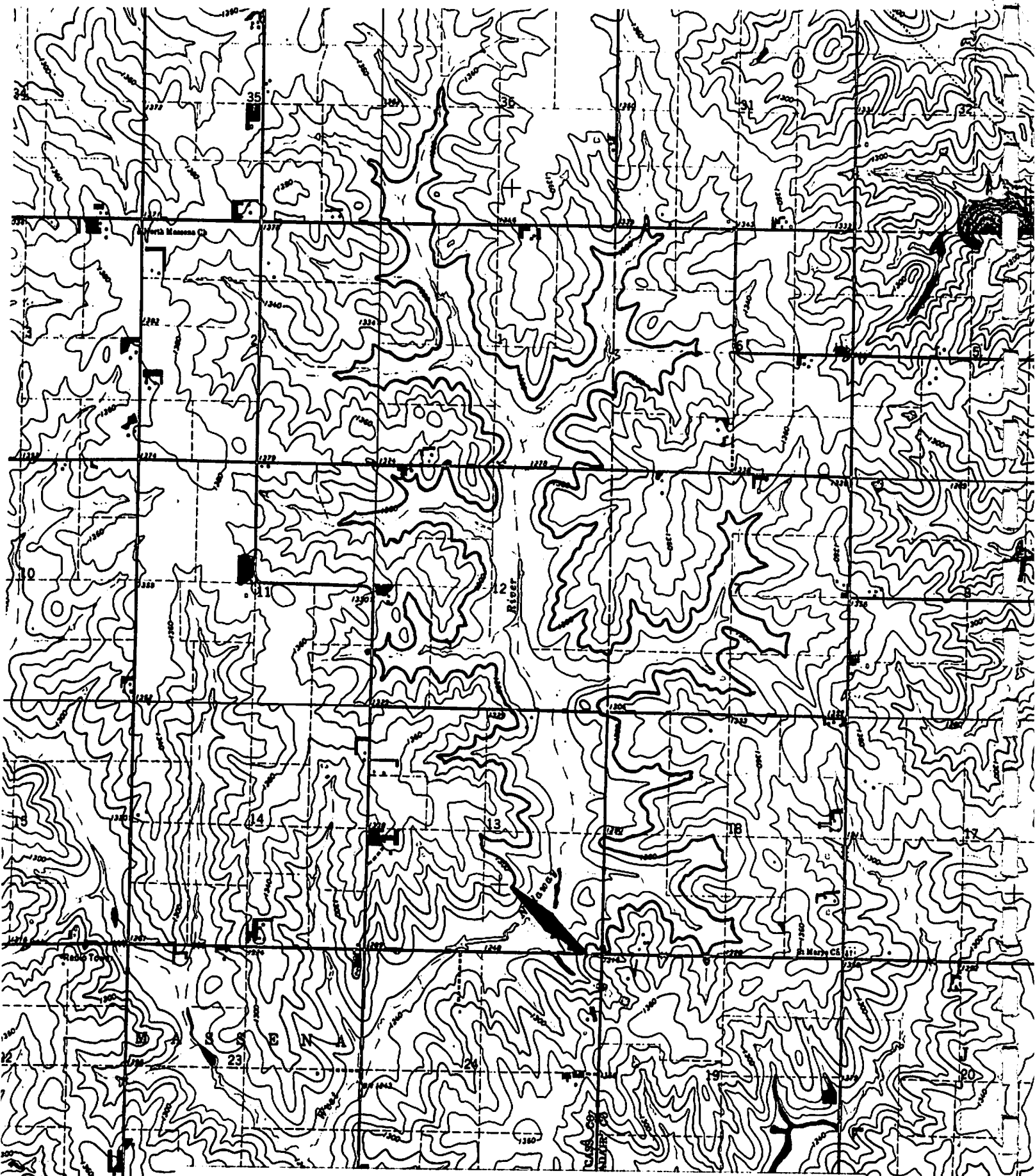
* Column 1 20 year design, Column 2 50 year design periods.



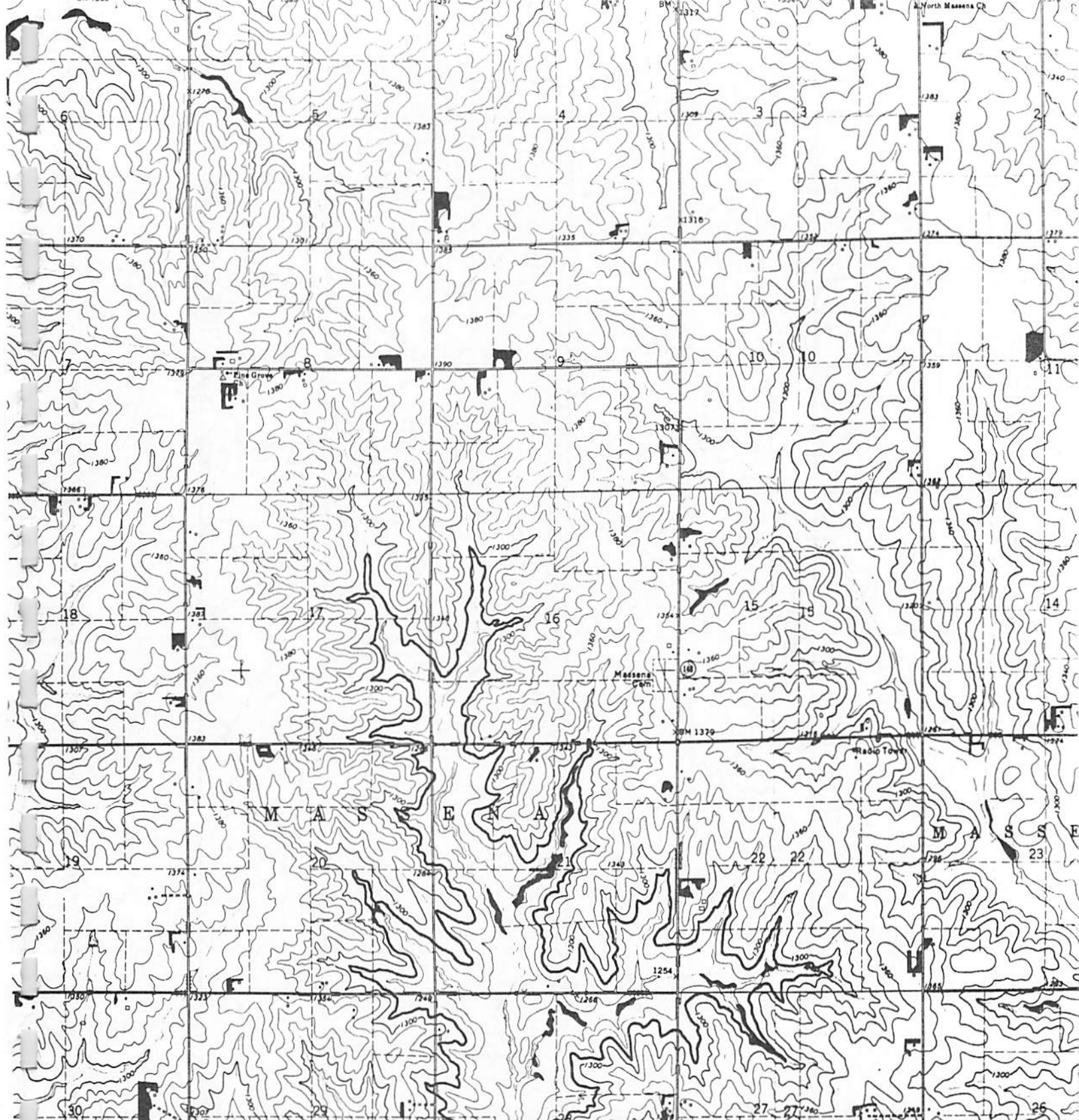
SITE NO.: 1 COUNTY: Cass
LOCATION: SECTION: 9 T 75N, R 37W
QUADRANGLE: Lewis
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



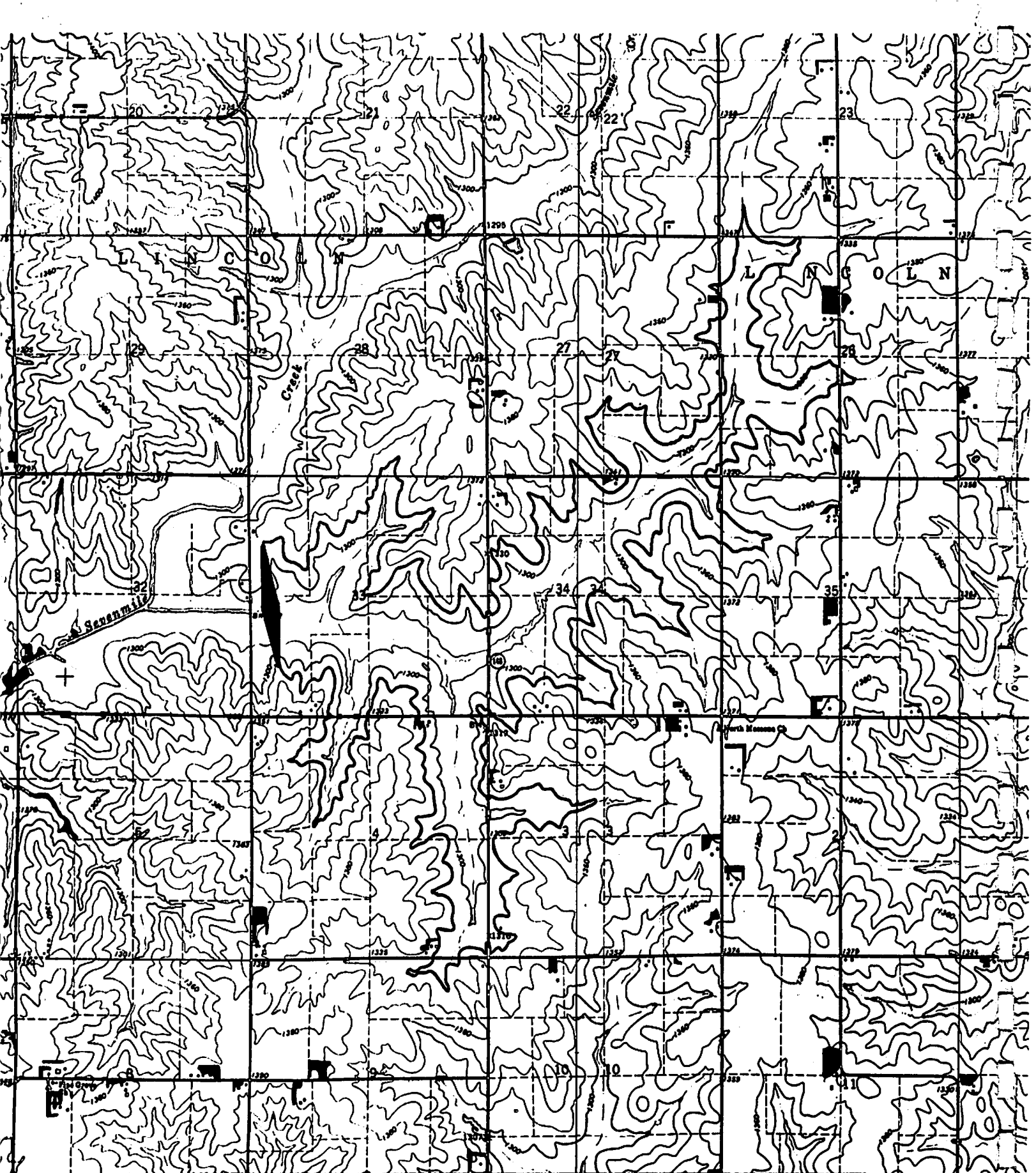
SITE NO.: 2 COUNTY: Cass
LOCATION: SECTION: 6 T 75N, R 36W
QUADRANGLE: Lewis, Anita SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 3 COUNTY: Cass
LOCATION: SECTION: 13 T 75N, R 34W
QUADRANGLE: Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

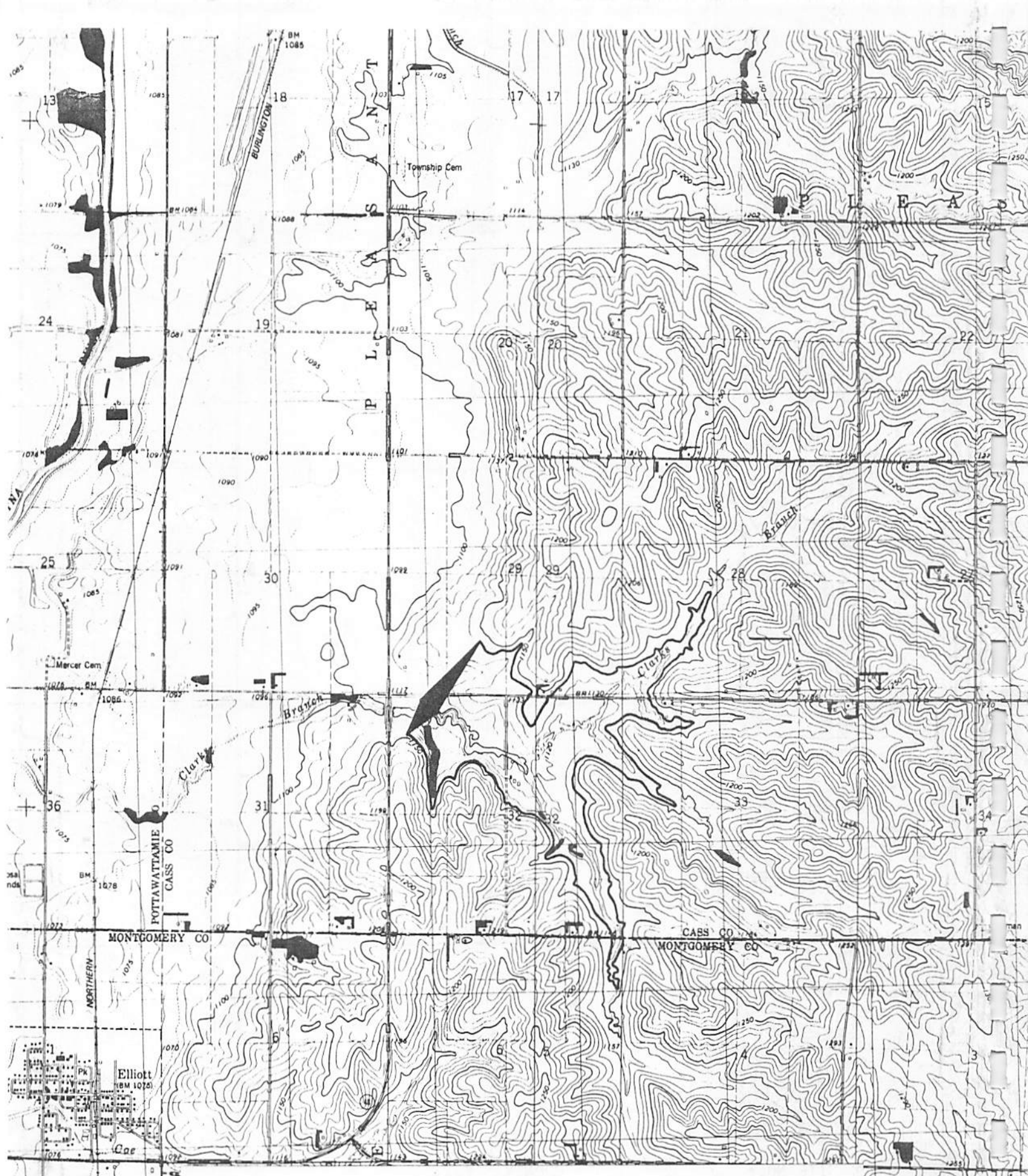


SITE NO.: 4 COUNTY: Cass
LOCATION: SECTION: 28 T 75N, R 34W
QUADRANGLE: Massena, Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

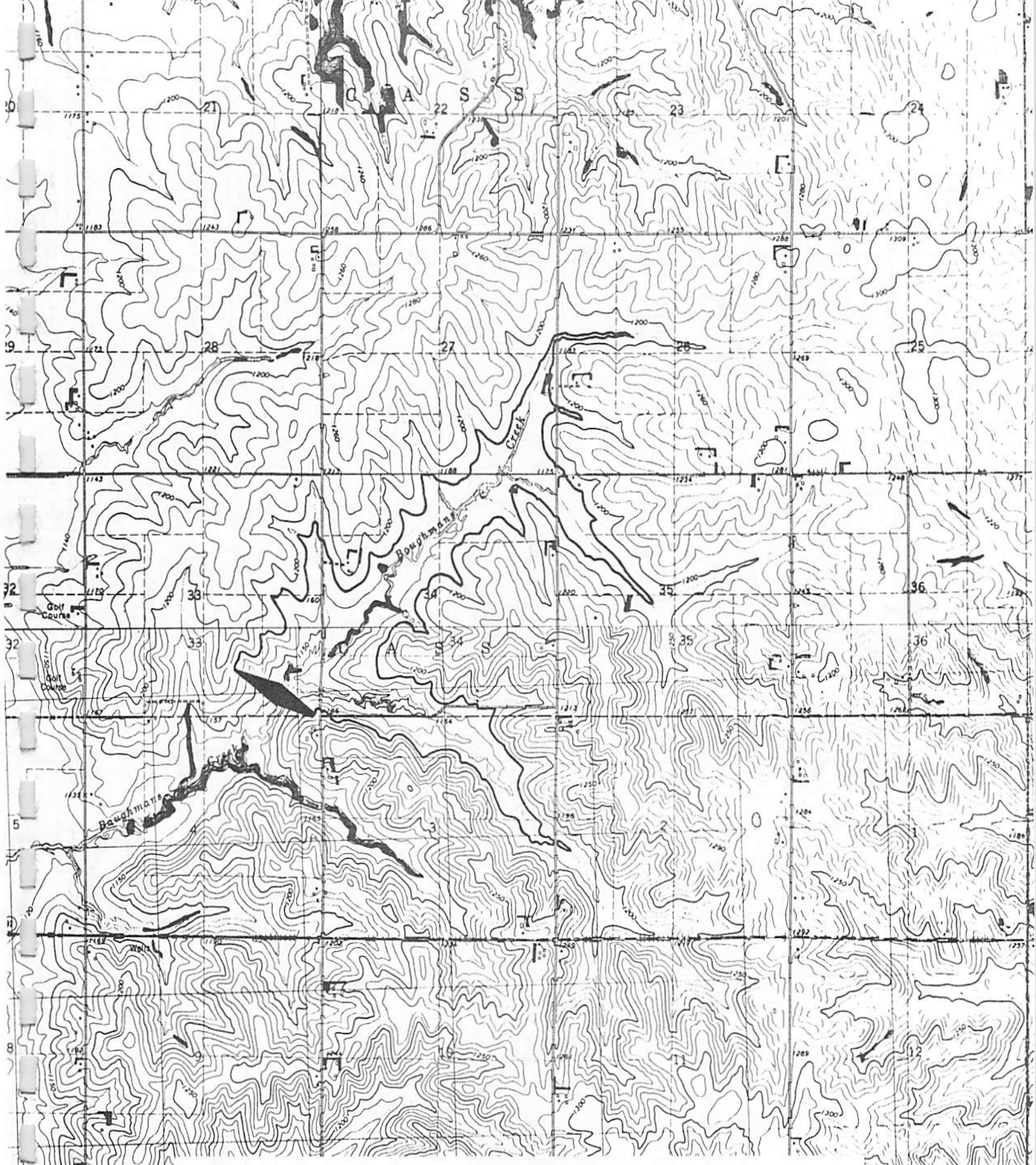


SITE NO.: 5 COUNTY: Cass
LOCATION: SECTION: 33 T 76N, R 34W
QUADRANGLE: Massena, Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 6 COUNTY: Cass
LOCATION: SECTION: 29, 32 T 74N, R 37W
QUADRANGLE: Griswold NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

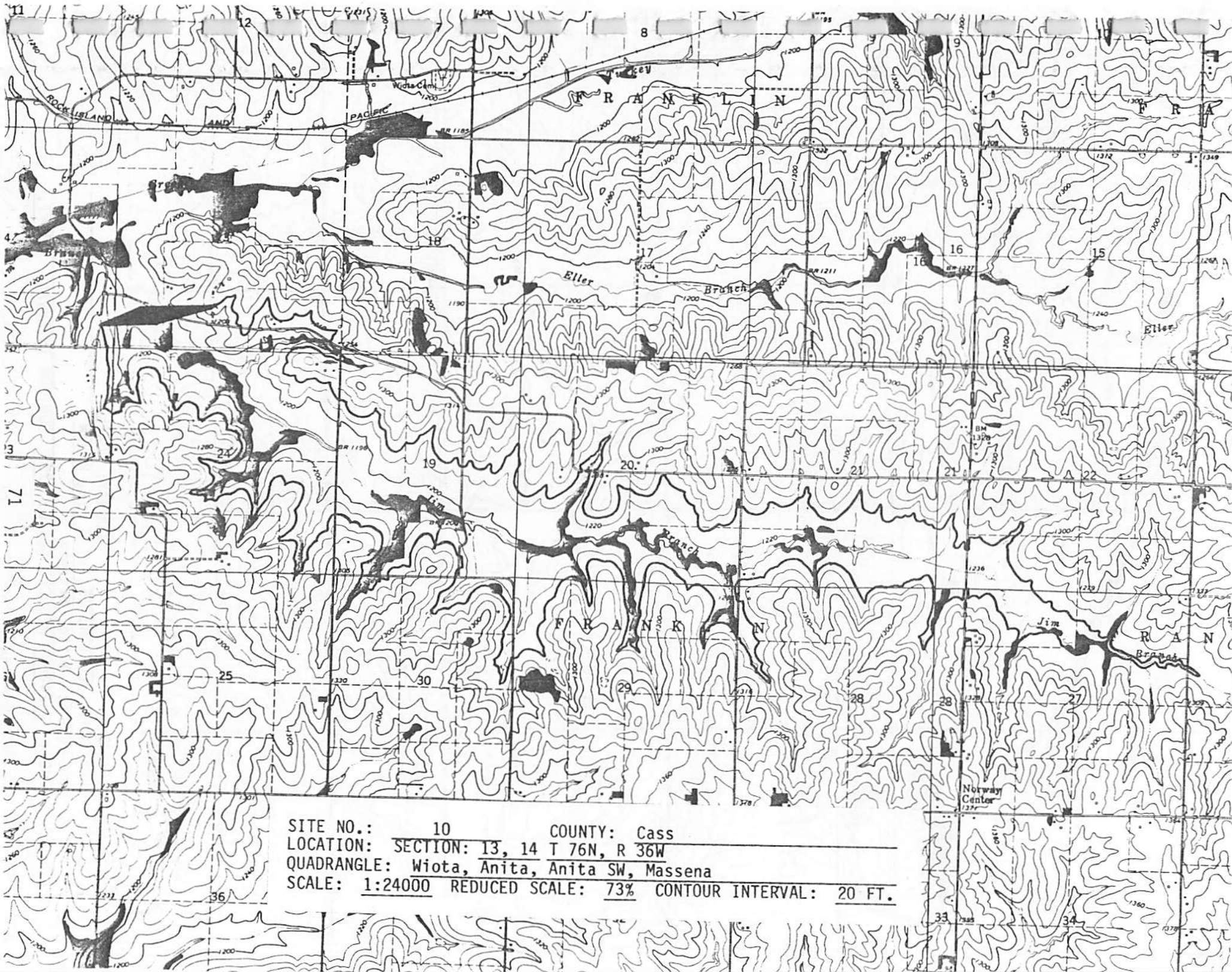


SITE NO.: 7 COUNTY: Cass
LOCATION: SECTION: 29, 32 T 74N, R 37W
QUADRANGLE: Griswold, Griswold NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



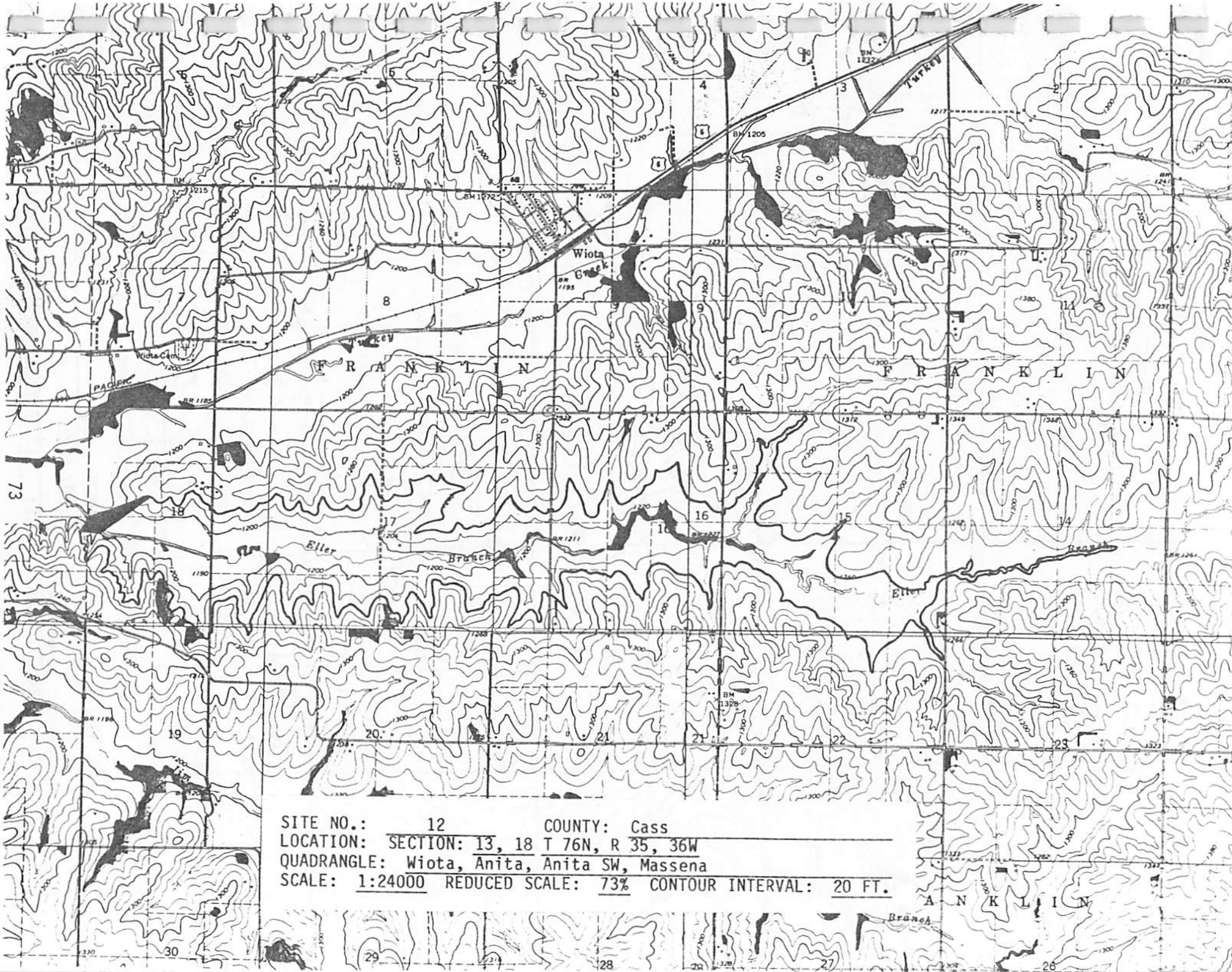
SITE NO.: 8 COUNTY: Cass
LOCATION: SECTION: 4, 33 T 74, 75N, R 37W
QUADRANGLE: Lewis, Griswold NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 9 COUNTY: Cass
LOCATION: SECTION: 6 T 75N, R 35W
QUADRANGLE: Anita SW, Massena
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

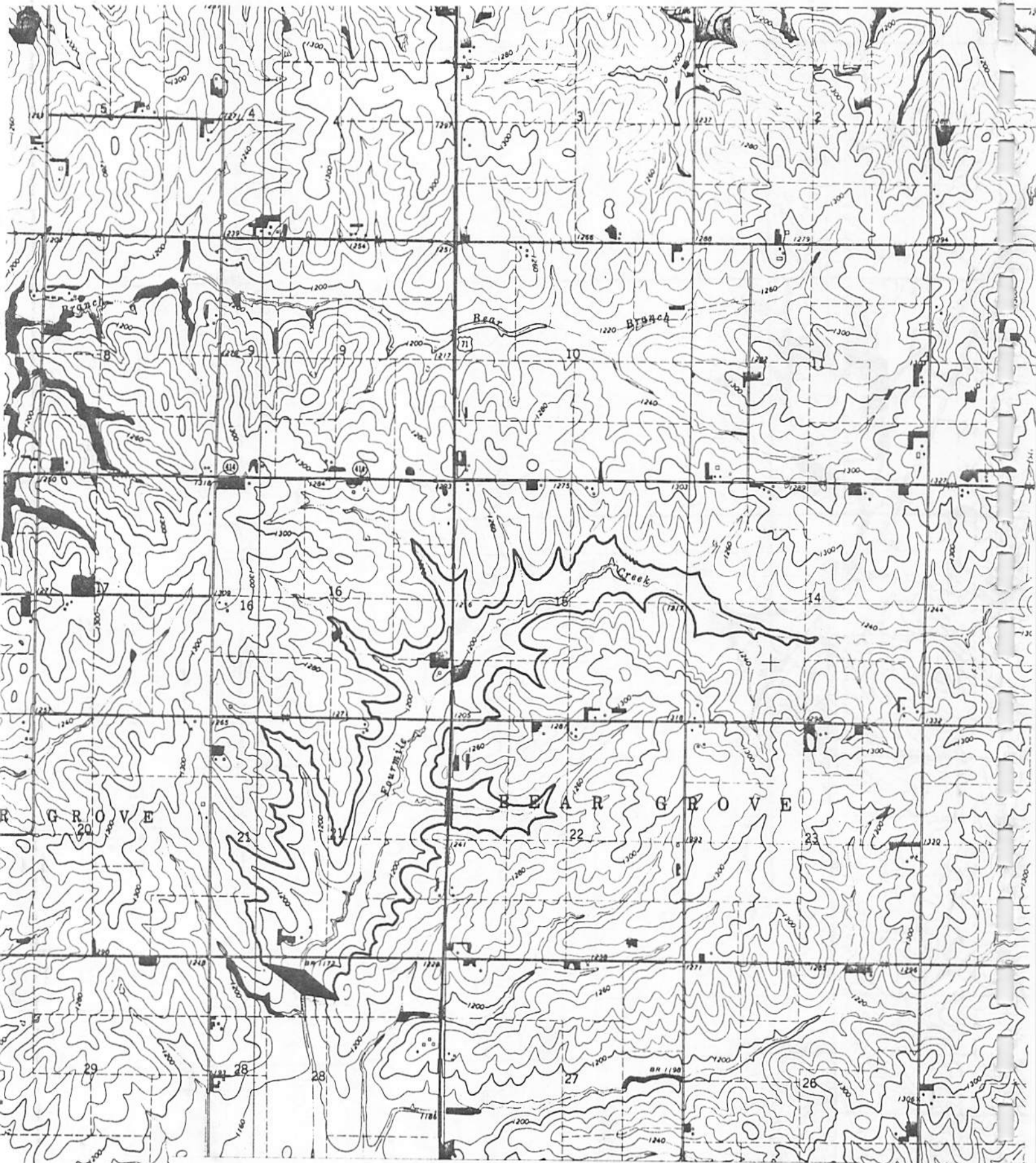


SITE NO.: 10 COUNTY: Cass
LOCATION: SECTION: 13, 14 T 76N, R 36W
QUADRANGLE: Wiota, Anita, Anita SW, Massena
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 11 COUNTY: Cass
LOCATION: SECTION: 15, 16 T 76N, R 35W
QUADRANGLE: Anita, Massena
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

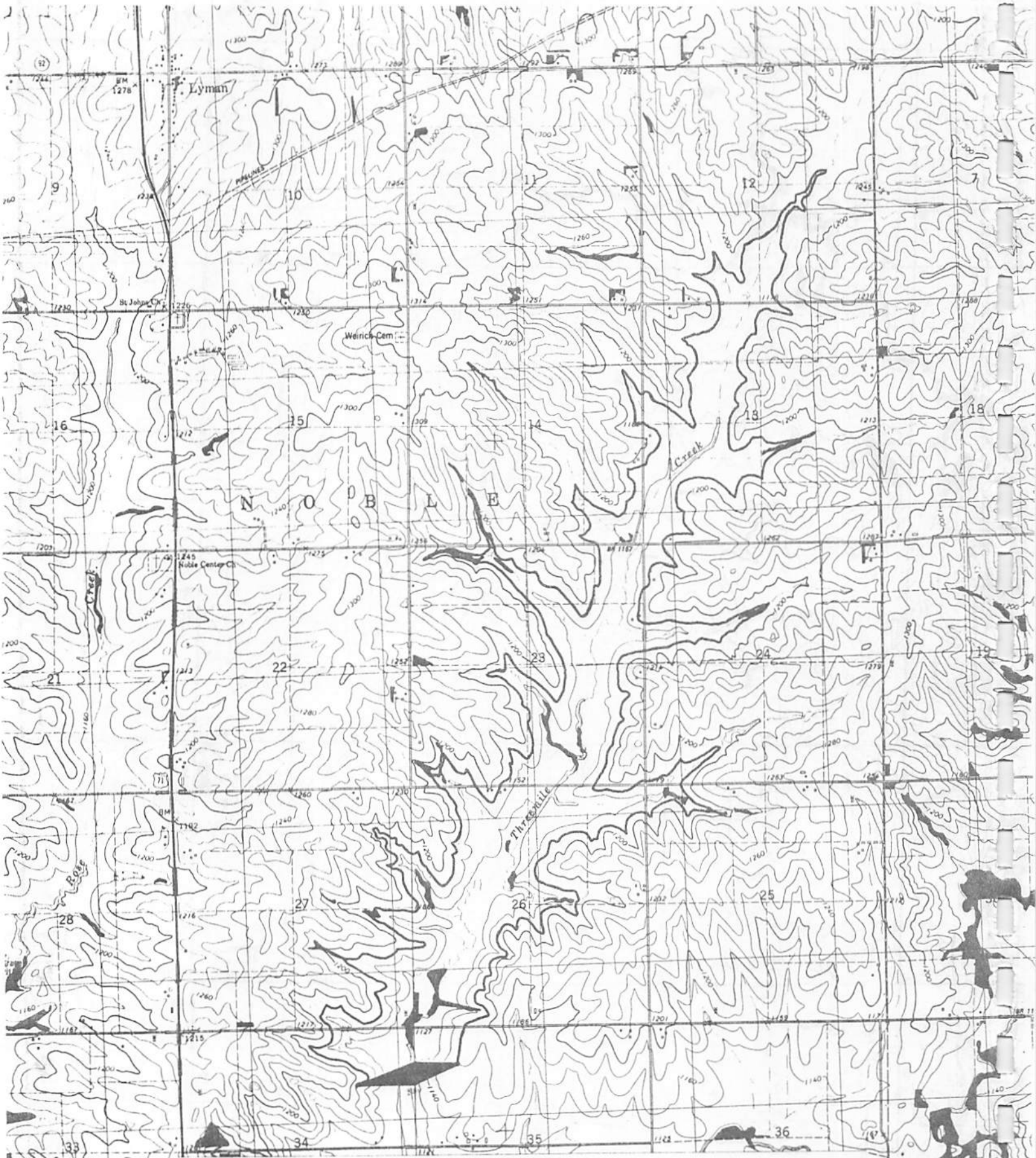


SITE NO.: 12 COUNTY: Cass
LOCATION: SECTION: 13, 18 T 76N, R 35, 36W
QUADRANGLE: Wiota, Anita, Anita SW, Massena
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



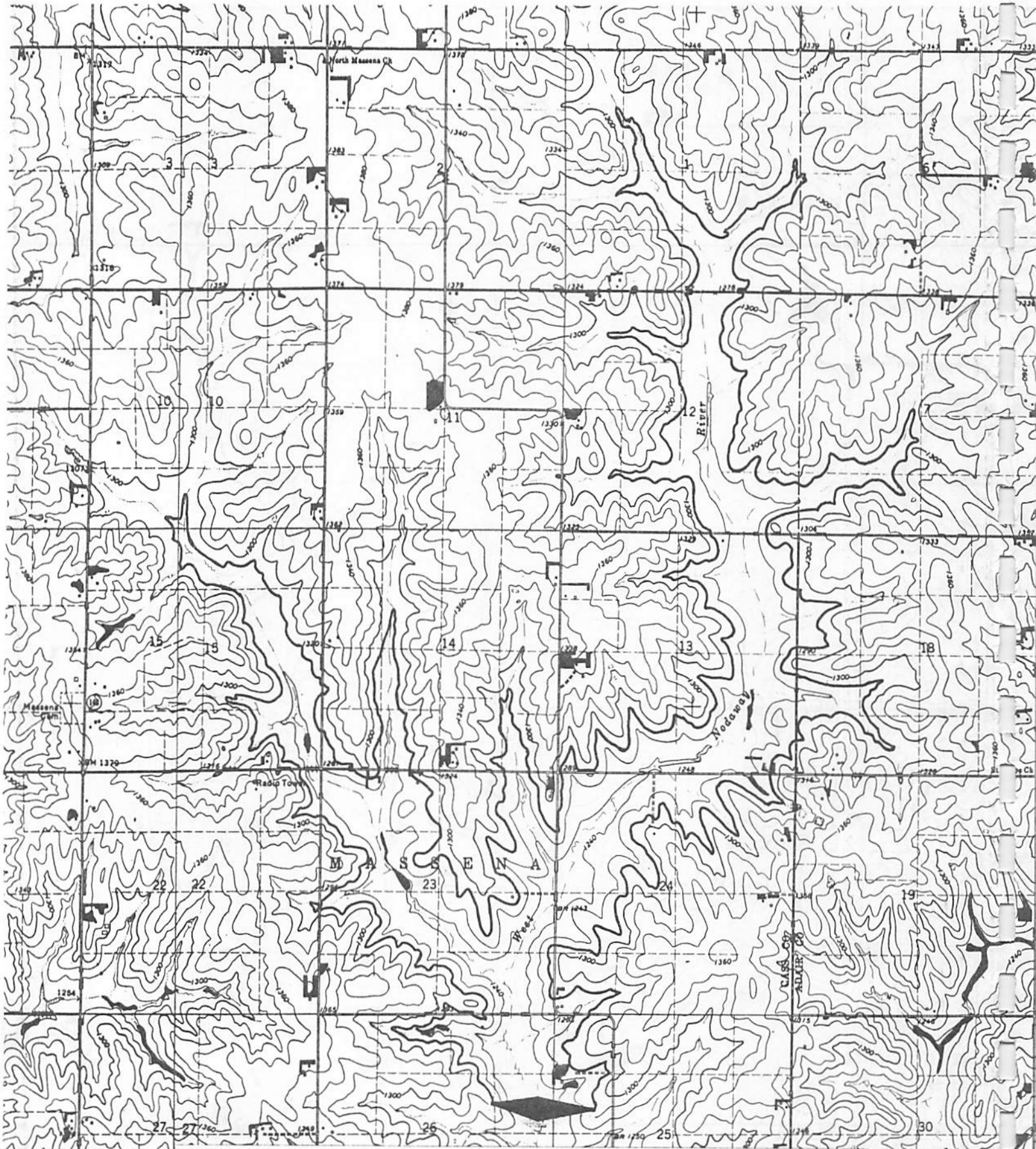
SITE NO.: 13 COUNTY: Cass
LOCATION: SECTION: 28 T 75N, R 36W
QUADRANGLE: Lewis, Anita SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

SITE NO.: 14 COUNTY: Cass
LOCATION: SECTION: 7 T 74N, R 34W
QUADRANGLE: Dewey, Bridgewater
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

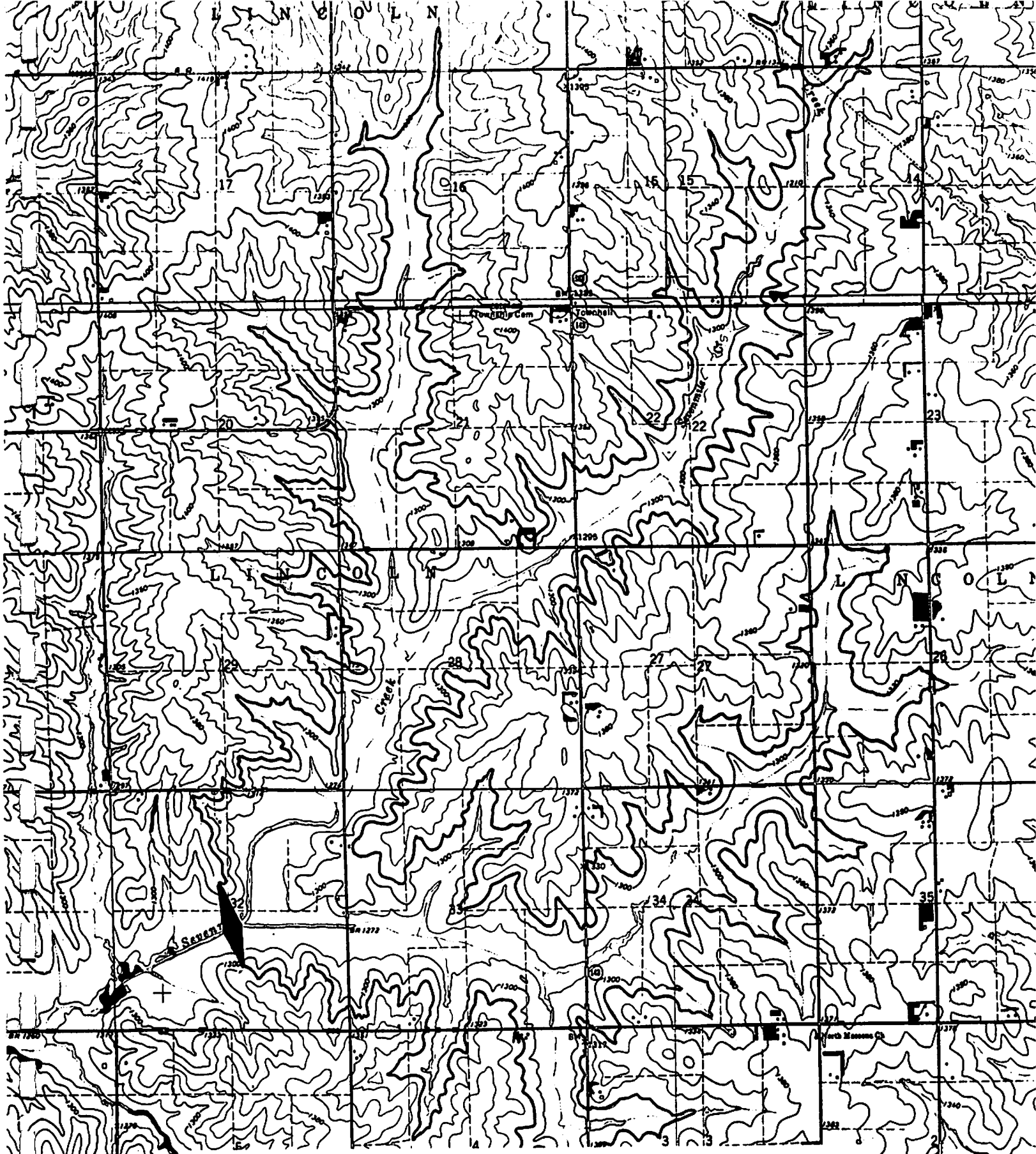


SITE NO.: 15 COUNTY: Cass
LOCATION: SECTION: 34, 35 T 74N, R 36W
QUADRANGLE: Grant
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

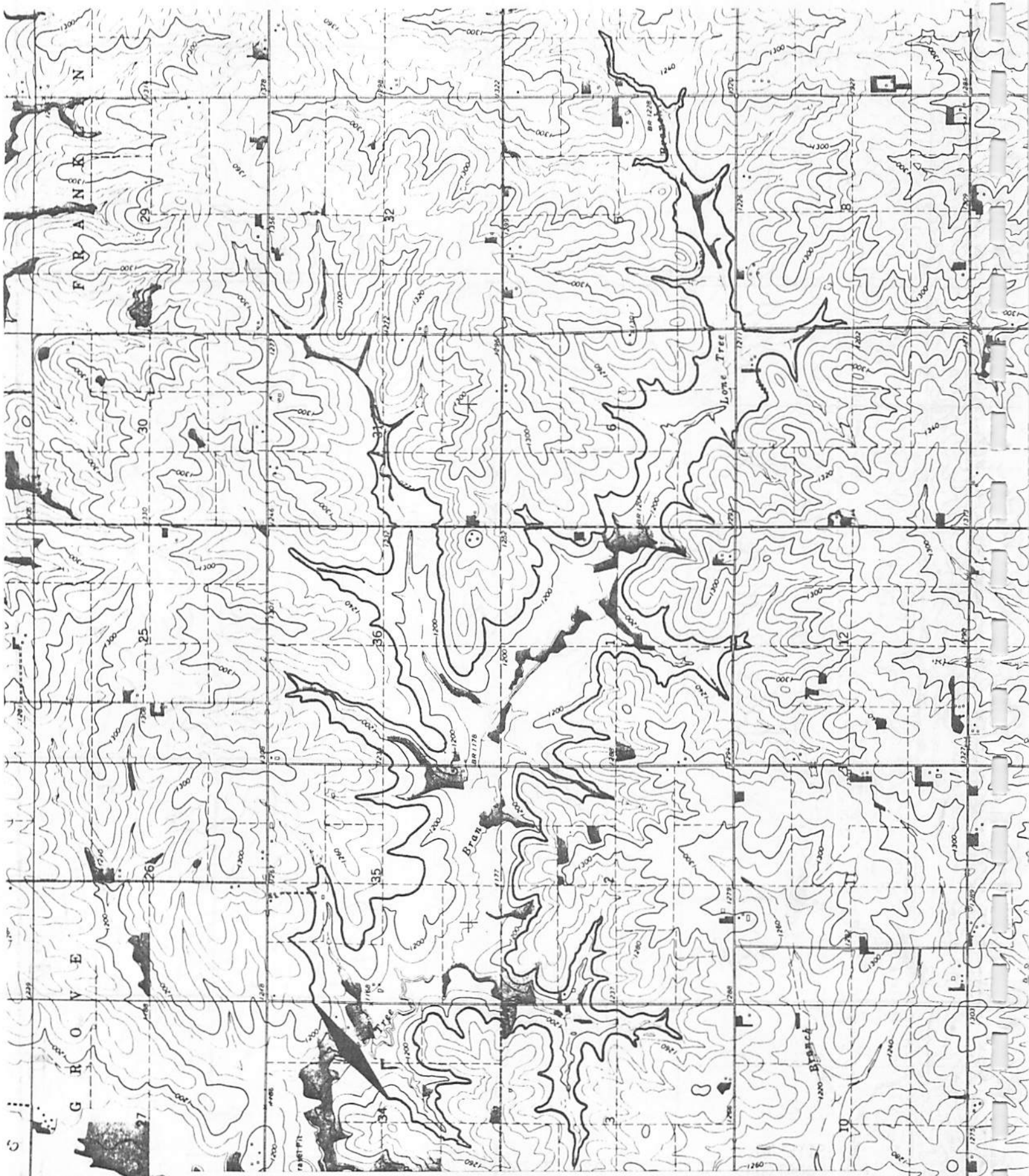
SITE NO.: 16 COUNTY: Cass
LOCATION: SECTION: 16, 17 T 74N, R 35W
QUADRANGLE: Anita SW, Massena, Grant, Dewey
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



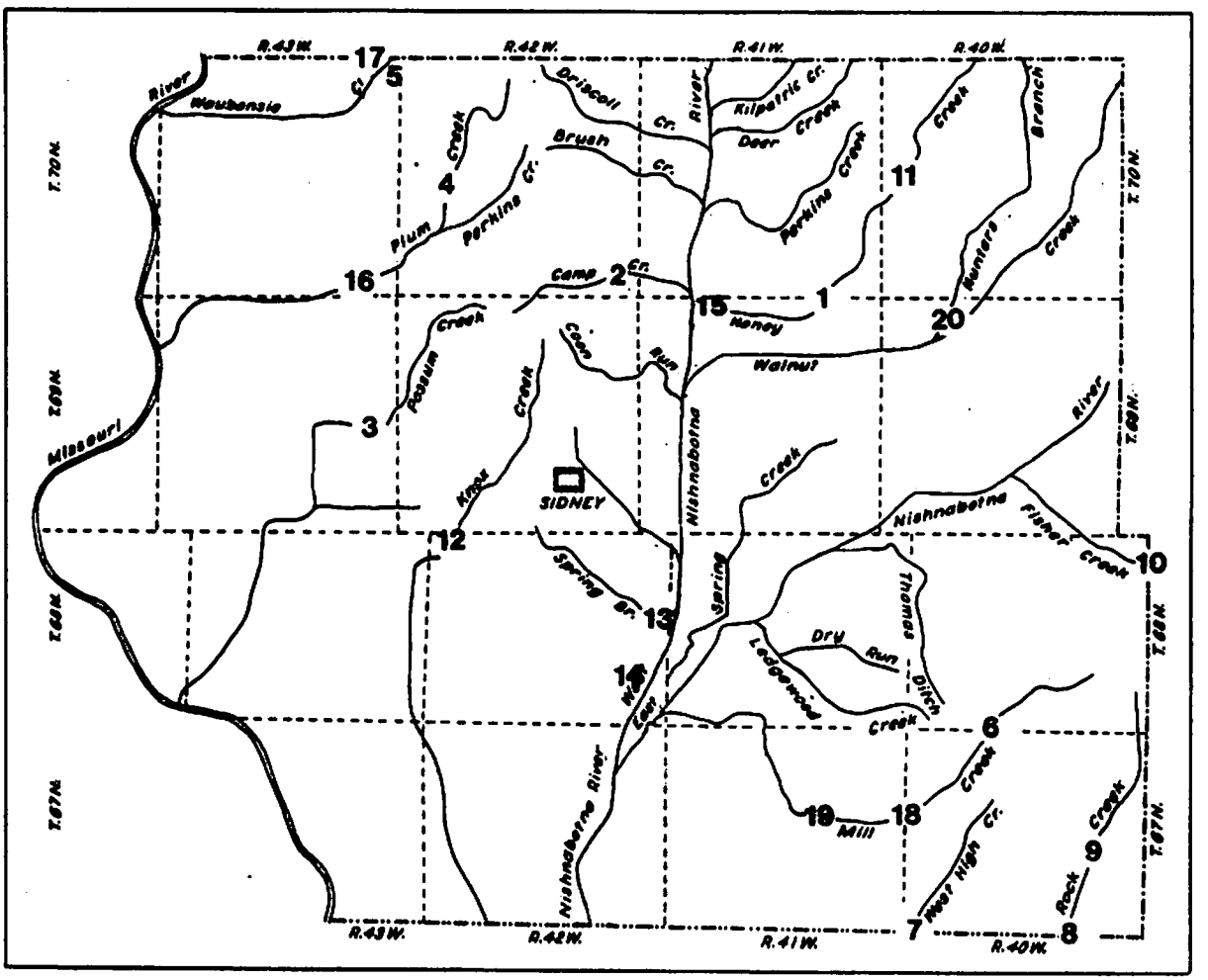
SITE NO.: 17 COUNTY: Cass
LOCATION: SECTION: 25, 26 T 75N, R 34W
QUADRANGLE: Massena, Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 18 COUNTY: Cass
LOCATION: SECTION: 32 T 76N, R 34W
QUADRANGLE: Anita, Adair South, Massena, Fontanelle SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 19 COUNTY: Cass
LOCATION: SECTION: 34 T 76N, R 36W
QUADRANGLE: Anita SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



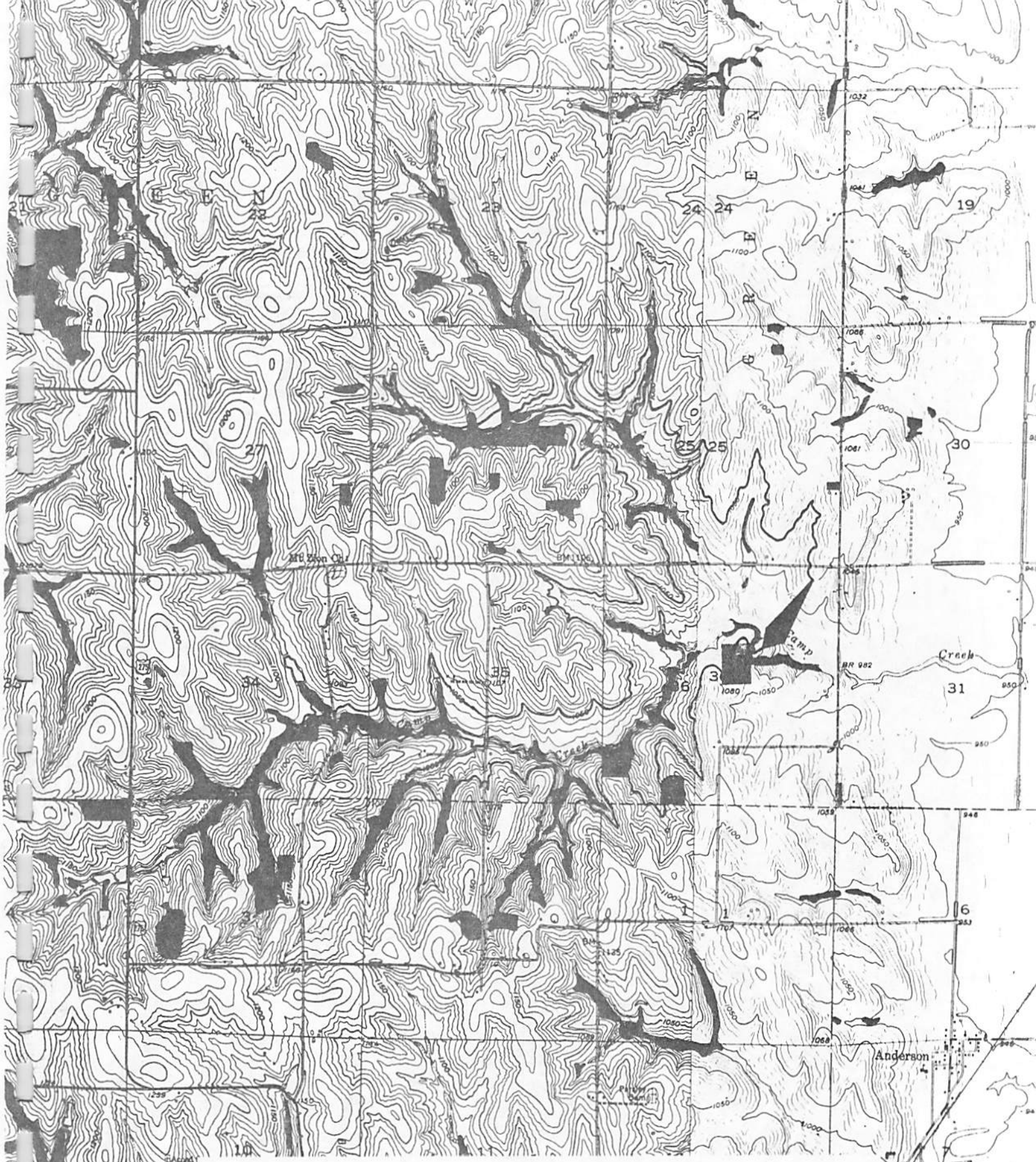
Index map for impoundment sites in Fremont County.

FREMONT COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	35	70	41	13.80	55	401	7347	5	1	10	289	289	416	1040	39	73	19	36	725	1366
										20	755	755	416	1040	64	93	32	49	1203	1844
2	36	70	42	10.10	65	653	14137	5	1	10	334	334	319	796	30	52	15	26	668	1157
										20	915	915	319	796	57	79	29	40	1262	1750
3	24	69	43	7.25	75	285	7117	5	1	10	374	374	240	600	21	34	11	17	624	990
										20	1061	1061	240	600	45	58	23	29	1323	1689
4	17	70	42	7.65	65	396	8571	5	1	10	368	368	251	528	29	41	14	21	633	916
										20	1039	1039	251	528	60	72	30	36	1320	1603
5	1	70	43	8.77	65	262	5668	5	1	10	352	352	282	705	29	49	15	24	649	1082
										20	981	981	282	705	58	78	29	38	1292	1725
6	33	68	40	8.17	45	630	9443	5	1	10	360	360	266	664	42	68	21	34	647	1059
										20	1011	1011	266	664	85	112	43	56	1319	1731
7	30	67	40	8.71	55	606	11107	5	1	10	353	353	281	702	35	58	17	29	651	1083
										20	983	983	281	702	69	92	35	46	1298	1731
8	26, 27	67	40	9.55	45	571	8558	5	1	10	342	342	304	759	43	73	22	37	667	1137
										20	941	941	304	759	83	113	42	57	1286	1757
9	23	67	40	7.40	55	767	14055	5	1	10	371	371	244	610	34	54	17	27	632	1008
										20	1053	1053	244	610	71	91	35	45	1332	1708
10	7	68	39	10.40	55	718	13162	5	1	10	330	330	327	817	36	63	18	31	675	1178
										20	900	900	327	817	67	94	34	47	1261	1764
11	18	70	40	6.79	45	467	7009	5	1	10	380	380	227	567	41	63	20	32	627	979
										20	1086	1086	227	567	88	110	44	55	1357	1708
12	7, 32	68, 69	42	9.76	65	306	6640	5	1	10	339	339	309	773	30	51	15	26	663	1138
										20	931	931	309	773	57	79	29	39	1269	1744
13	13, 24	68	42	6.91	55	255	4682	5	1	10	379	379	230	575	33	52	17	26	625	980
										20	1080	1080	230	575	71	90	36	45	1346	1700
14	26	68	42	2.29	65	204	4416	5	1	10	453	453	89	224	25	31	13	16	556	692
										20	1373	1373	89	224	68	74	34	37	1496	1633
15	3	69	41	18.10	55	394	7230	12	2	10	792	792	525	1312	72	115	36	57	1353	2161
										20	1087	1087	525	1312	88	131	44	65	1656	2485
16	36	70	43	22.10	55	376	6895	12	2	10	711	711	623	1557	73	124	36	62	1370	2329
										20	954	954	623	1557	87	136	43	68	1630	2589
17	1	70	43	20.90	55	291	5326	12	2	10	734	734	594	1484	72	121	36	61	1364	2279
										20	1000	1000	594	1484	87	136	44	68	1636	2551
18	7,18	67	40	16.10	45	793	11894	12	2	10	836	836	475	1187	87	135	44	67	1354	2190
										20	1154	1154	475	1187	109	156	54	78	1643	2341
19	14	67	41	21.70	55	765	14029	12	2	10	719	719	613	1533	73	123	36	61	1369	2313
										20	976	976	613	1533	87	137	43	68	1632	2577
20	32	70	40	20.10	55	580	10640	12	2	10	750	750	574	1435	72	119	36	60	1361	2245
										20	1024	1024	574	1435	87	134	44	67	1642	2526

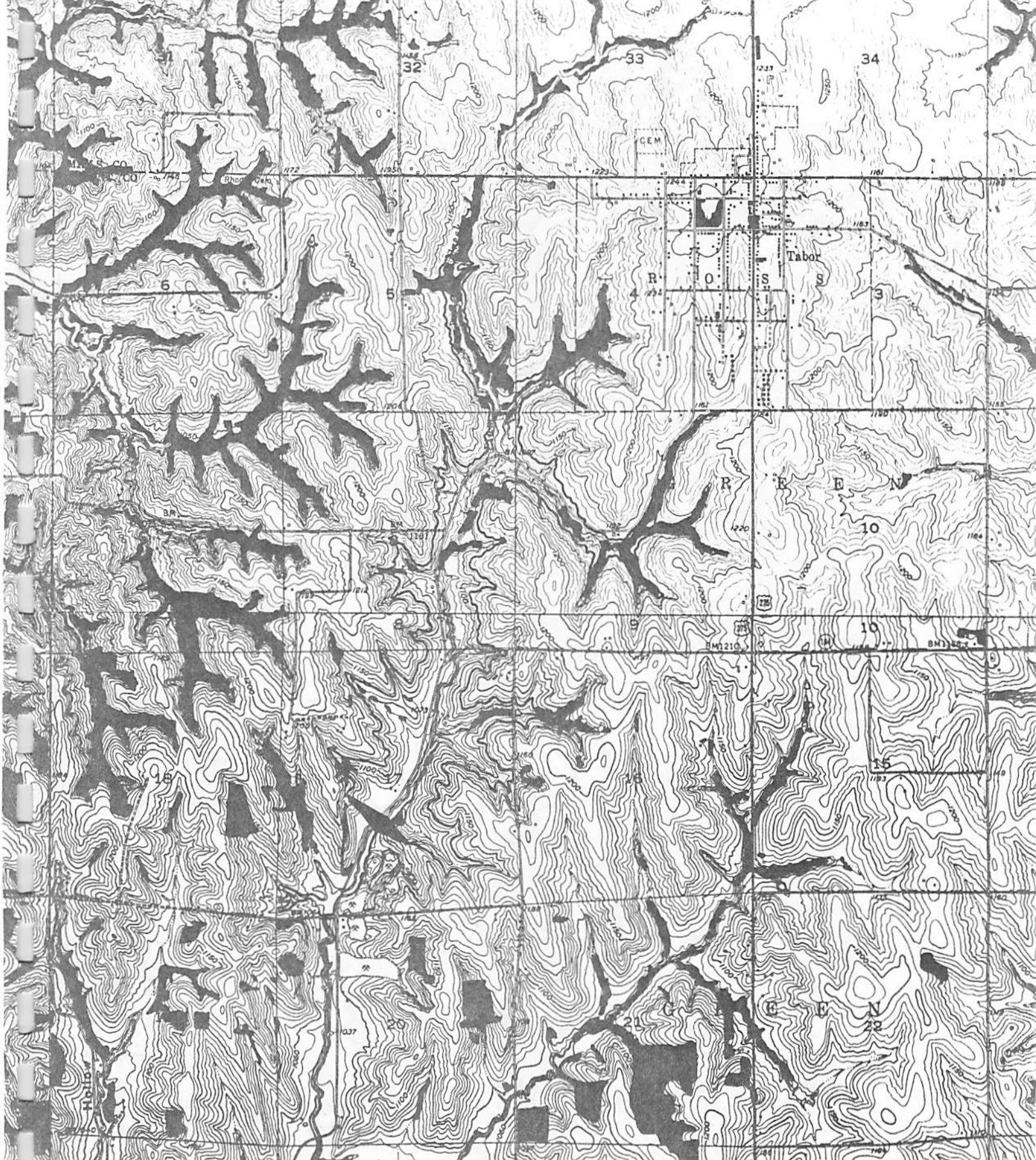
* Column 1 20 year design, Column 2 50 year design periods.

SITE NO.: 1 COUNTY: Fremont
LOCATION: SECTION: 35 T 70N, R 41W
QUADRANGLE: Randolph, Shenandoah W
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

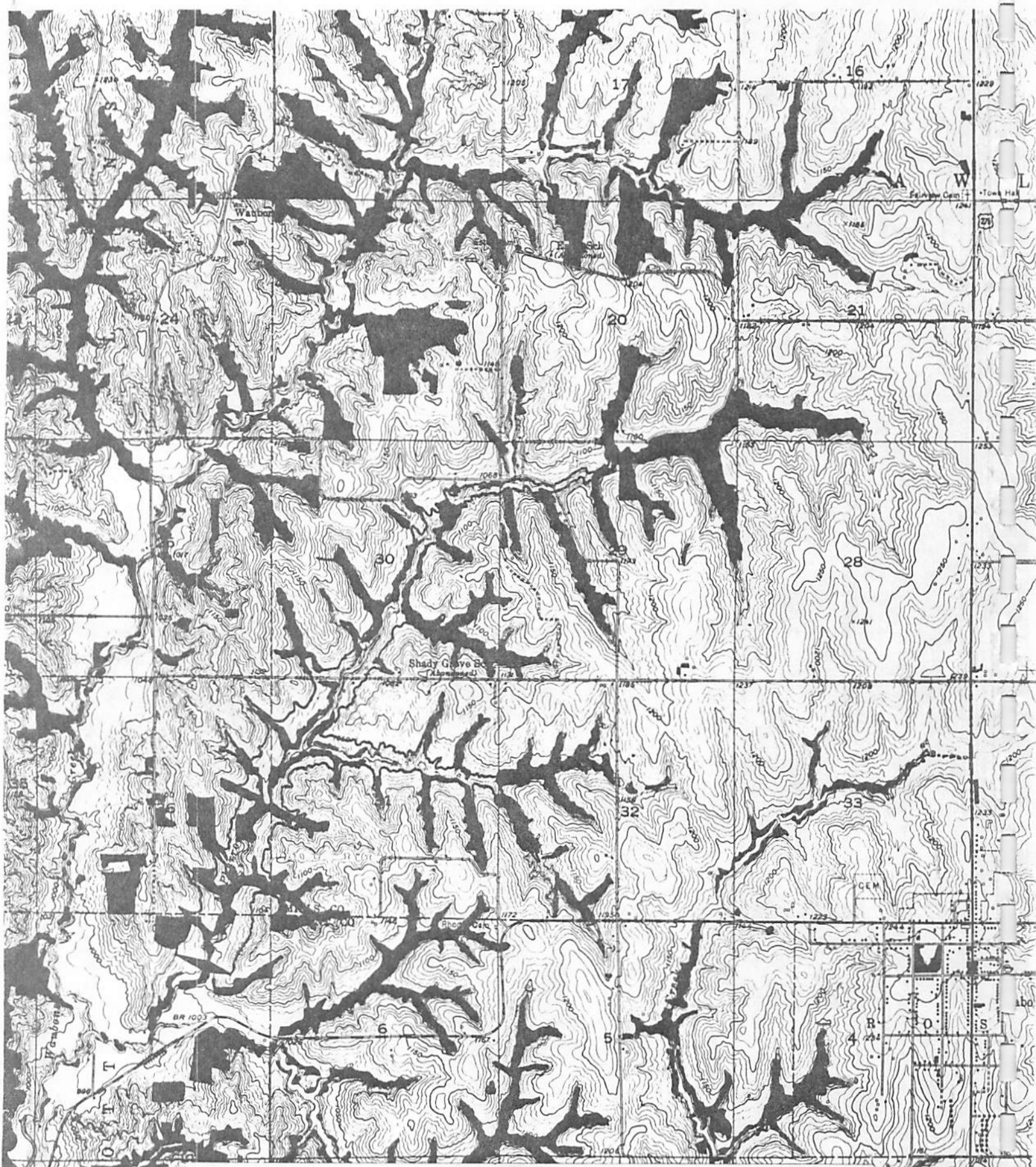


SITE NO.: 2 COUNTY: Fremont
LOCATION: SECTION: 36 T 70N, R 42W
QUADRANGLE: Tabor SW, Randolph
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

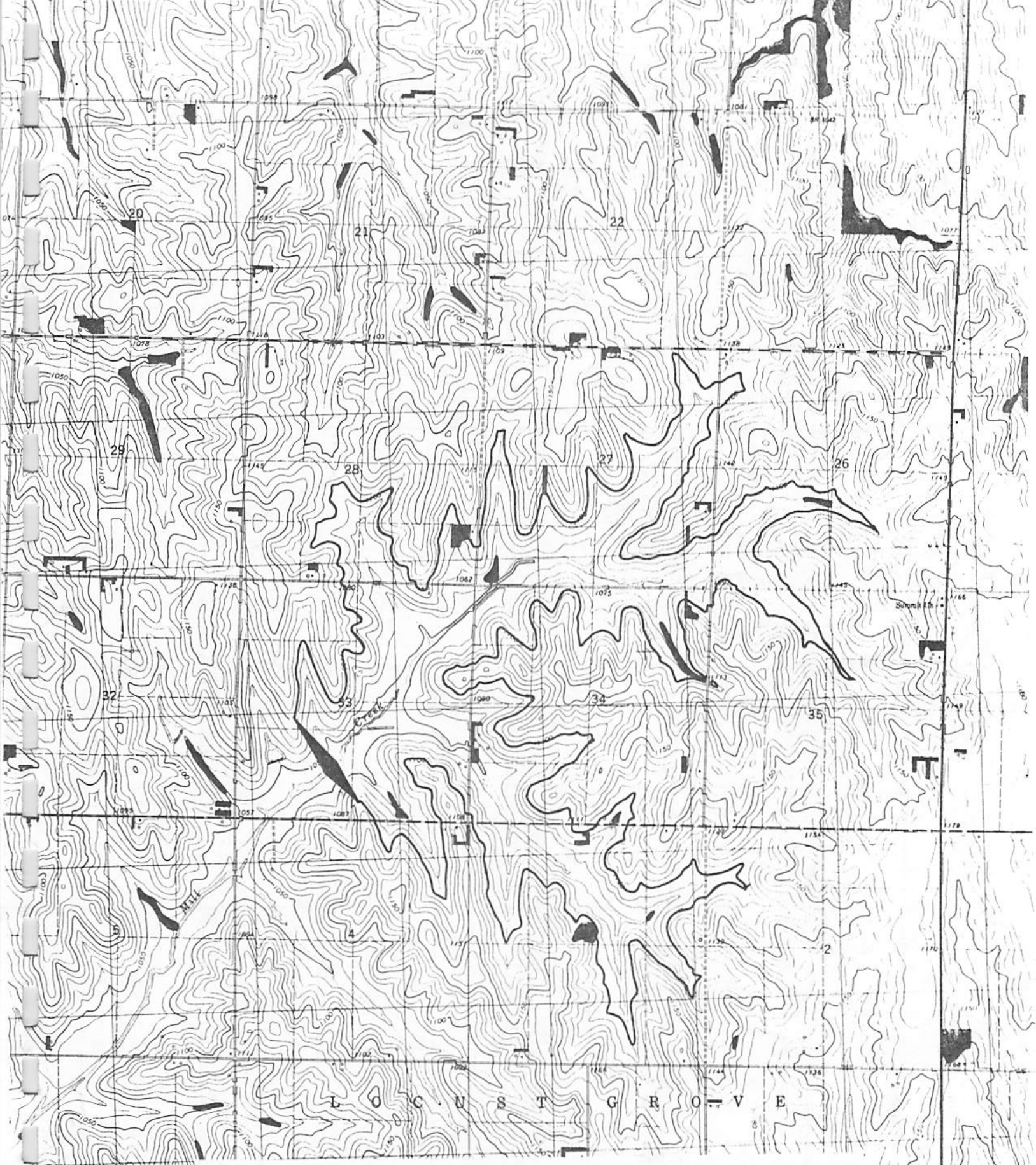
SITE NO.: 3 COUNTY: Fremont
LOCATION: SECTION: 24 T 69N, R 43W
QUADRANGLE: Tabor SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



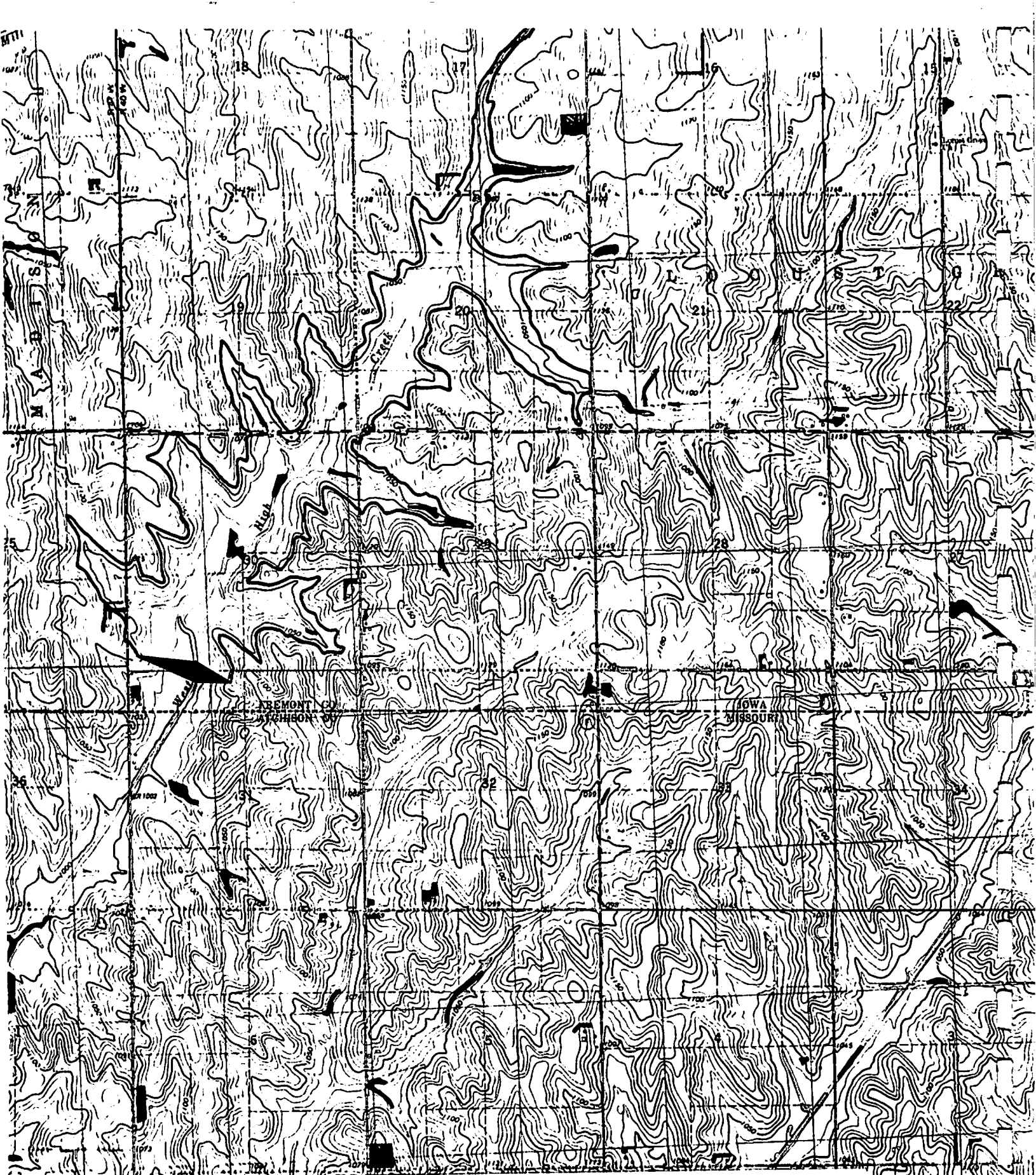
SITE NO.: 4 COUNTY: Fremont
LOCATION: SECTION: 17 T 70N, R 42W
QUADRANGLE: Tabor, Tabor SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



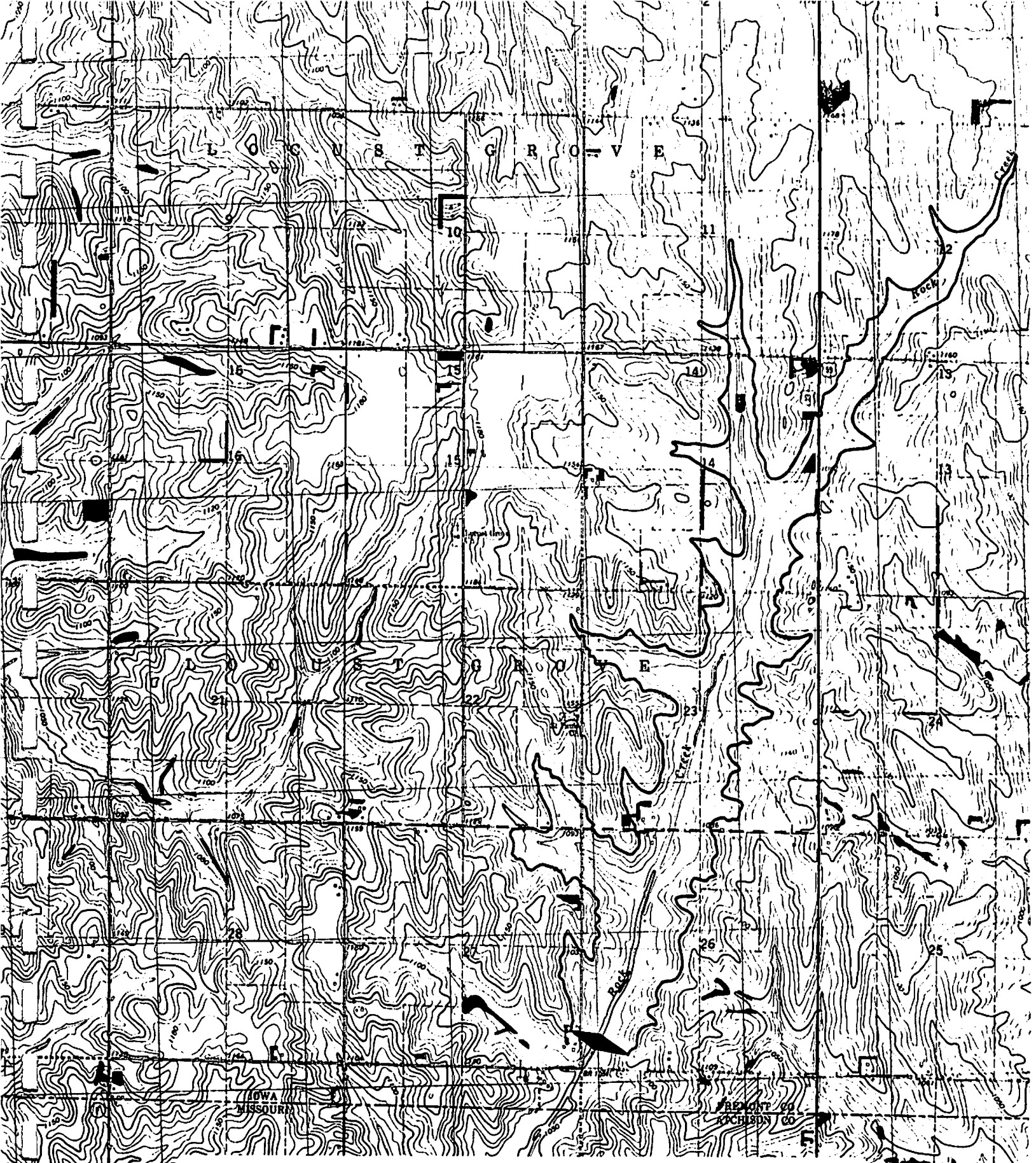
SITE NO.: 5 COUNTY: Fremont
LOCATION: SECTION: 1 T 70N, R 43W
QUADRANGLE: Tabor
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



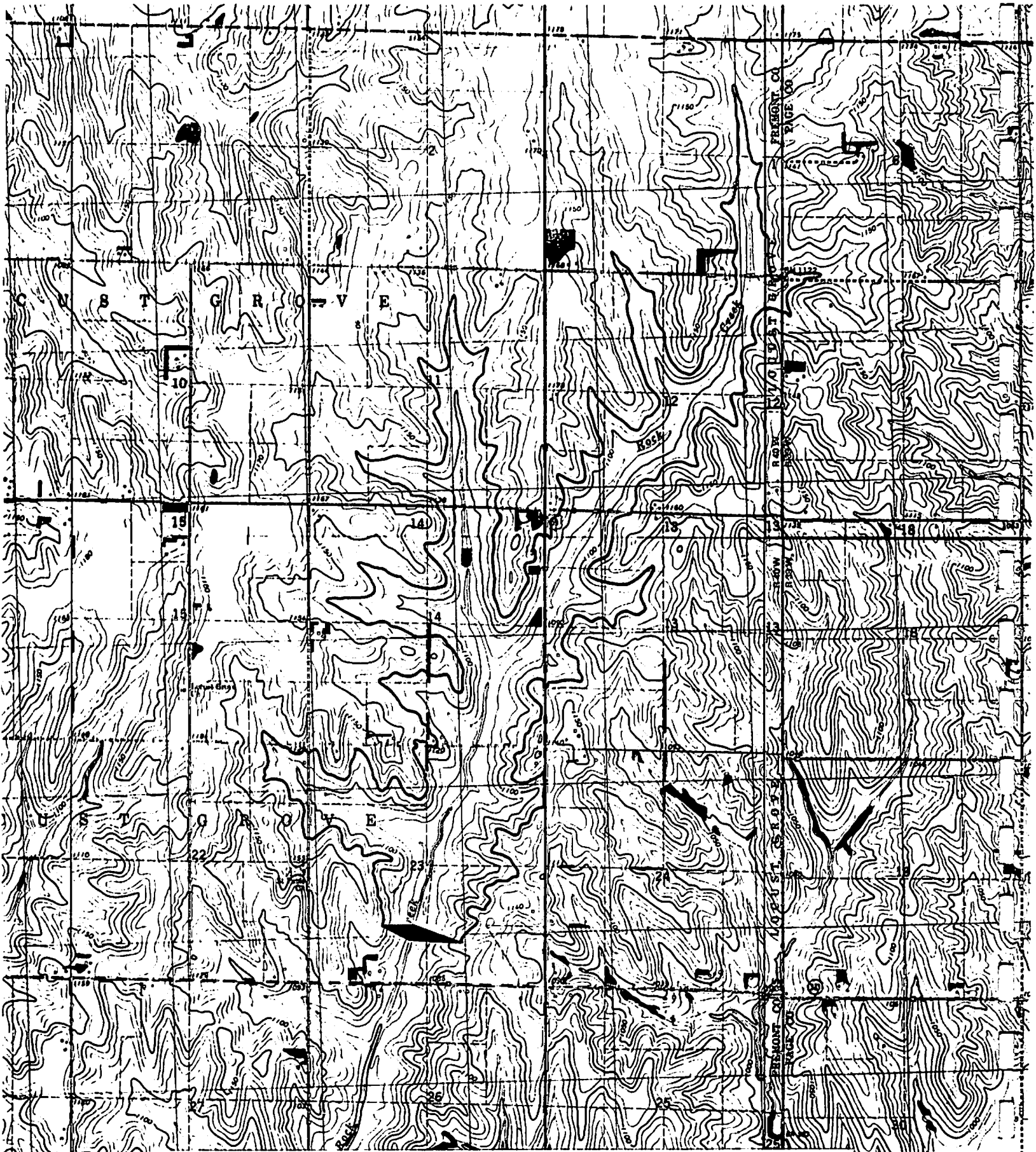
SITE NO.: 6 COUNTY: Fremont
LOCATION: SECTION: 33 T 68N, R 40W
QUADRANGLE: Farragut
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



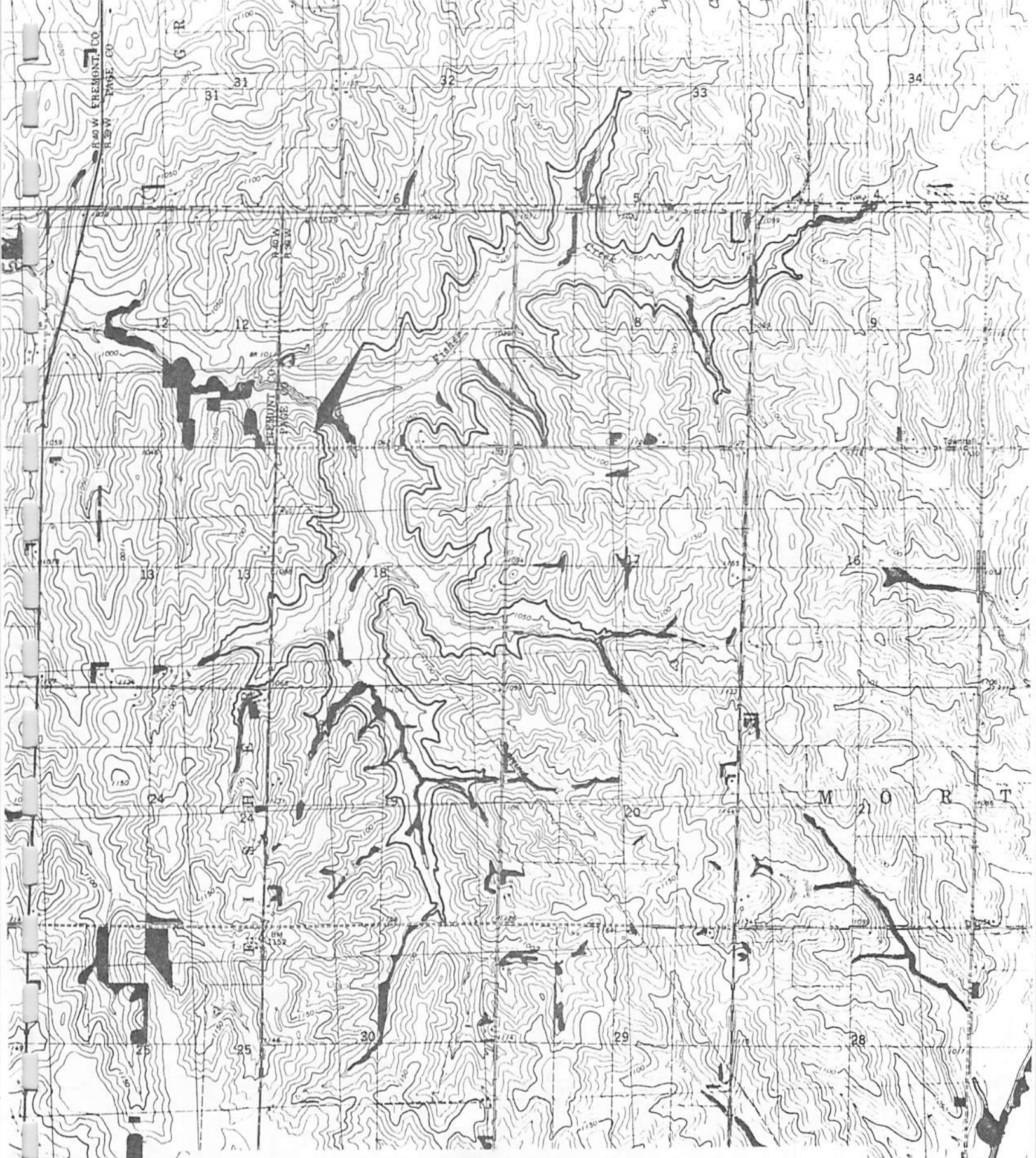
SITE NO.: 7 COUNTY: Fremont
LOCATION: SECTION: 30 T 67N, R 40W
QUADRANGLE: Farmers City
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



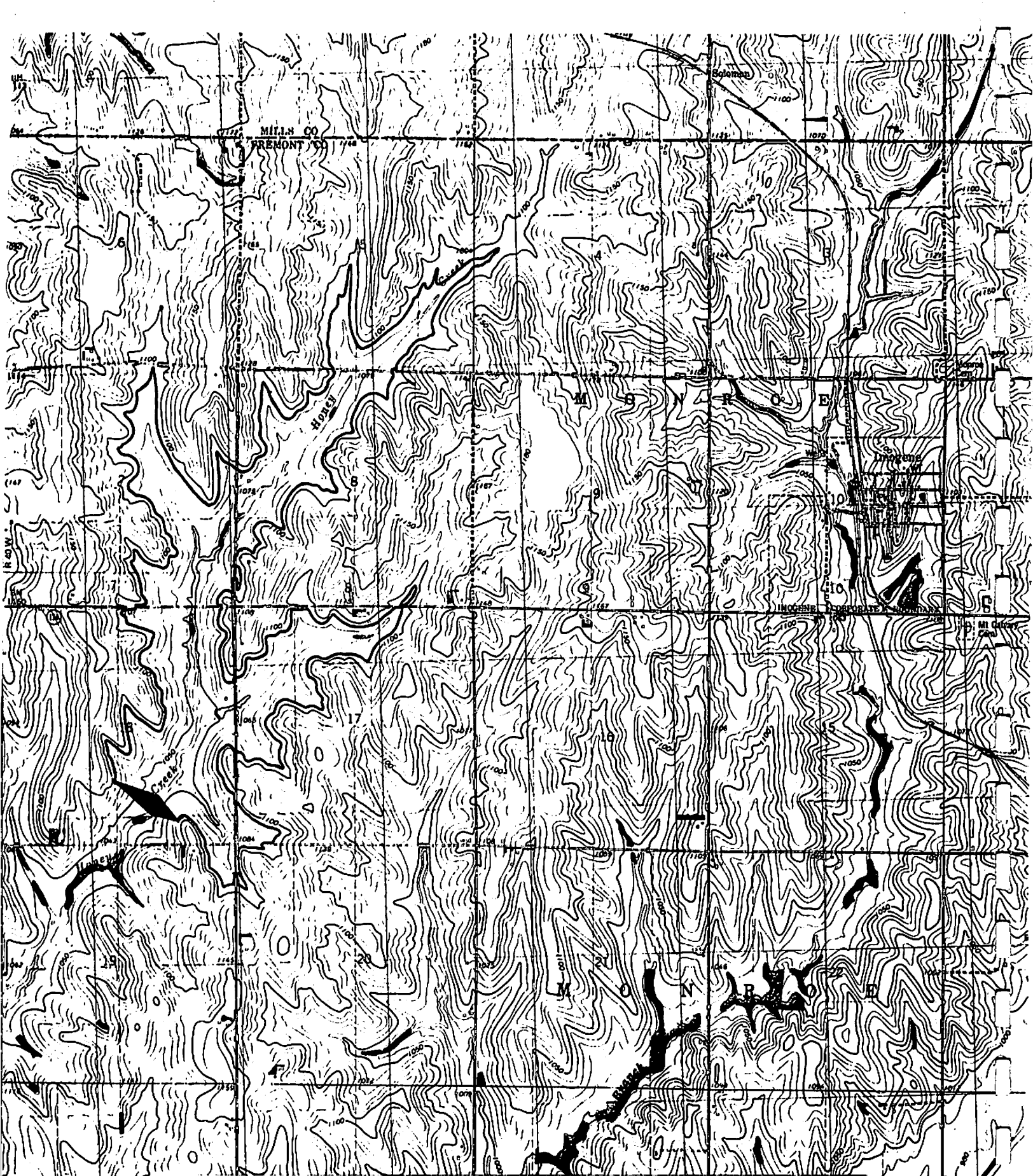
SITE NO.: 8 COUNTY: Fremont
LOCATION: SECTION: 26, 27 T 67N, R 40W
QUADRANGLE: Farragut, Farmers City
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 9 COUNTY: Fremont
LOCATION: SECTION: 23 T 67N, R 40W
QUADRANGLE: Farragut, Bingham, Farmers City, Westboro
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



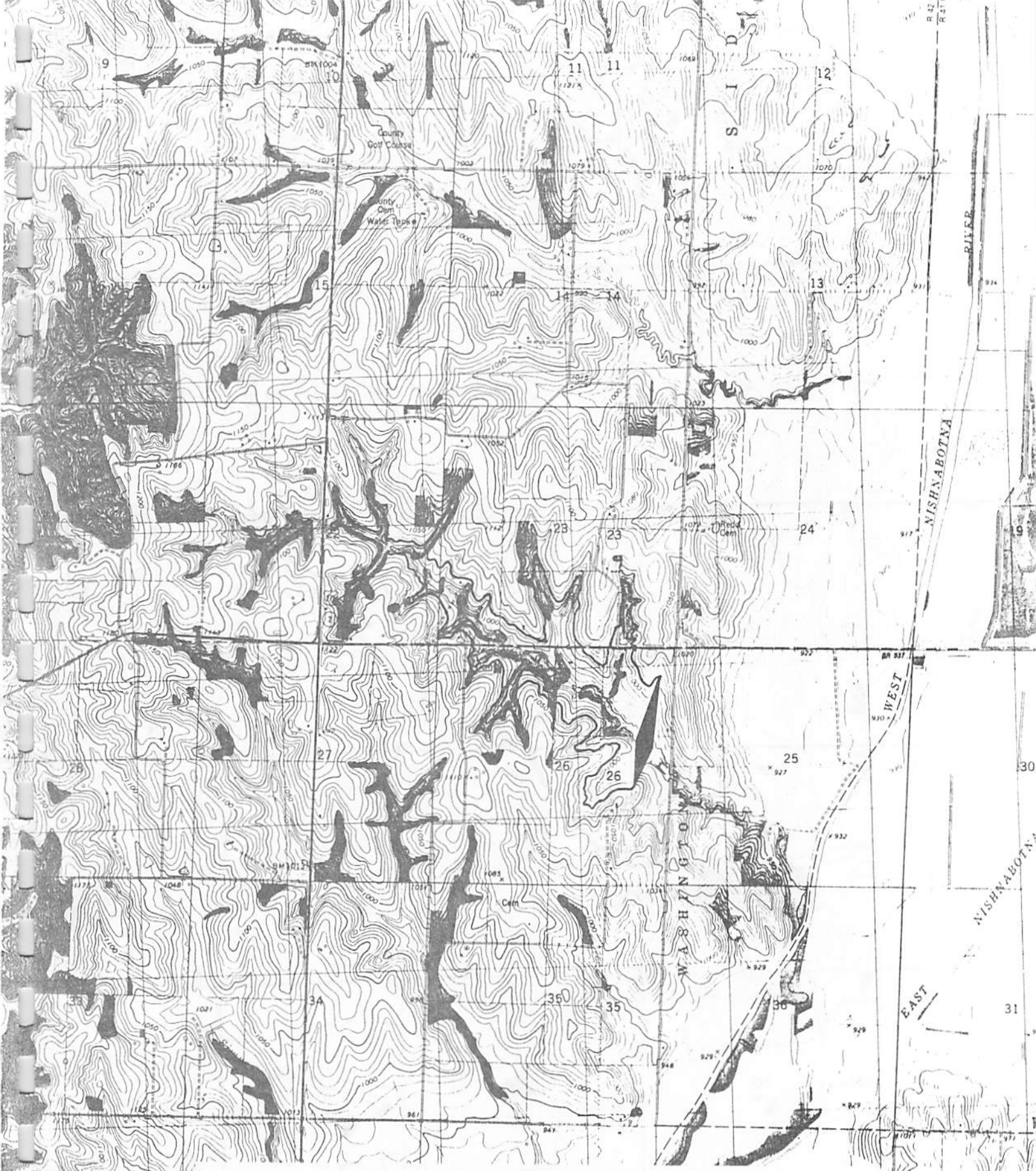
SITE NO.: 10 COUNTY: Fremont
LOCATION: SECTION: 7 T 68N, R 39W
QUADRANGLE: Farragut, Bingham
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



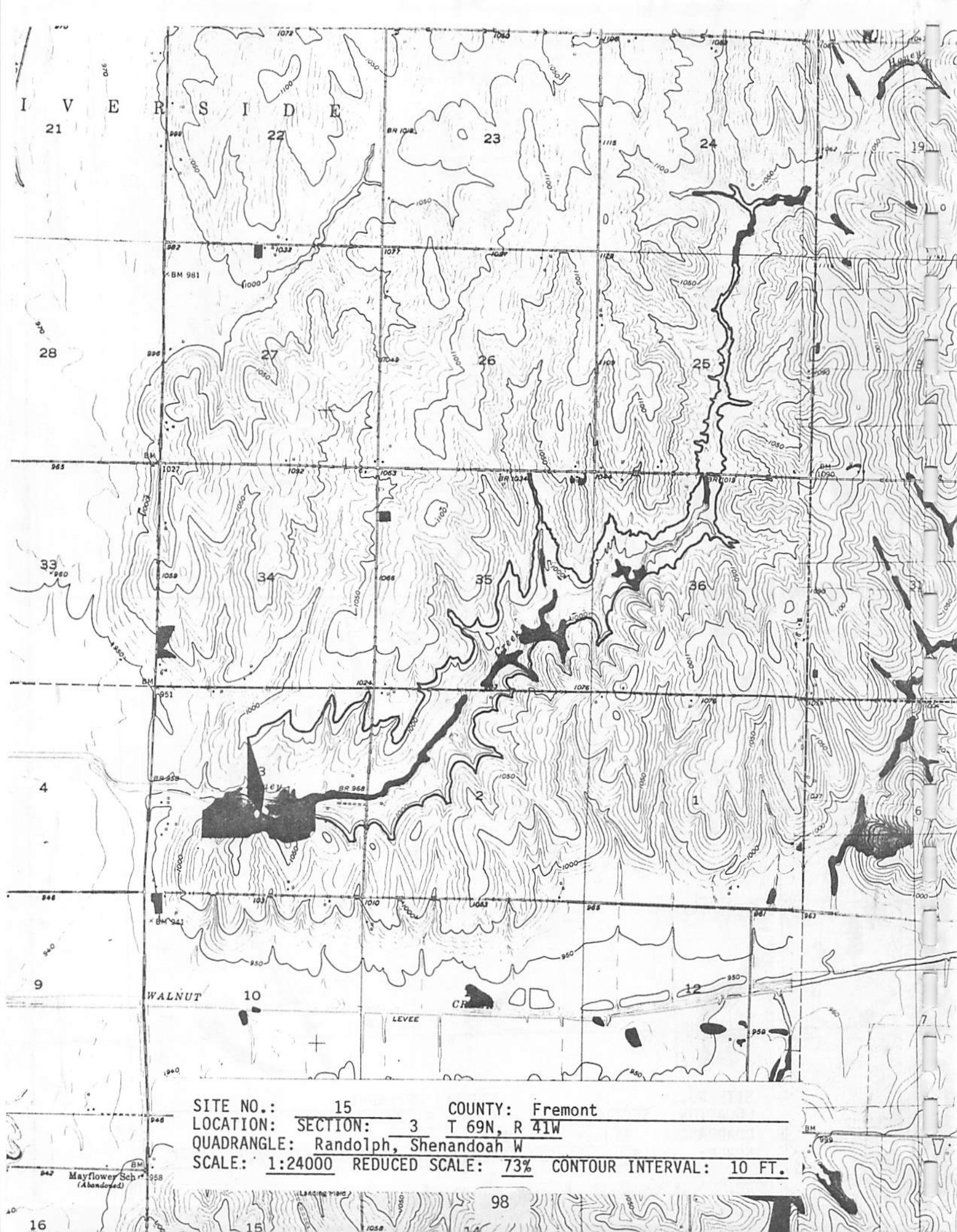
SITE NO.: 11 COUNTY: Fremont
LOCATION: SECTION: 18 T 70N, R 40W
QUADRANGLE: Imogene, Shenandoah W
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 12 COUNTY: Fremont
LOCATION: SECTION: 7, 32 T 68, 69N, R 42W
QUADRANGLE: Tabor SW, Sidney
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

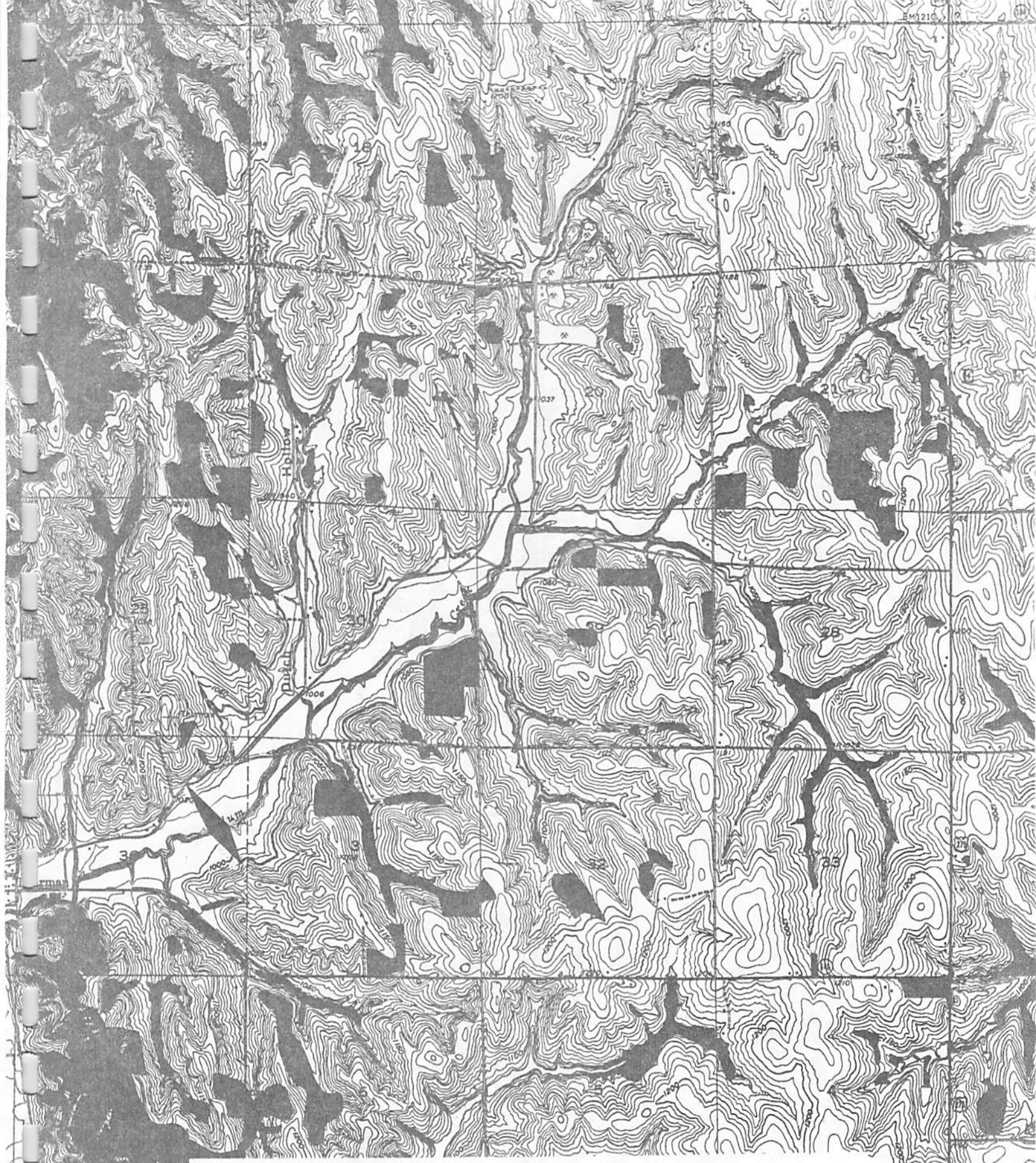
SITE NO.: 13 COUNTY: Fremont
LOCATION: SECTION: 13, 24 T 68N, R 42W
QUADRANGLE: Sidney, Riverton
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



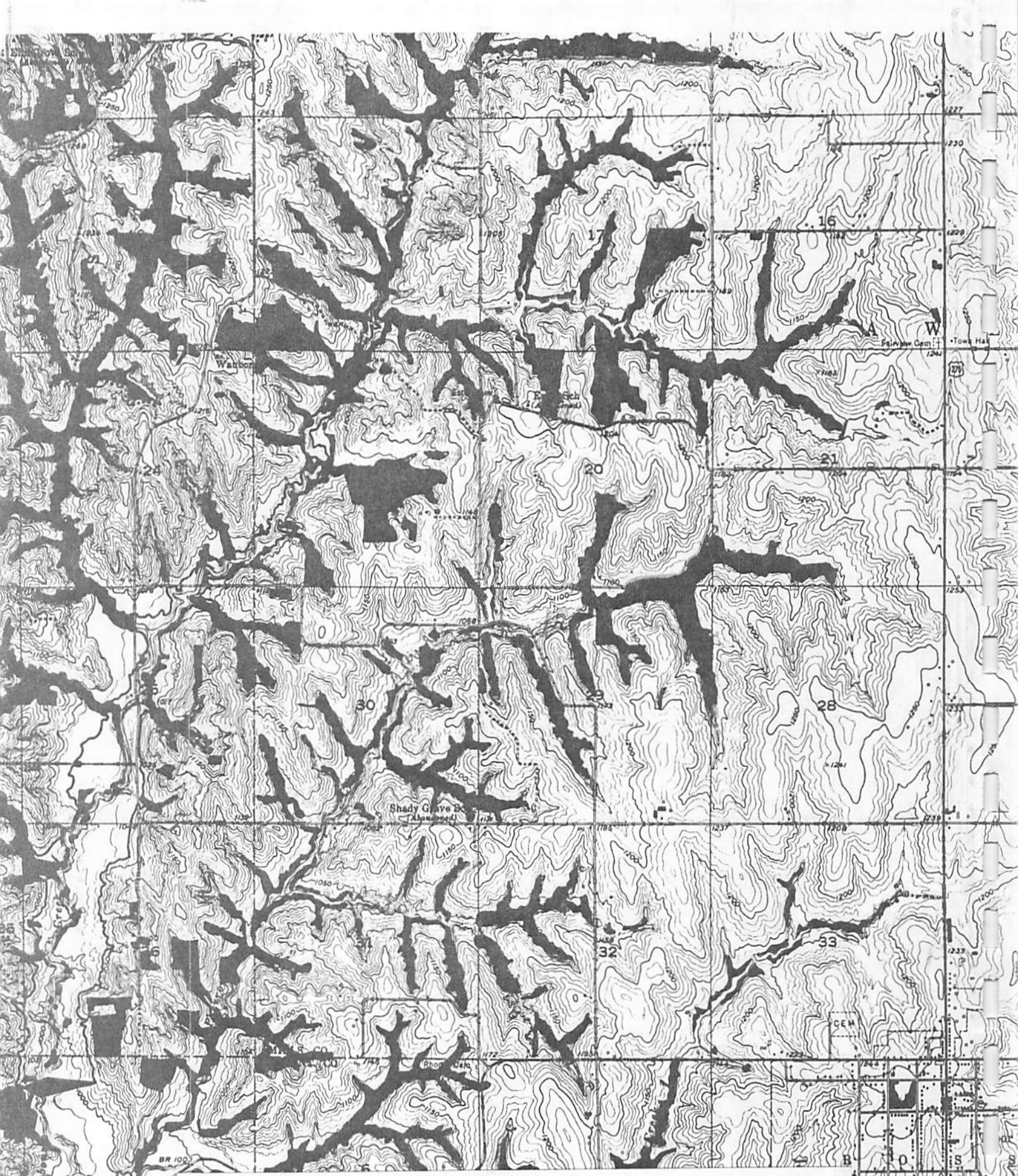
SITE NO.: 14 COUNTY: Fremont
LOCATION: SECTION: 26 T 68N, R 42W
QUADRANGLE: Sidney, Riverton
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



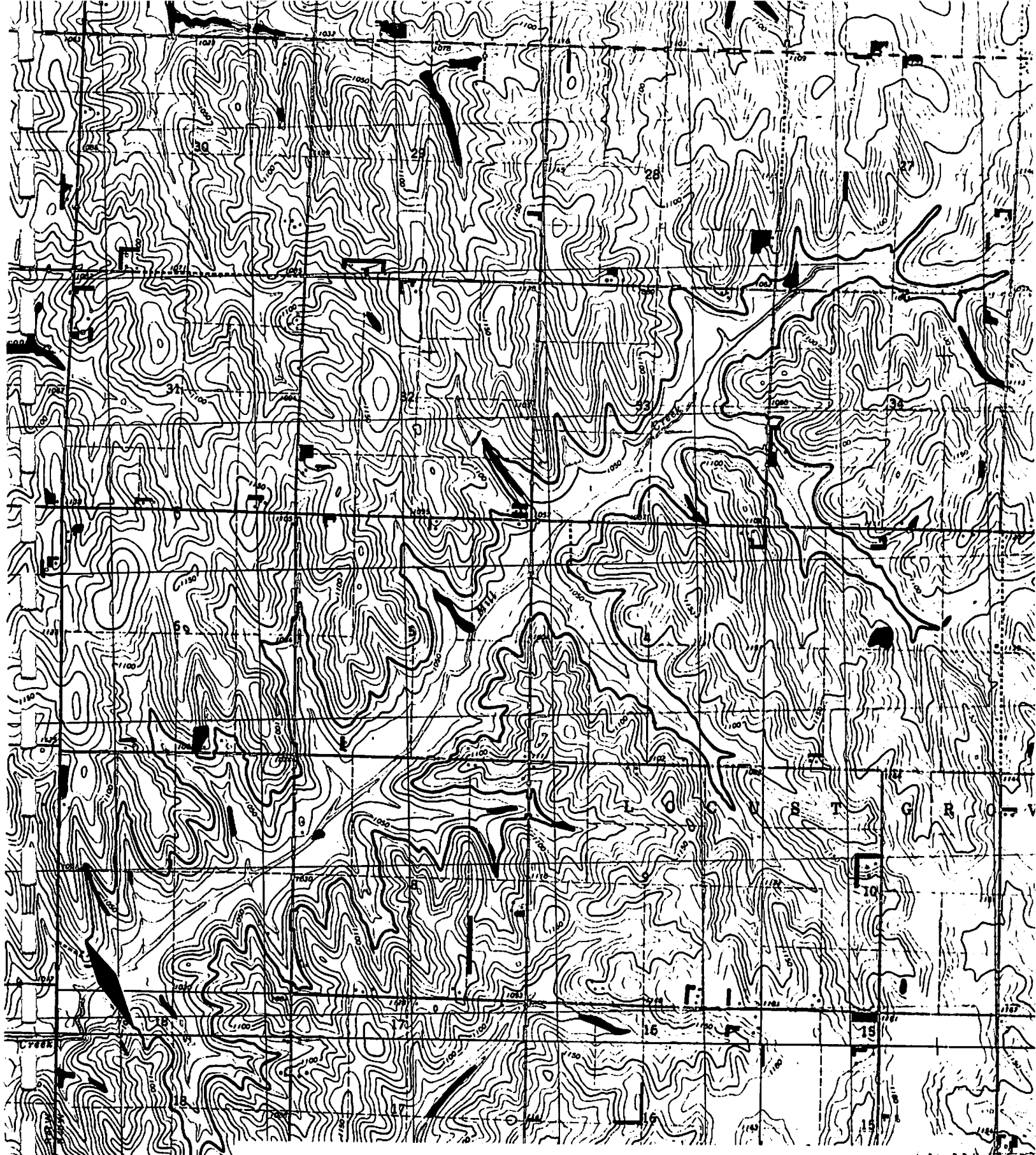
SITE NO.: 15 COUNTY: Fremont
LOCATION: SECTION: 3 T 69N, R 41W
QUADRANGLE: Randolph, Shenandoah W
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 16 COUNTY: Fremont
LOCATION: SECTION: 36 T 70N, R 43W
QUADRANGLE: Tabor SW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



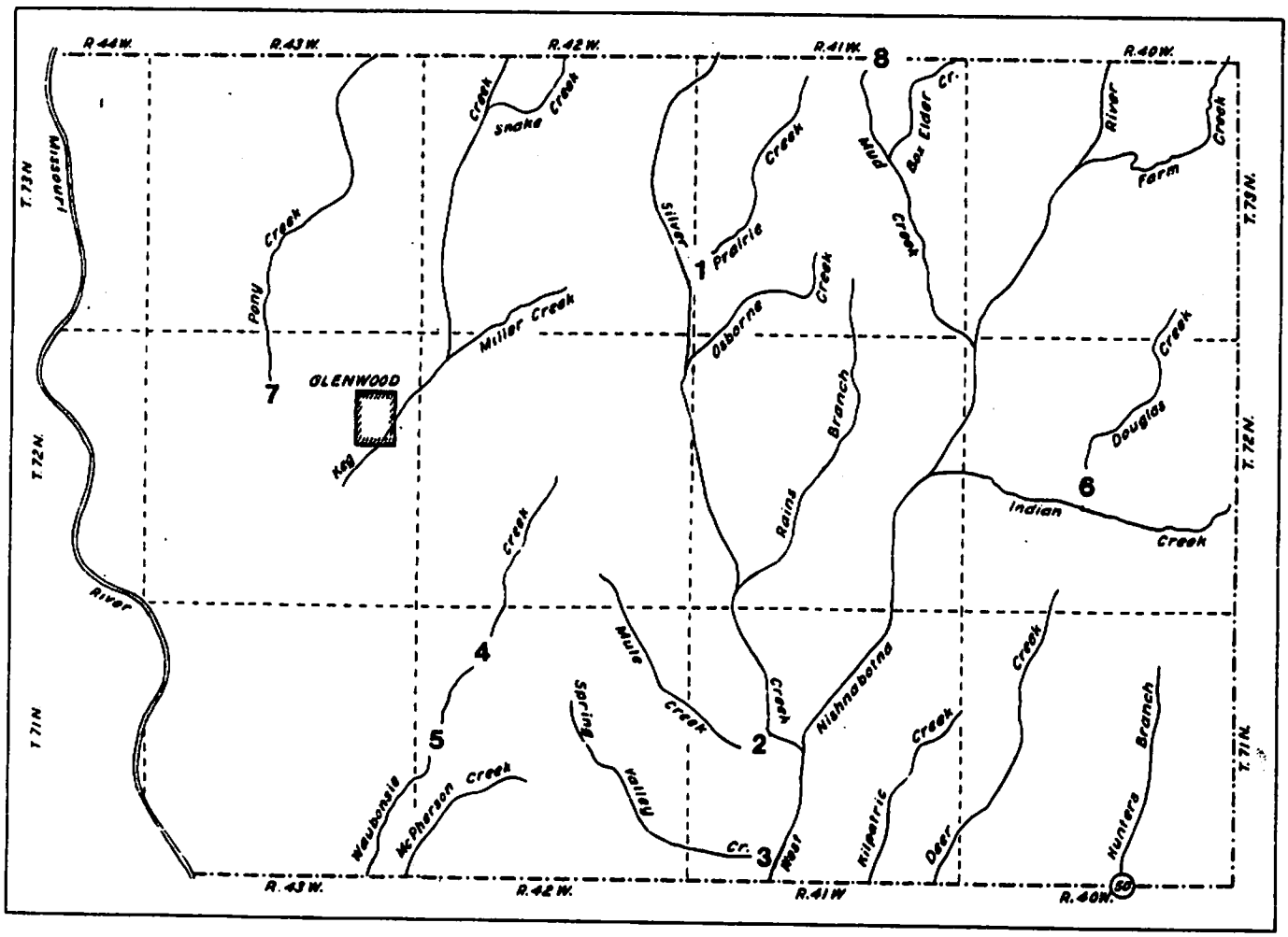
SITE NO.: 17 COUNTY: Fremont
LOCATION: SECTION: 1 T 70N, R 43W
QUADRANGLE: Tabor
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 18 COUNTY: Fremont
LOCATION: SECTION: 7, 18 T 67N, R 40W
QUADRANGLE: Farragut, Farmers City
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 19 COUNTY: Fremont
LOCATION: SECTION: 14 T 67N, R 41W
QUADRANGLE: Riverton, Farragut, McElroy, Farmers City
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 20 COUNTY: Fremont
LOCATION: SECTION: 32 T 70N, R 40W
QUADRANGLE: Imogene, Shenandoah
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

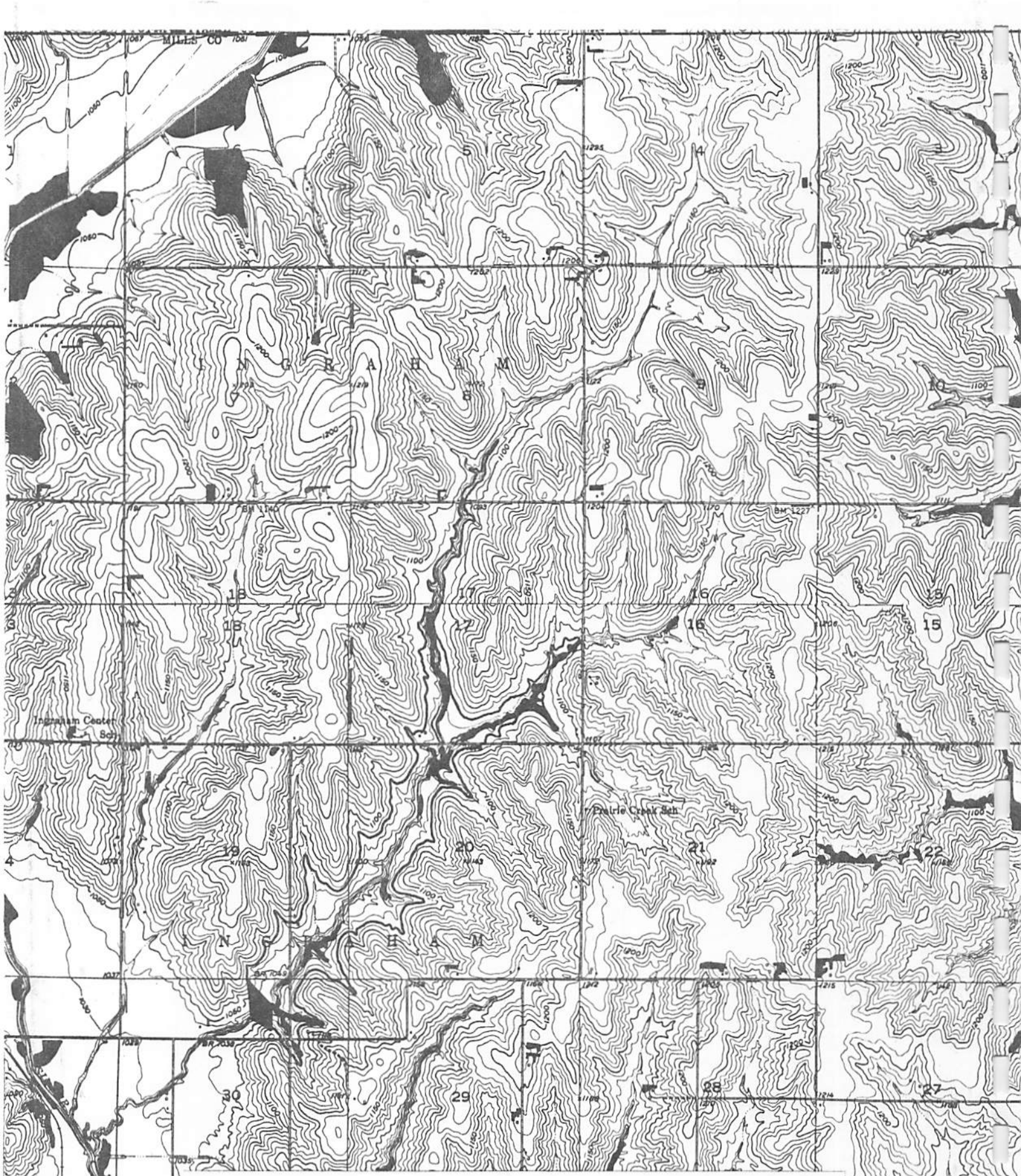


Index map for impoundment sites in Mills County.

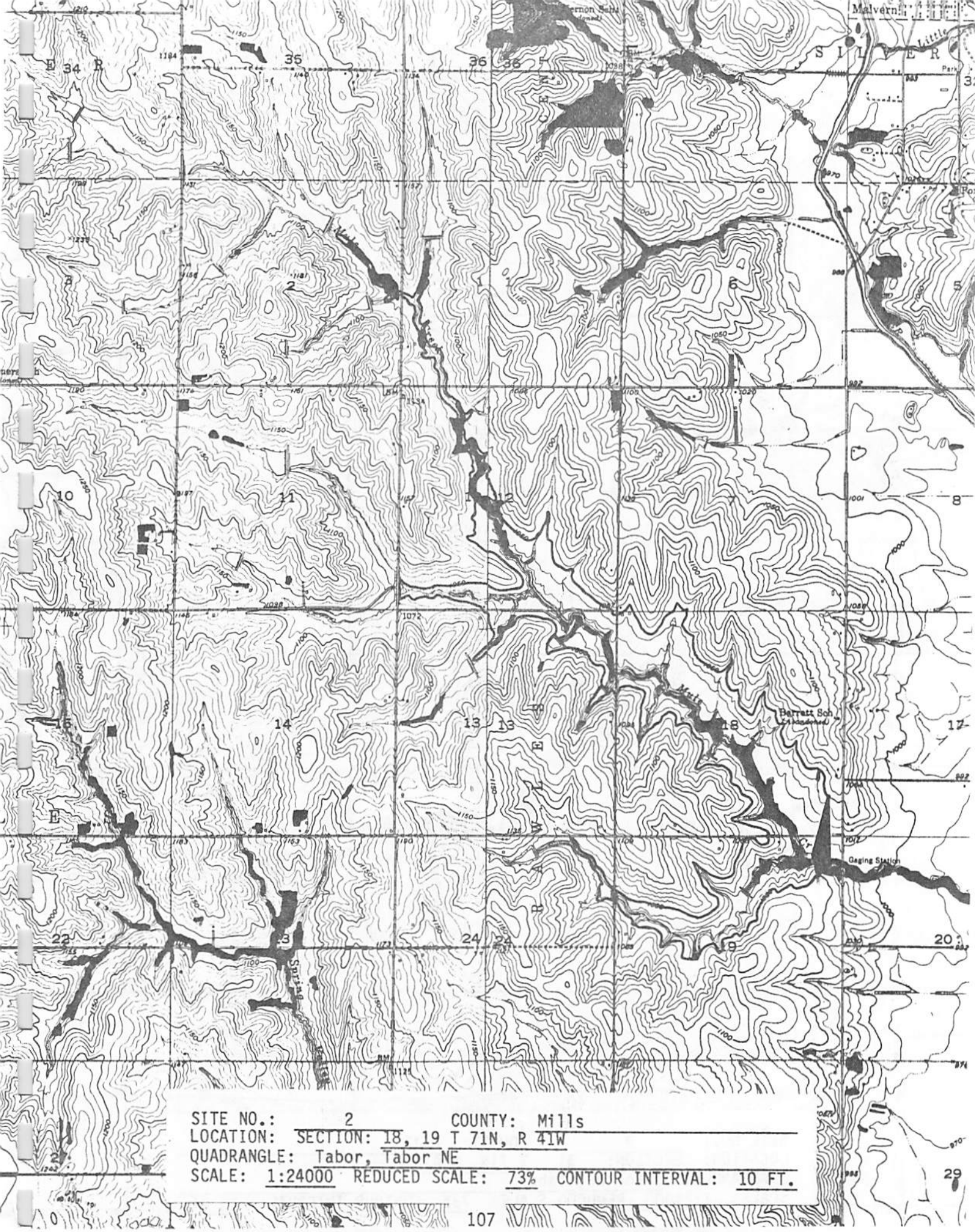
MILLS COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS			SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)	Sediment Storage Requirement* (acre-feet)	Recalculated Surface Area* (acres)	Evaporation Storage Requirement* (acre-feet)	Total Scaled Required Storage* (acre-feet)
1	30	73	41	7.55	45	190	2856	5	1	10	369 369	248 621	41 66	21 33	638 1023
										20	1044 1044	248 621	86 111	43 56	1336 1721
2	18, 19	71	41	11.20	55	393	7197	5	1	10	320 320	348 870	36 65	18 33	686 1223
										20	864 864	348 870	66 95	33 47	1245 1781
3	31	71	41	3.49	55	267	4900	5	1	10	356 356	275 686	34 57	17 28	648 1071
										20	995 995	275 686	69 92	35 46	1304 1727
4	5	71	42	7.83	55	182	3344	5	1	10	365 365	256 640	34 55	17 27	638 1033
										20	1029 1029	256 640	70 91	35 46	1320 1715
5	18	71	42	14.60	65	438	9498	5	1	10	281 281	437 1092	33 63	17 32	734 1404
										20	724 724	437 1092	54 84	27 42	1187 1857
6	21	72	40	7.27	45	227	3399	5	1	10	373 373	240 601	41 65	21 33	634 1007
										20	1060 1060	240 601	87 111	43 55	1343 1716
7	9	72	43	15.90	55	142	2609	12	2	10	840 840	470 1174	72 110	36 55	1346 2070
										20	1161 1161	470 1174	89 127	45 64	1675 2399
8	3	73	41	18.80	55	956	17534	12	2	10	777 777	542 1355	72 116	36 58	1355 2191
										20	1065 1065	542 1355	88 132	44 66	1651 2486

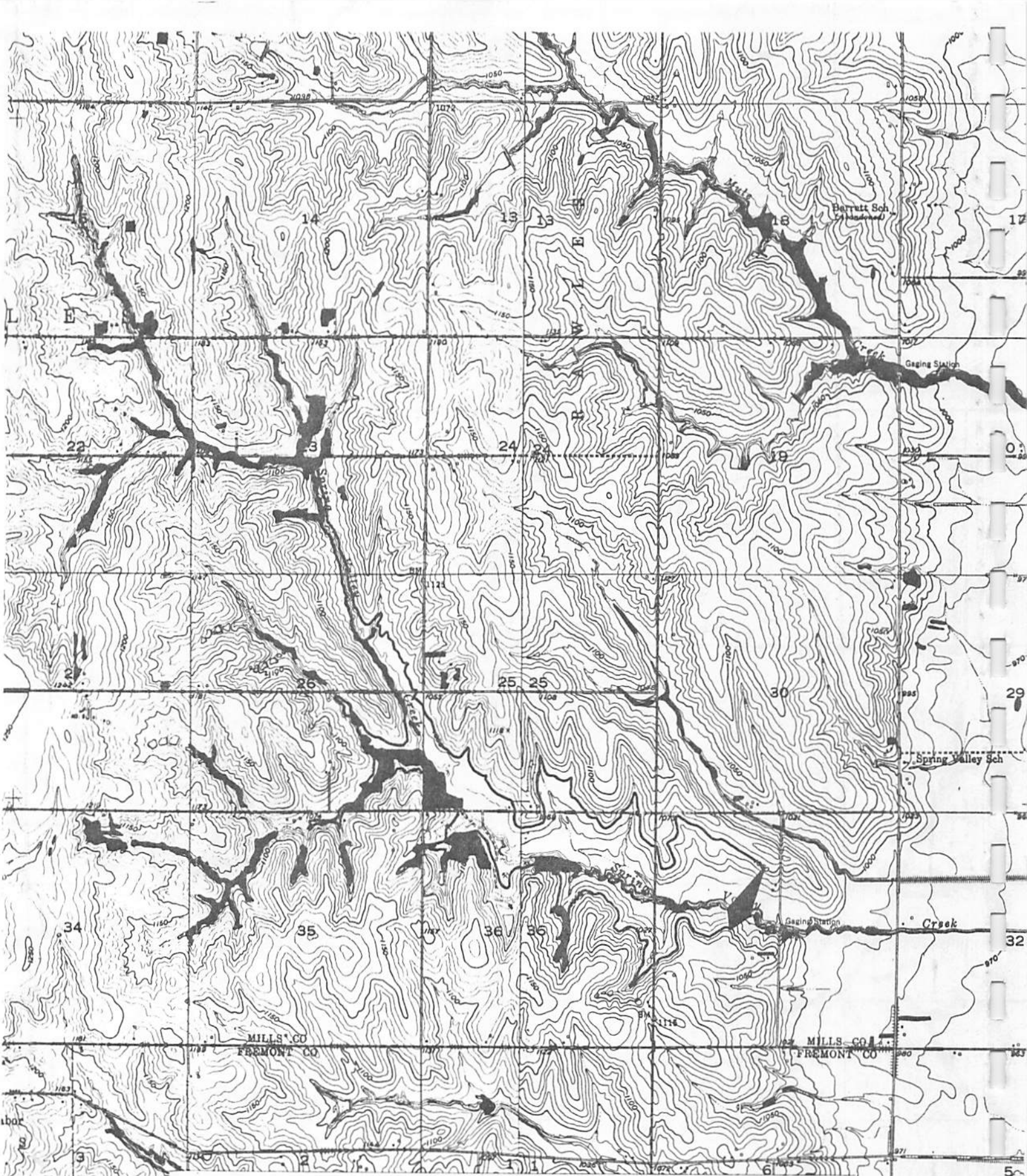
* Column 1 20 year design, Column 2 50 year design periods.



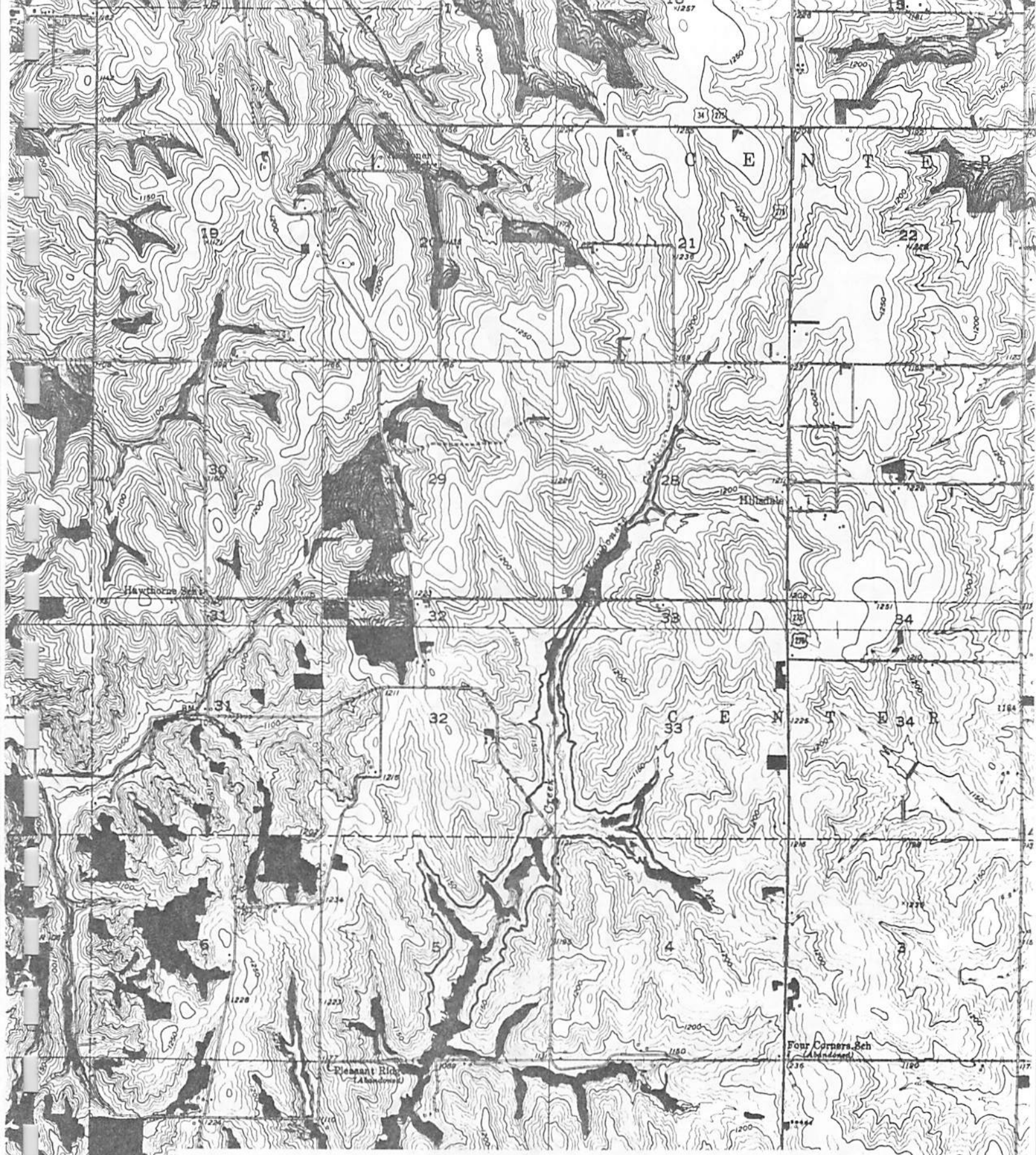
SITE NO.: 1 COUNTY: Mills
LOCATION: SECTION: 30 T 73N, R 41W
QUADRANGLE: Treynor, Malvern
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



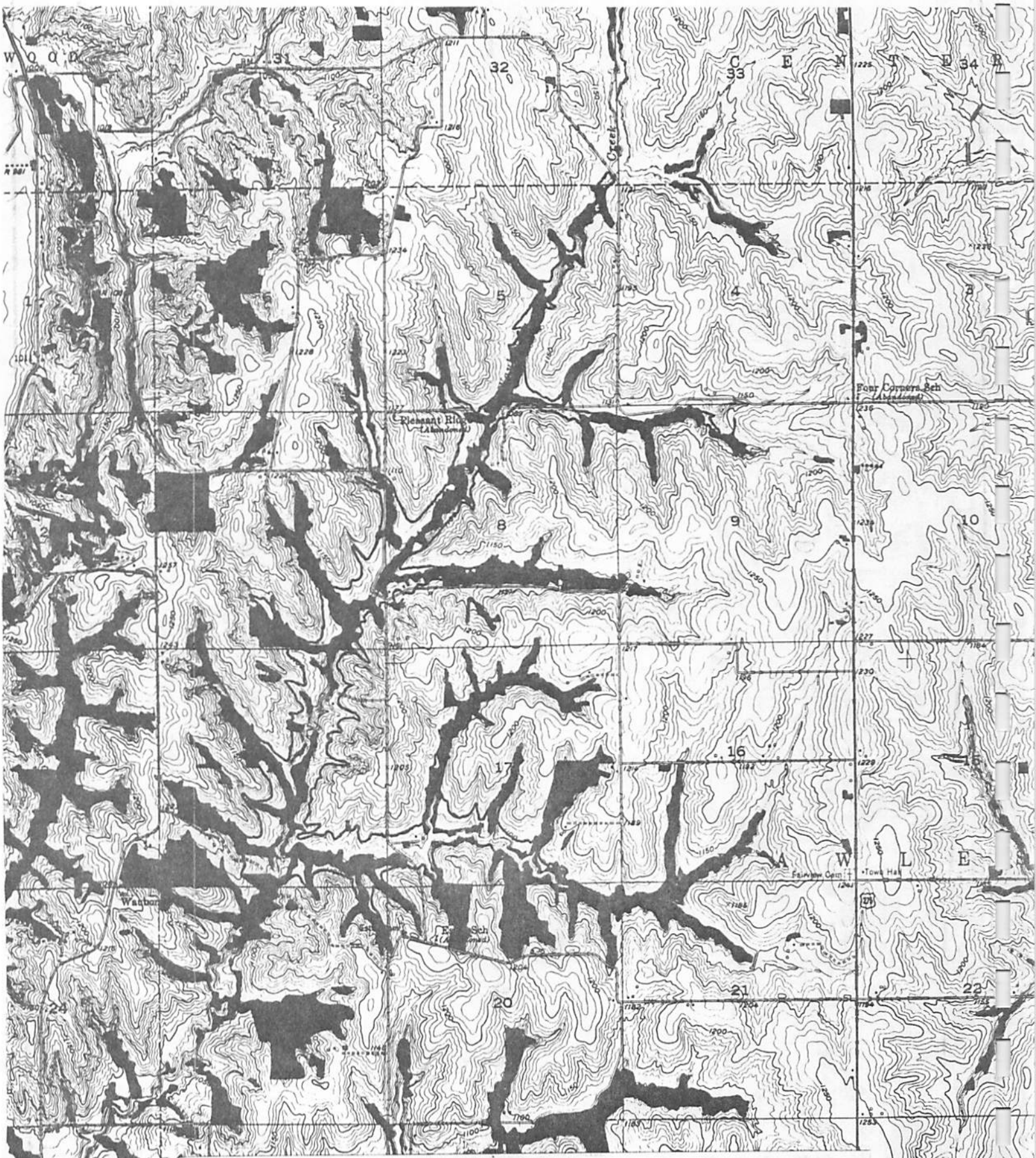
SITE NO.: 2 COUNTY: Mills
LOCATION: SECTION: 18, 19 T 71N, R 41W
QUADRANGLE: Tabor, Tabor NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



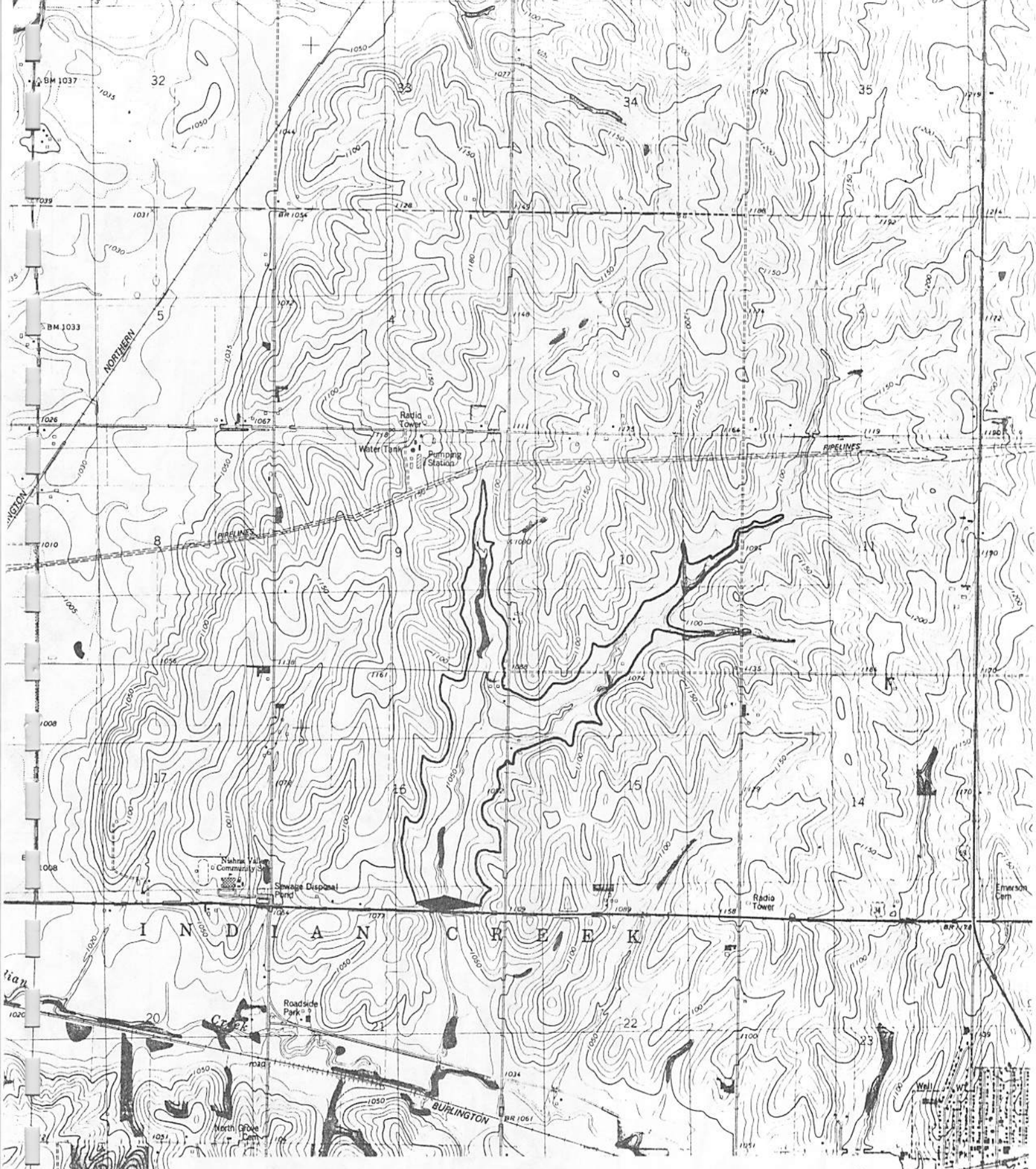
SITE NO.: 3 COUNTY: Mills
LOCATION: SECTION: 31 T 71N, R 41W
QUADRANGLE: Tabor NE, Tabor
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 4 COUNTY: Mills
LOCATION: SECTION: 5 T 71N, R 42W
QUADRANGLE: Glenwood, Treynor
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

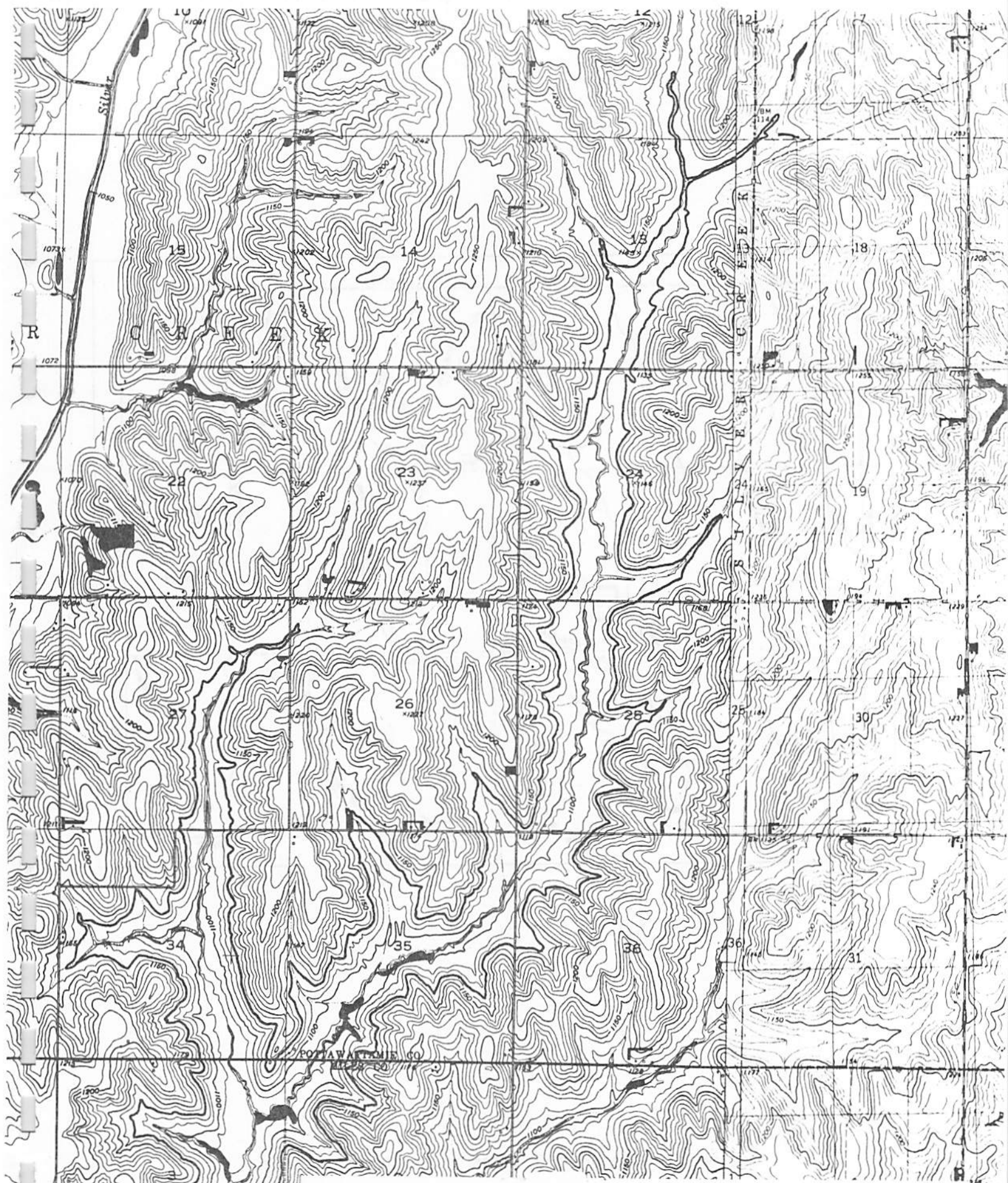


SITE NO.: 5 COUNTY: Mills
LOCATION: SECTION: 18 T 71N, R 42W
QUADRANGLE: Tabor
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 6 COUNTY: Mills
LOCATION: SECTION: 21 T 72N, R 40W
QUADRANGLE: Emerson
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 7 COUNTY: Mills
LOCATION: SECTION: 9 T 72N, R 43W
QUADRANGLE: Pacific Junction
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



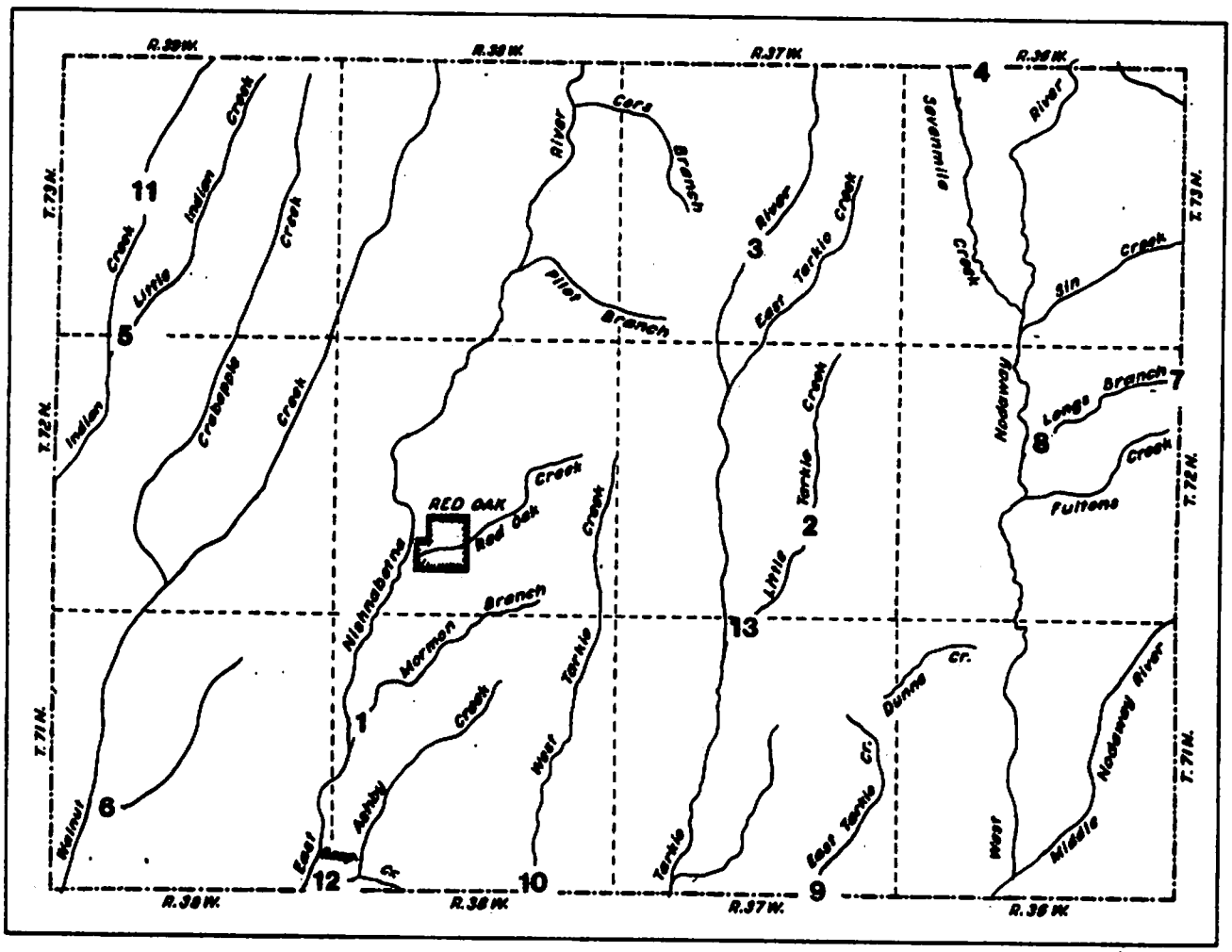
113

SITE NO.: 8 COUNTY: Mills

LOCATION: SECTION: 3 T 73N, R 41W

QUADRANGLE: Treynor, Carson

SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

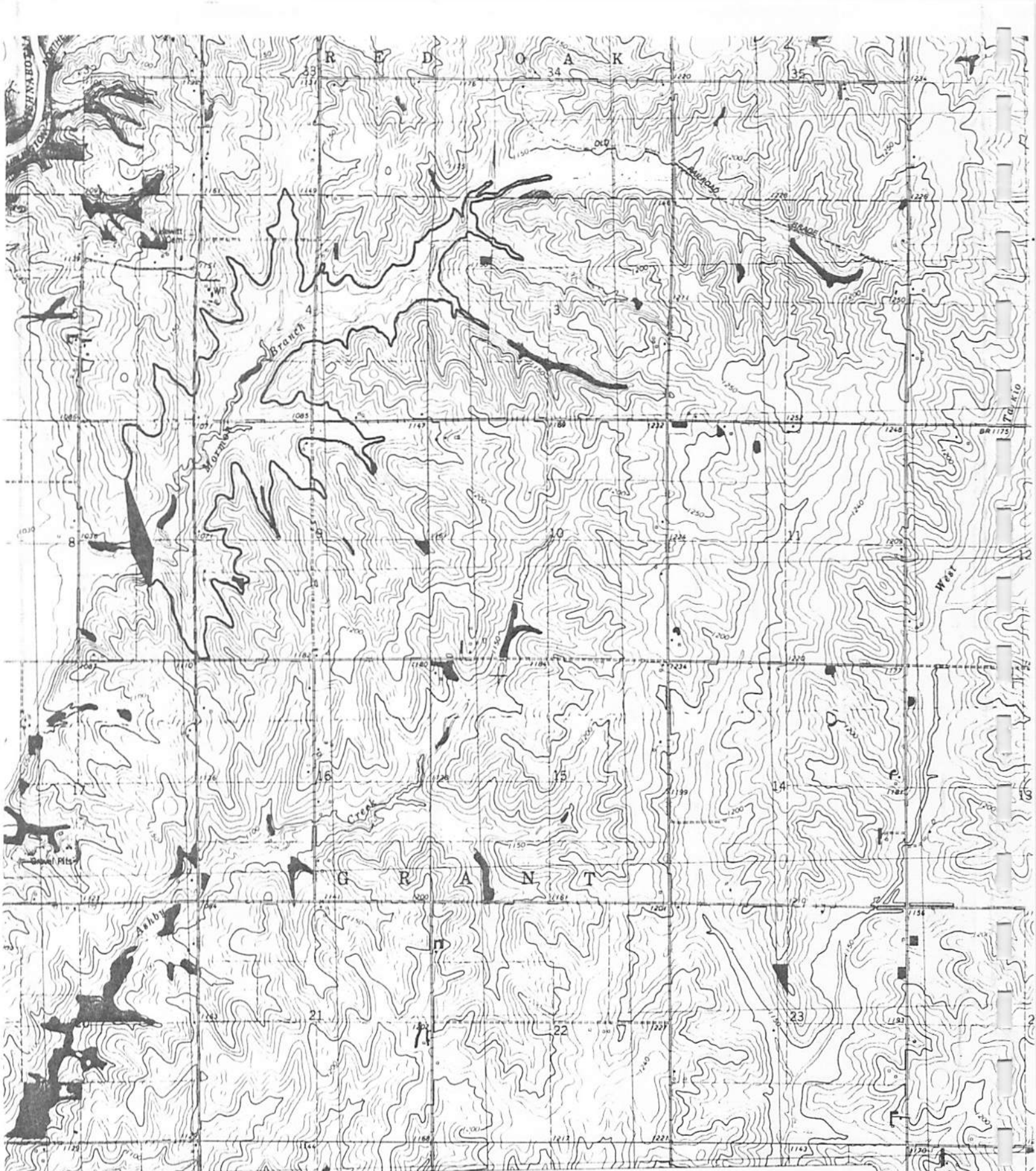


Index map for impoundment sites in Montgomery County.

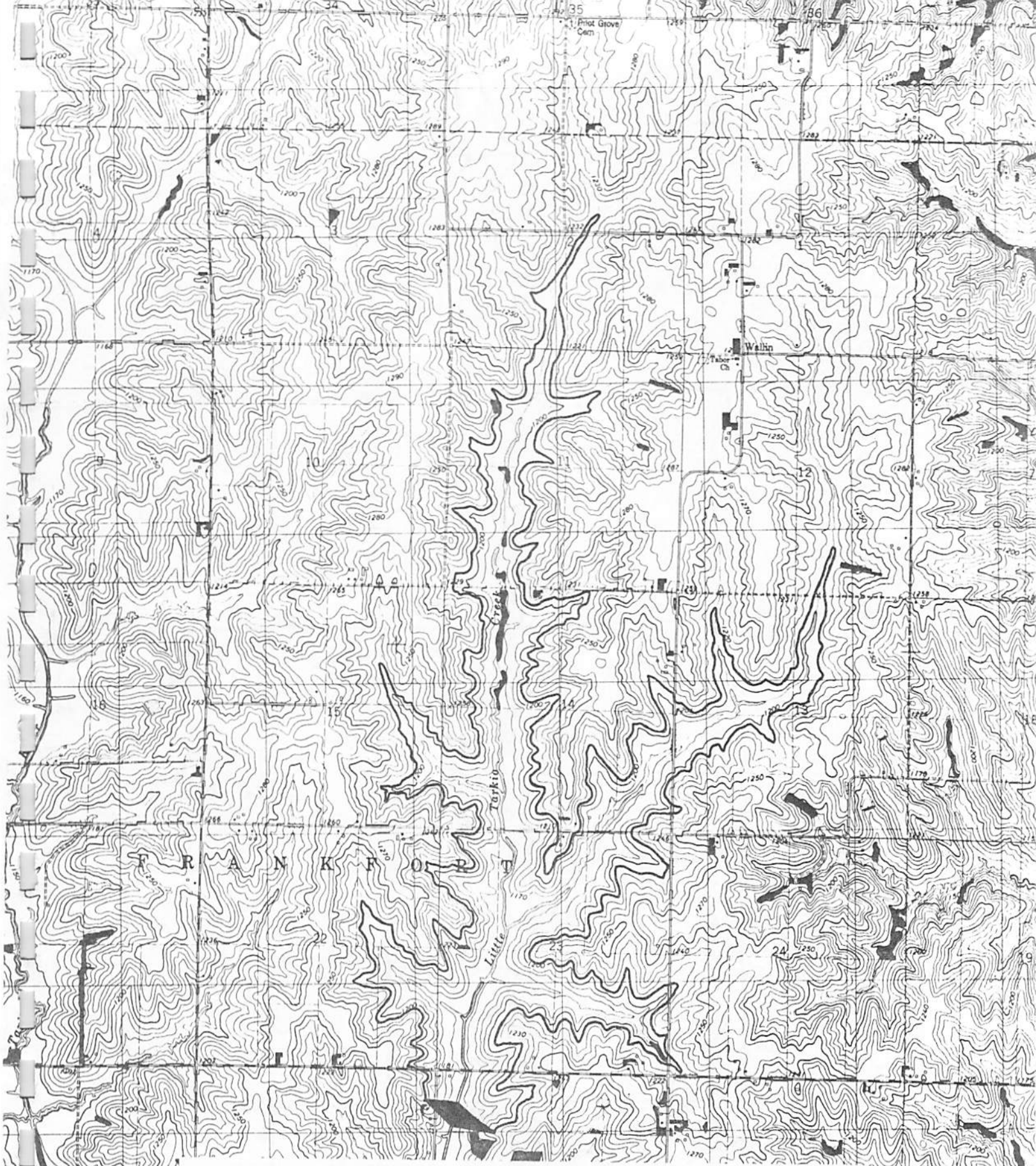
MONTGOMERY COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS			POPULATION	WITHDRAWAL	LOW-FLOW RECURRENCE	SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Served (1000's)	Rate (feet³/sec)	Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	8	71	38	8.26	65	403	8727	5	1	10	359	359	268	670	29	48	15	24	642	1053
										20	1006	1006	268	670	59	77	30	39	1304	1716
2	26, 27	72	37	8.42	55	757	13374	5	1	10	356	356	268	669	34	56	17	28	641	1053
										20	998	998	268	669	70	91	35	46	1301	1713
3	21, 22	73	37	10.70	45	708	10618	5	1	10	326	326	335	837	44	76	22	39	683	1597
										20	887	887	335	837	81	115	41	57	1261	1781
4	5, 32	73, 74	36	9.03	55	400	7336	5	1	10	349	349	289	724	35	59	17	29	655	1101
										20	967	967	289	724	69	92	34	46	1291	1737
5	5, 32	72, 73	39	8.32	55	416	7632	5	1	10	358	358	270	675	34	56	17	28	645	1051
										20	1003	1003	270	675	69	92	35	46	1308	1724
6	29	71	39	6.51	45	210	3155	5	1	10	385	385	219	547	40	62	20	31	623	962
										20	1102	1102	219	547	88	110	44	55	1365	1704
7	1	72	36	6.60	60	470	9398	5	1	10	383	383	221	553	30	47	15	23	620	960
										20	1097	1097	221	553	66	83	33	41	1351	1692
8	10	72	36	11.00	60	478	9557	5	1	10	323	323	343	857	33	59	17	30	682	1209
										20	873	873	343	857	61	87	30	43	1246	1773
9	35	71	37	6.97	45	687	10303	5	1	10	378	378	232	580	41	64	20	32	630	989
										20	1076	1076	232	580	87	110	44	55	1352	1711
10	35	71	38	20.40	35	818	9539	12	2	10	744	744	581	1454	114	188	57	94	1383	2232
										20	1015	1015	581	1454	137	68	212	106	1665	2574
11	17	73	39	19.80	45	774	11614	12	2	10	756	756	567	1417	88	44	145	72	1367	2246
										20	1033	1033	567	1417	107	163	53	82	1653	2532
12	31	71	38	17.20	45	327	4909	12	2	10	811	811	502	1256	88	138	44	69	1358	2136
										20	1117	1117	502	1256	108	158	54	79	1673	2452
13	34	72	37	16.20	55	687	12587	12	2	10	834	834	477	1193	72	111	36	55	1347	2082
										20	1151	1151	477	1193	88	128	44	64	1673	2408

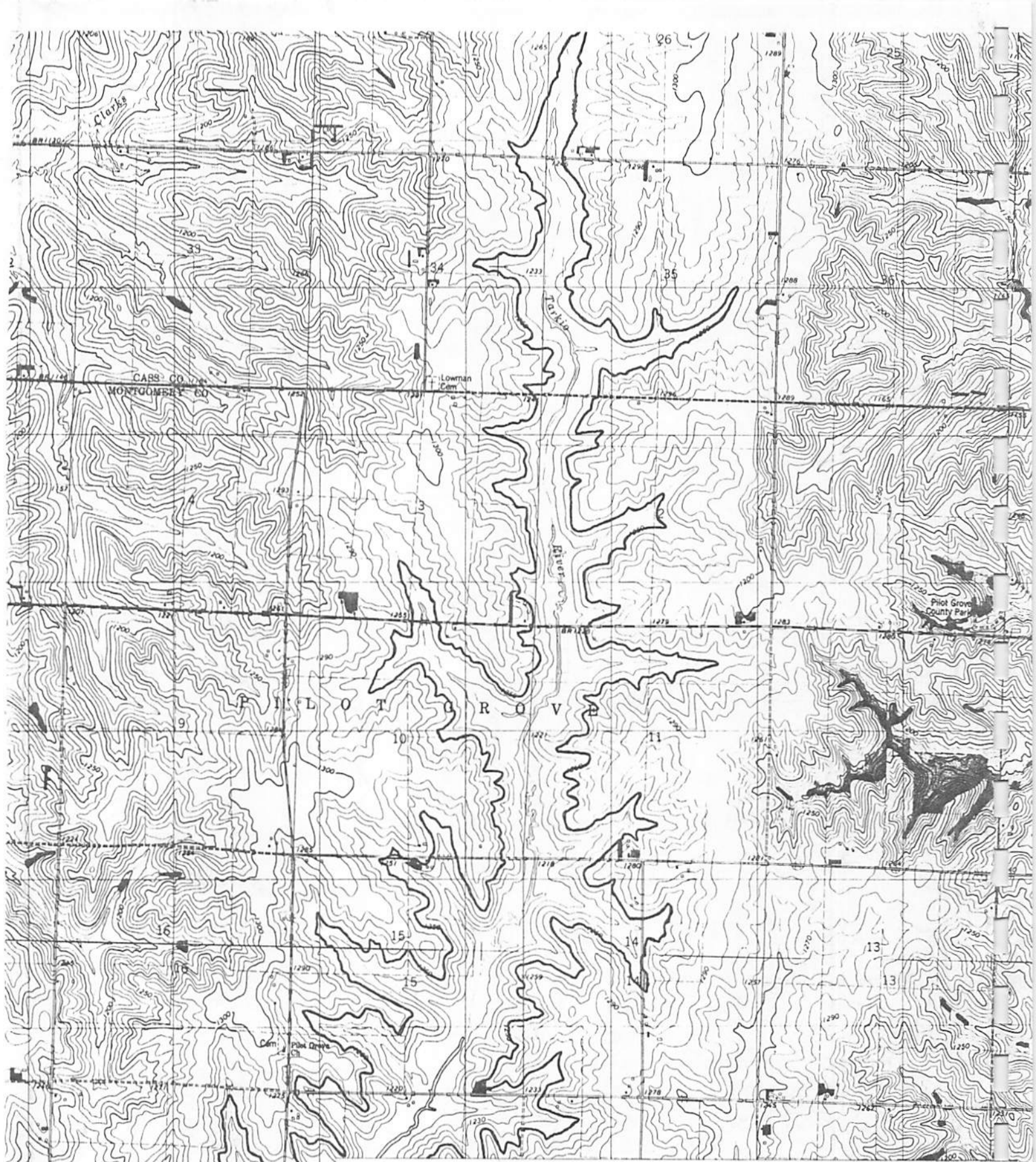
* Column 1 20 year design, Column 2 50 year design periods.



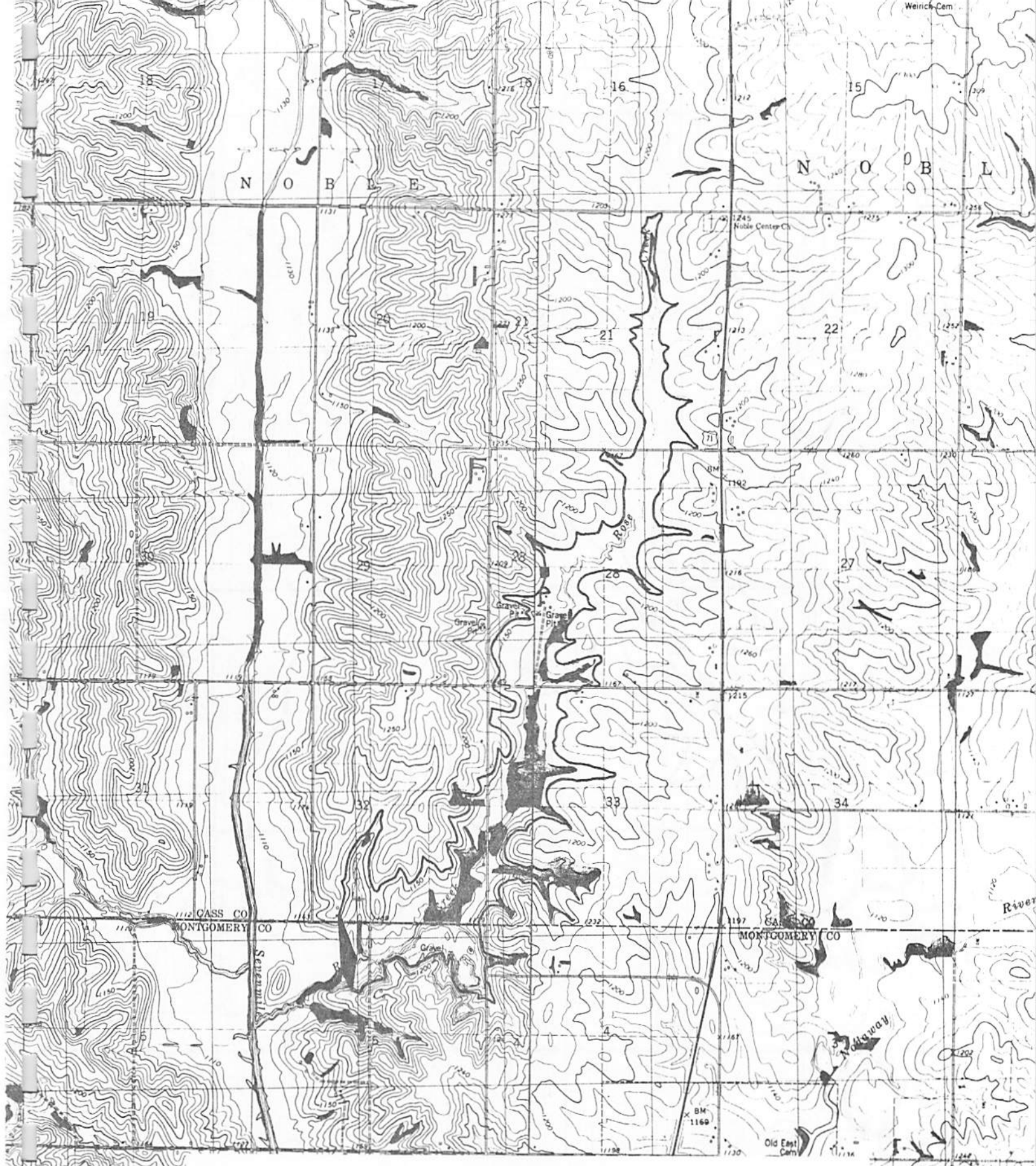
SITE NO.: 1 COUNTY: Montgomery
LOCATION: SECTION: 8 T 71N, R 38W
QUADRANGLE: Red Oak South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 2 COUNTY: Montgomery
LOCATION: SECTION: 26, 27 T 72N, R 37W
QUADRANGLE: Wallin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

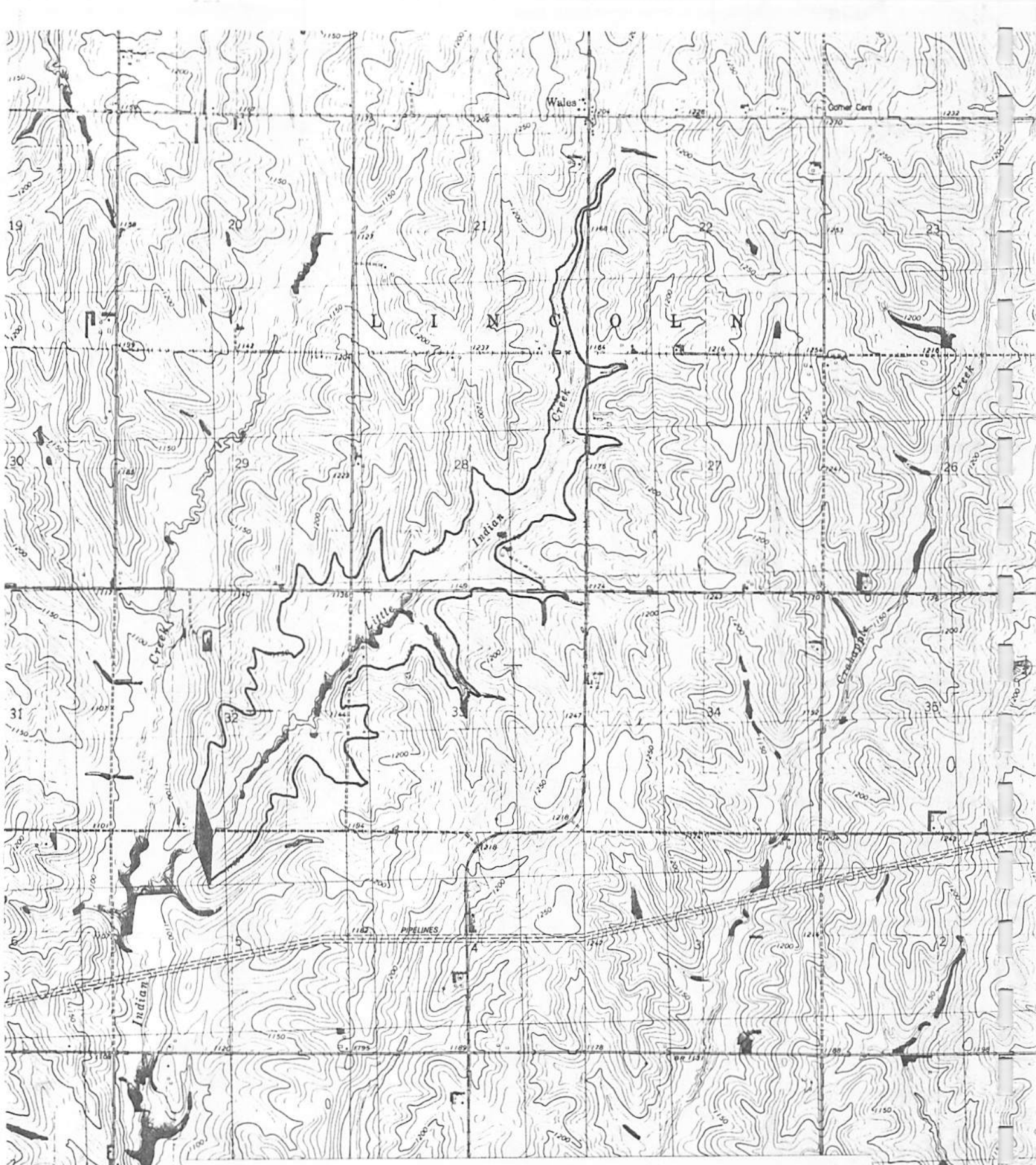


SITE NO.: 3 COUNTY: Montgomery
LOCATION: SECTION: 21, 22 T 73N, R 37W
QUADRANGLE: Griswold NE, Wallin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

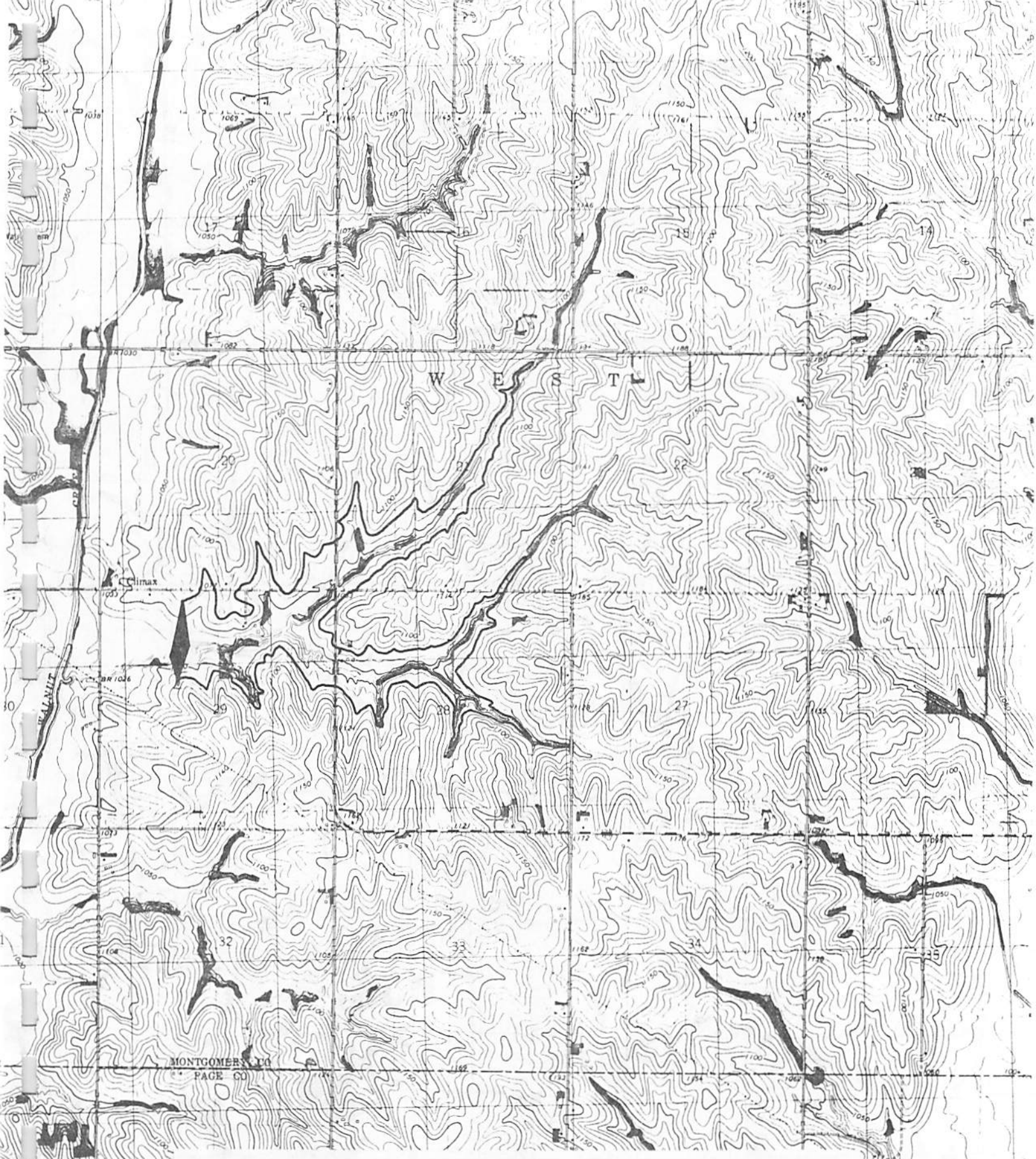


SITE NO.: 4 COUNTY: Montgomery
LOCATION: SECTION: 5, 32 T 73, 74N, R 36W
QUADRANGLE: Griswold NE, Grant
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10, 20 FT.

G L A

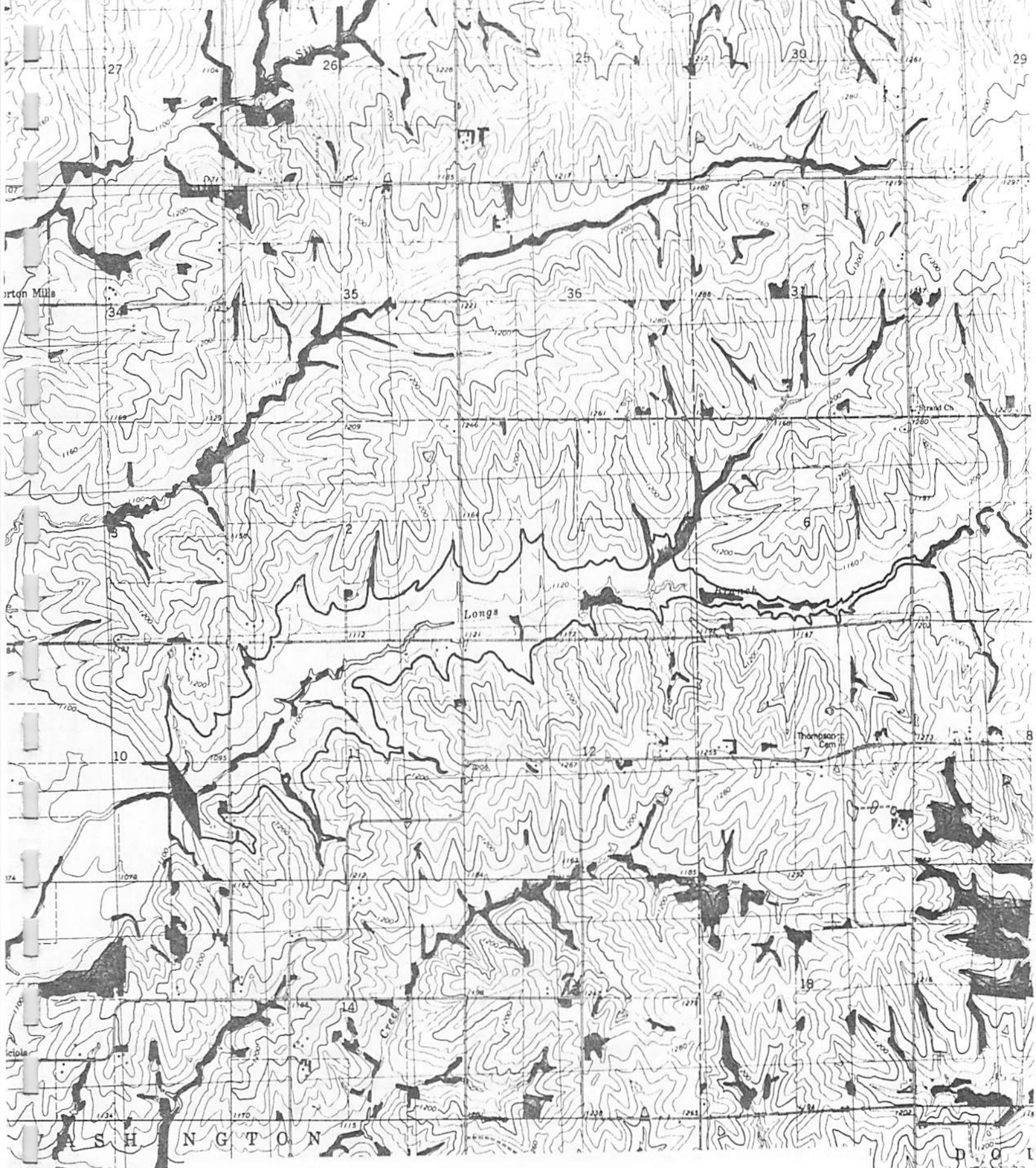


SITE NO.: 5 COUNTY: Montgomery
LOCATION: SECTION: 5, 32 T 72, 73N, R 39W
QUADRANGLE: Wales
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

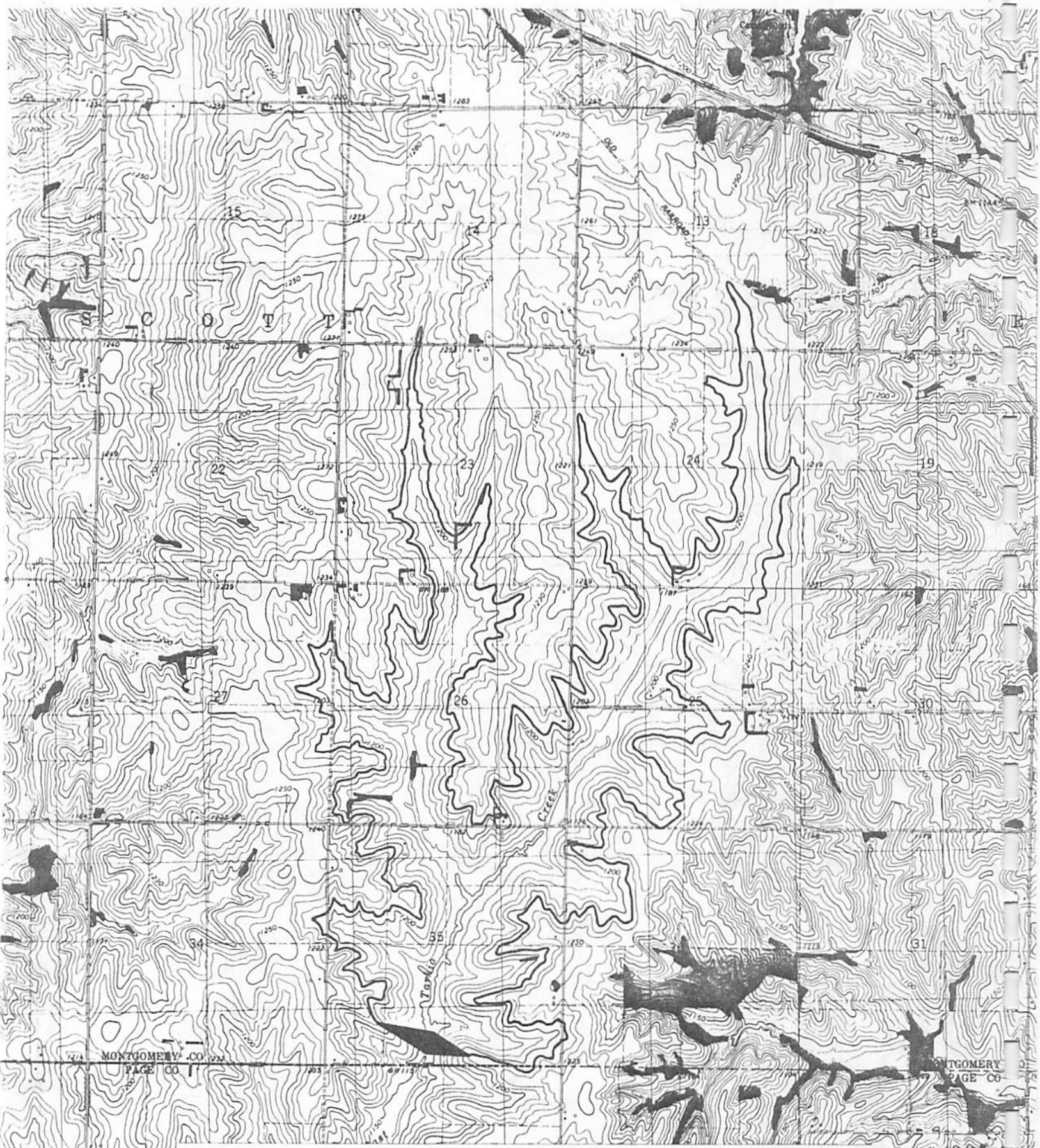


SITE NO.: 6 COUNTY: Montgomery
LOCATION: SECTION: 29 T 71N, R 39W
QUADRANGLE: Coburg
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 7 COUNTY: Montgomery
LOCATION: SECTION: 1 T 72N, R 36W
QUADRANGLE: Morton Mills
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.

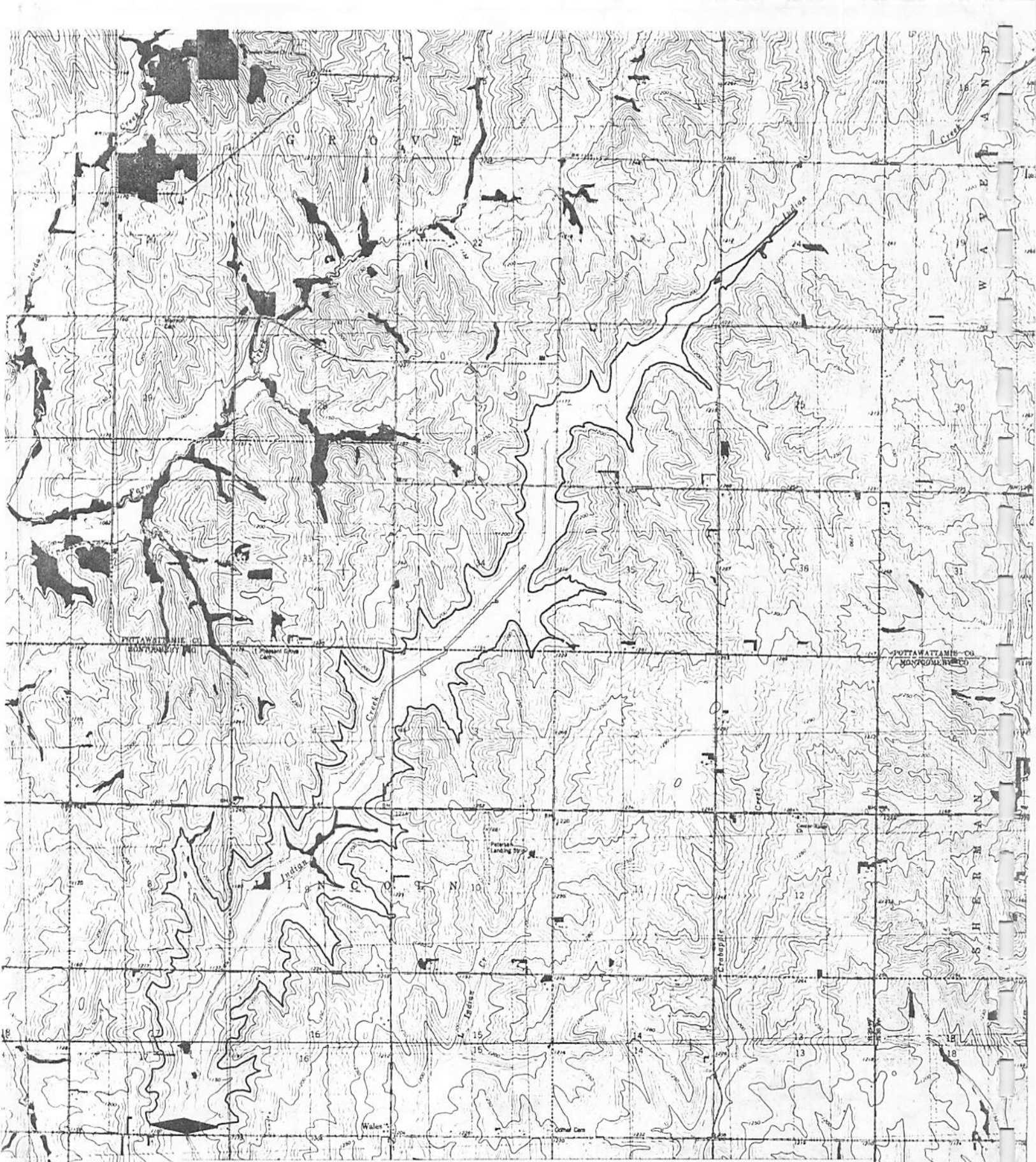


SITE NO.: 8 COUNTY: Montgomery
LOCATION: SECTION: 10 T 72N, R 36W
QUADRANGLE: Morton Mills
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20 FT.



SITE NO.: 9 COUNTY: Montgomery
LOCATION: SECTION: 35 T 71N, R 37W
QUADRANGLE: Stanton
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

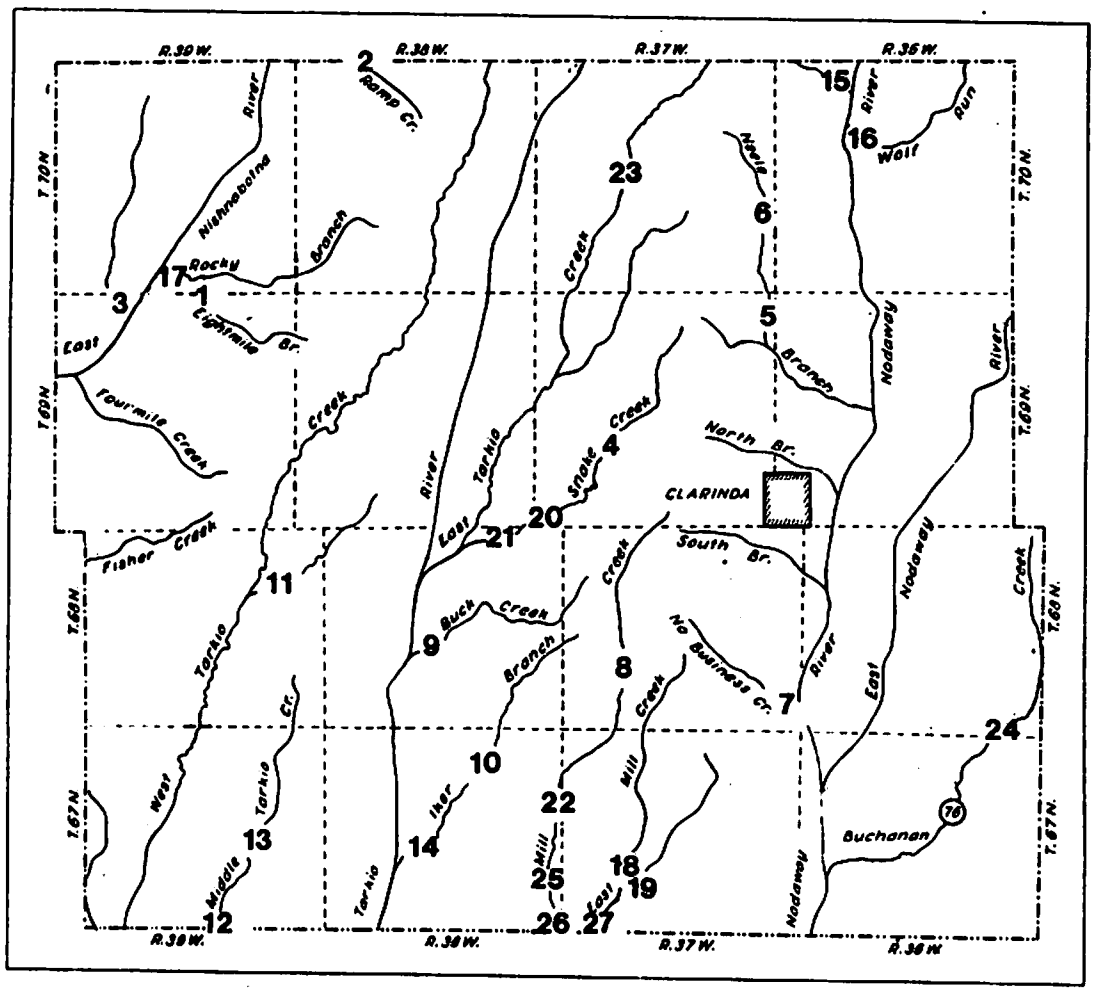
SITE NO.: 10 COUNTY: Montgomery
LOCATION: SECTION: 35 T 71N, R 38W
QUADRANGLE: Red Oak South
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.



SITE NO.: 11 COUNTY: Montgomery
LOCATION: SECTION: 17 T 73N, R 39W
QUADRANGLE: Carson NE
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.

SITE NO.: 12 COUNTY: Montgomery
LOCATION: SECTION: 31 T 71N, R 38W
QUADRANGLE: Red Oak South, Coburg
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 13 COUNTY: Montgomery
LOCATION: SECTION: 34 T 72N, R 37W
QUADRANGLE: Wallin, Stanton
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

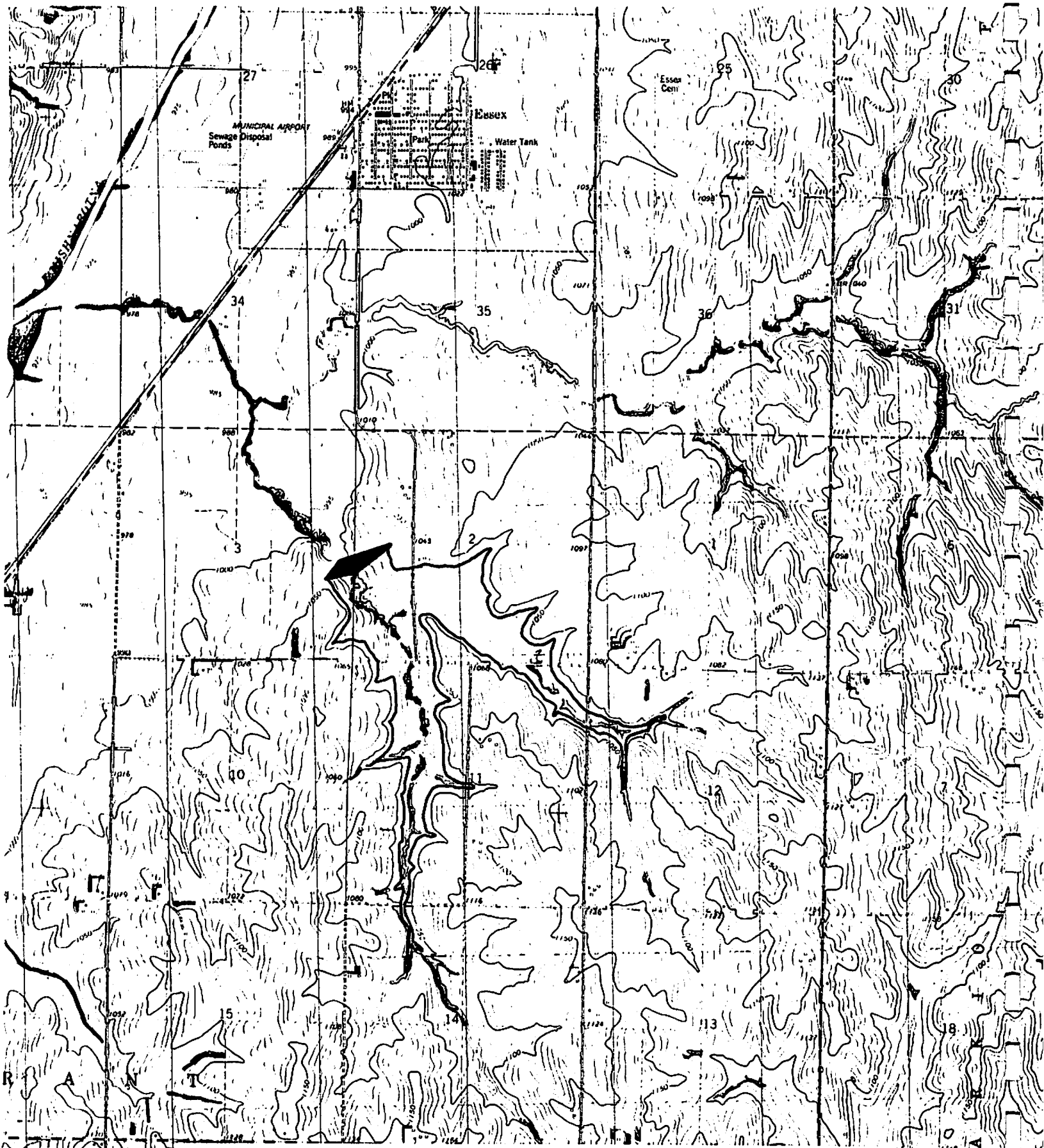


Index map for impoundment sites in Page County.

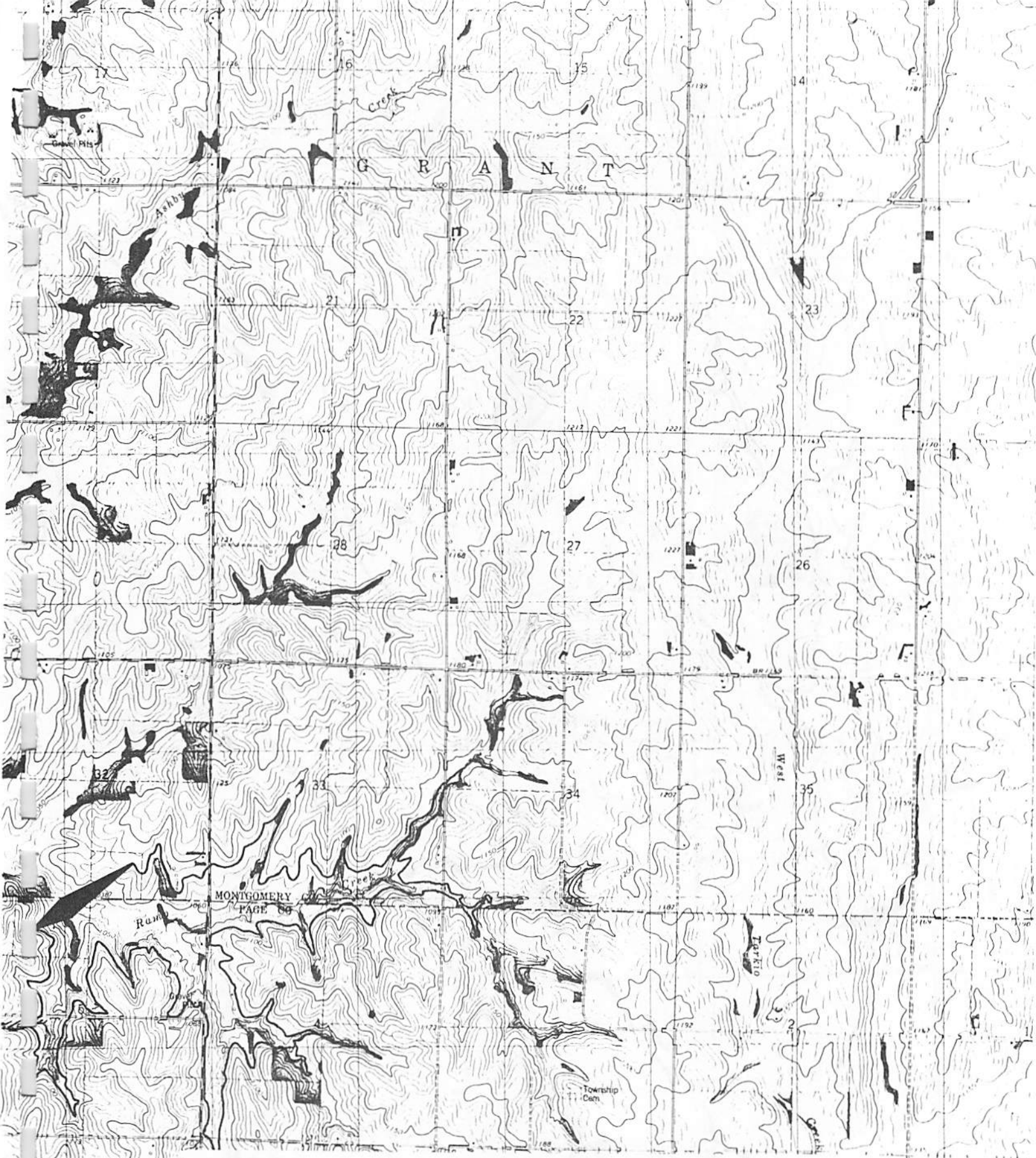
PAGE COUNTY

SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles^2)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet^3/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	2, 3	69	39	6.52	45	167	2497	5	1	10	385	385	219	548	40	62	20	31	624	963
										20	1102	1102	219	548	88	110	44	55	1355	1704
2	5, 32	70, 71	38	7.25	45	286	4291	5	1	10	374	374	240	600	41	65	21	32	634	1006
										20	1061	1061	240	600	87	111	43	55	1344	1716
3	32	70	39	6.39	55	214	3915	5	1	10	386	386	215	538	33	50	16	25	618	950
										20	1109	1109	215	538	72	90	36	45	1361	1692
4	20, 21	69	37	5.82	55	515	9449	5	1	10	395	395	199	497	32	49	16	25	611	916
										20	1143	1143	199	497	73	89	36	45	1378	1684
5	1	69	37	11.80	45	337	5060	5	1	10	313	313	364	910	45	82	23	41	699	1263
										20	837	837	364	910	80	117	40	58	1241	1805
6	24	70	37	5.66	55	328	6013	5	1	10	398	398	194	485	32	48	16	24	608	907
										20	1152	1152	194	485	73	90	37	45	1383	1682
7	25, 36	68	37	5.48	45	160	2394	5	1	10	400	400	189	472	39	58	20	29	609	901
										20	1163	1163	189	472	90	109	45	55	1397	1689
8	29	68	37	6.74	55	484	8879	5	1	10	381	381	225	563	33	52	17	26	623	970
										20	1089	1089	225	563	72	90	36	45	1350	1698
9	21, 28	68	38	8.48	55	321	8835	5	1	10	356	356	274	686	23	38	11	19	642	1061
										20	995	995	274	686	46	61	23	31	1292	1711
10	2, 3	67	38	7.29	45	325	4872	5	1	10	373	373	241	602	41	65	21	33	634	1008
										20	1059	1059	241	602	87	111	43	55	1343	1716
11	14	68	39	6.31	55	430	7876	5	1	10	388	388	213	532	33	50	16	25	617	945
										20	1114	1114	213	532	72	90	36	45	1363	1691
12	34	67	39	10.60	35	186	2171	5	1	10	328	328	332	830	57	99	28	50	688	1207
										20	891	891	332	830	105	148	52	74	1276	1795
13	14	67	39	5.29	55	508	9315	5	1	10	403	403	183	458	32	47	16	24	602	884
										20	1175	1175	183	458	74	90	37	45	1395	1677
14	15, 16	67	38	12.90	55	674	12359	5	1	10	300	300	393	982	38	70	19	35	711	1317
										20	791	791	393	982	65	97	32	48	1216	1821
15	5	70	36	5.50	55	242	4442	5	1	10	400	400	189	473	32	48	16	24	605	897
										20	1162	1162	189	473	74	90	37	45	1388	1680
16	10, 15	70	36	4.42	45	240	3604	5	1	10	417	417	157	393	38	54	19	27	593	836
										20	1229	1229	157	393	92	108	46	54	1432	1675
17	1, 36	69, 70	39	7.98	35	169	1975	5	1	10	363	363	260	651	53	87	27	43	650	1057
										20	1021	1021	260	651	110	143	55	72	1337	1744
18	20	67	37	8.11	55	493	9044	5	1	10	361	361	264	660	34	56	17	28	642	1049
										20	1014	1014	264	660	70	91	35	46	1313	1720
19	20, 21	67	37	6.76	55	373	6838	5	1	10	381	381	226	565	33	52	17	26	623	971
										20	1088	1088	226	565	72	90	36	45	1350	1698
20	31	69	37	15.00	55	742	13595	12	2	10	838	838	472	1181	72	110	36	55	1346	2074
										20	1158	1158	472	1181	89	128	45	64	1675	2402
21	11	68	38	13.40	35	302	3522	12	2	10	786	786	532	1331	113	181	56	90	1374	2207
										20	1077	1077	532	1331	138	206	69	103	1679	2511
22	7, 12	67	37, 38	14.80	45	434	6516	12	2	10	866	866	442	1104	87	131	44	66	1351	2036
										20	1200	1200	442	1104	110	154	55	77	1697	2342
23	16	70	37	15.70	55	955	17499	12	2	10	845	845	465	1162	71	110	35	55	1345	2061
										20	1168	1169	465	1162	90	127	45	63	1678	2362
24	36	68	36	17.70	55	532	9759	12	2	10	801	801	515	1287	72	114	36	57	1351	2145
										20	1100	1130	515	1287	88	130	44	65	1659	2453
25	24	67	39	15.80	55	648	11475	12	2	10	820	820	492	1231	72	112	36	56	1384	2137
										20	1130	1130	492	1231	89	44	129	64	1667	2825
26	31, 36	67	37, 38	24.70	55	505	9253	12	2	10	663	663	685	1712	74	130	37	65	1384	2440
										20	663	663	685	1712	86	142	43	71	1620	2475
27	31	67	37	16.40	55	605	11084	12	2	10	829	829	482	1206	72	111	36	56	1387	2091
										20	1144	1144	482	1206	89	129	44	58	1671	2418

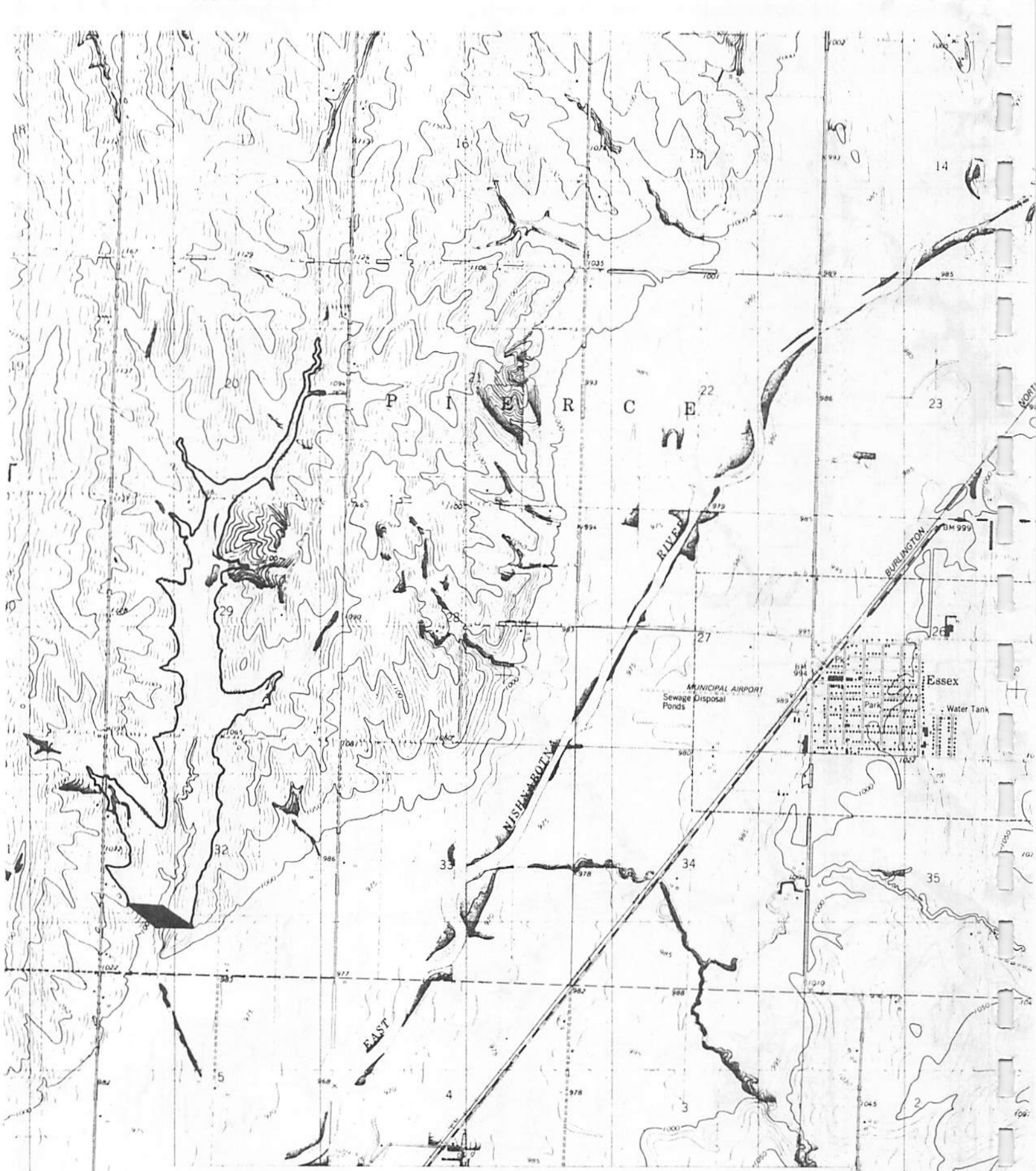
* Column 1 20 year design, Column 2 50 year design periods.



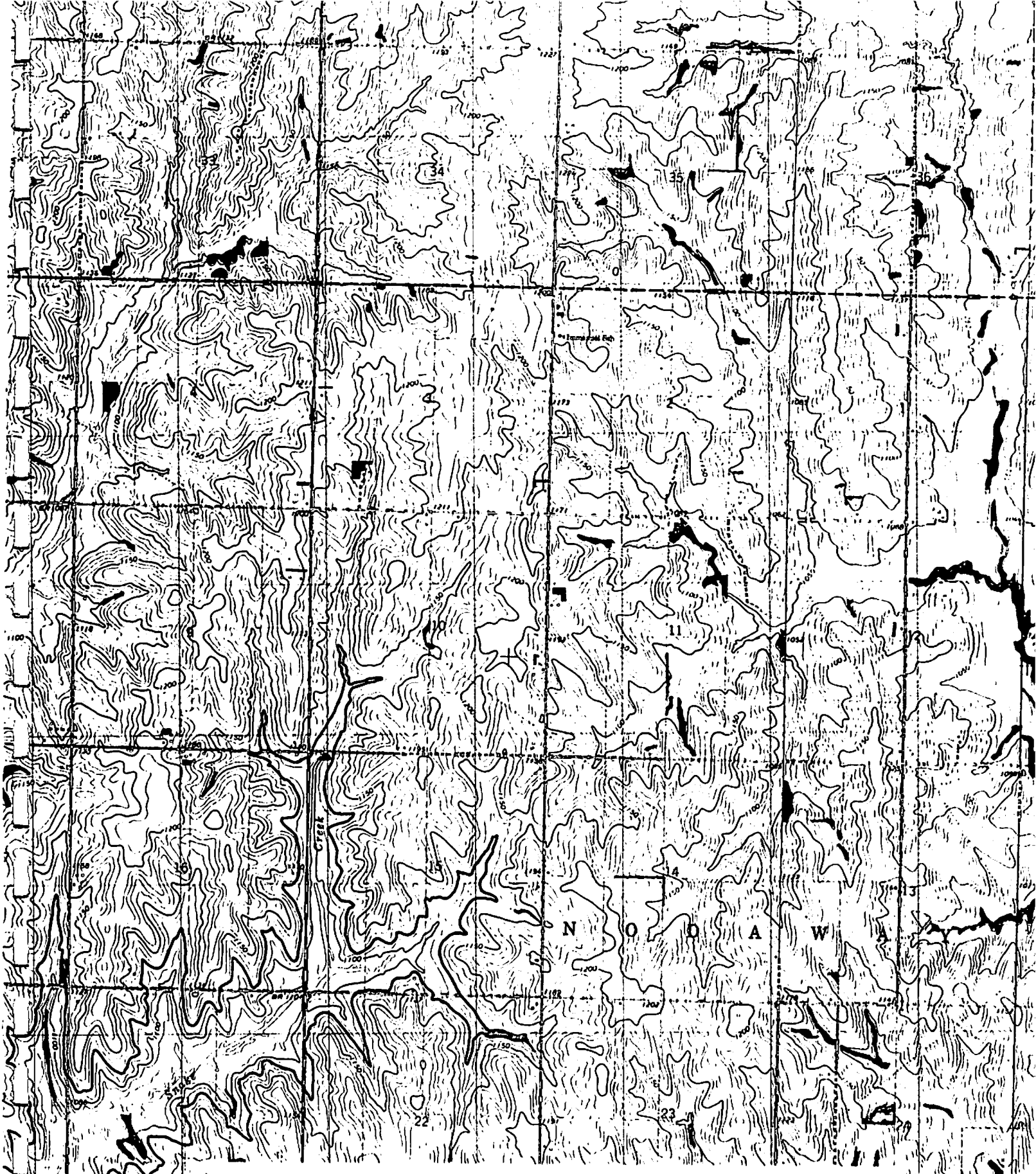
SITE NO.: 1 COUNTY: Page
LOCATION: SECTION: 2, 3 T 69N, R 39W
QUADRANGLE: Shenandoah East
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



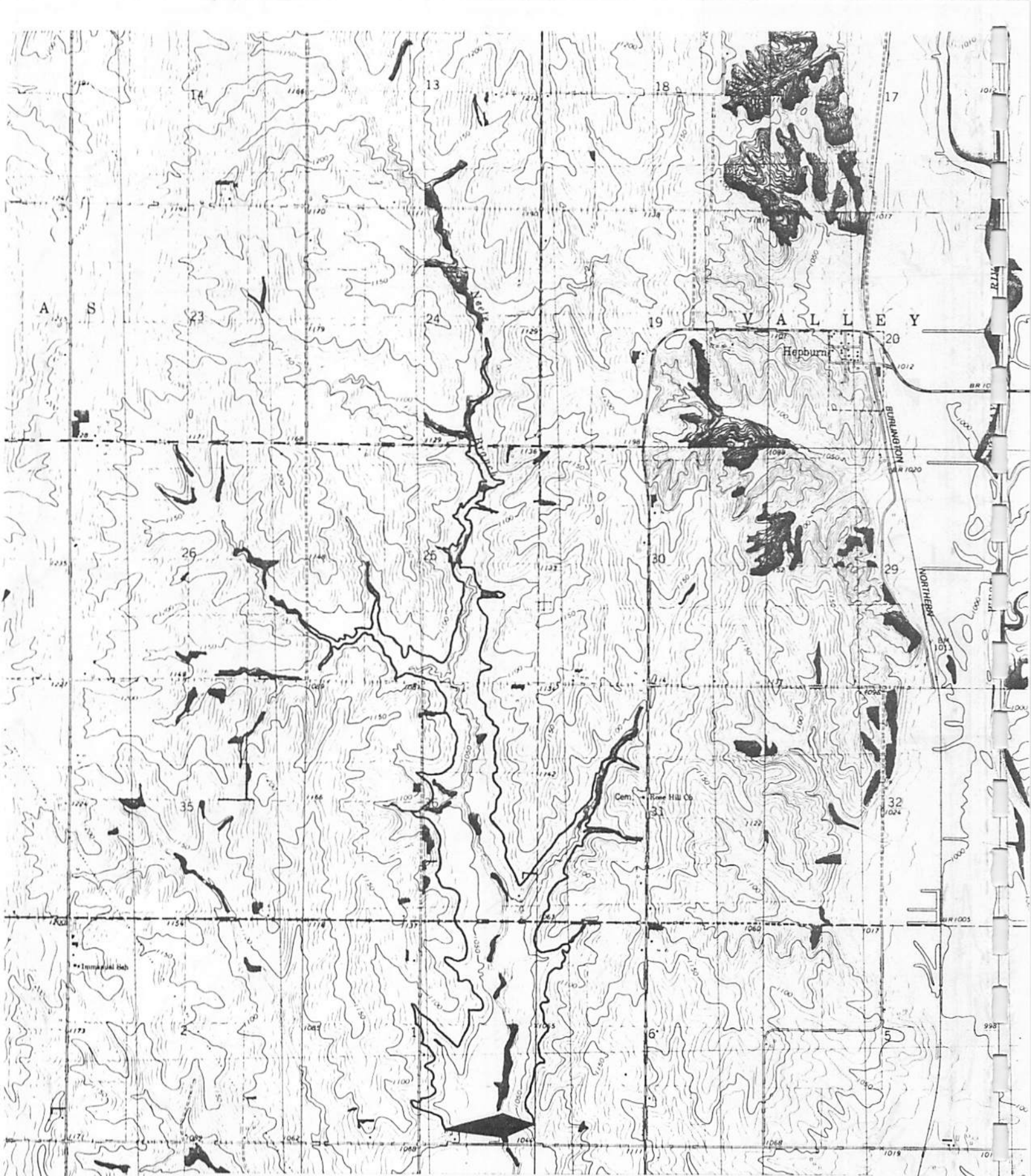
SITE NO.: 2 COUNTY: Page
LOCATION: SECTION: 5, 32 T 70, 71N, R 38W
QUADRANGLE: Red Oak South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



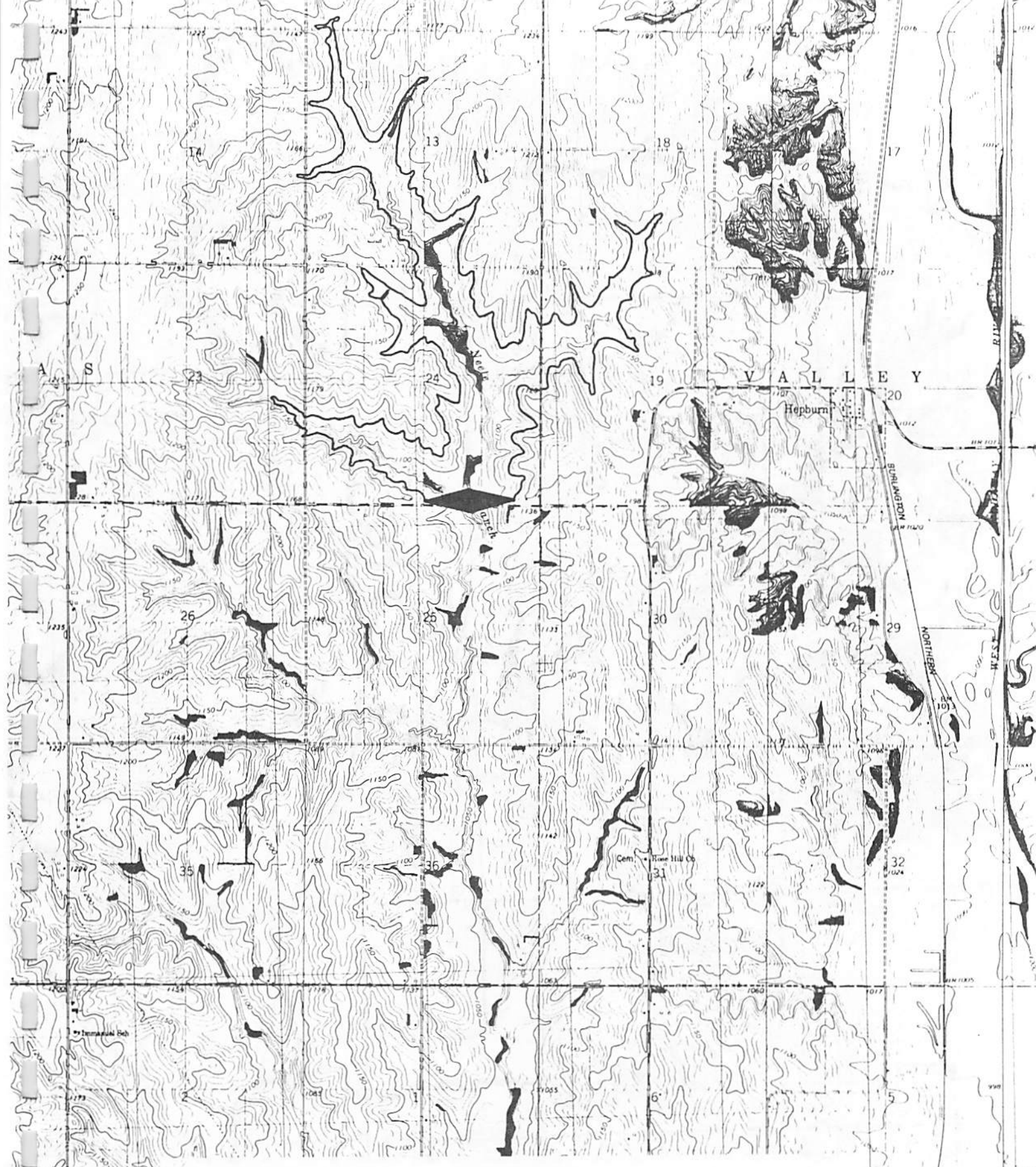
SITE NO.: 3 COUNTY: Page
LOCATION: SECTION: 32 T 70N, R 39W
QUADRANGLE: Shenandoah East
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



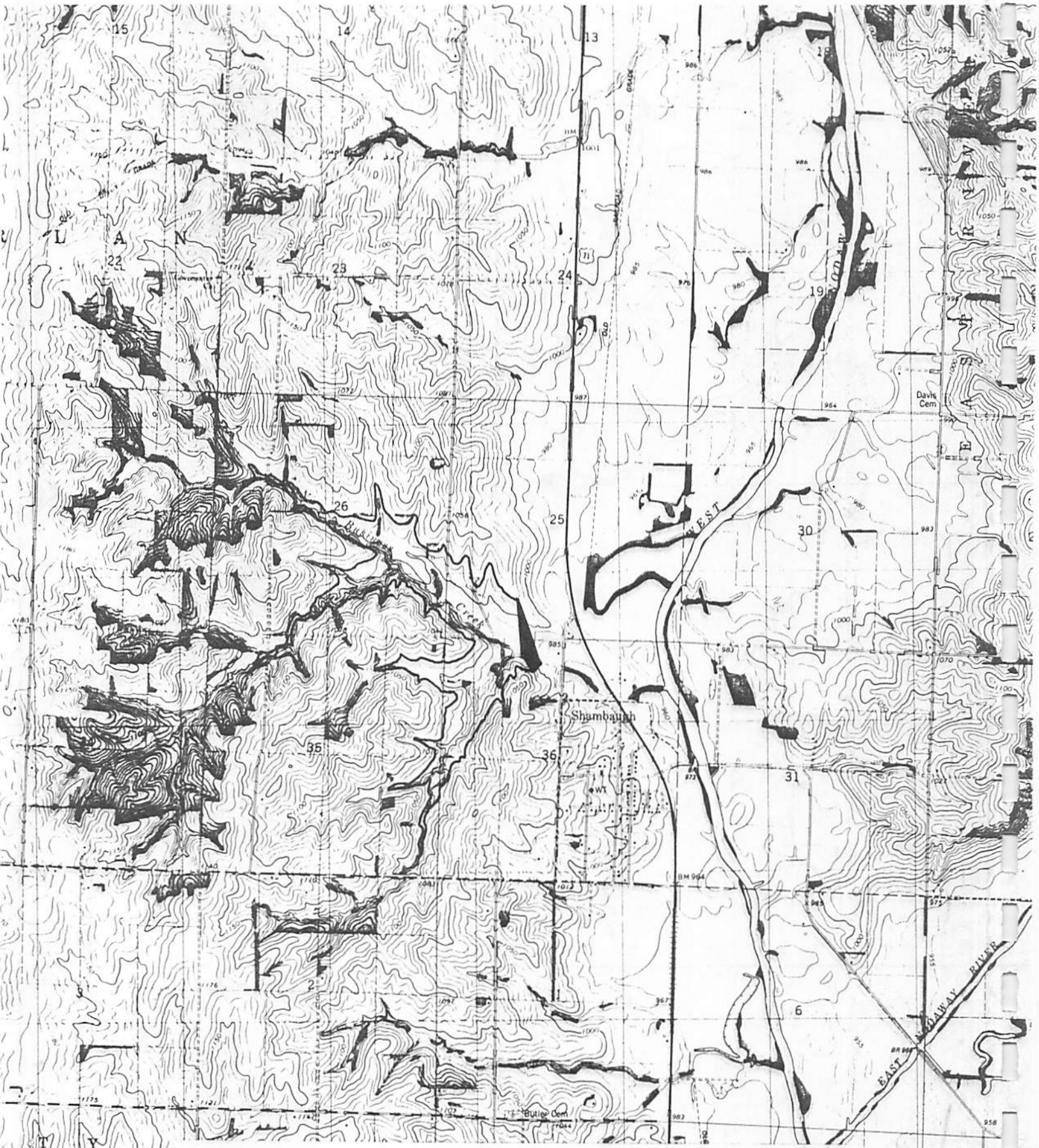
SITE NO.: 4 COUNTY: Page
LOCATION: SECTION: 20, 21 T 69N, R 37W
QUADRANGLE: Clarinda North
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



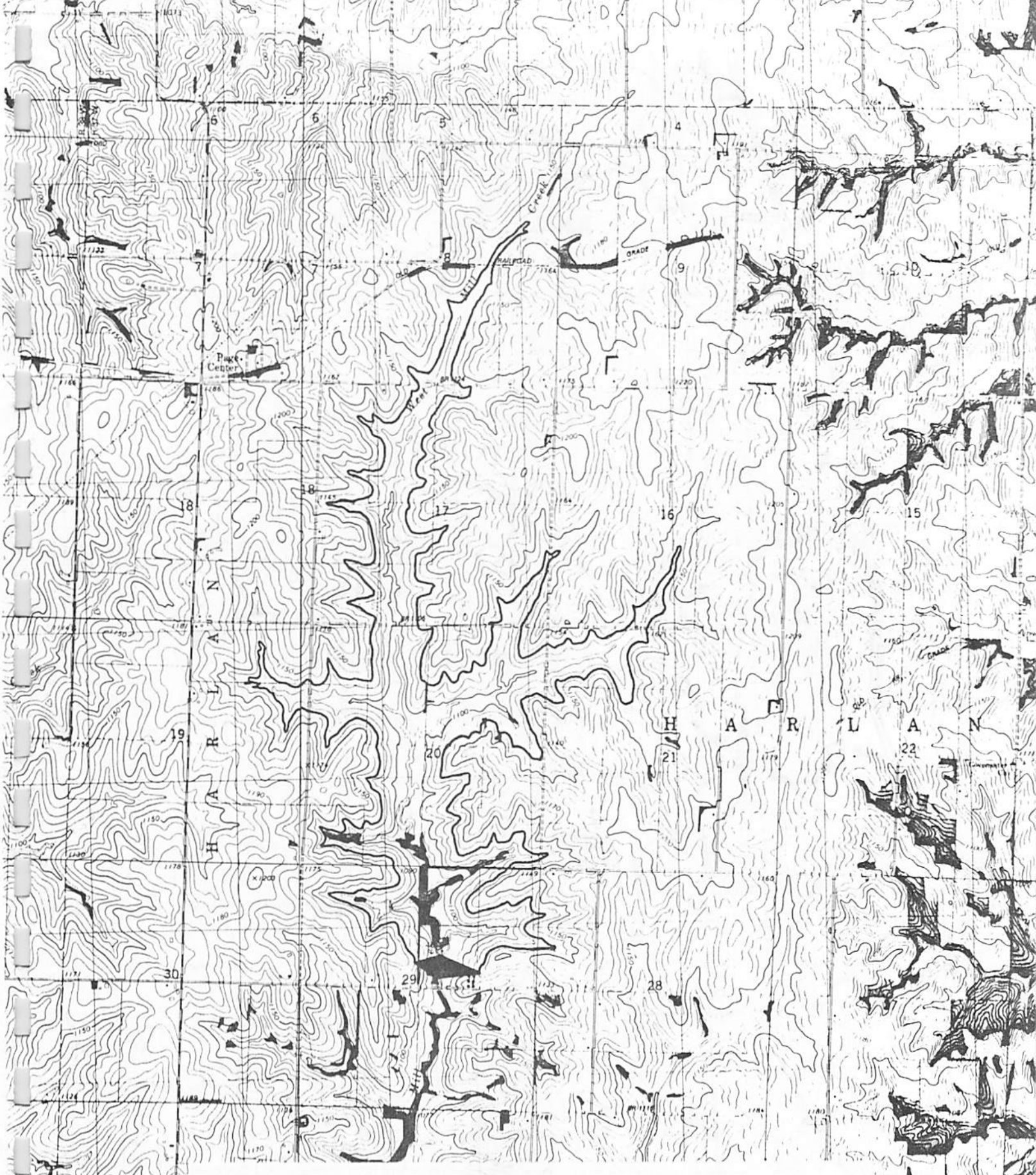
SITE NO.: 5 COUNTY: Page
LOCATION: SECTION: 1 T 69N, R 37N
QUADRANGLE: Clarinda North
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



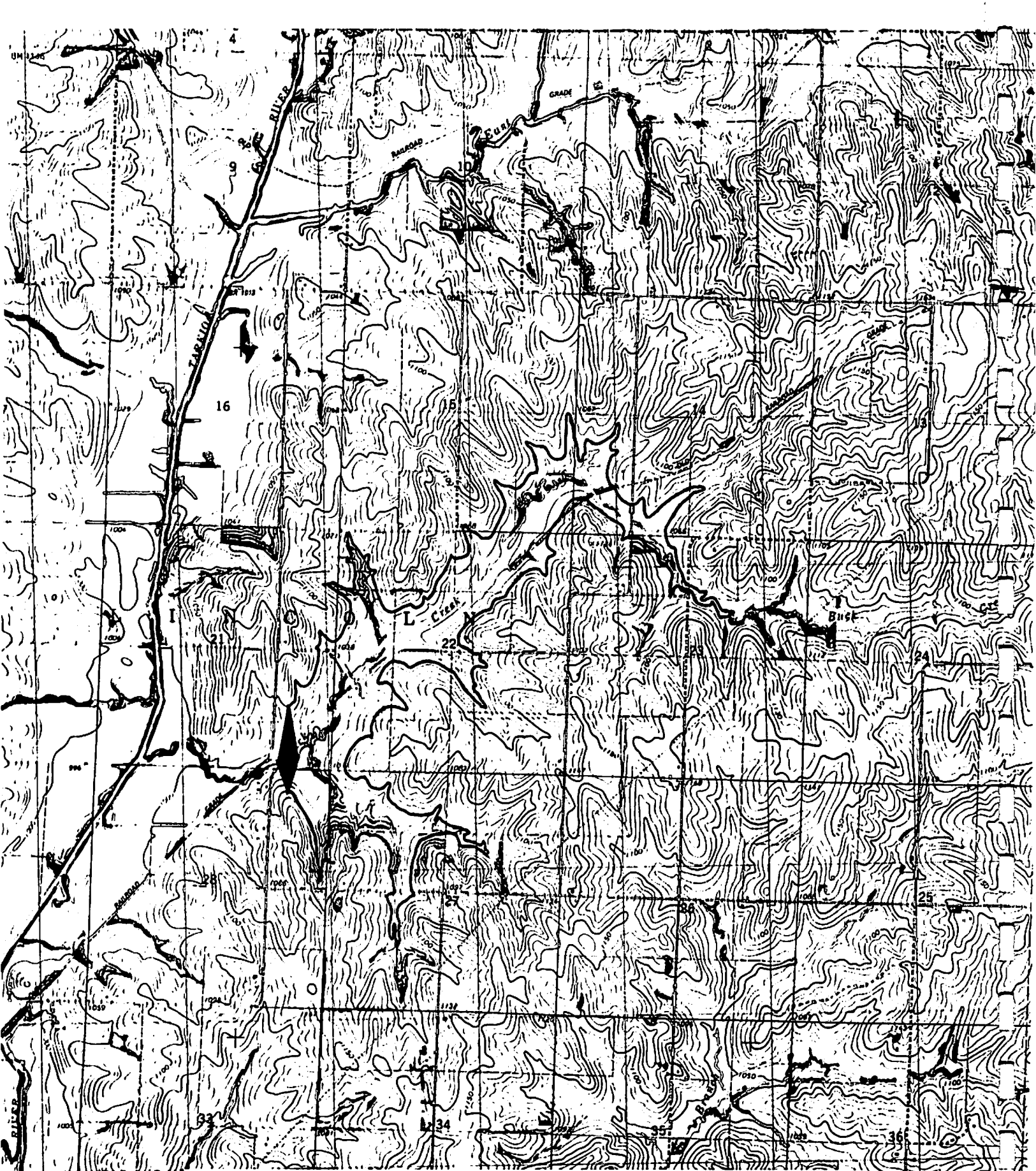
SITE NO.: 6 COUNTY: Page
LOCATION: SECTION: 24 T 70N, R 37W
QUADRANGLE: Clarinda North
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



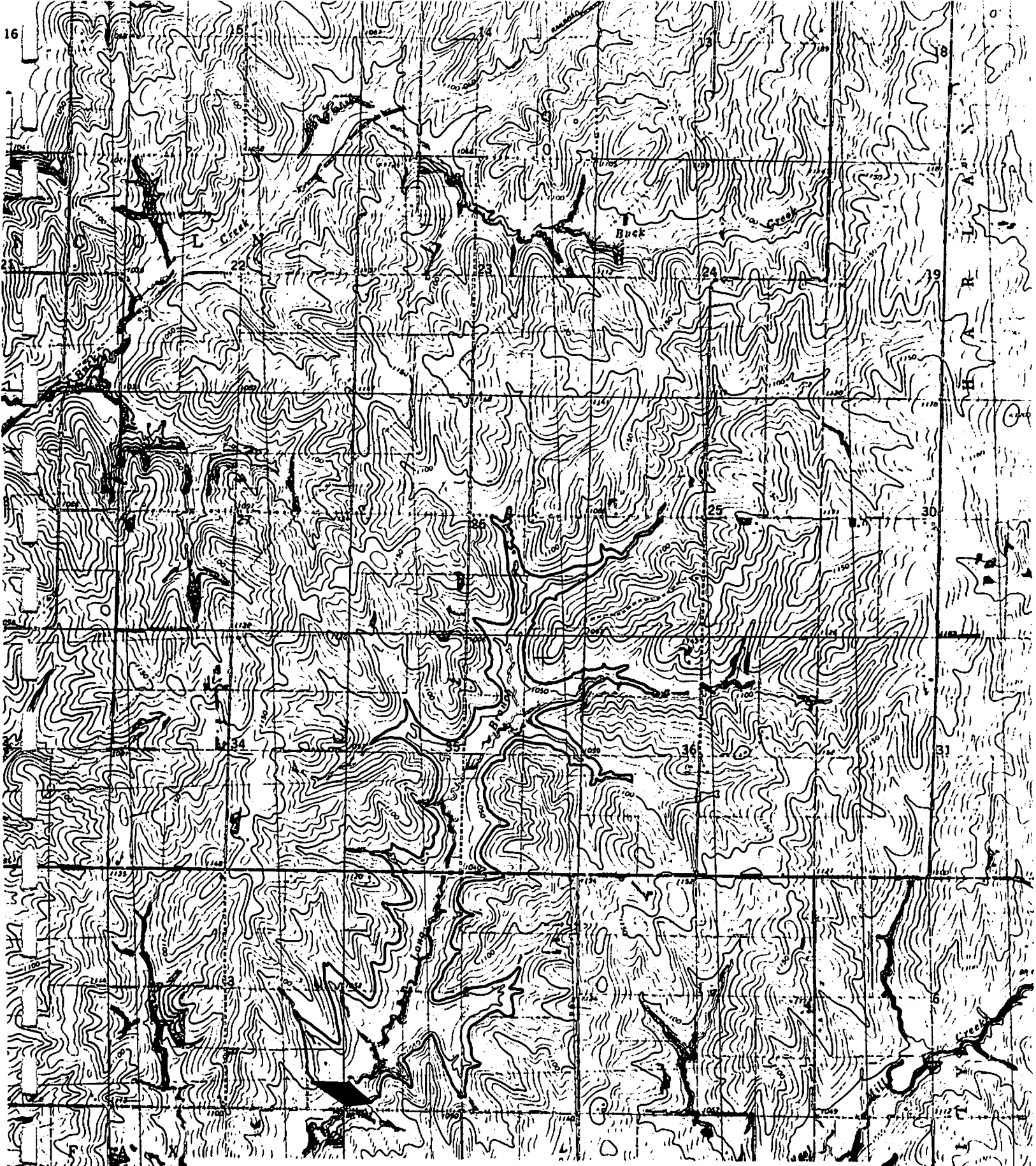
SITE NO.: 7 COUNTY: Page
LOCATION: SECTION: 25, 36 T 68N, R 37W
QUADRANGLE: Clarinda South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



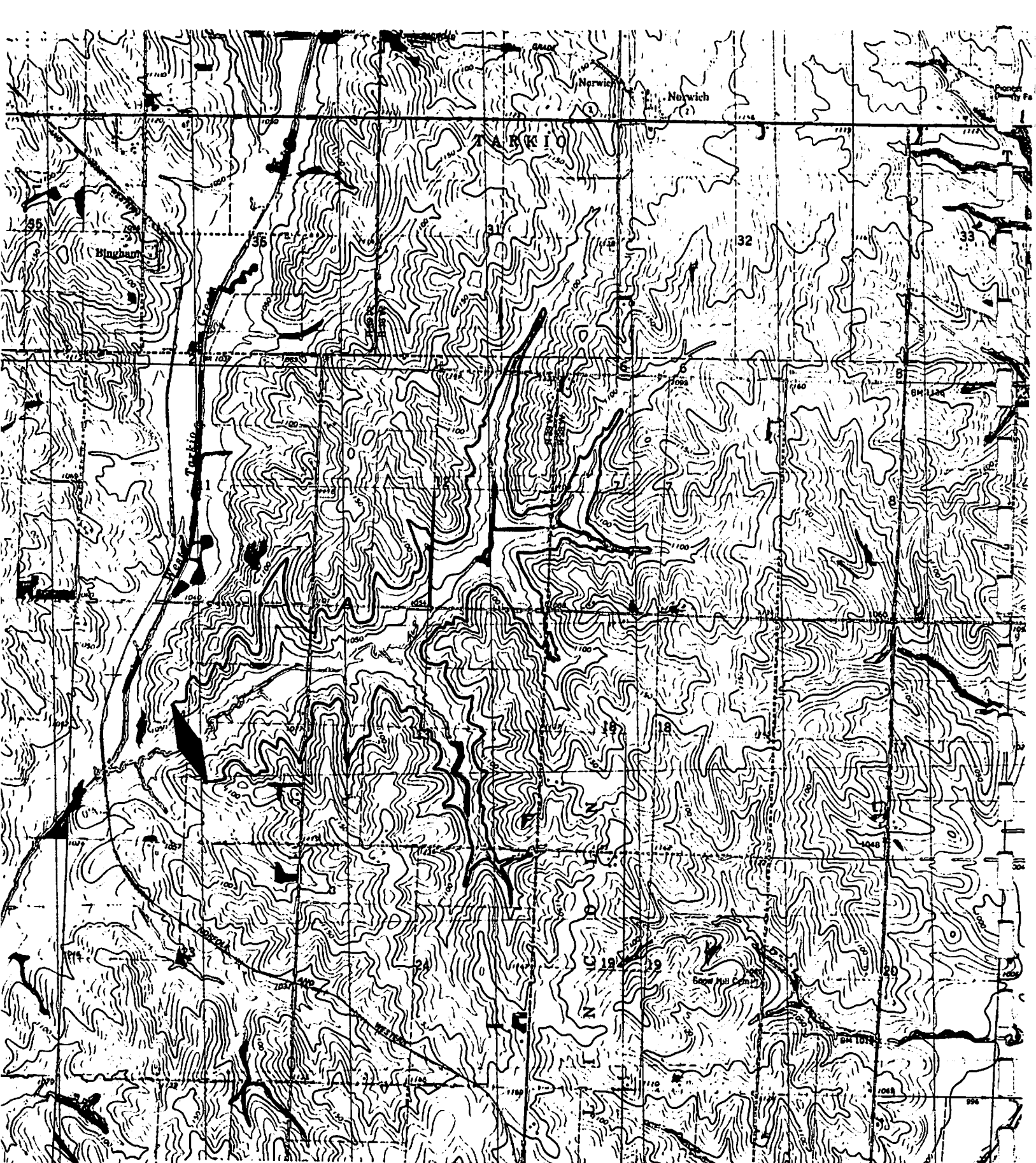
SITE NO.: 8 COUNTY: Page
LOCATION: SECTION: 29 T 68N, R 37W
QUADRANGLE: Coin, Clarinda South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



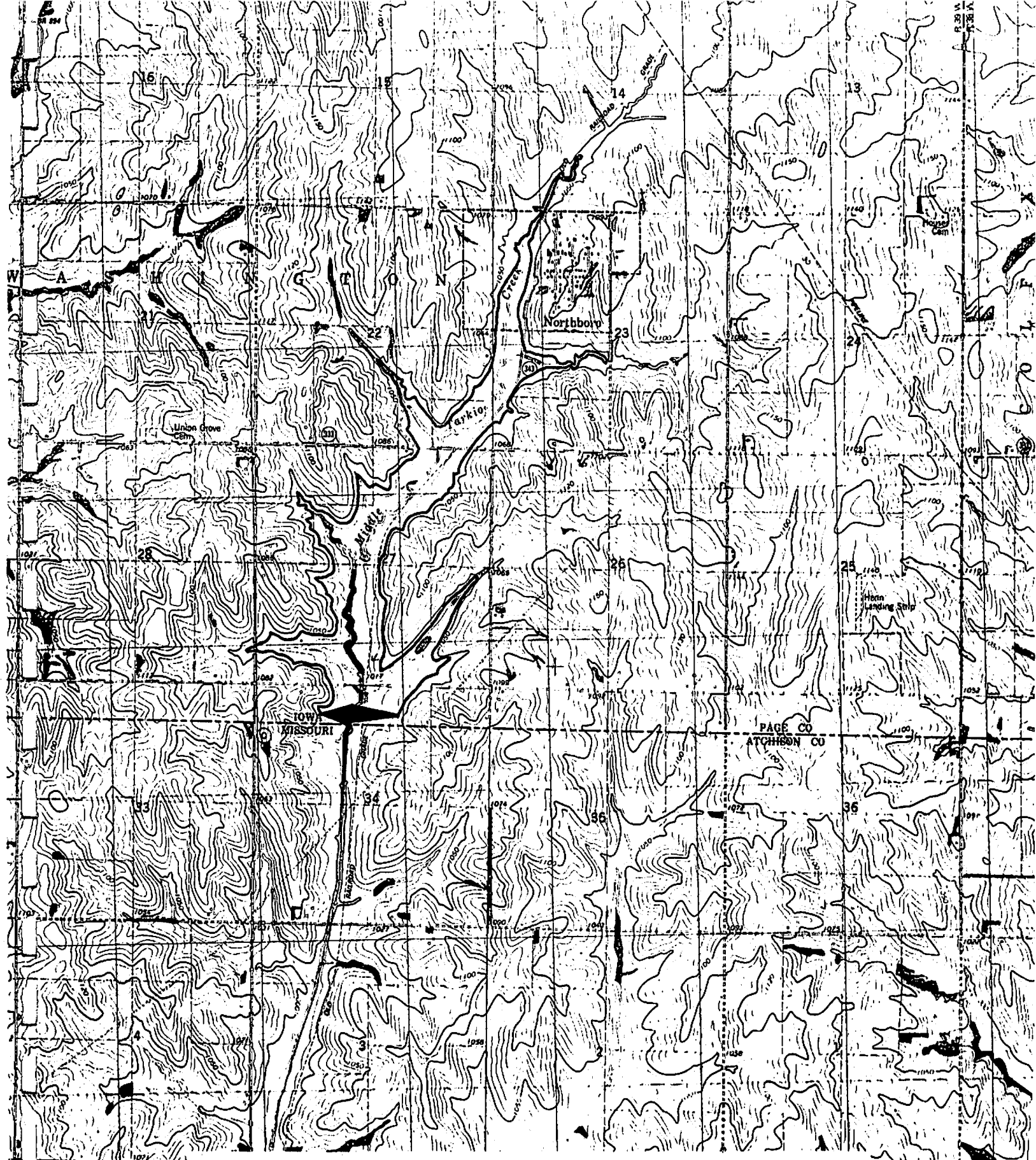
SITE NO.: 9 COUNTY: Page
LOCATION: SECTION: 21, 28 T 68N, R 38W
QUADRANGLE: Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



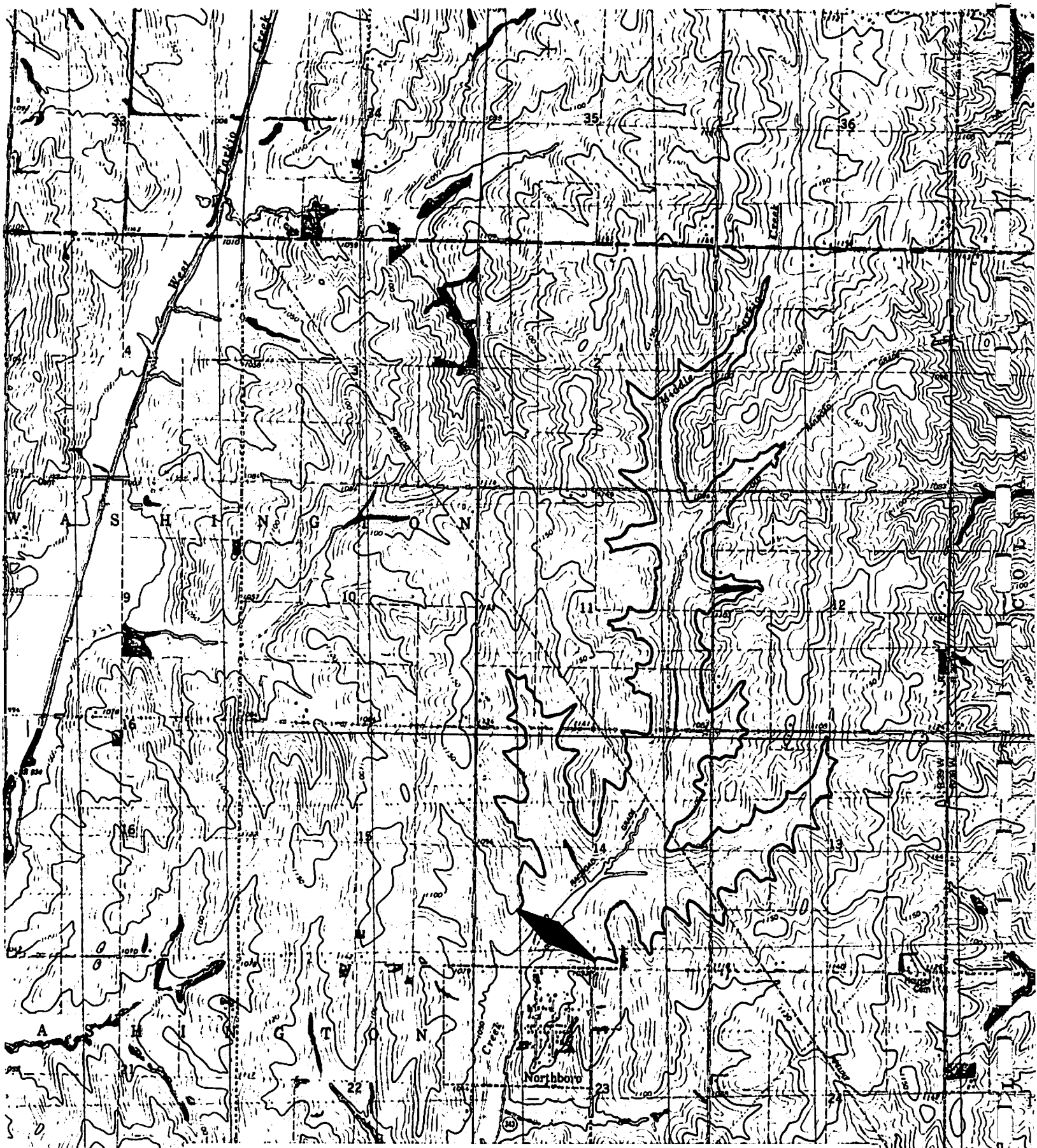
SITE NO.: 10 COUNTY: Page
LOCATION: SECTION: 2, 3 T 67N, R 38W
QUADRANGLE: Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



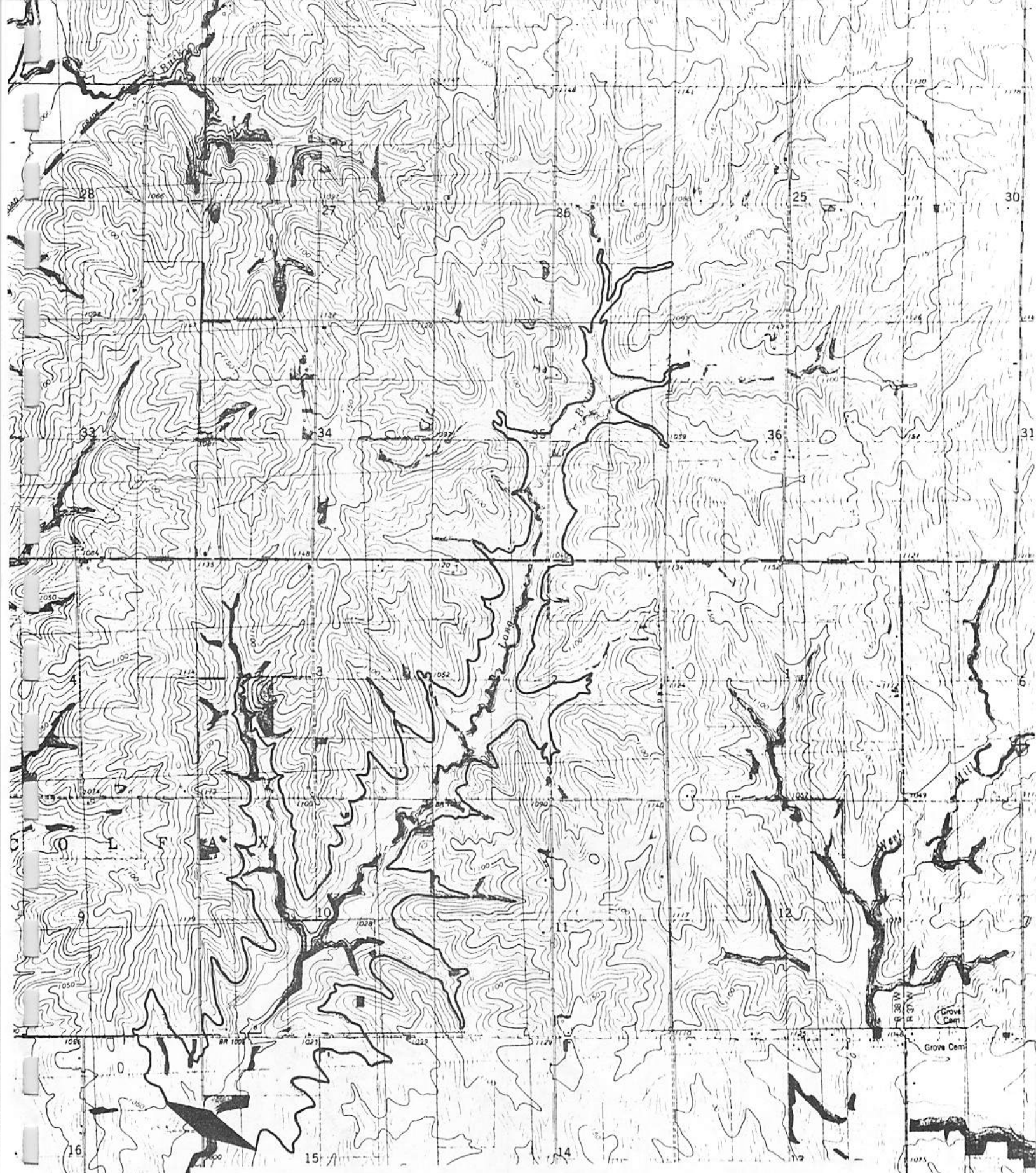
SITE NO.: 11 COUNTY: Page
LOCATION: SECTION: 14 T 68N, R 39W
QUADRANGLE: Bingham, Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



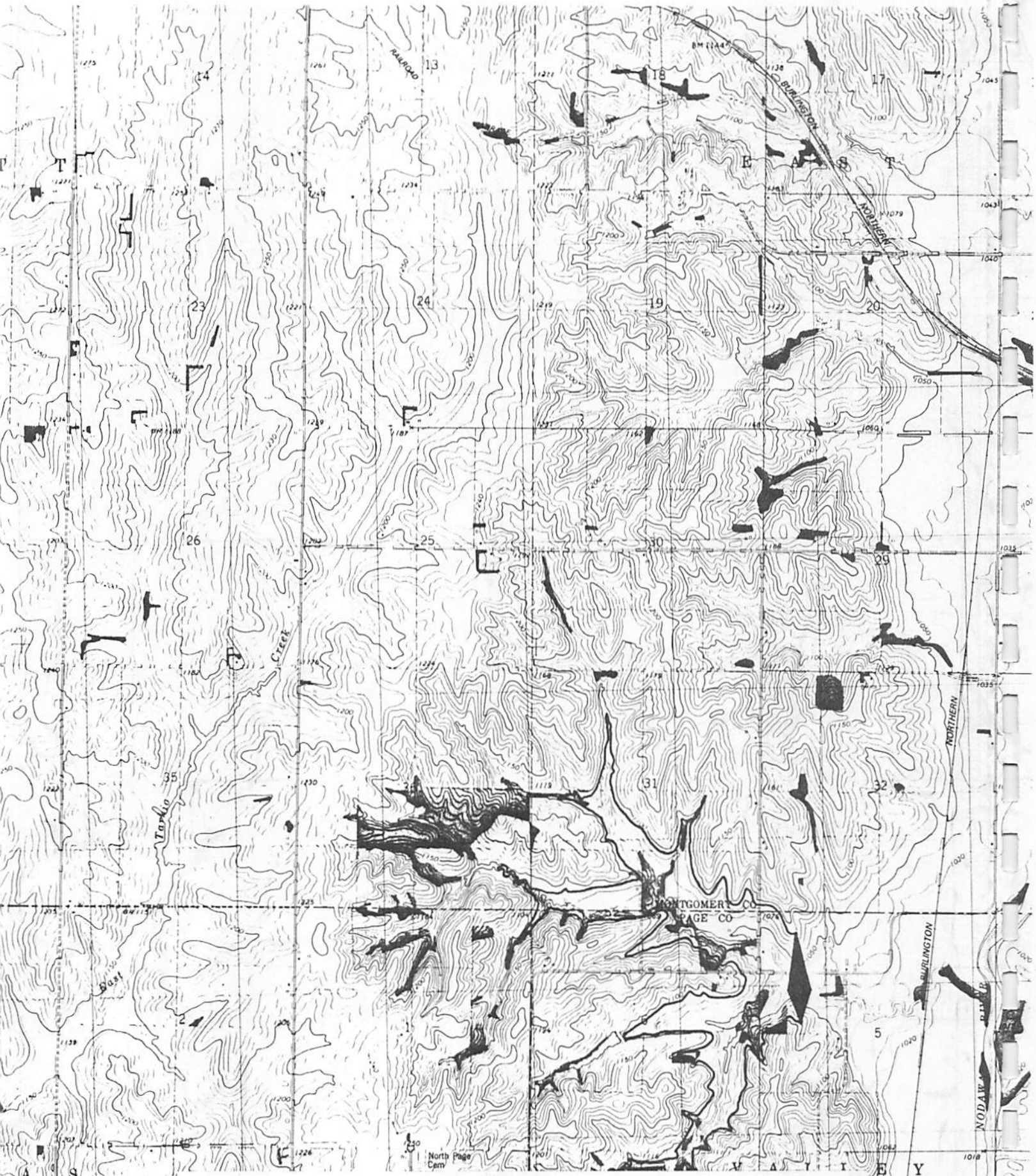
SITE NO.: 12 COUNTY: Page
LOCATION: SECTION: 34 T 67N, R 39W
QUADRANGLE: Westboro
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



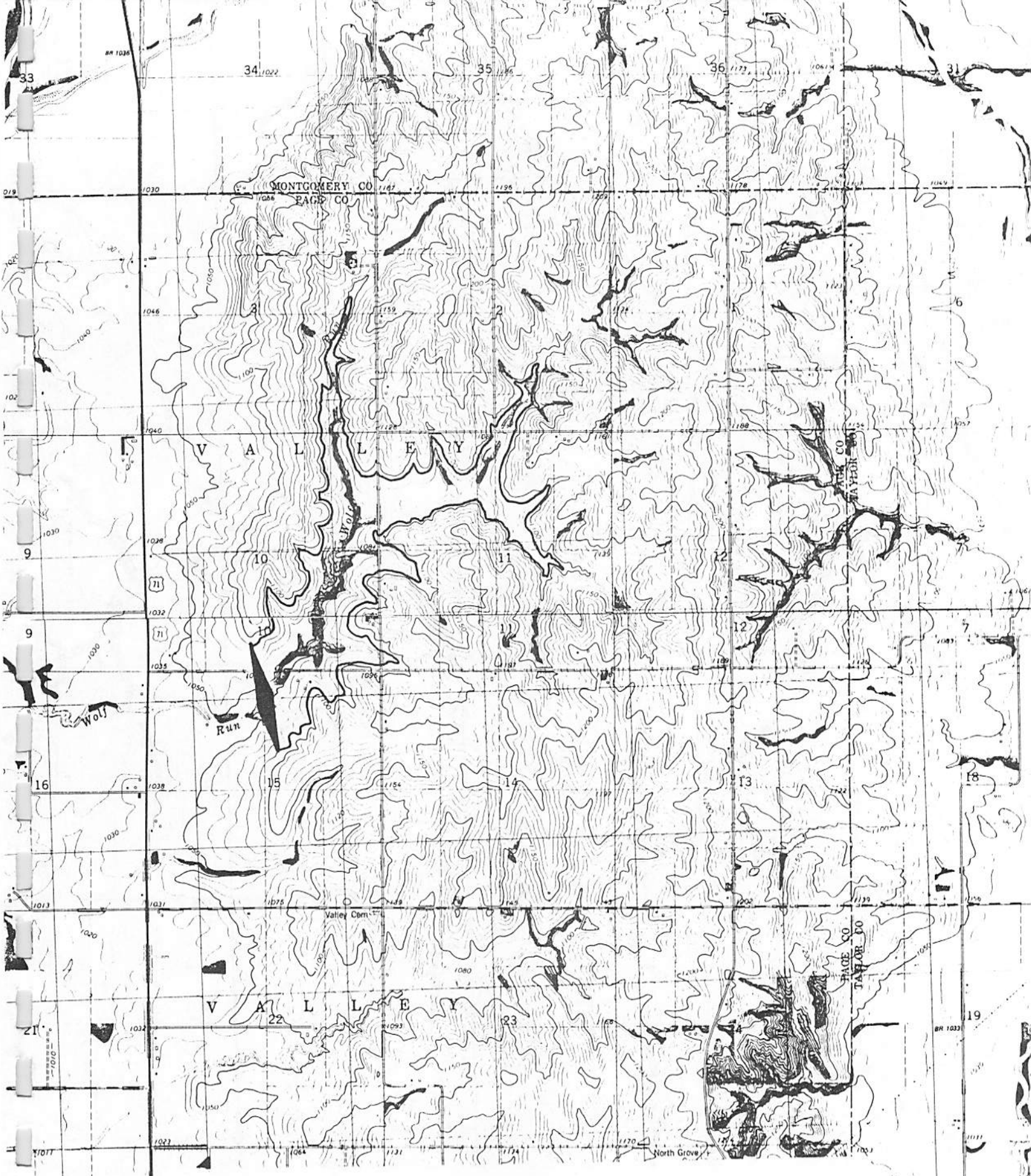
SITE NO.: 13 COUNTY: Page
LOCATION: SECTION: 14 T 67N, R 39W
QUADRANGLE: Bingham, Westboro
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



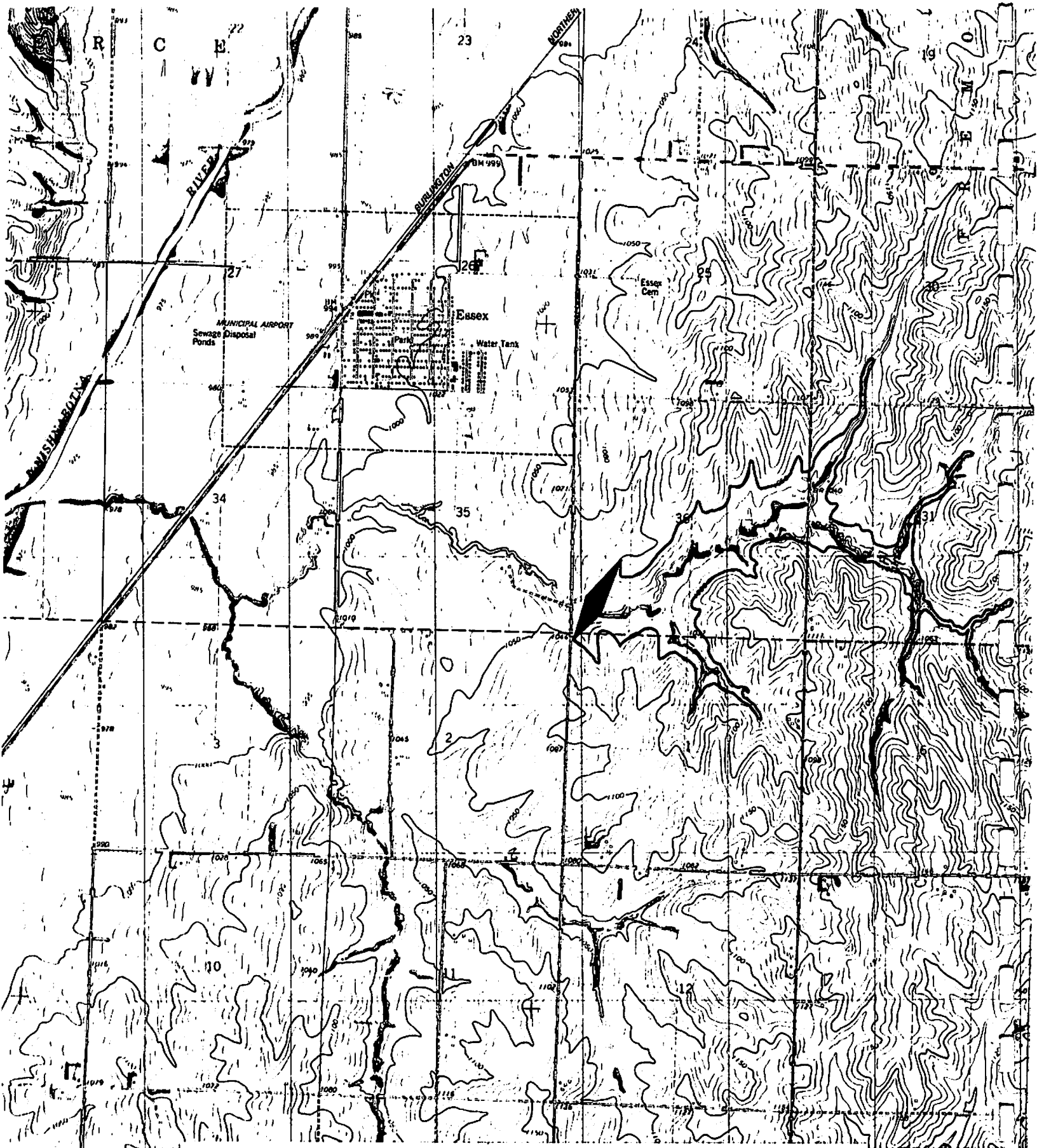
SITE NO.: 14 COUNTY: Page
LOCATION: SECTION: 15, 16 T 67N, R 38W
QUADRANGLE: Coin, Blanchard
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



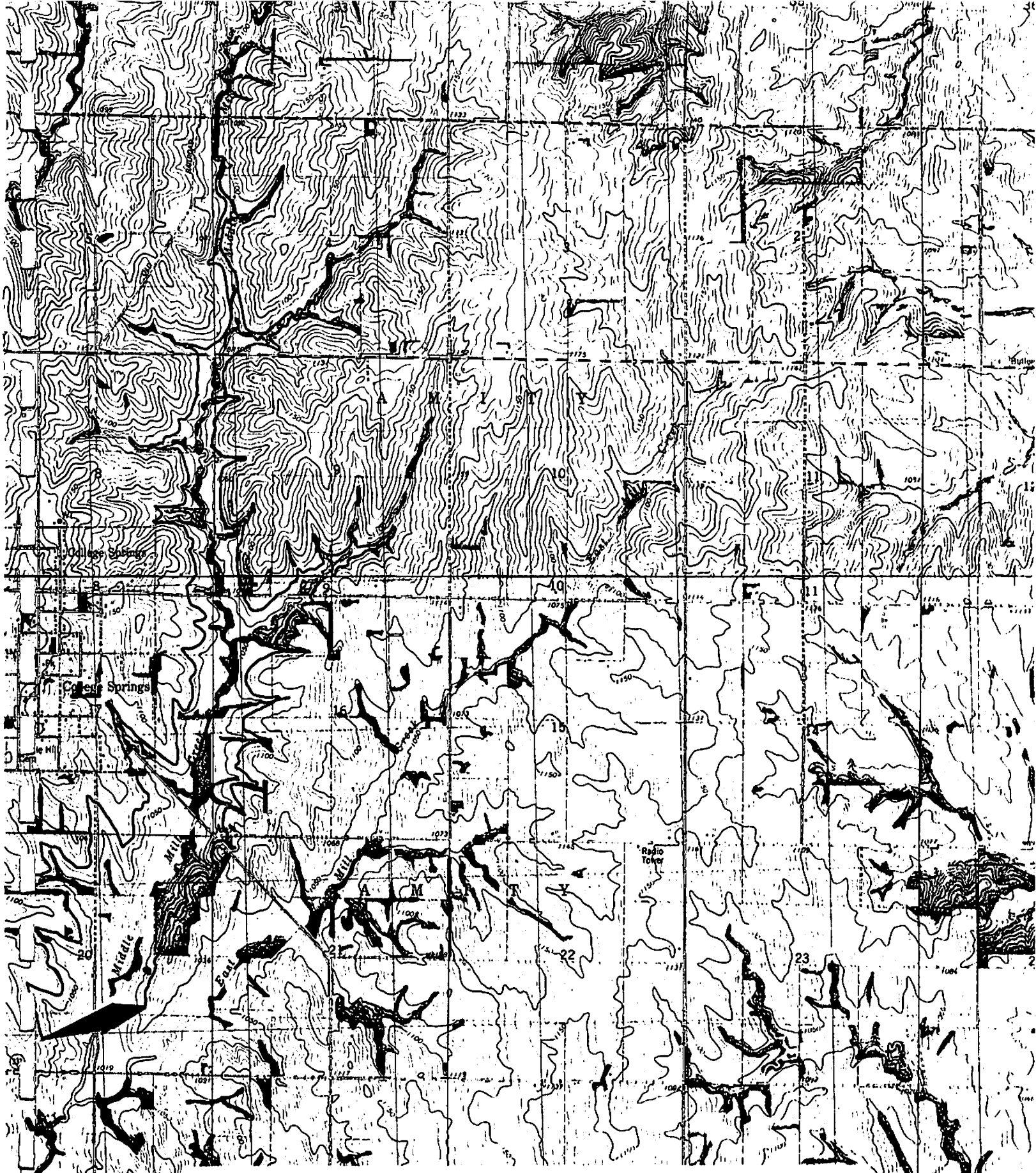
SITE NO.: 15 COUNTY: Page
LOCATION: SECTION: 5 T 70N, R 36W
QUADRANGLE: Stanton
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



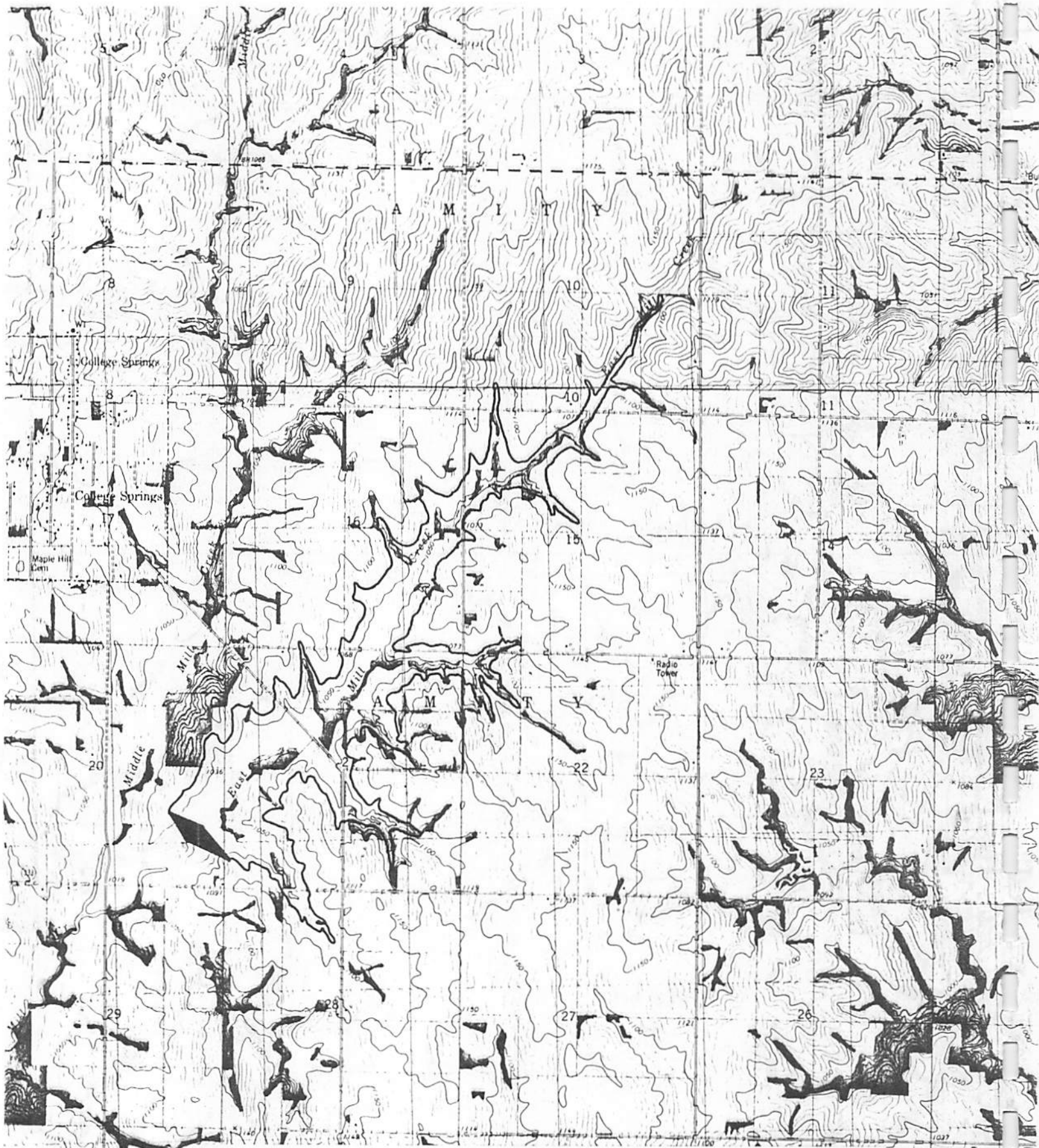
SITE NO.: 16 COUNTY: Page
LOCATION: SECTION: 10, 15 T 70N, R 36W
QUADRANGLE: Villisca, Hawleyville
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



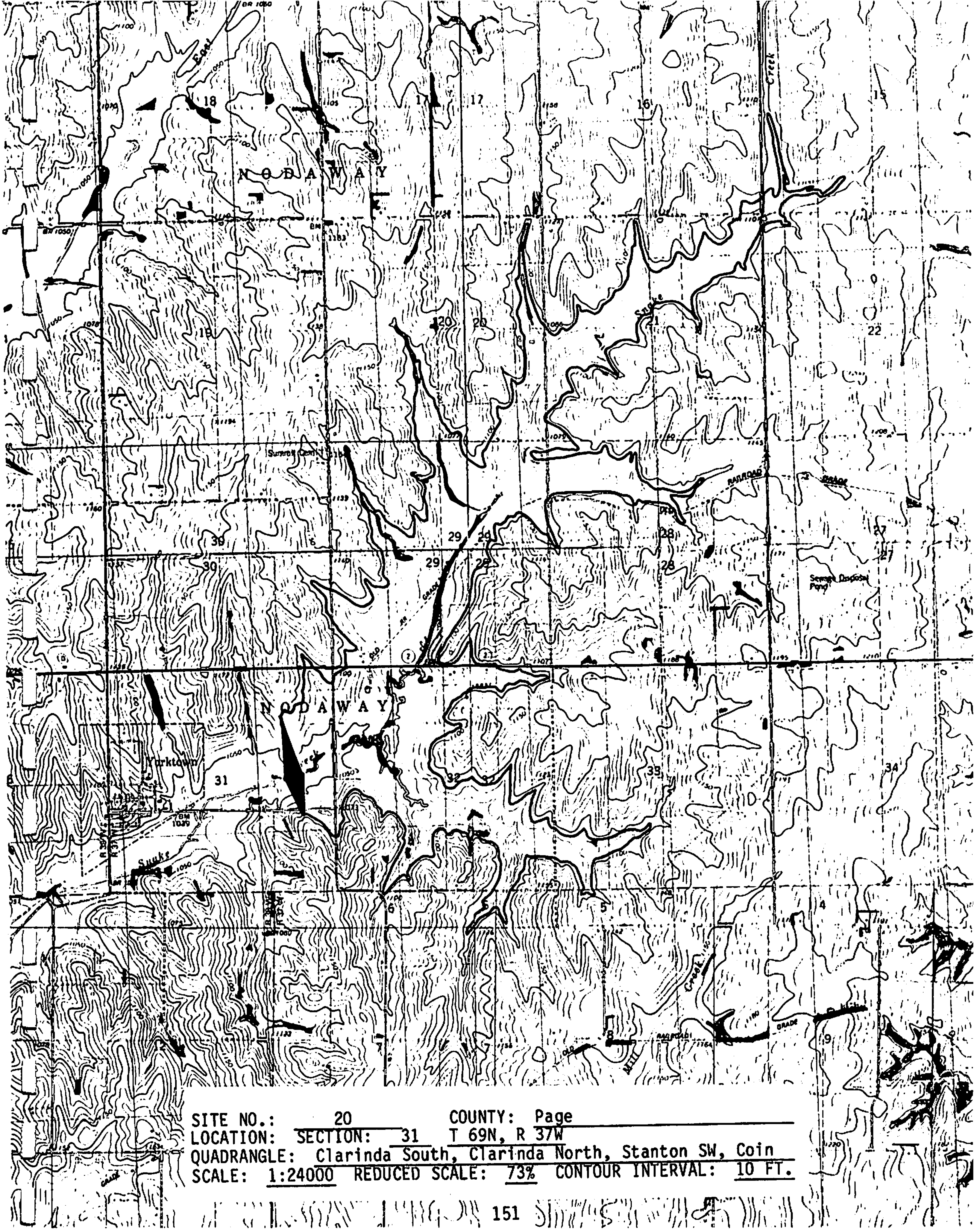
SITE NO.: 17 COUNTY: Page
LOCATION: SECTION: 1, 36 T 69, 70N, R 39W
QUADRANGLE: Shenandoah East
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



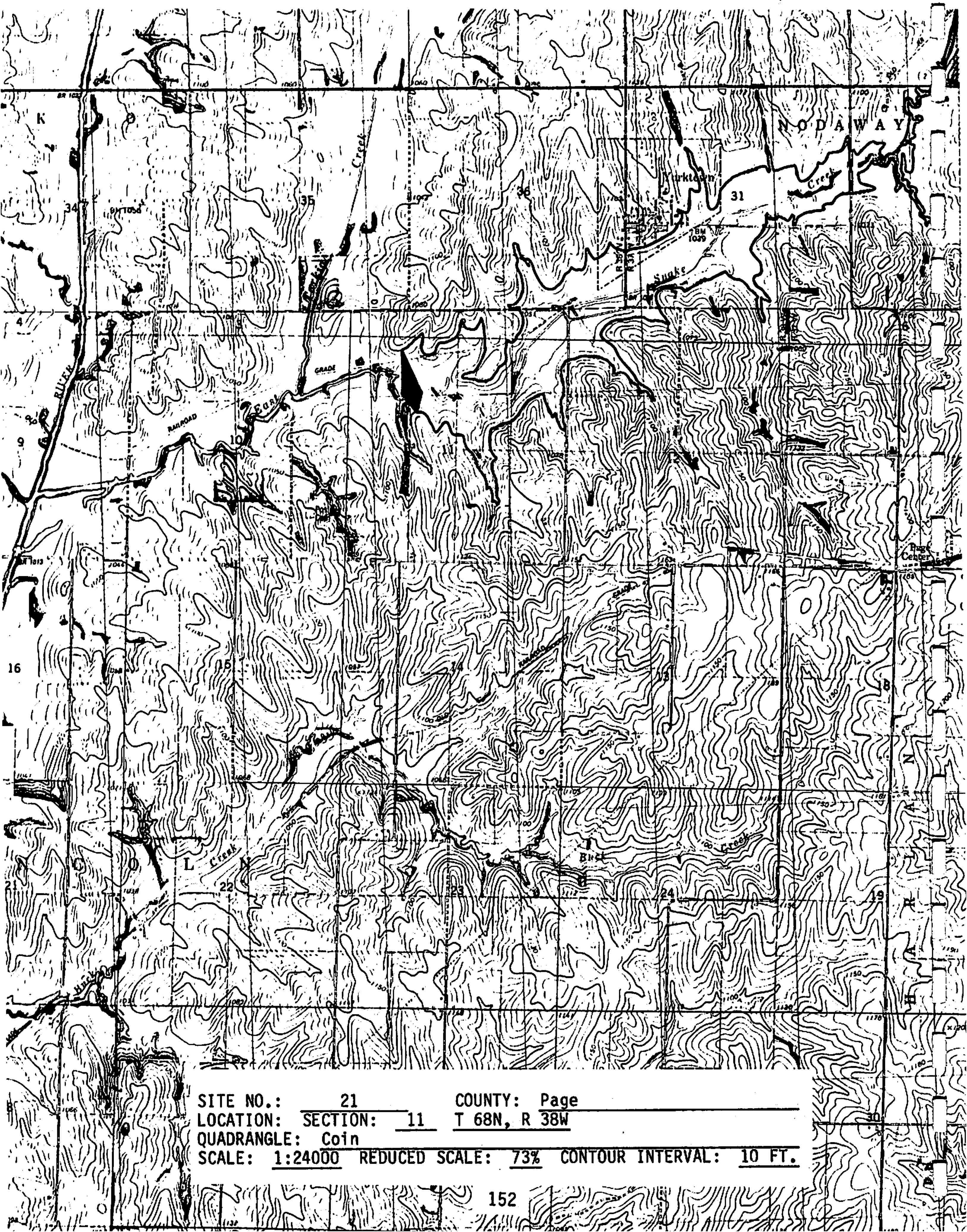
SITE NO.: 18 COUNTY: Page
LOCATION: SECTION: 20 T 67N, R 37W
QUADRANGLE: Clarinda South, Clearmont
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



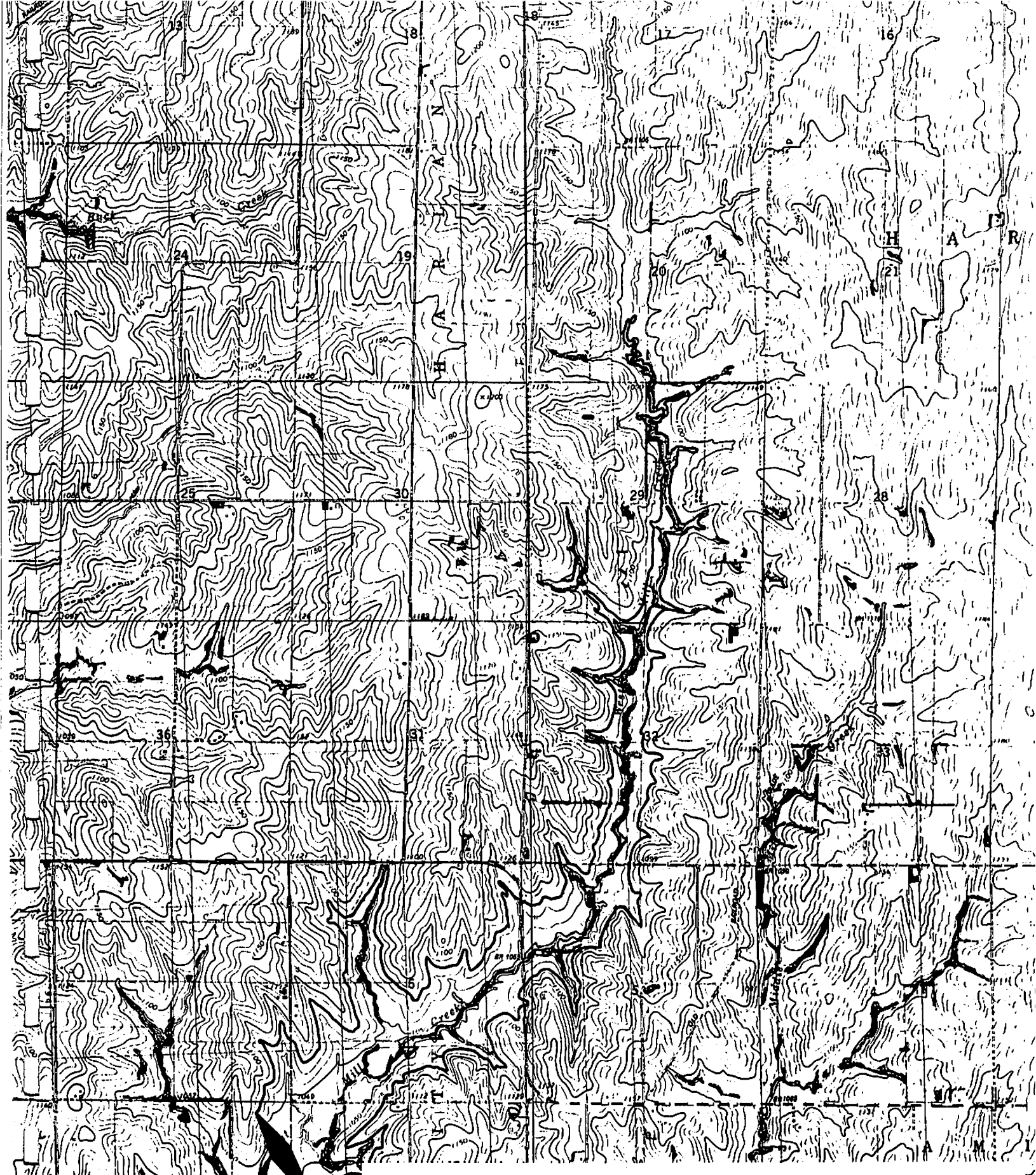
SITE NO.: 19 COUNTY: Page
LOCATION: SECTION: 20, 21 T 67N, R 37W
QUADRANGLE: Clarinda South, Clearmont
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 20 COUNTY: Page
LOCATION: SECTION: 31 T 69N, R 37W
QUADRANGLE: Clarinda South, Clarinda North, Stanton SW, Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

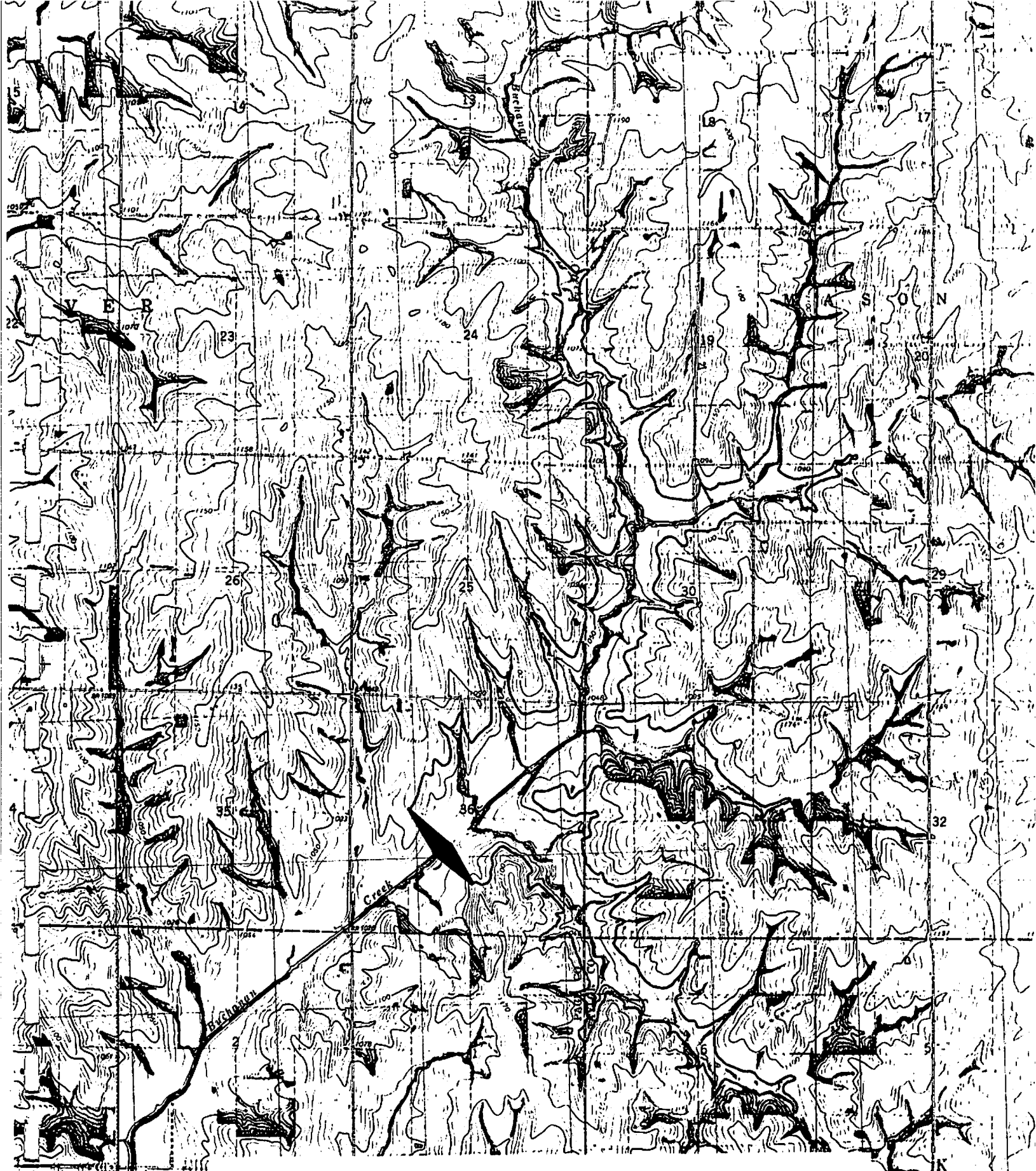


SITE NO.: 21 COUNTY: Page
LOCATION: SECTION: 11 T 68N, R 38W
QUADRANGLE: Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

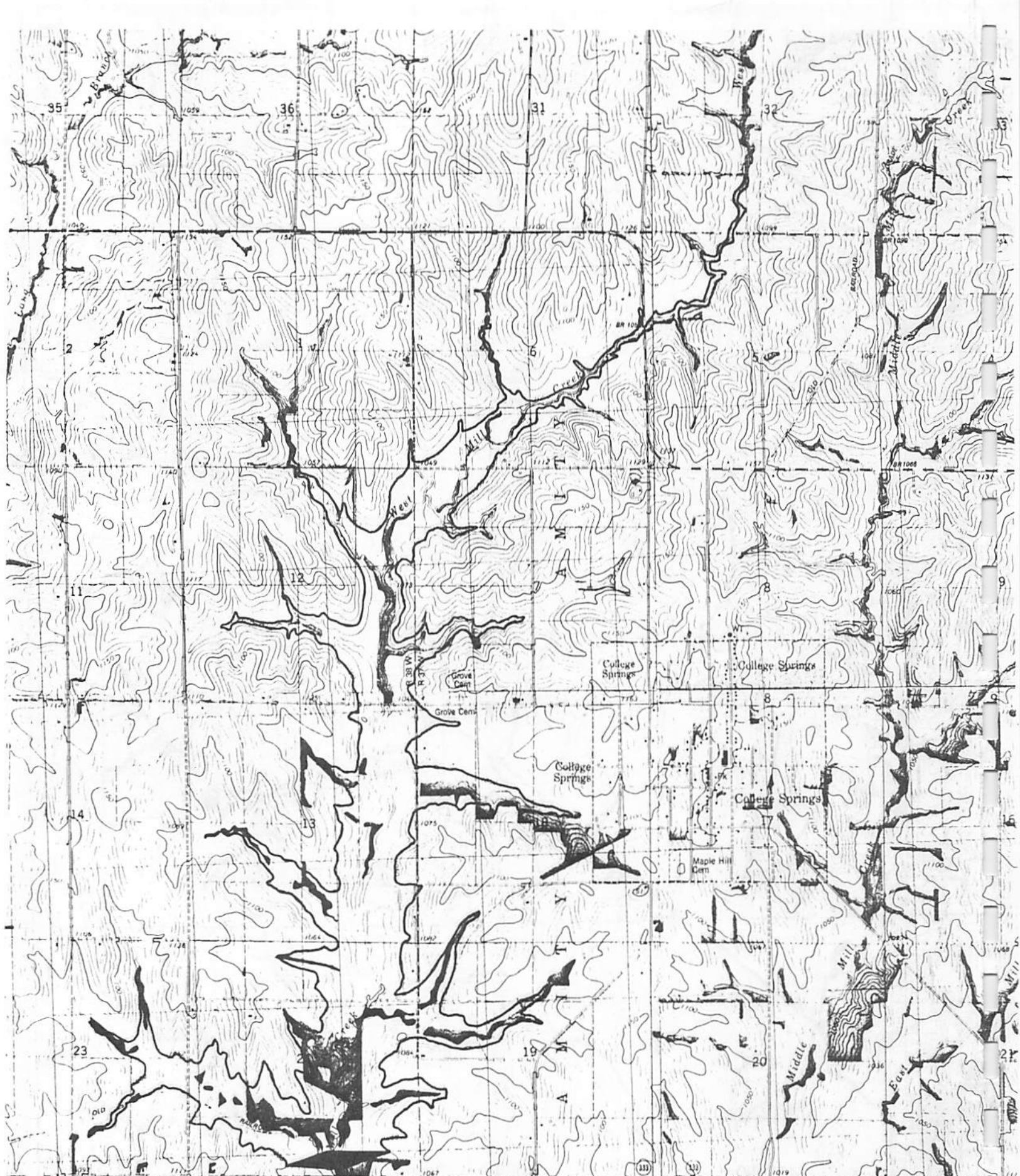


SITE NO.: 22 COUNTY: Page
LOCATION: SECTION: 7, 12 T 67N, R 37, 38W
QUADRANGLE: Clarinda South, Coin
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

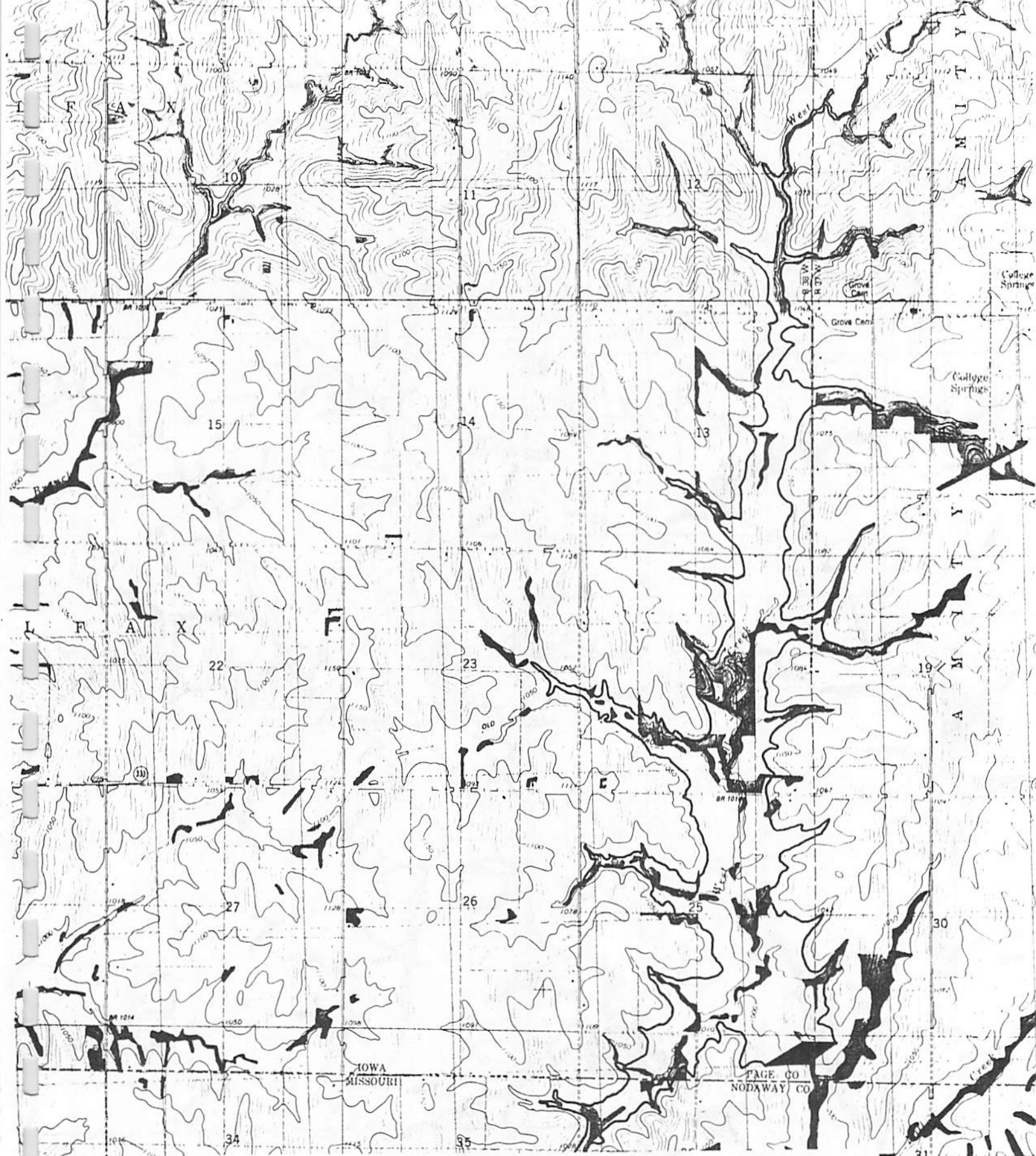
SITE NO.: 23 COUNTY: Page
LOCATION: SECTION: 16 T 70N, R 37W
QUADRANGLE: Stanton, Clarinda North
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



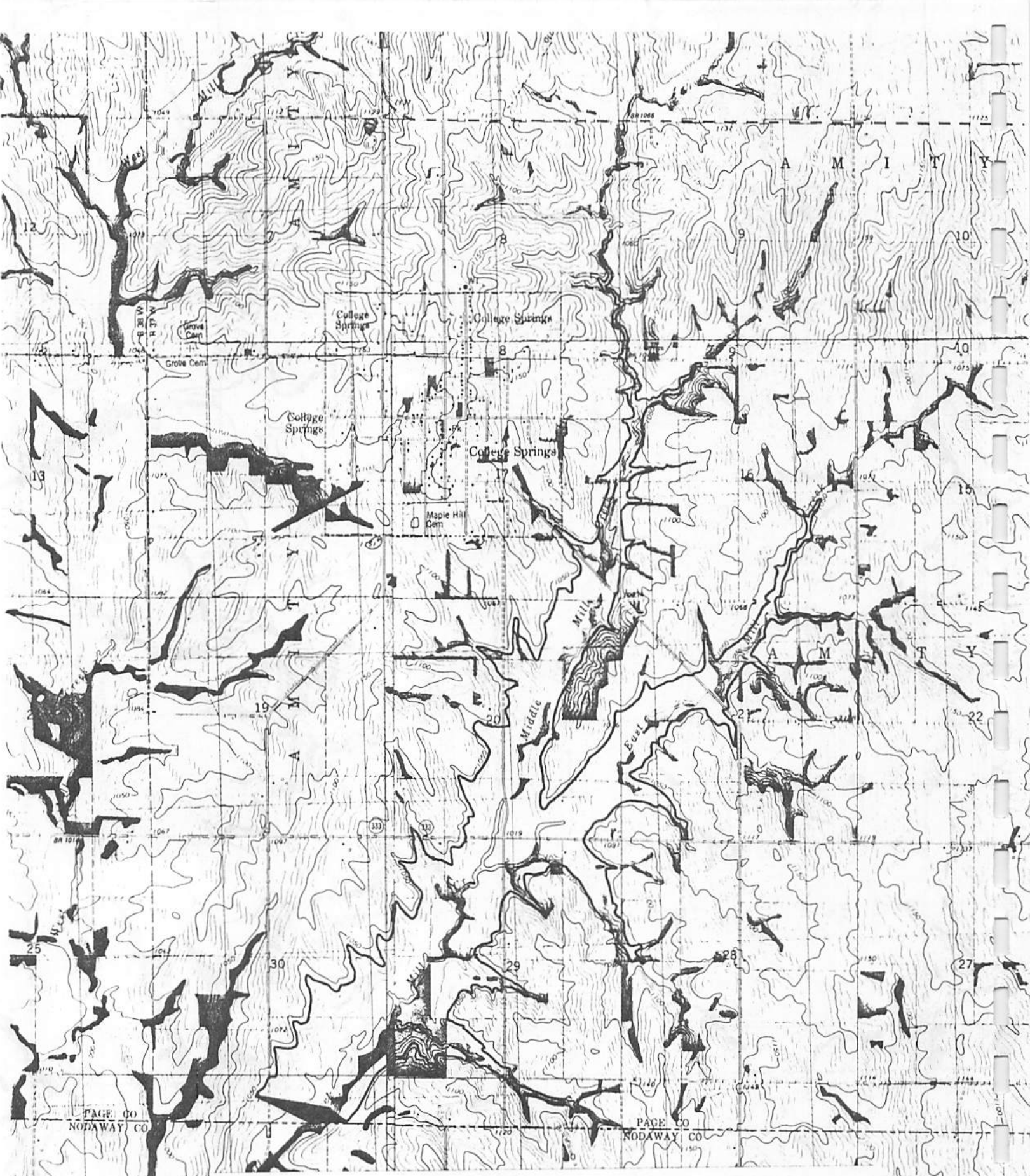
SITE NO.: 24 COUNTY: Page
LOCATION: SECTION: 36 T 68N, R 36W
QUADRANGLE: New Market
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



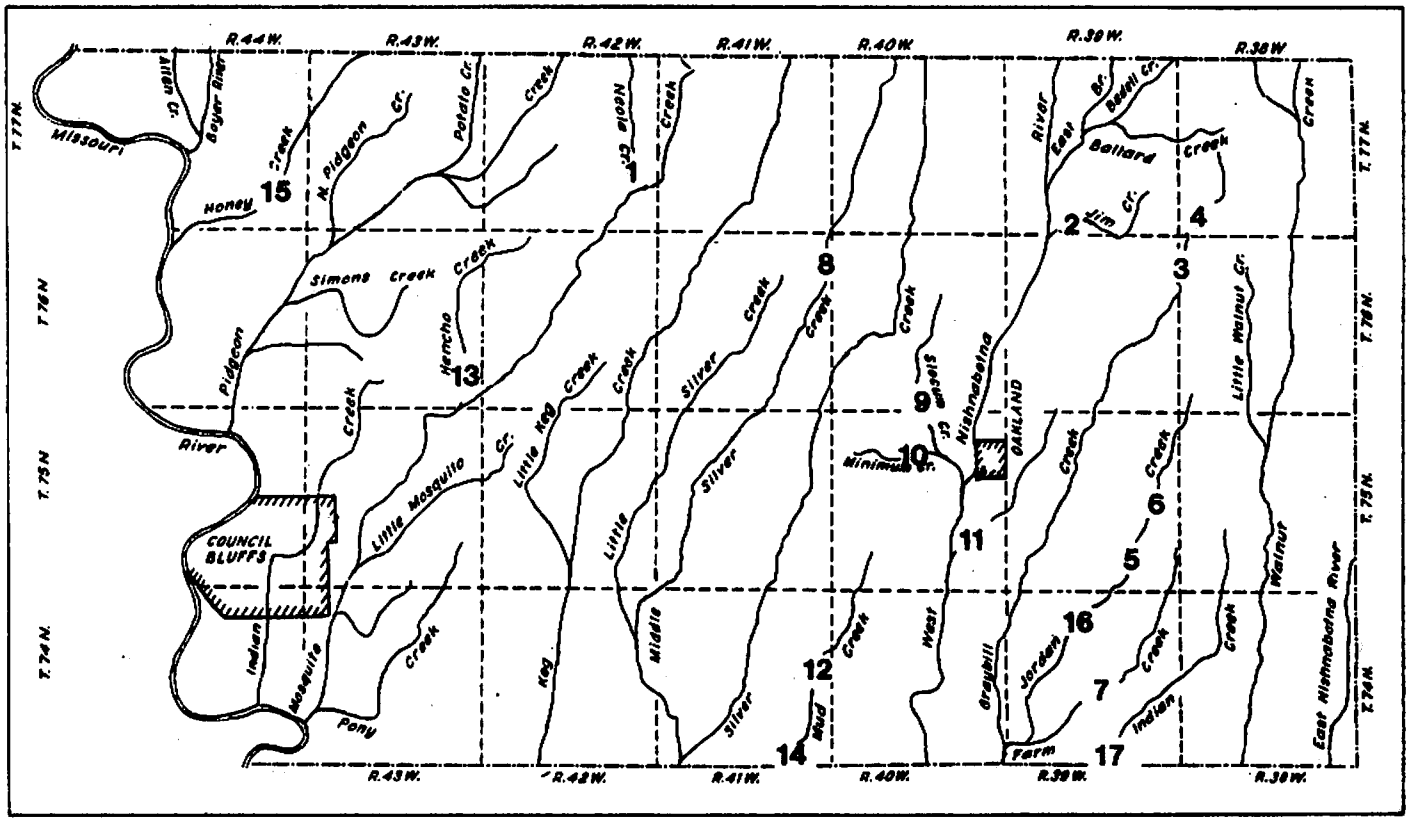
SITE NO.: 25 COUNTY: Page
LOCATION: SECTION: 24 T 67N, R 38W
QUADRANGLE: Clarinda South, Coin, Clearmont, Blanchard
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 26 COUNTY: Page
LOCATION: SECTION: 31, 36 T 67N, R 37, 38W
QUADRANGLE: Coin, Blanchard
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 27 COUNTY: Page
LOCATION: SECTION: 31 T 67N, R 31W
QUADRANGLE: Clearmont, Blanchard, Coin, Clarinda South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



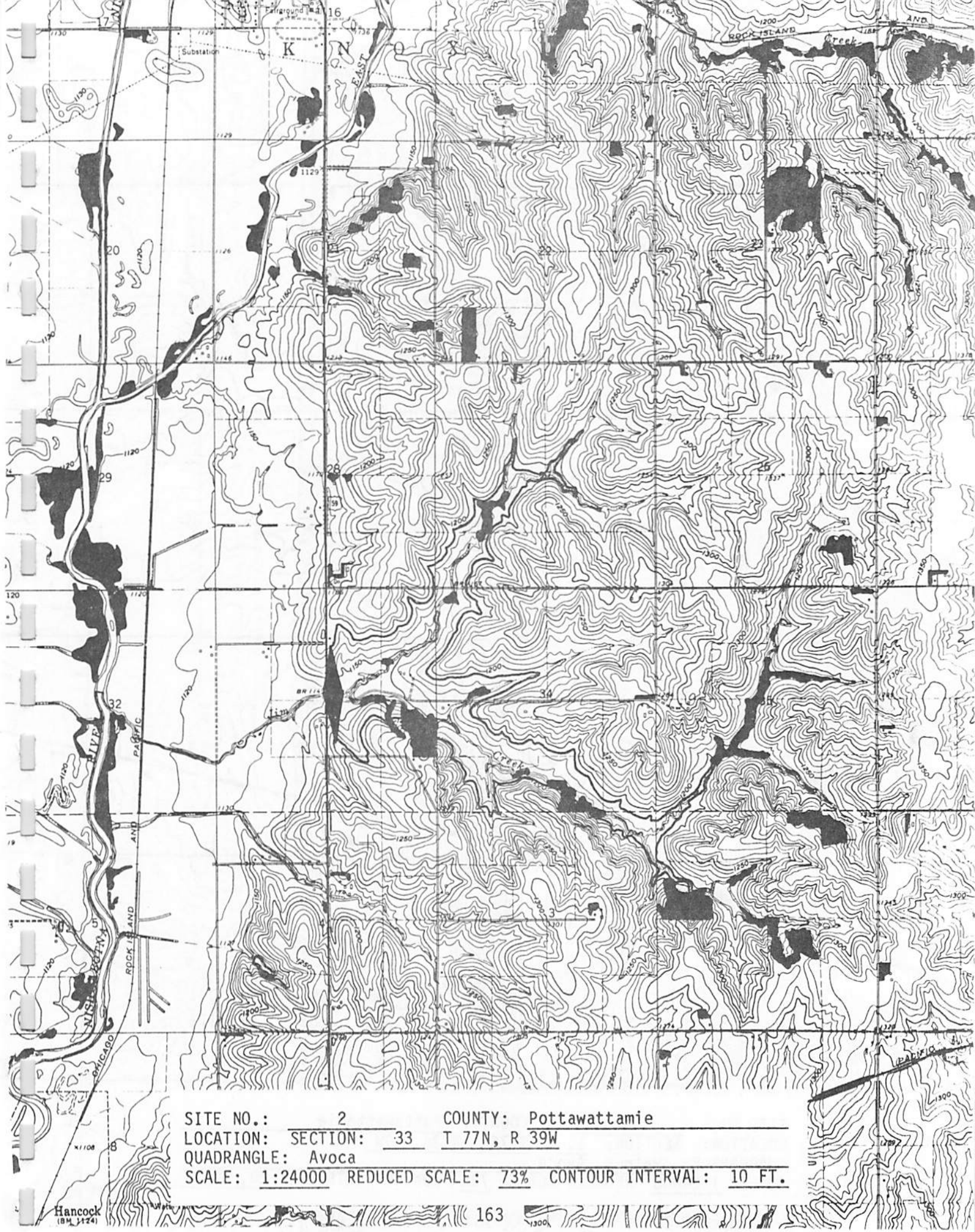
Index map for impoundment sites in Pottawattamie County.

POTTAWATTAMIE COUNTY

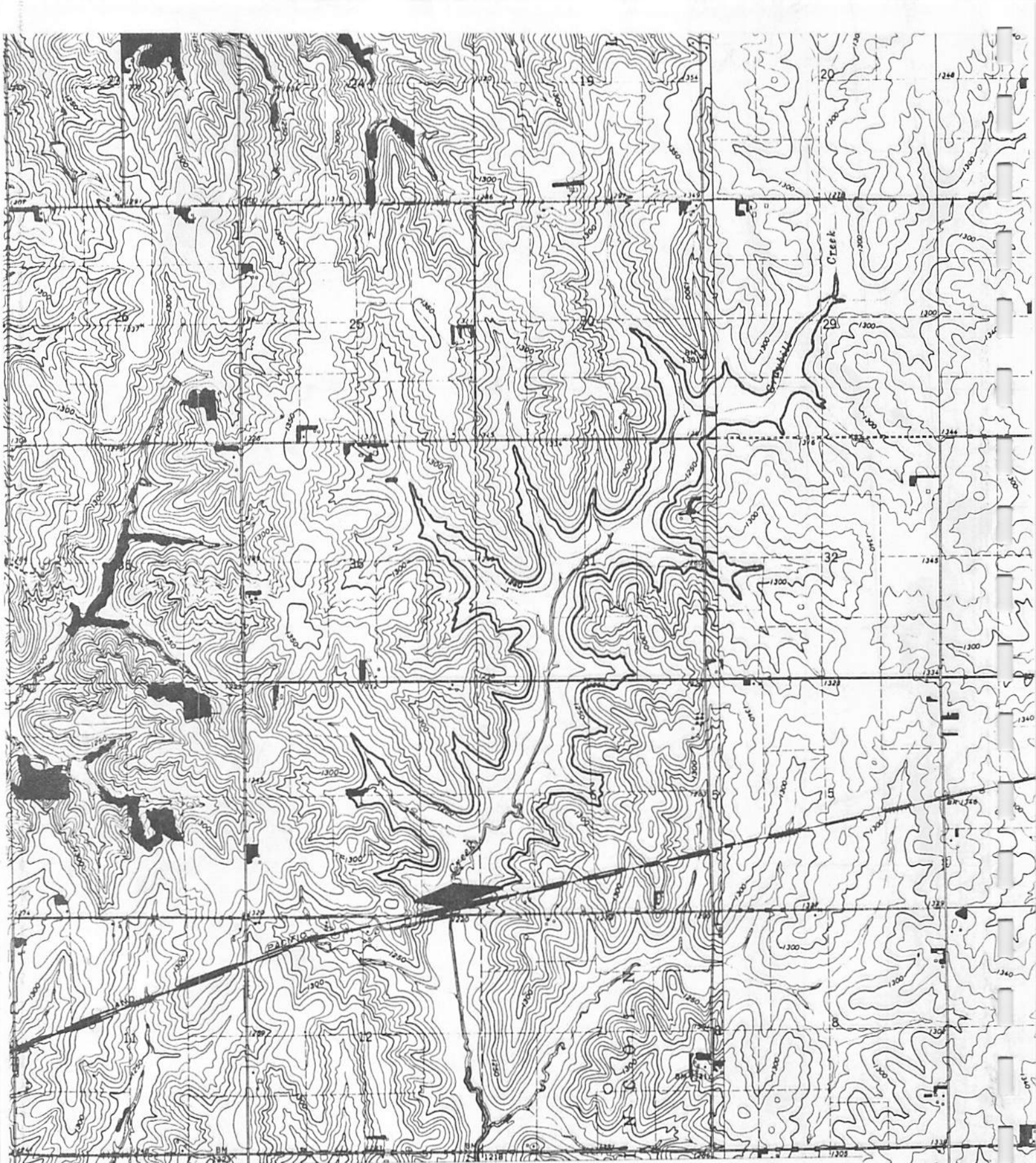
SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	24	77	42	7.02	45	263	3951	5	1	10	377	377	233	583	41	64	20	32	631	992
										20	1073	1073	233	583	87	111	44	55	1350	1712
2	33	77	39	8.19	55	266	4874	5	1	10	360	360	266	666	34	56	17	28	643	1054
										20	1010	1010	266	666	70	91	35	46	1311	1721
3	1, 6	76	38, 39	8.82	45	413	6198	5	1	10	351	351	284	709	42	71	21	35	656	1095
										20	978	978	284	709	84	112	42	56	1303	1742
4	31	77	38	7.10	45	619	9277	5	1	10	376	376	236	589	41	64	20	32	632	997
										20	1069	1069	236	589	87	111	43	55	1348	1713
5	26	75	39	16.40	45	507	7608	5	1	10	261	261	482	1206	50	98	25	49	769	1516
										20	659	659	482	1206	76	124	38	62	1180	1927
6	13	75	39	8.22	45	288	4315	5	1	10	360	360	267	668	42	69	21	34	648	1062
										20	1009	1009	267	668	85	112	43	56	1318	1732
7	22	74	39	9.93	45	298	4471	5	1	10	337	337	314	785	43	75	21	37	672	1159
										20	923	923	314	785	82	114	41	57	1278	1765
8	1	76	41	13.60	45	840	12594	5	1	10	292	292	411	1027	47	88	23	44	726	1363
										20	762	762	411	1027	78	119	39	60	1212	1849
9	3, 10	75	40	6.46	55	353	6465	5	1	10	385	385	217	543	33	51	16	25	619	954
										20	1105	1105	217	543	72	90	36	45	1359	1693
10	10	75	40	5.33	45	144	2163	5	1	10	403	403	184	461	39	58	20	29	607	892
										20	1172	1172	184	461	91	109	45	54	1402	1687
11	25	75	40	7.20	55	337	6183	5	1	10	374	374	238	596	33	53	17	27	629	997
										20	1064	1064	238	595	71	91	36	45	1337	1705
12	13	74	41	9.02	45	562	8425	5	1	10	349	349	289	723	43	71	21	35	659	1107
										20	967	967	289	723	84	113	42	56	1292	1747
13	25	76	43	9.79	55	397	7276	5	1	10	338	338	310	775	35	61	18	30	666	1144
										20	929	929	310	775	68	93	34	47	1273	1751
14	35	74	41	13.90	55	773	14167	5	1	10	288	288	419	1047	39	73	19	36	726	1371
										20	751	751	419	1047	64	98	32	49	1201	1446
15	26	77	44	24.40	45	230	3450	12	2	10	668	668	678	1694	90	158	45	79	1391	2441
										20	900	900	678	1694	105	173	53	87	1630	2681
16	1	74	39	25.90	45	685	10270	12	2	10	642	642	713	1783	90	162	45	81	1400	2586
										20	860	860	713	1783	105	176	53	88	1626	2732
17	34	74	39	15.00	45	734	11007	12	2	10	861	861	447	1117	87	132	44	66	1352	2044
										20	1193	1193	447	1117	109	154	55	77	1695	2347

* Column 1 20 year design, Column 2 50 year design periods.

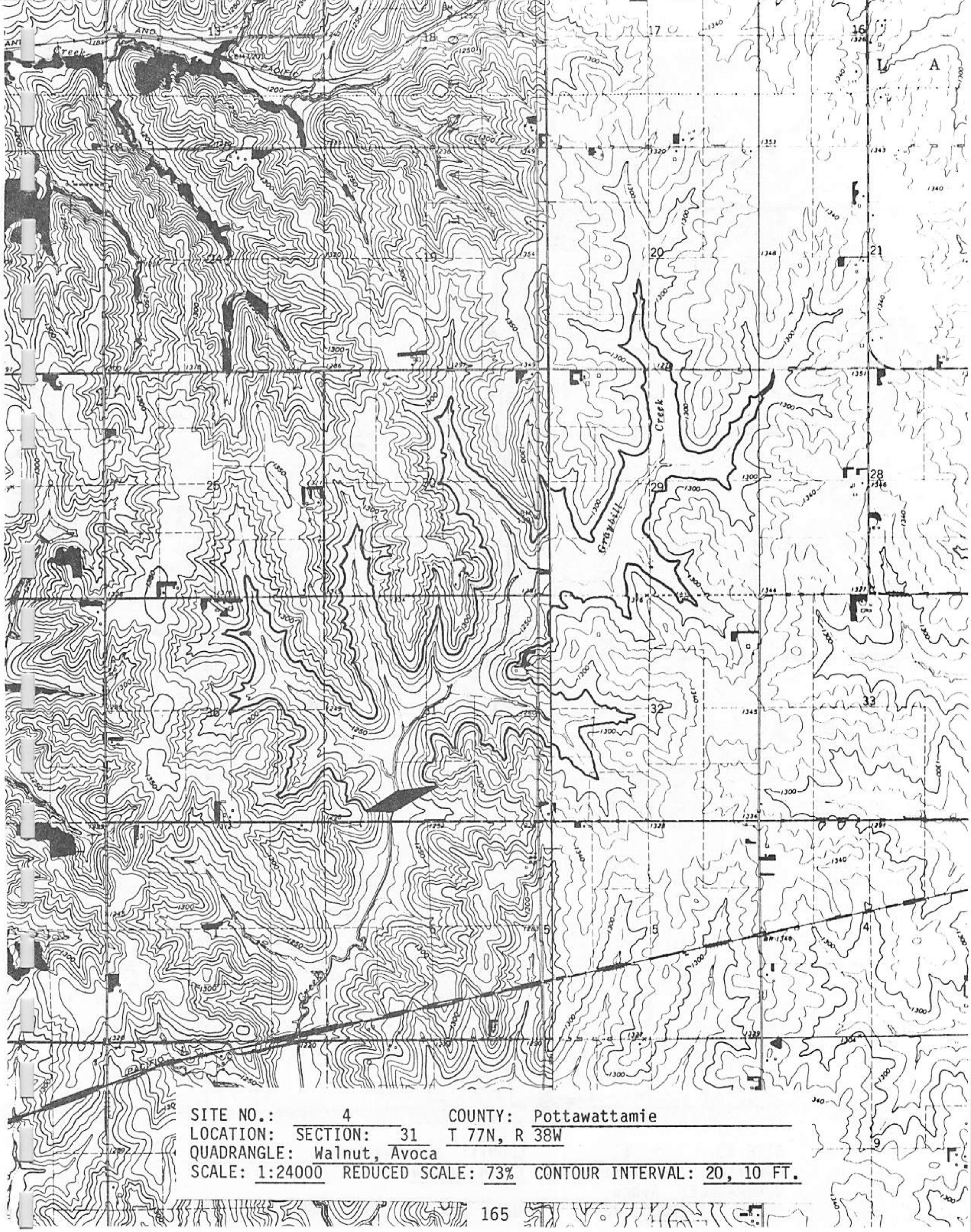
SITE NO.: 1 COUNTY: Pottawattamie
LOCATION: SECTION: 24 T 77N, R 42W
QUADRANGLE: Neola, Underwood
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



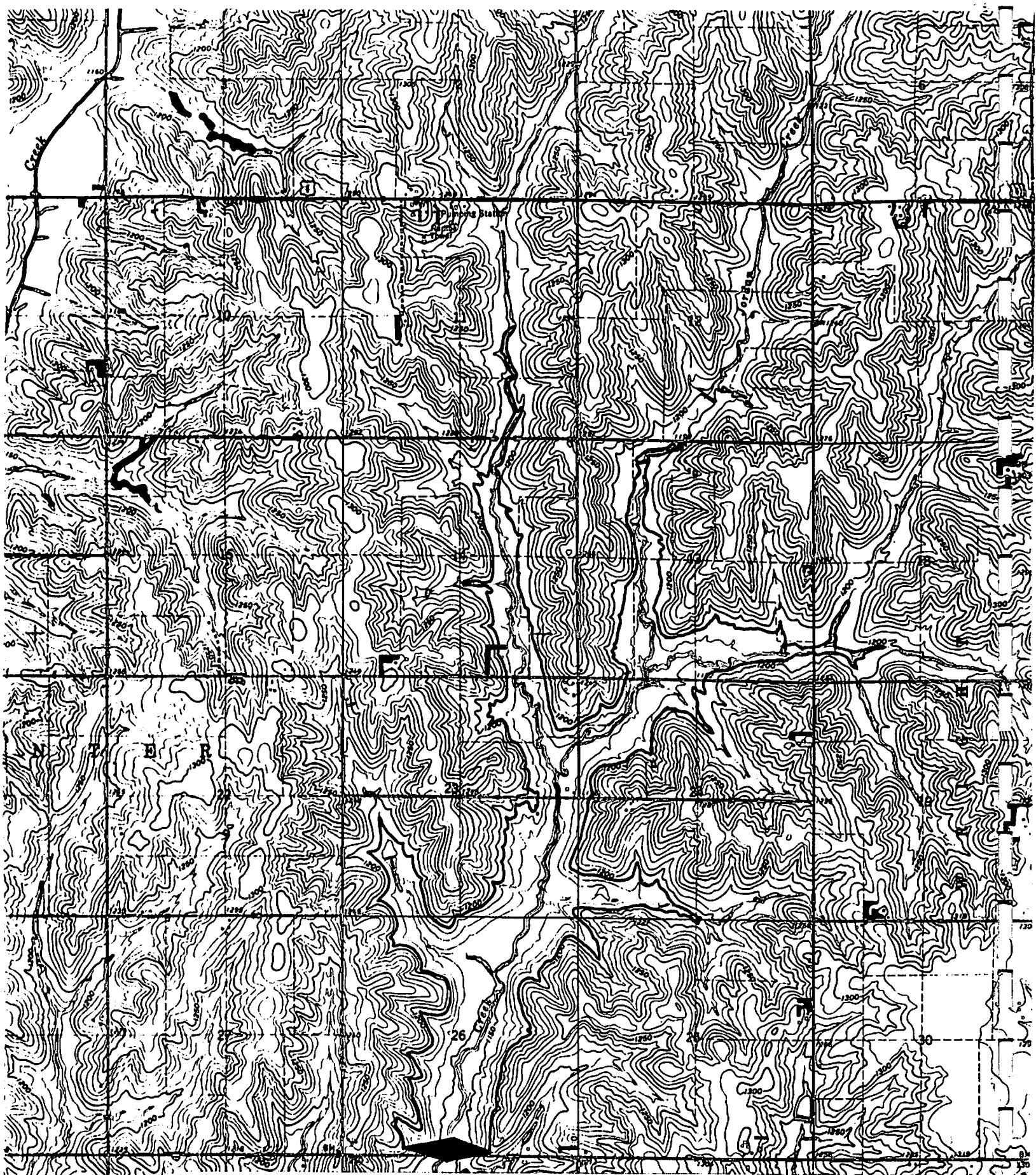
SITE NO.: 2 COUNTY: Pottawattamie
LOCATION: SECTION: 33 T 77N, R 39W
QUADRANGLE: Avoca
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



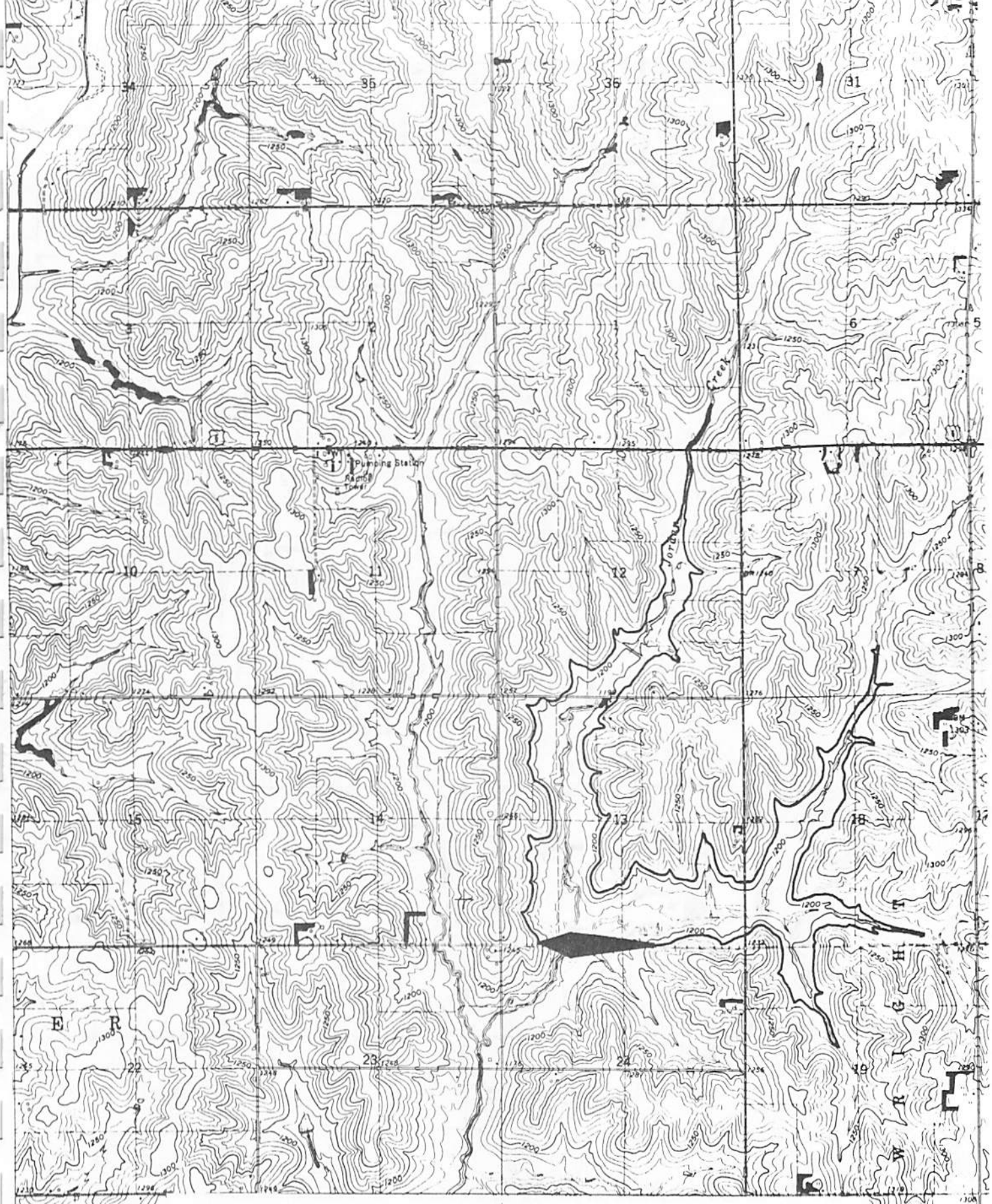
SITE NO.: 3 COUNTY: Pottawattamie
LOCATION: SECTION: 1, 6 T 76N, R 38, 39W
QUADRANGLE: Walnut, Avoca
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20, 10 FT.



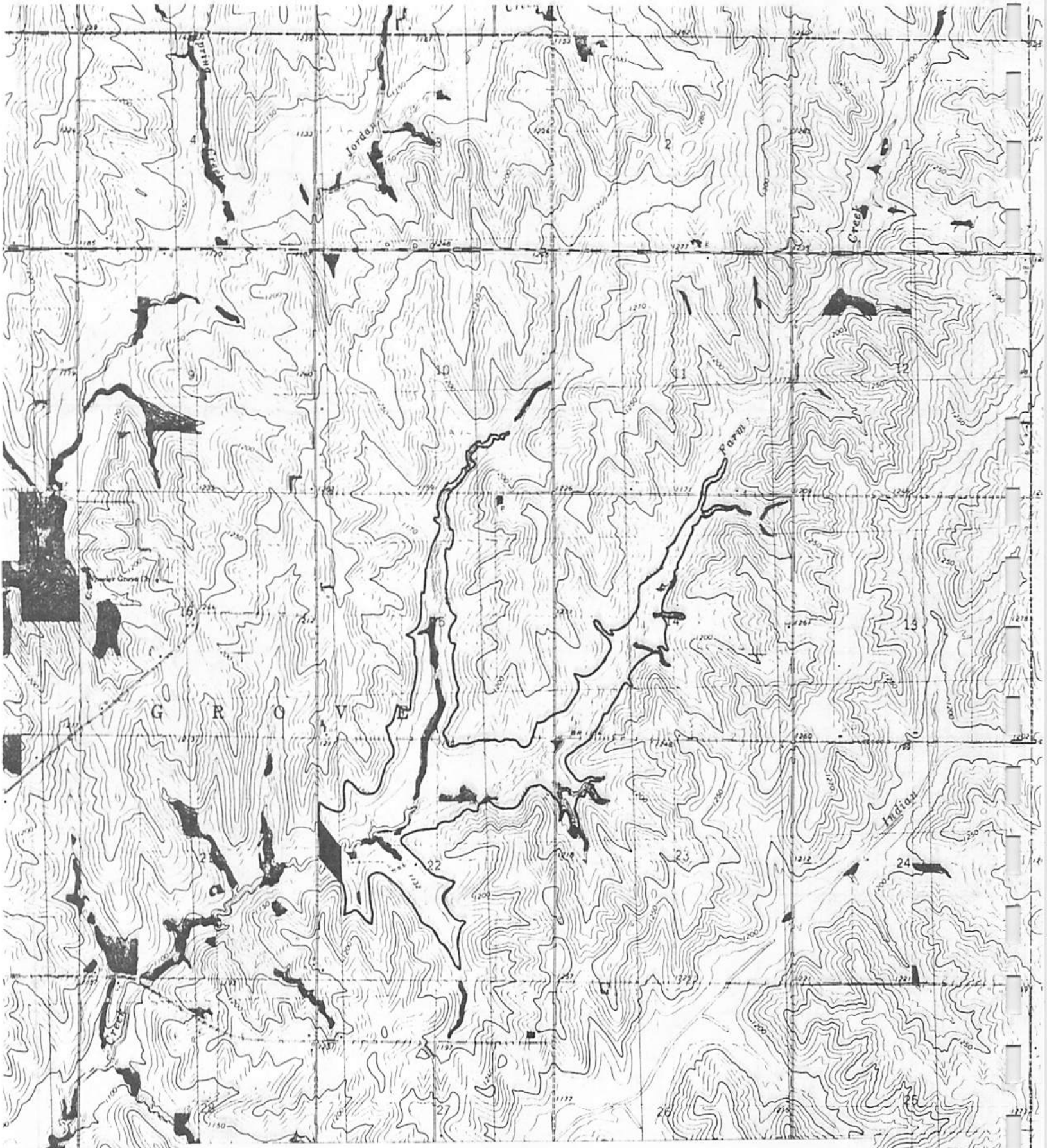
SITE NO.: 4 COUNTY: Pottawattamie
LOCATION: SECTION: 31 T 77N, R 38W
QUADRANGLE: Walnut, Avoca
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 20, 10 FT.



SITE NO.: 5 COUNTY: Pottawattamie
LOCATION: SECTION: 26 T 75N, R 39W
QUADRANGLE: Avoca
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

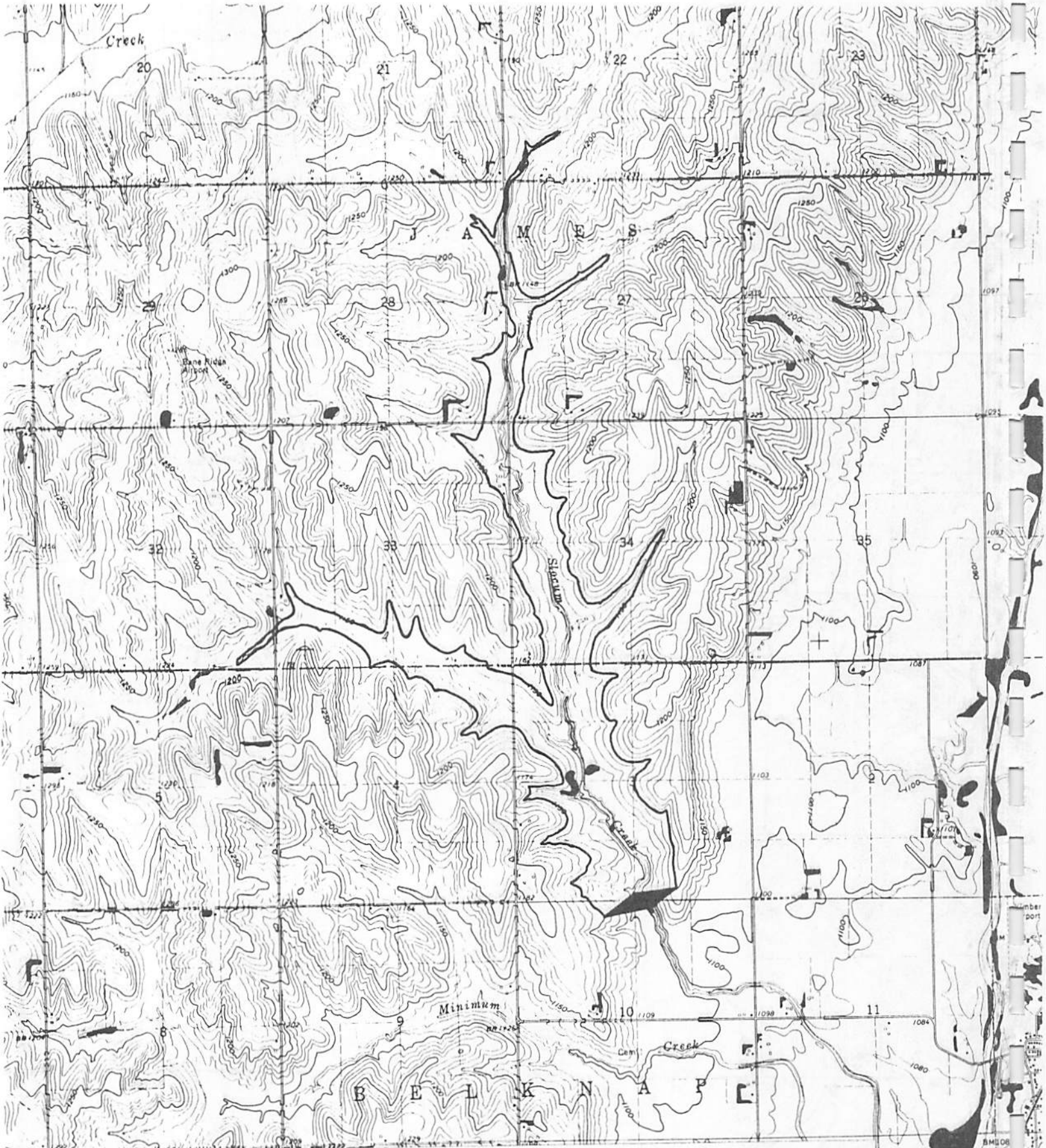


SITE NO.: 6 COUNTY: Pottawattamie
LOCATION: SECTION: 13 T 75N, R 39W
QUADRANGLE: Avoca SE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

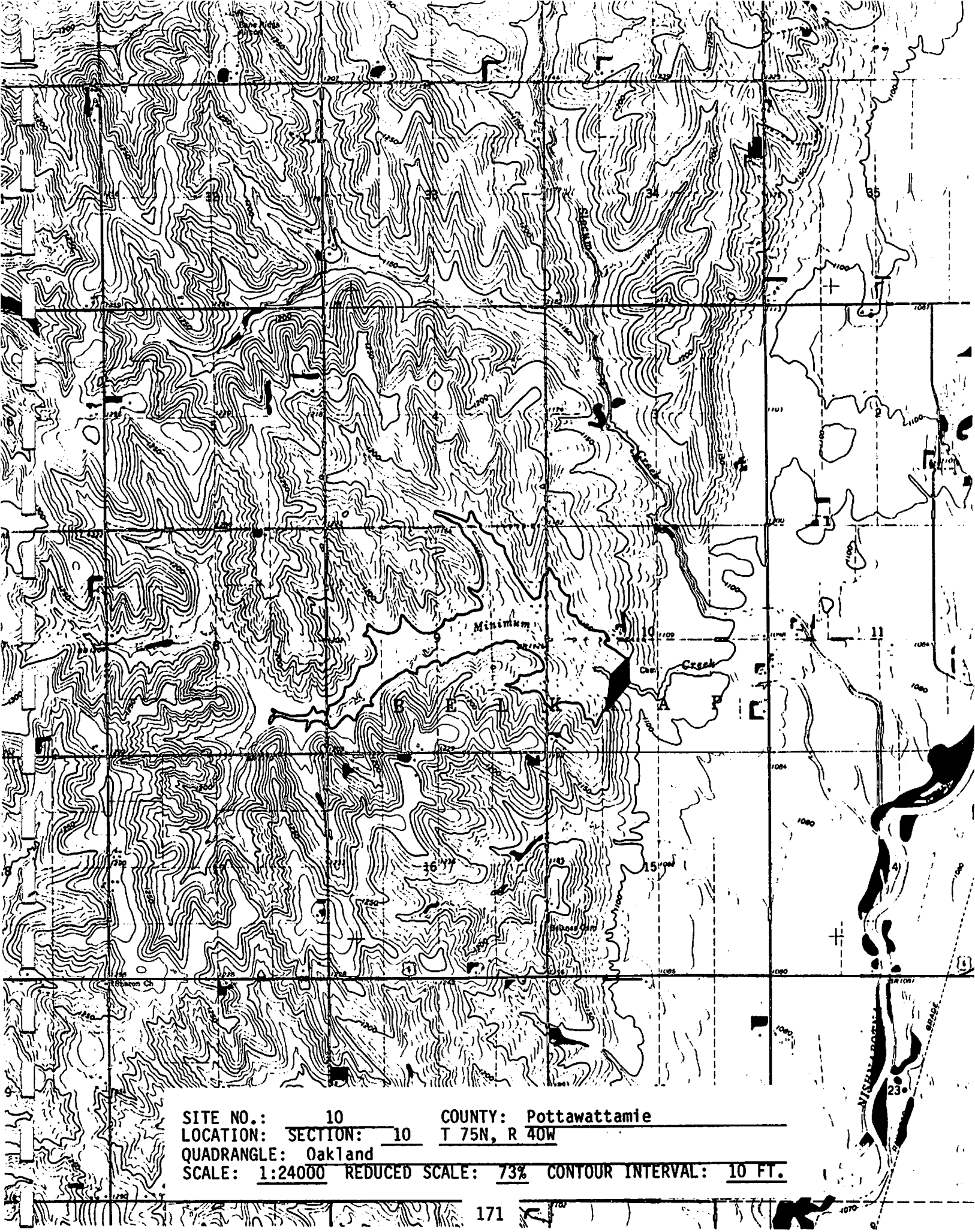


SITE NO.: 7 COUNTY: Pottawattamie
LOCATION: SECTION: 22 T 74N, R 39W
QUADRANGLE: Carson NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

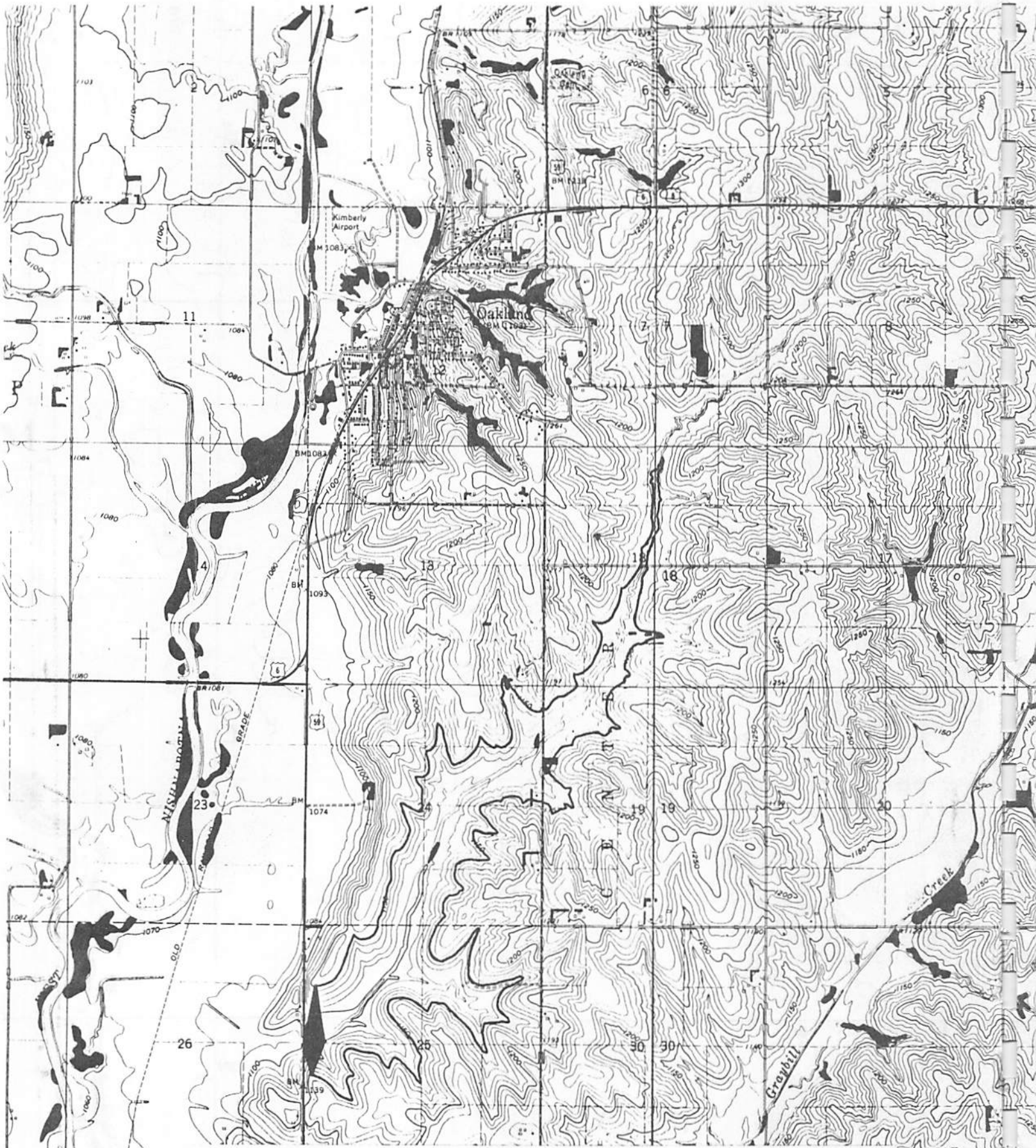
SITE NO.: 8 COUNTY: Pottawattamie
LOCATION: SECTION: 1 T 76N, R 41W
QUADRANGLE: Avoca NW
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



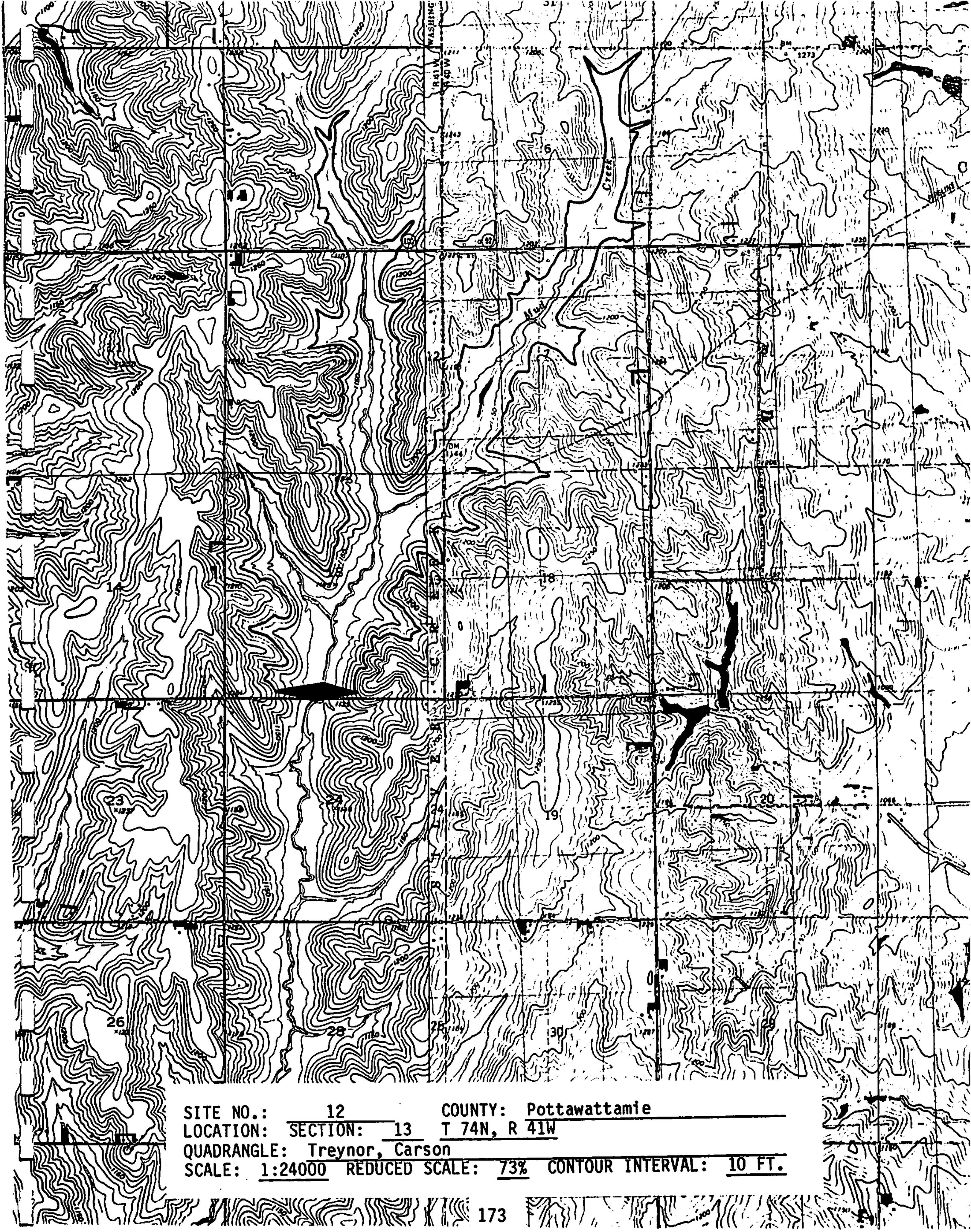
SITE NO.: 9 COUNTY: Pottawattamie
LOCATION: SECTION: 3, 10 T 75N, R 40W
QUADRANGLE: Oakland
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



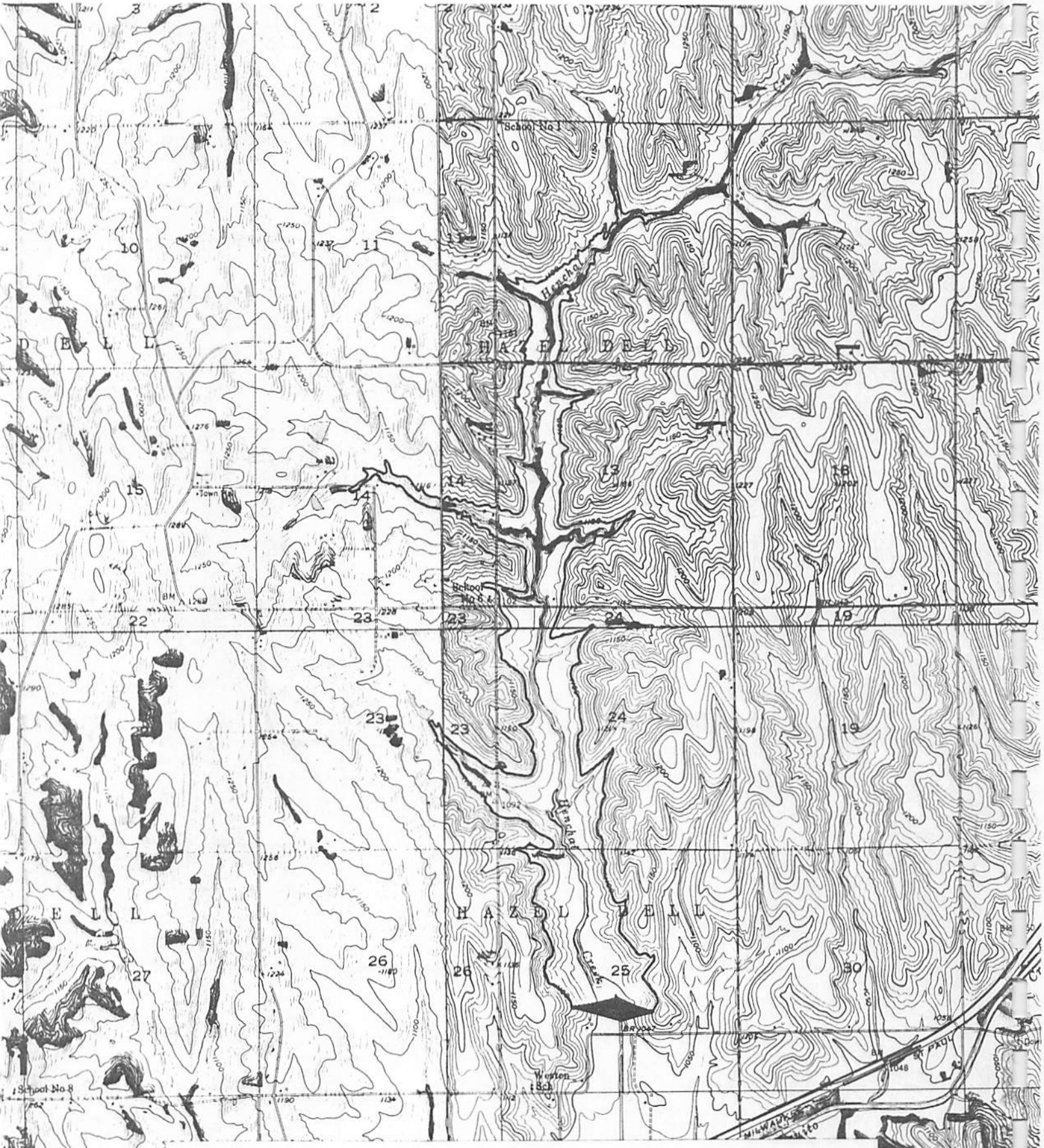
SITE NO.: 10 COUNTY: Pottawattamie
LOCATION: SECTION: 10 T 75N, R 40W
QUADRANGLE: Oakland
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



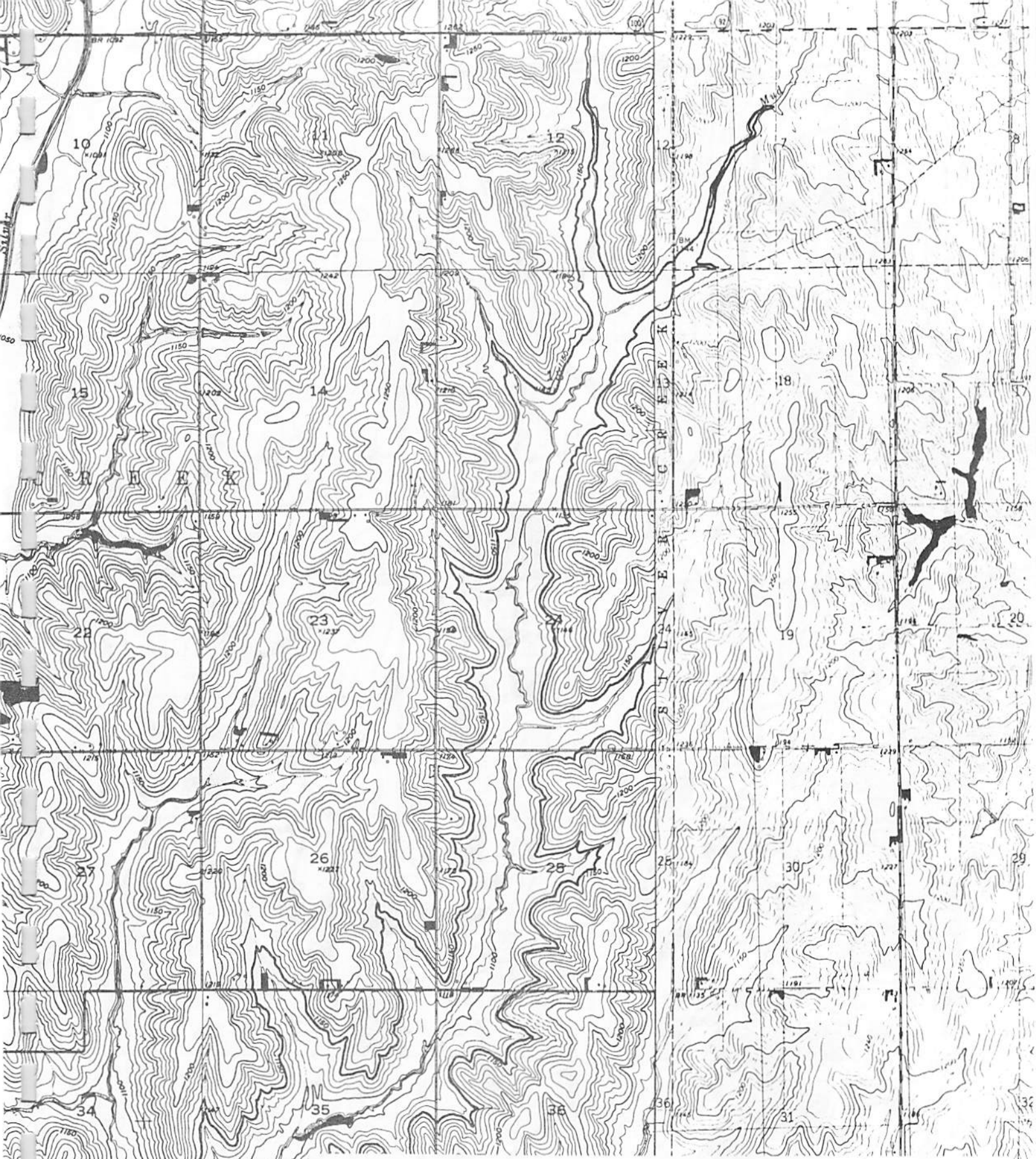
SITE NO.: 11 COUNTY: Pottawattamie
LOCATION: SECTION: 25 T 75N, R 40W
QUADRANGLE: Avoca SE, Oakland
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 12 COUNTY: Pottawattamie
LOCATION: SECTION: 13 T 74N, R 41W
QUADRANGLE: Treynor, Carson
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

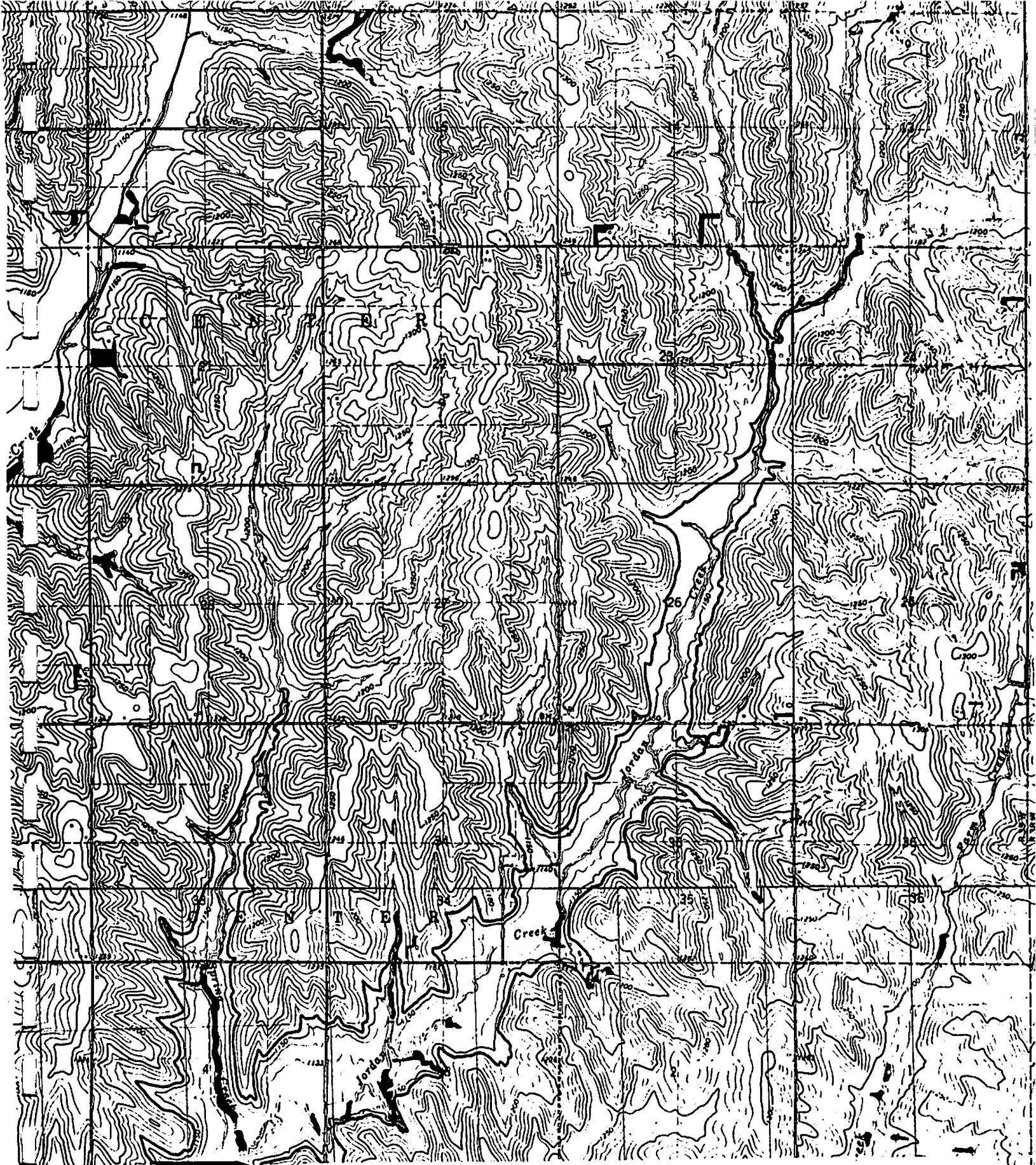


SITE NO.: 13 COUNTY: Pottawattamie
LOCATION: SECTION: 25 T 76N, R 43W
QUADRANGLE: Honey Creek, McClelland, Council Bluffs N, Underwood
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



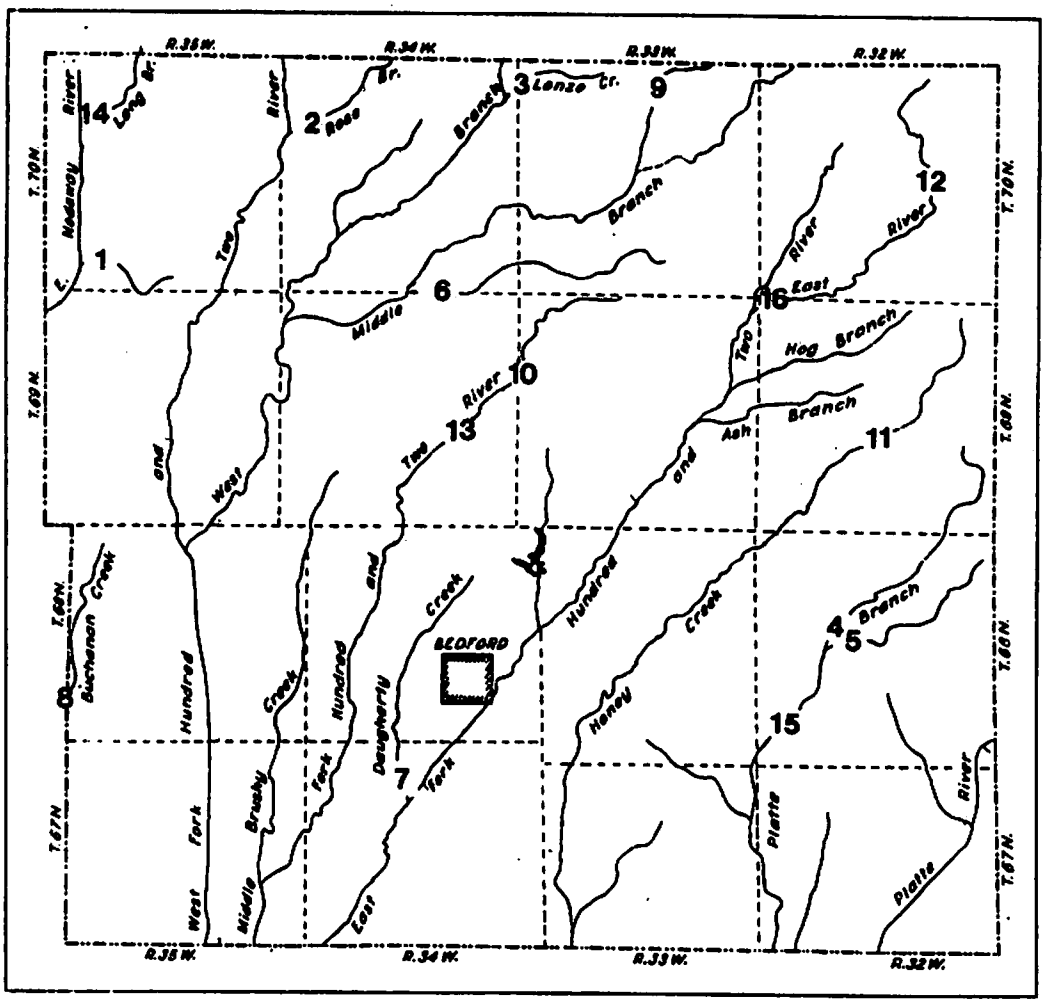
SITE NO.: 14 COUNTY: Pottawattamie
LOCATION: SECTION: 35 T 74N, R 41W
QUADRANGLE: Treynor, Carson
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 15 COUNTY: Pottawattamie
LOCATION: SECTION: 26 T 77N, R 44W
QUADRANGLE: Honey Creek
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 16 COUNTY: Pottawattamie
LOCATION: SECTION: 4 T 74N, R 39W
QUADRANGLE: Avoca SE, Carson NE
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 17 COUNTY: Pottawattamie
LOCATION: SECTION: 34 T 74N, R 39W
QUADRANGLE: Carson NE, Griswold
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

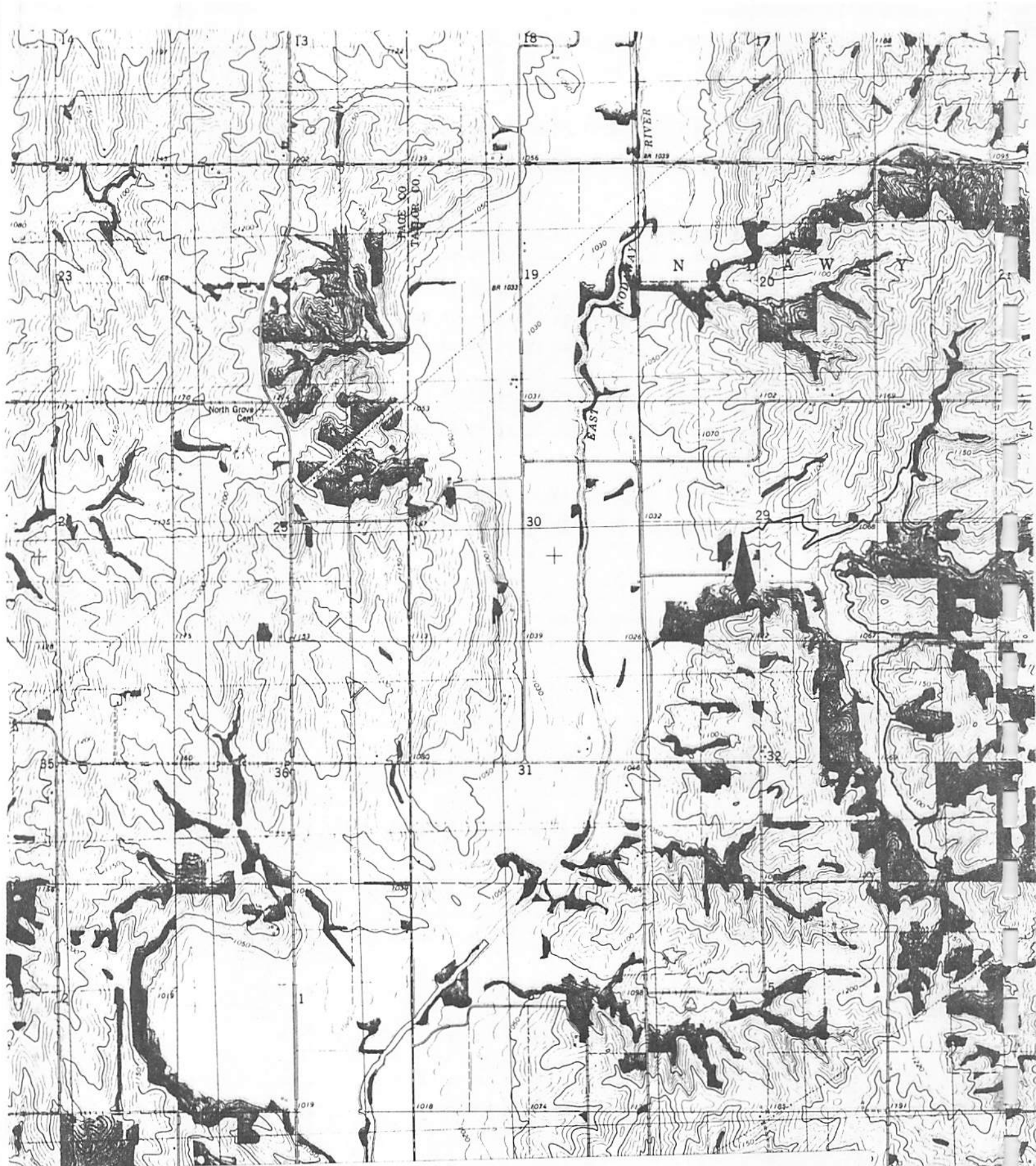


Index map for impoundment sites in Taylor County.

TAYLOR COUNTY

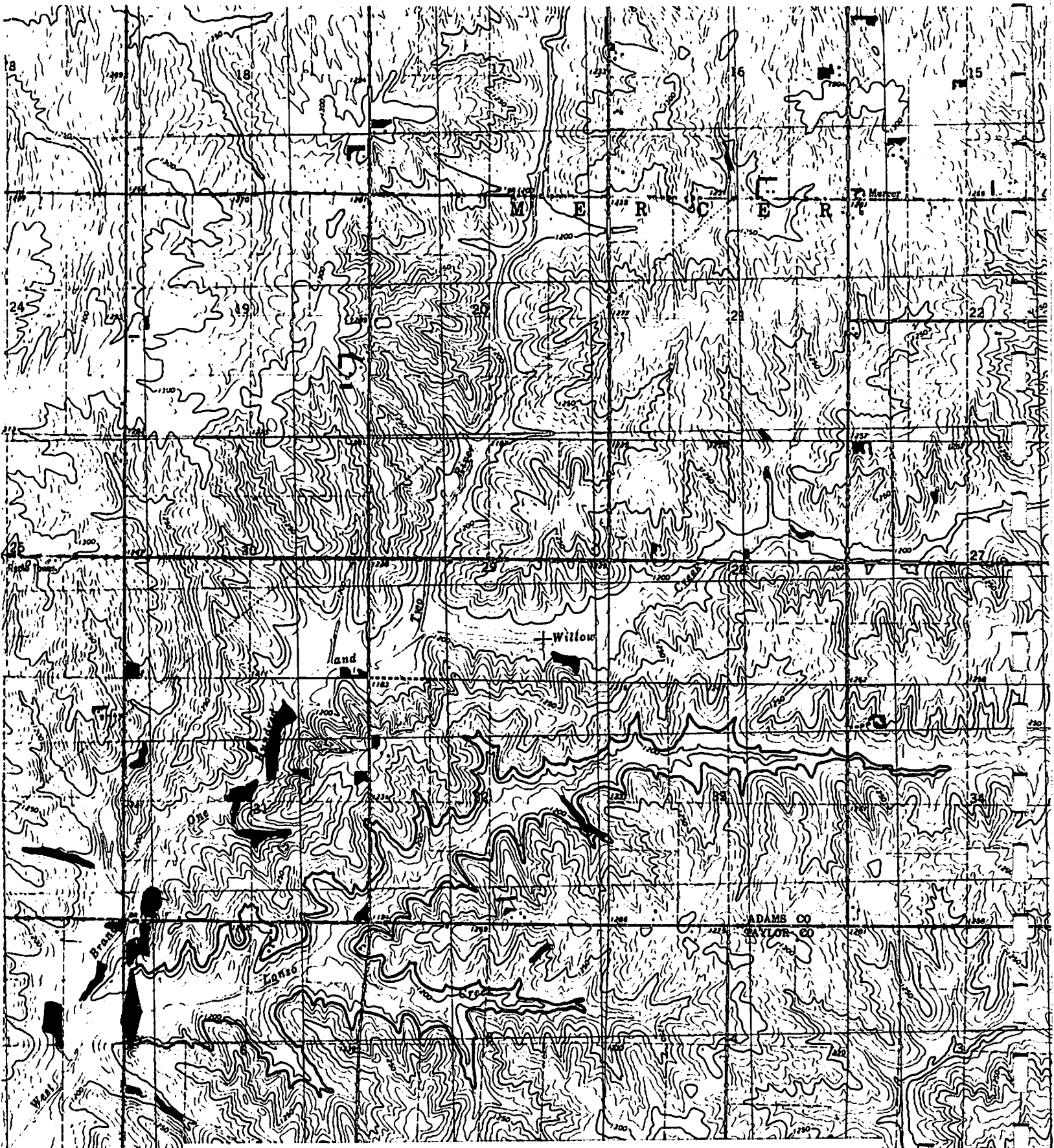
SITE	LOCATION			WATERSHED AREA	NON-SCALED IMPOUNDMENTS						SCALED DRAFT RATE/STORAGE REQUIREMENTS									
	Sec.	Twp(N)	Rng(W)	(miles²)	Maximum Depth (feet)	Surface Area (acres)	Total Volume (acre-feet)	Population Served (1000's)	Withdrawal Rate (feet³/sec)	Low-Flow Recurrence Interval Assumed (years)	Water Supply Volume Requirement* (acre-feet)		Sediment Storage Requirement* (acre-feet)		Recalculated Surface Area* (acres)		Evaporation Storage Requirement* (acre-feet)		Total Scaled Required Storage* (acre-feet)	
1	29	70	35	6.18	45	172	2577	5	1	10	390	390	209	523	40	61	20	30	619	943
										20	1121	1121	209	523	89	110	44	55	1375	1699
2	7	70	34	10.30	45	800	12000	5	1	10	331	331	324	810	44	76	22	38	677	1179
										20	905	905	324	810	82	114	41	57	1270	1772
3	6	70	33	7.53	35	374	4359	5	1	10	370	370	248	619	53	85	27	42	644	1031
										20	1045	1045	248	619	111	143	55	71	1349	1736
4	9	68	32	11.20	35	765	8921	5	1	10	320	320	348	870	57	102	29	51	697	1241
										20	864	864	348	870	104	149	52	74	1263	1808
5	9, 16	68	32	6.52	55	763	13993	5	1	10	384	384	219	548	33	51	16	25	619	957
										20	1102	1102	219	548	72	90	36	45	1357	1694
6	34	70	34	8.84	55	785	14387	5	1	10	351	351	284	711	35	58	17	29	652	1090
										20	977	977	284	711	69	92	34	46	1295	1733
7	4, 9	67	34	6.00	35	194	2266	5	1	10	392	392	204	510	51	77	26	39	622	941
										20	1132	1132	204	510	115	141	57	70	1393	1712
8	25, 30	68	35, 36	9.26	65	478	10366	5	1	10	345	345	296	739	30	50	15	25	656	1110
										20	955	955	296	739	58	78	29	39	1280	1734
9	3	70	33	5.50	45	694	10477	5	1	10	399	399	189	473	39	58	20	29	608	902
										20	1162	1162	189	473	90	108	45	54	1396	1689
10	7, 12, 18	69	34	7.29	45	598	8973	5	1	10	373	373	241	602	41	65	21	32	634	1008
										20	1059	1059	241	602	87	111	43	55	1343	1716
11	22	69	32	6.31	35	531	6194	5	1	10	388	388	213	532	51	79	26	39	626	959
										20	1114	1114	213	532	114	141	57	71	1384	1717
12	23	70	32	6.27	45	878	13168	5	1	10	388	388	212	530	40	61	20	31	619	948
										20	1116	1116	212	530	88	110	44	55	1372	1701
13	23	69	34	14.1	55	1058	19389	12	2	10	882	882	424	1060	71	106	36	53	1341	1995
										20	1226	1226	424	1060	90	125	45	62	1695	2348
14	8, 9	70	35	14.8	55	605	11097	12	2	10	866	866	442	1104	72	108	36	54	1343	2024
										20	1200	1200	442	1104	90	126	45	63	1687	2368
15	31, 36	68	32, 33	24.9	45	1270	19048	12	2	10	659	659	690	1724	90	159	45	79	1394	2463
										20	887	887	690	1724	105	174	53	87	1629	2693
16	6, 31	70	32	19.2	45	1775	2663	12	2	10	769	769	552	1380	88	143	44	72	1365	2220
										20	1052	1052	552	1380	107	162	54	81	1657	2513

* Column 1 20 year design, Column 2 50 year design

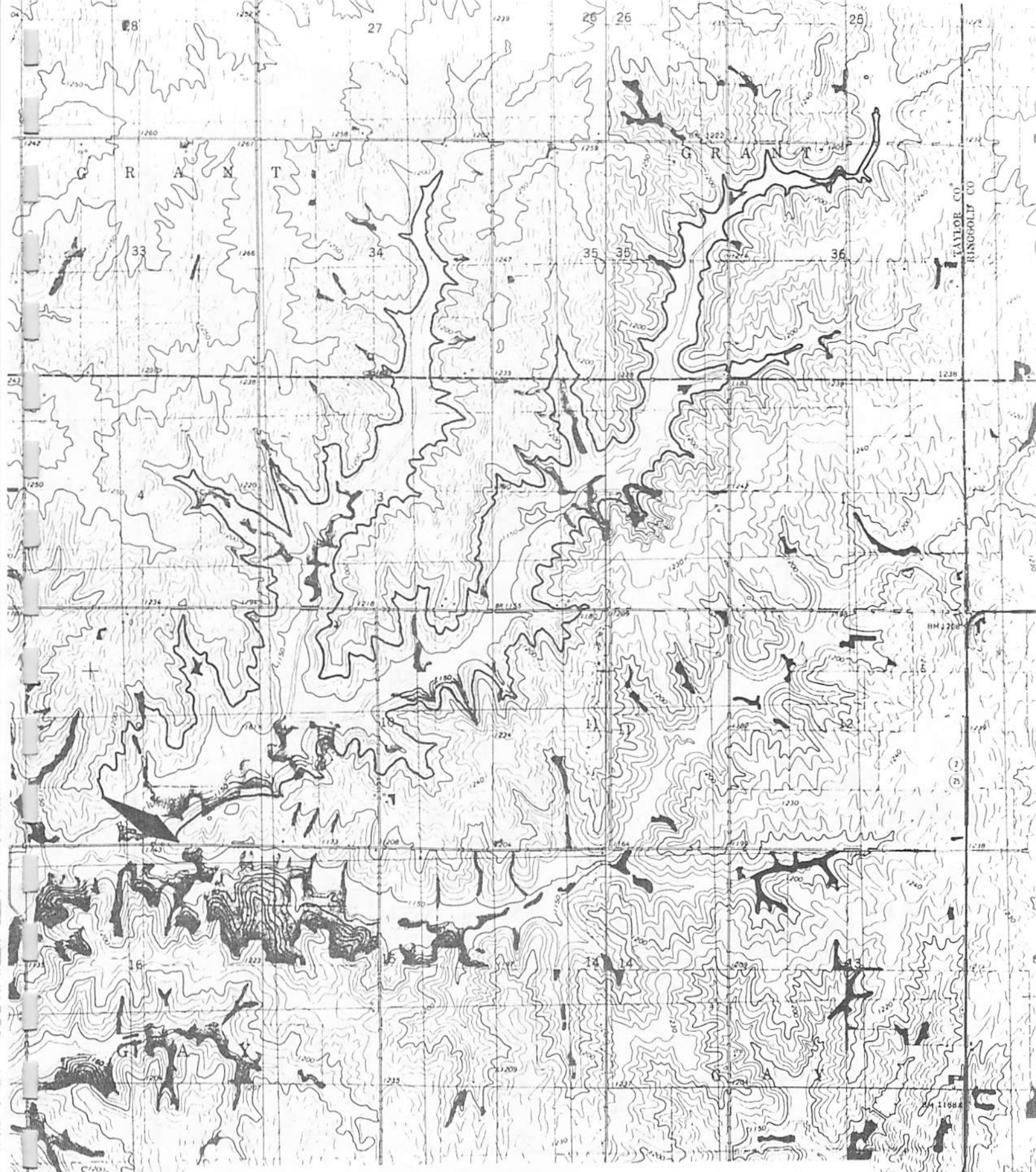


SITE NO.: 1 COUNTY: Taylor
LOCATION: SECTION: 29 T 70N, R 35W
QUADRANGLE: Hawleyville
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

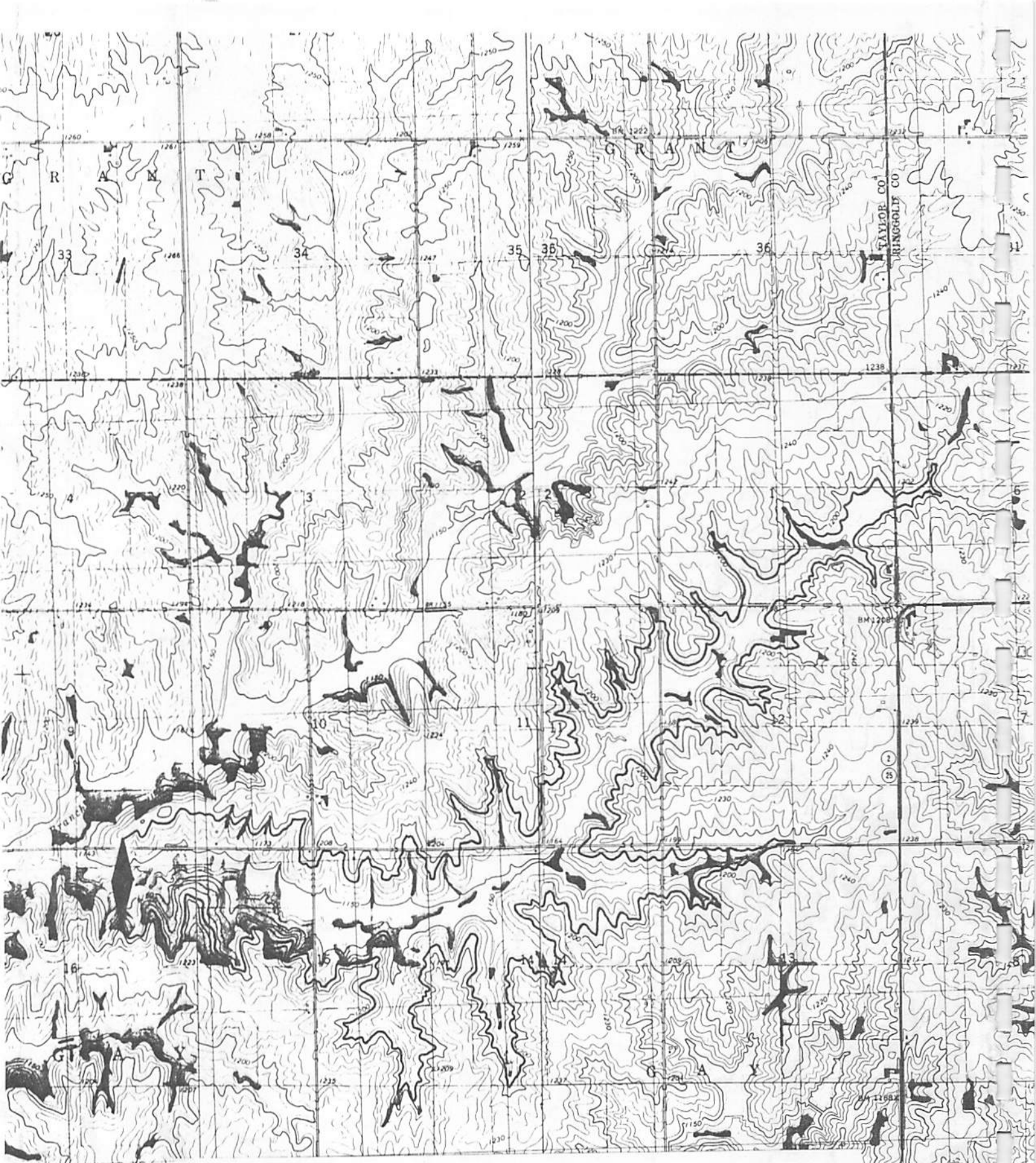
SITE NO.: 2 COUNTY: Taylor
LOCATION: SECTION: 7 T 70N, R 34W
QUADRANGLE: Guss, Gravity, Corning South, Brooks
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



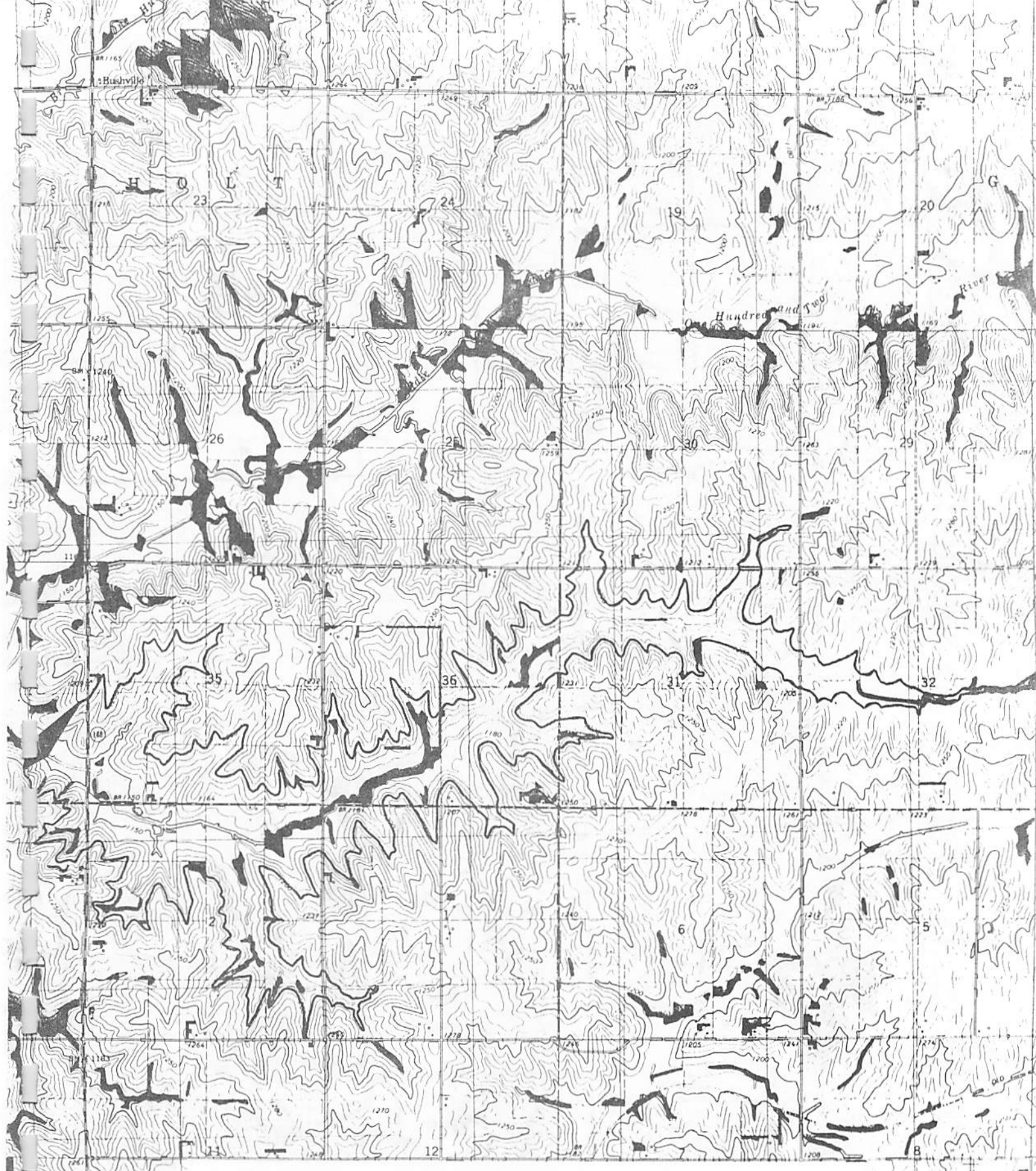
SITE NO.: 3 COUNTY: Taylor
LOCATION: SECTION: 6 T 70N, R 33W
QUADRANGLE: Corning South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



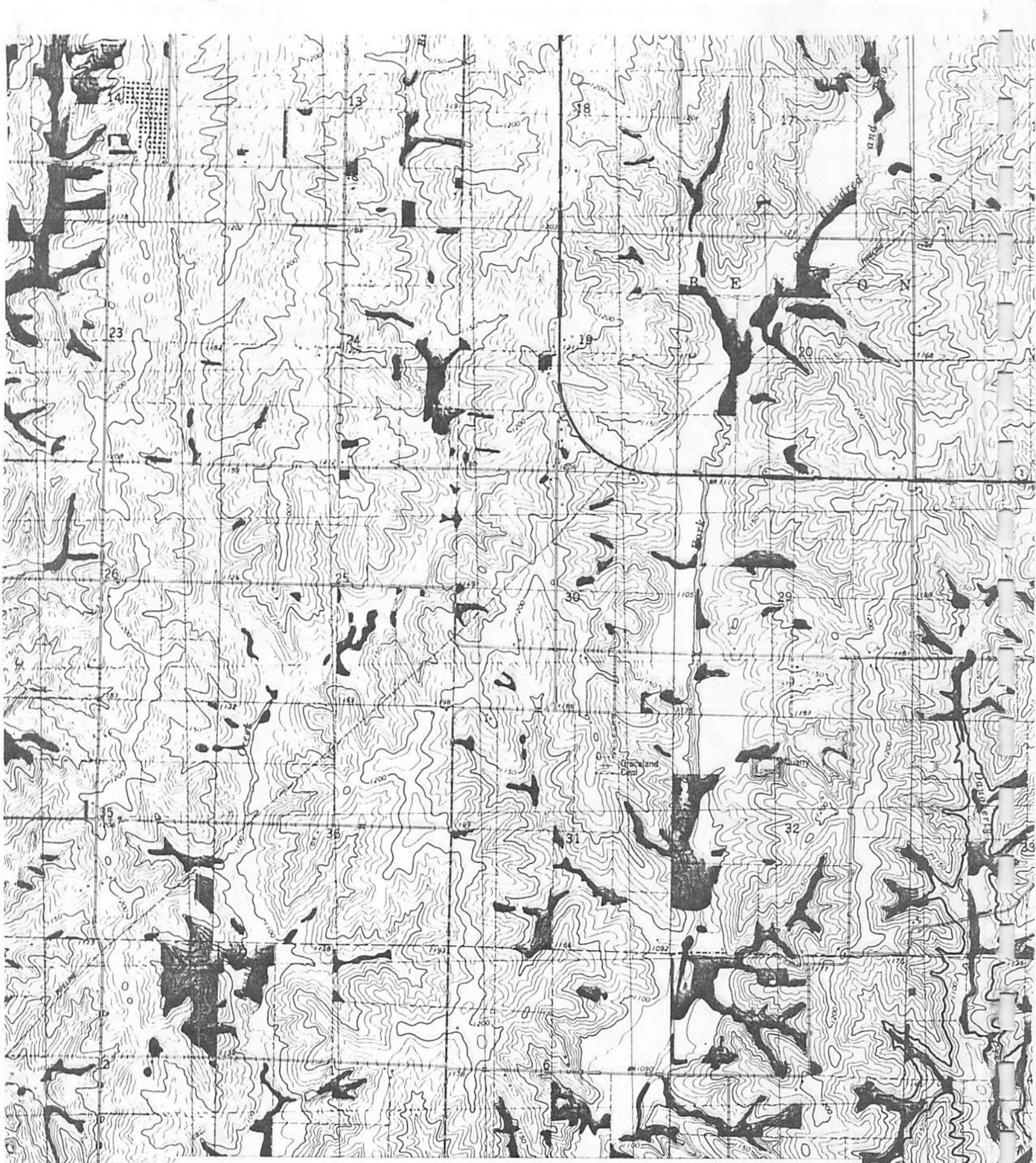
SITE NO.: 4 COUNTY: Taylor
LOCATION: SECTION: 9 T 68N, R 32W
QUADRANGLE: Maloy, Conway
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



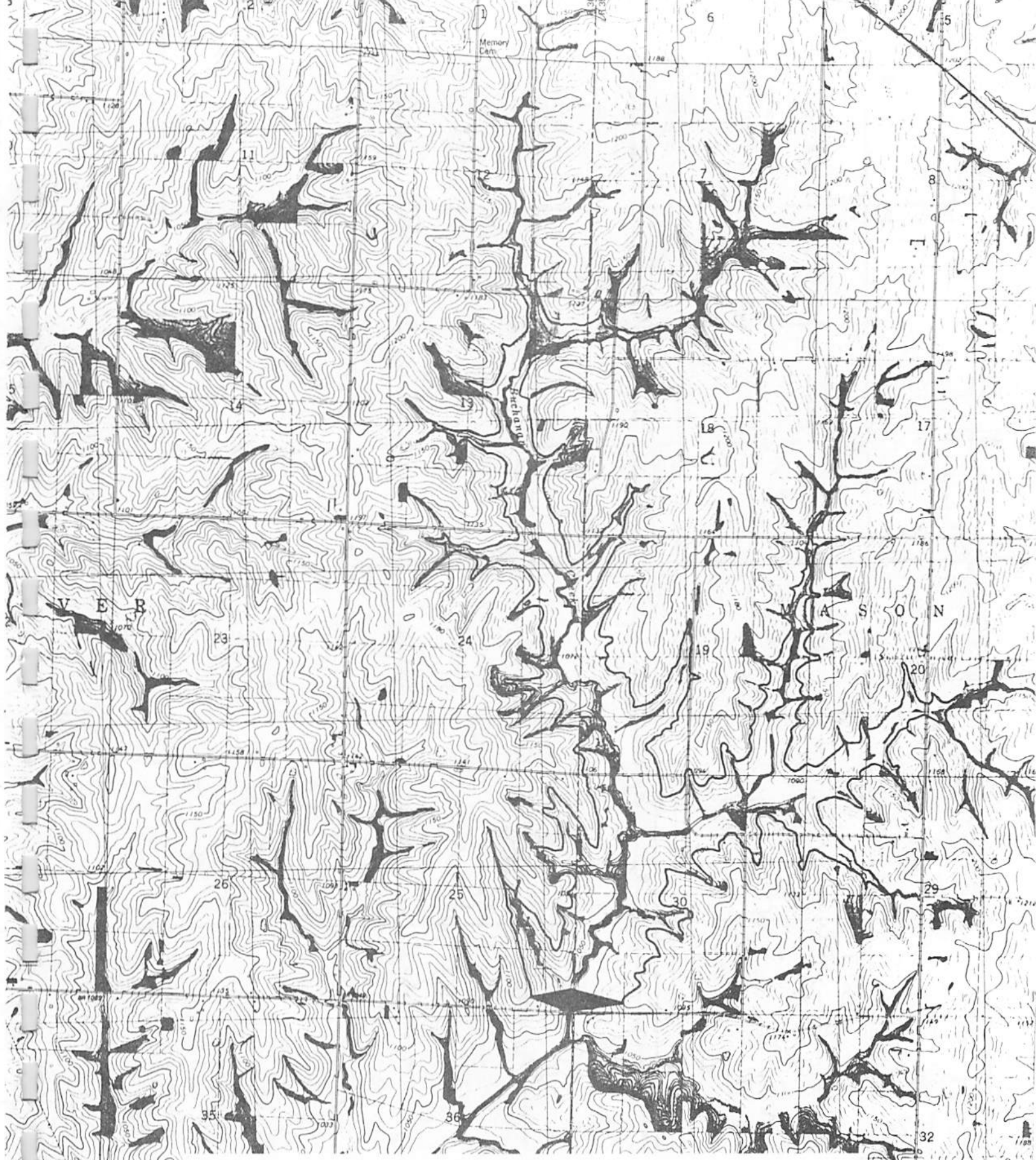
SITE NO.: 5 COUNTY: Taylor
LOCATION: SECTION: 9, 16 T 68N, R 32W
QUADRANGLE: Conway, Maloy
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



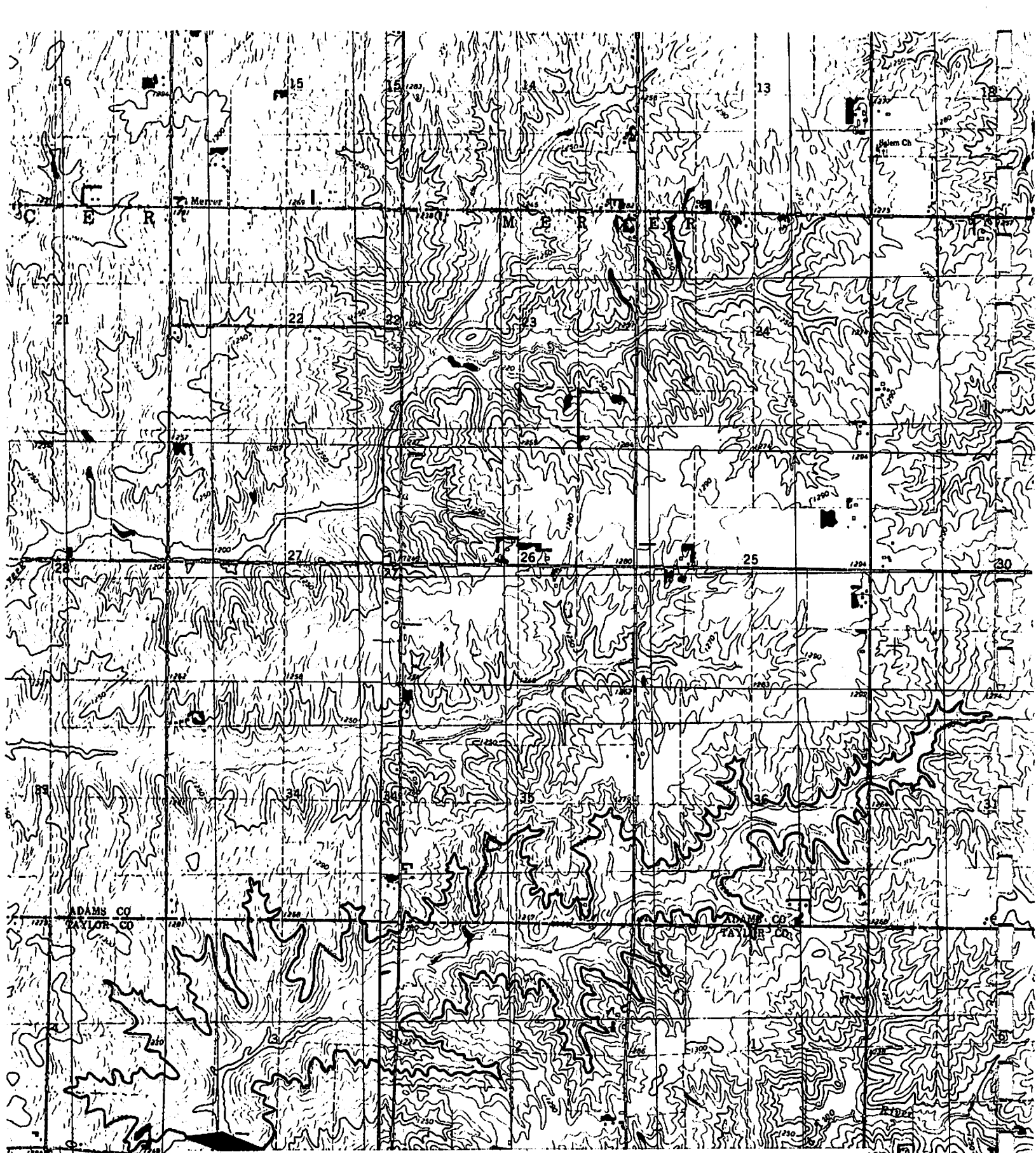
SITE NO.: 6 COUNTY: Taylor
LOCATION: SECTION: 34 T 70N, R 34W
QUADRANGLE: Gravity
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



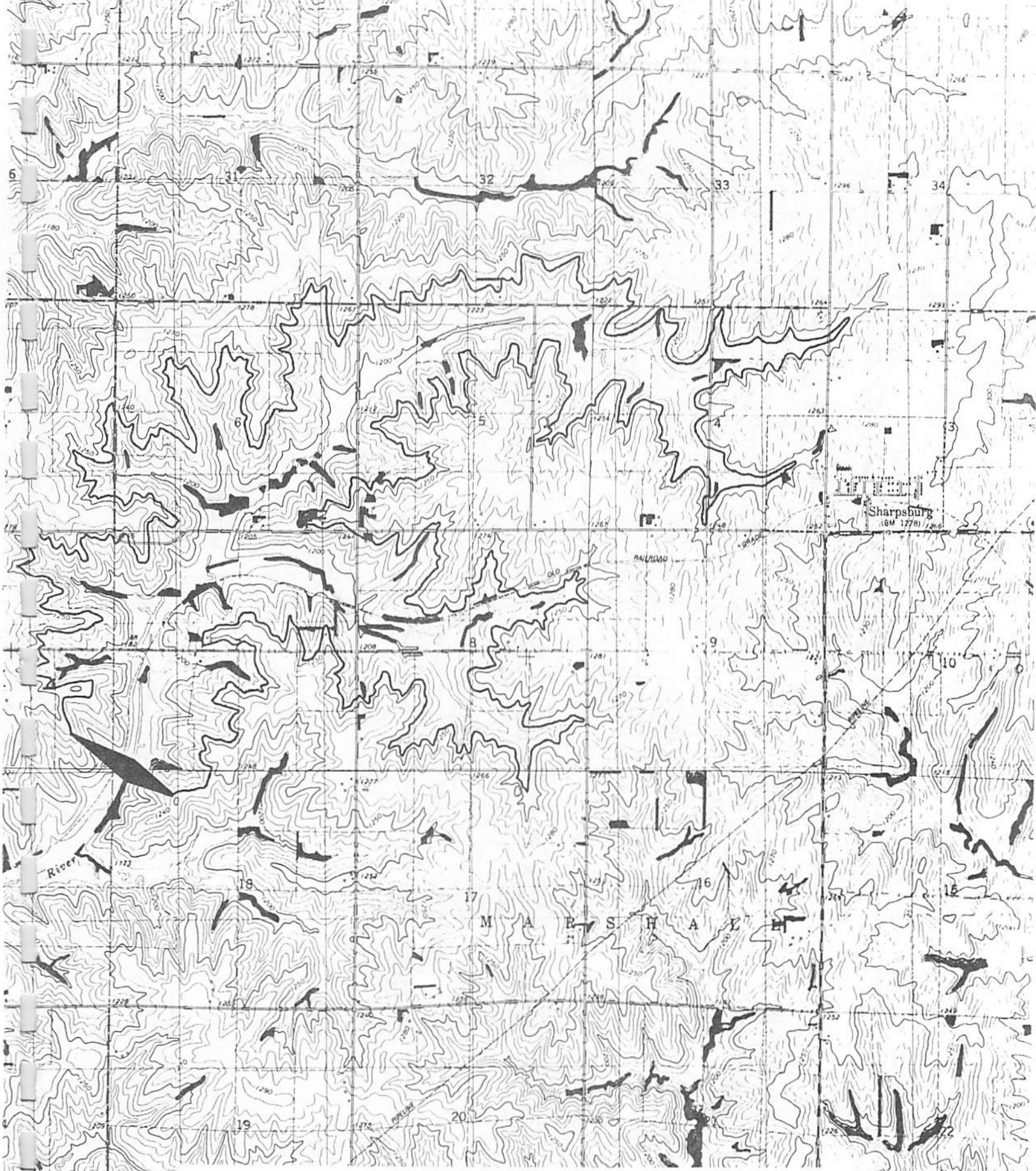
SITE NO.: 7 COUNTY: Taylor
LOCATION: SECTION: 4, 9 T 67N, R 34W
QUADRANGLE: Ladora
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



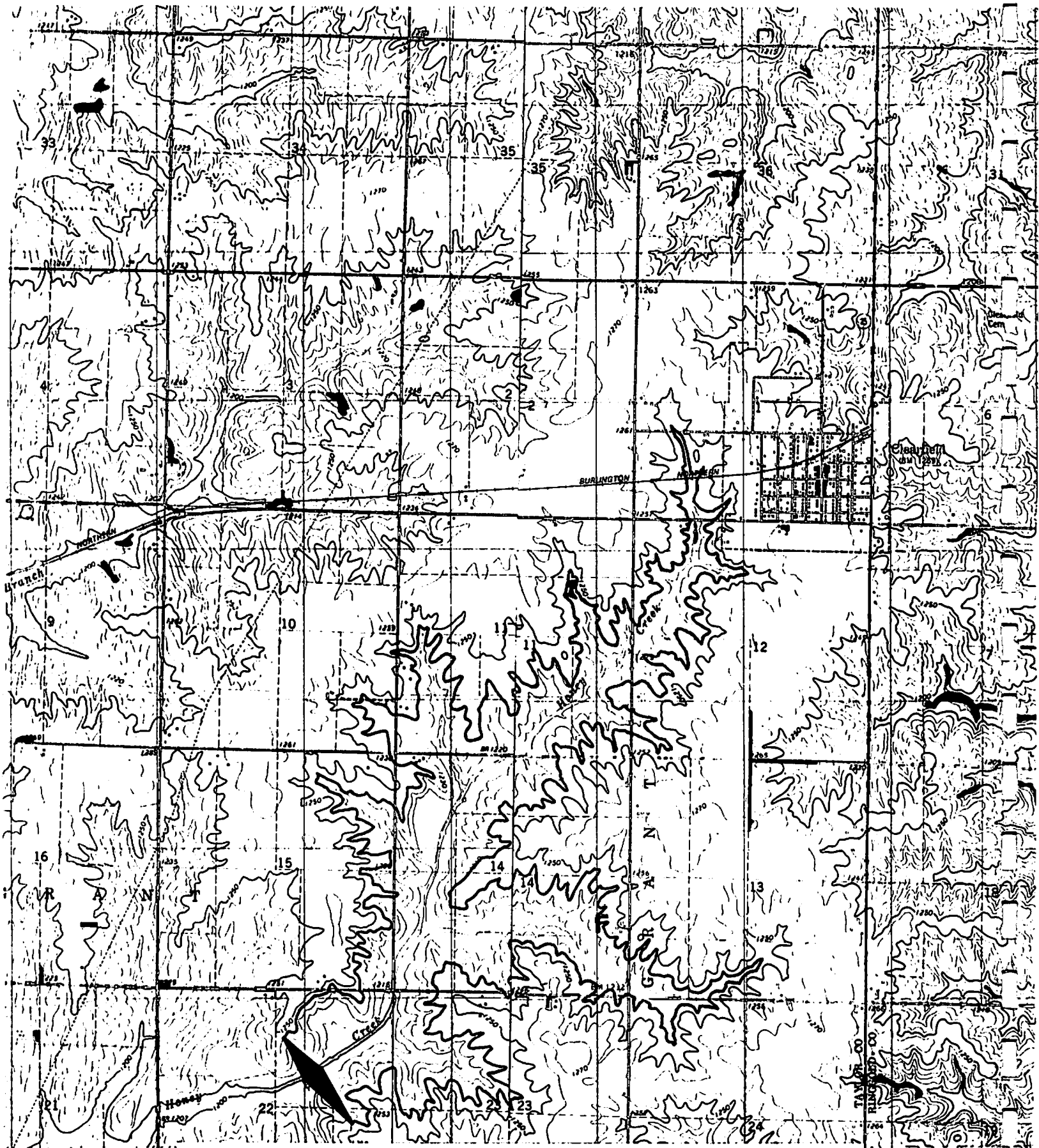
SITE NO.: 8 COUNTY: Taylor
LOCATION: SECTION: 25, 30 T 68N, R 35, 36W
QUADRANGLE: New Market
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 9 COUNTY: Taylor
LOCATION: SECTION: 3 T 70N, R 33W
QUADRANGLE: Lenox, Corning South
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

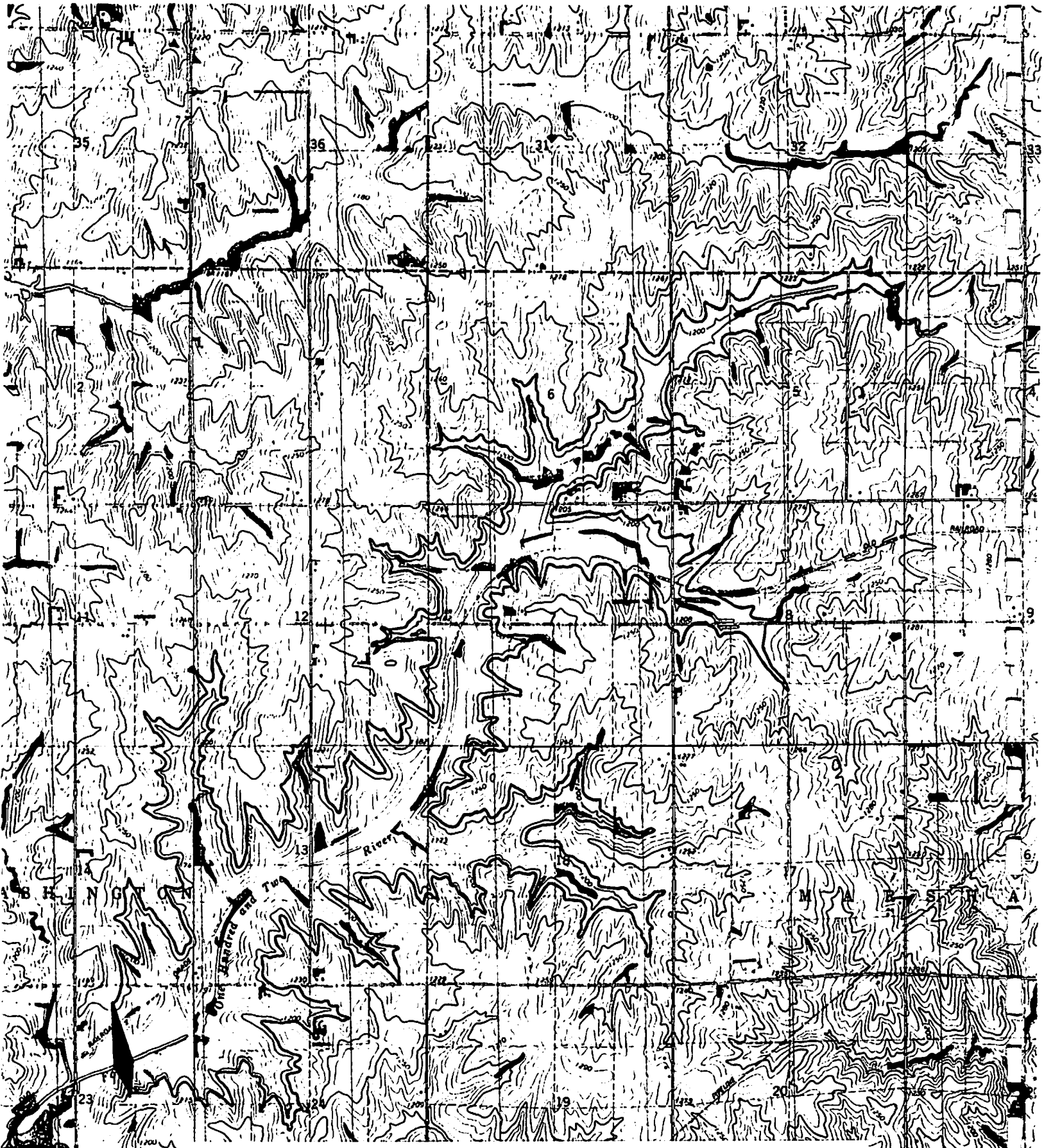


SITE NO.: 10 COUNTY: Taylor
LOCATION: SECTION: 7, 12, 18 T 69N, R 34W
QUADRANGLE: Gravity
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

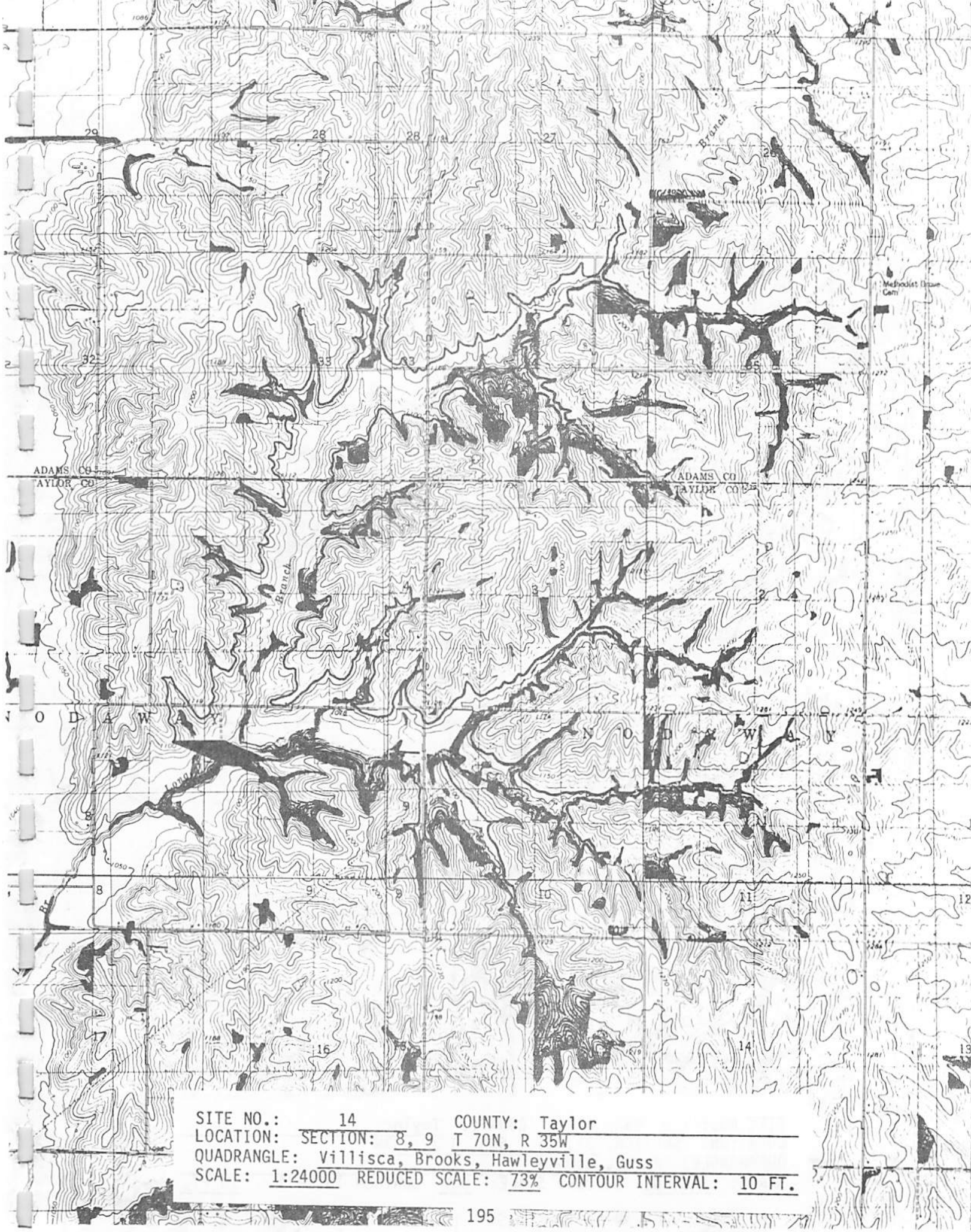


SITE NO.: 11 COUNTY: Taylor
LOCATION: SECTION: 22 T 69N, R 32W
QUADRANGLE: Merle Junction, Clearfield
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 12 COUNTY: Taylor
LOCATION: SECTION: 23 T 70N, R 32W
QUADRANGLE: Lenox, Kent, Merle Junction, Clearfield
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

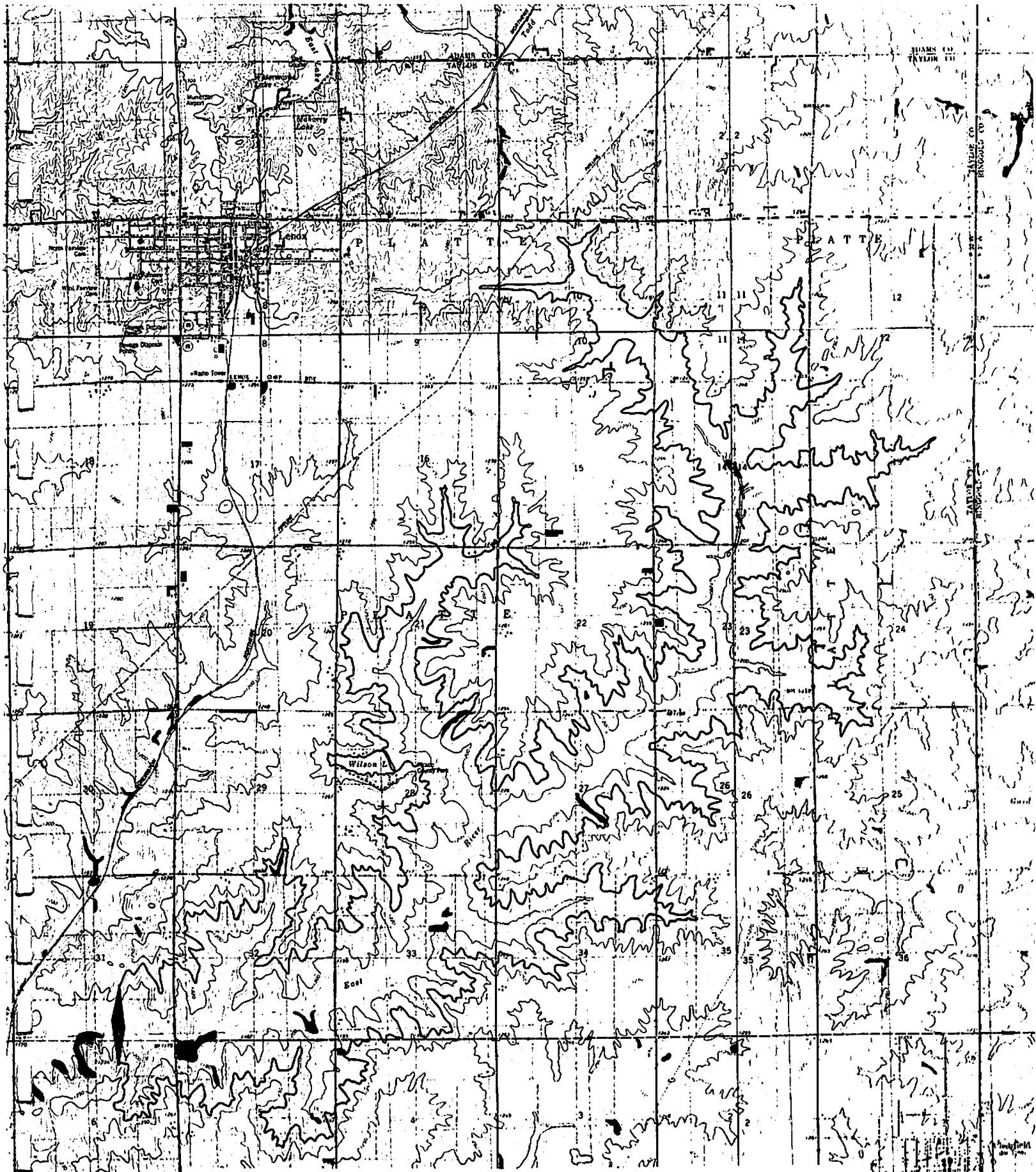


SITE NO.: 13 COUNTY: Taylor
LOCATION: SECTION: 23 T 69N, R 34W
QUADRANGLE: Gravity
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.



SITE NO.: 14 COUNTY: Taylor
LOCATION: SECTION: 8, 9 T 70N, R 35W
QUADRANGLE: Villisca, Brooks, Hawleyville, Guss
SCALE: 1:24000 REDUCED SCALE: 73% CONTOUR INTERVAL: 10 FT.

SITE NO.: 15 COUNTY: Taylor
LOCATION: SECTION: 31, 36 T 68N, R 32, 33W
QUADRANGLE: Maloy, Conway
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.



SITE NO.: 16 COUNTY: Taylor
LOCATION: SECTION: 6, 31 T 70N, R 32W
QUADRANGLE: Kent, Lenox, Clearfield, Merle Junction
SCALE: 1:24000 REDUCED SCALE: 50% CONTOUR INTERVAL: 10 FT.

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APPENDIX A

Watershed Yield vs. Drainage Area

For each of the counties in the study, watershed areas were compared with the known areas required to sustain the yield of the two chosen population categories. The estimates were based on methods developed by the U.S. Geological Survey (Heinitz, 1970) and the Iowa Department of Environmental Quality (IDEQ, 1980). The U.S. Geological Survey method allows the determination of watershed yield at ungaged stream sites by applying a regional regression relation. The equation for the relation is:

$$Q = .0000007063\ A^{1.013}\ P^{3.88} \qquad (1)$$

where:

Q = average stream discharge in cubic feet per second

A = drainage basin area in square miles

P = average annual precipitation in inches

and

all other numerical values are regression coefficients.

The IDEQ method was derived to ascertain the minimum drainage area required to meet specific water withdrawal (supply) demands. The method is expressed by the following equation:

$$A_b = \left(\frac{D}{8146\ C}\right)^{0.987} \qquad (2)$$

where:

A_b = minimum drainage area required to sustain an impoundment, in acres

D = annual withdrawal demand in gallons

C = estimated average annual basin discharge in inches

and

0.987 = the reciprocal of the regression coefficient 1.013, from Eq. 1

8146 = a constant (27,152 gallons per acre-inch multiplied by the D/Q ratio = 0.3), to convert A_b directly into acres.

Note

Subsequent to the calculations that were made in this study to estimate watershed yields using the relation of equation (1), new regional relations were developed and have been published by U.S.G.S., Lara, 1979. The new method established new regression equations for three separate Iowa regions. The relation for Region II which encompasses the counties studied in this report, is expressed by the following equation:

$$Q_a = 0.19\ A^{0.98}\ (P - 25)^{0.57} \qquad (3)$$

where:

Q_a = average annual discharge in cubic feet per second

A = drainage basin area in square miles

P = average annual precipitation in inches

and

all other numerical values are regression coefficients.

The method expressed by equation (3) is a refinement of that expressed by equation (1) and gives slightly larger estimates of watershed yield. Resulting values of the two methods are given in Table 1. The data on the county tables were not recalculated because of the small differences in the value of Q_a by the two methods, and because equation (1) provides a more conservative estimate.

Tables 2 and 3 give the data values used in equation 1 to estimate water yield in the study area.

Table 1. Comparative analysis of average discharge relations.

Area (square miles)	$Q = .0000007063\ A^{1.013}p^{3.88}$ (cubic feet/second)	$Qa = 0.19A^{0.98}(P-25)^{0.57}$ (cubic feet/second)
5	2.495	2.789
10	5.035	5.501
15	7.592	8.185
20	10.160	10.851
25	12.738	13.503
50	25.705	26.635

Table 2. Listing of values for calculation of average discharge at ungaged sites.

County	Normal Annual* Precipitation (inches)	Annual Runoff C** (inches)	$(8146\ C)^{0.987}$ Computed
Adair	31	5.5	38,980
Adams	32	5.5	38,980
Cass	31	5.0	35,480
Fremont	32	5.0	35,480
Mills	32	4.75	33,729
Montgomery	32	5.0	35,480
Page	33	5.5	38,980
Pottawattamie	31	4.5	31,976
Taylor	33	5.75	40,728

* Waite, 1979
** Iowa Natural Resources Council, 1978

Table 3. Drainage area requirements.

County	Required Drainage Area Population 5,000 (acres)	Required Drainage Area Population 12,000 (acres)
Adair	3656	8676
Adams	3656	8676
Cass	4017	9531
Fremont	4017	9531
Mills	4225	10026
Montgomery	4017	9531
Page	3656	8676
Pottawattamie	4457	10576
Taylor	3499	8303

APPENDIX B

Computation of Storage Volume

The average-end method is normally used in calculating impoundment storage volumes. The method requires measuring the area enclosed by successive contours, averaging them, then multiplying by the contour interval. The incremental volumes are then added to obtain the total reservoir storage volume. Although the method is accurate, it is very time consuming.

In this study an alternative method developed by Dawes and Terstriep (1966) was used to determine storage volumes. And, although the method sacrifices a certain amount of accuracy, it is much faster. The method involves planimetering the area of the uppermost impoundment contour and multiplying this area by one-third of the impoundment's maximum depth:

$$S = \frac{DA}{3} \qquad (4)$$

where:

S = total storage volume in acre-feet

D = maximum depth of impoundment in feet

A = surface area in acres.

Dawes and Terstriep (1966) indicated that this method would produce values of storage volume that would be within 10 percent agreement with the average-end method. Before selecting the method for application in this study, comparative tests of the two methods were made for several sites in Taylor and Fremont Counties. The comparative data is shown in Figure 1. The comparison indicated an average difference of 8.8 percent between the values determined by the two methods. This level of accuracy was determined to be adequate for the study, particularly when the time factor was considered. The comparative data is shown in Figure 1.

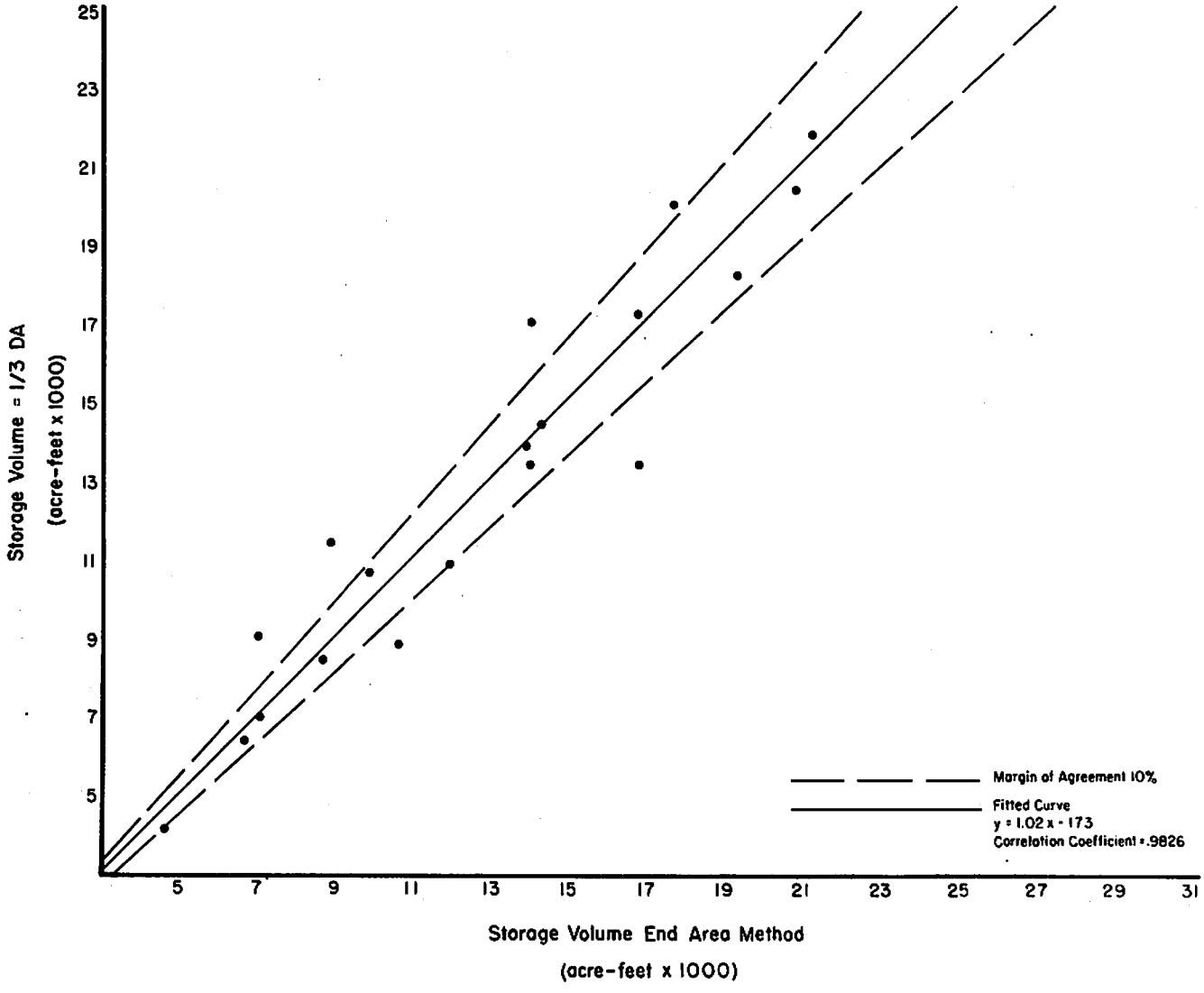

Figure 1. Comparison of end area method and Dawes/Terstriep $\left(S = \frac{DA}{3}\right)$ storage volume methods for sites in Taylor and Fremont Counties.

APPENDIX C

Derivation of Relationship Between Within-Year Draft-Rate Storage and Drainage Basin Area

The design of a water supply impoundment must consider the balance between the water-yield characteristics of the contributing watershed and the nature of the withdrawal demand. In particular, enough water must be stored to compensate for seasonal inflow variability, and more critically, to compensate for very low-flow periods resulting from local or regional drought. For smaller impoundments, where little or no carryover storage is anticipated, the normal practice is to allow for enough storage to meet the withdrawal demand of any given year. Thus, the key in determining the design storage capacity is predicting the contributing watersheds water-yield during periods of low flow. In most cases, the design storage capacity is based on critical low flows that can be expected to occur once in ten or once in twenty years.

The frequency and duration of minimum streamflows are determined either by direct observation (measurement of streamflow over a period of years) or some reliable method of extrapolating observed data to ungaged stream locations. In either case about 30 years of data is desirable. Good information on stream low flows is available for many Iowa streams, and for several years has been published by the U.S. Geological Survey and the Iowa Natural Resources Council.

To characterize low-flow conditions in the study area, low-flow data for several gage sites in the region were used to construct a series of frequency mass curves. For each gage site, two frequency mass curves were developed, one for low flows occurring once in ten years, and one for low-flows occurring once in twenty years. The method used is described in Riggs and Hardison (1973). On each frequency-mass curve, lines were drawn representing the cumulative demand of the two selected draft rates used in the study--respectively 1 and 2 cubic feet per second (see Figure 2). According to the method, the maximum vertical separation between the draft rate line and the frequency curve is the required storage in cubic feet second days.

For each of the available sites, data taken from the frequency-mass curves and the draft-storage plots were graphed against drainage basin areas--draft-rate storage vs. drainage basin area above the gage site. These plots are shown in Figures 3 and 4. These data were regressed to derive regional relations between draft storage requirements and drainage-basin areas. The regression relation has the form of the following equation:

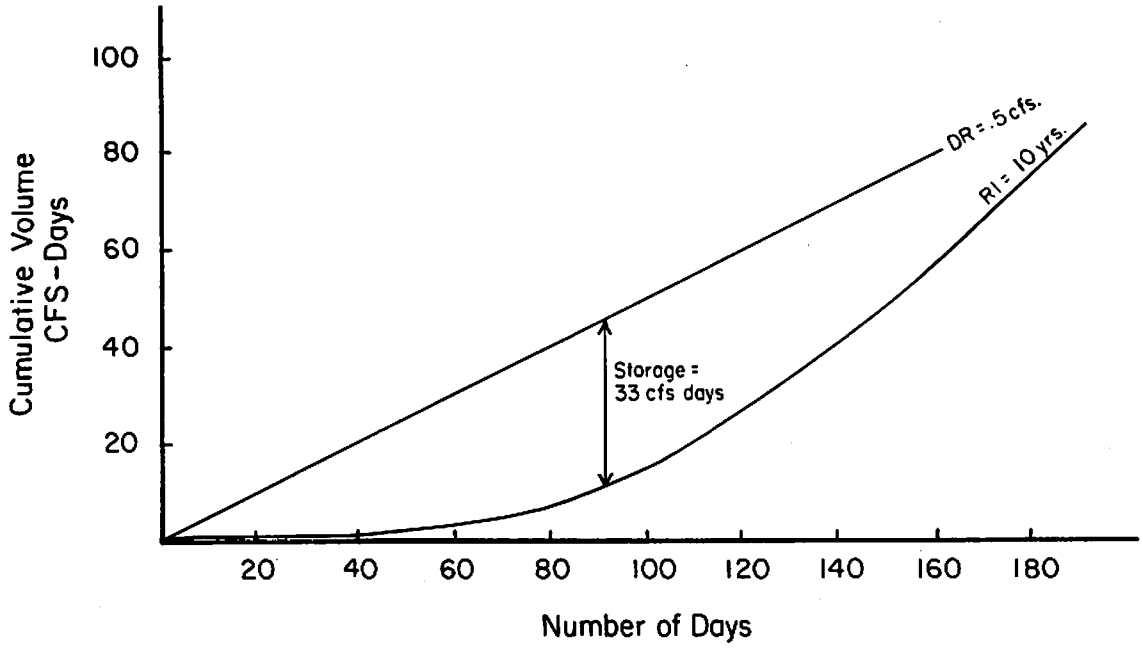

Figure 2. Frequency-mass curve for U.S.G.S. gaging station 6-8090.

$$S = ae^{bA} \tag{5}$$

where:

S = storage in cubic foot second days

e = the logarithm to the base 2.7183

A = drainage basin area in square miles

and

a and b are regression coefficients.

The method yielded the following four equations which were used in the study to estimate draft rate storage volumes.

Draft Rate (cfs)	Low-flow Recurrence Interval Assumed (years)	Equation
1.0	10	$S = \frac{250}{e^{.039A}}$
1.0	20	$S = \frac{781}{e^{.052A}}$
2.0	10	$S = \frac{652}{e^{.027A}}$
2.0	20	$S = \frac{945}{e^{.030A}}$

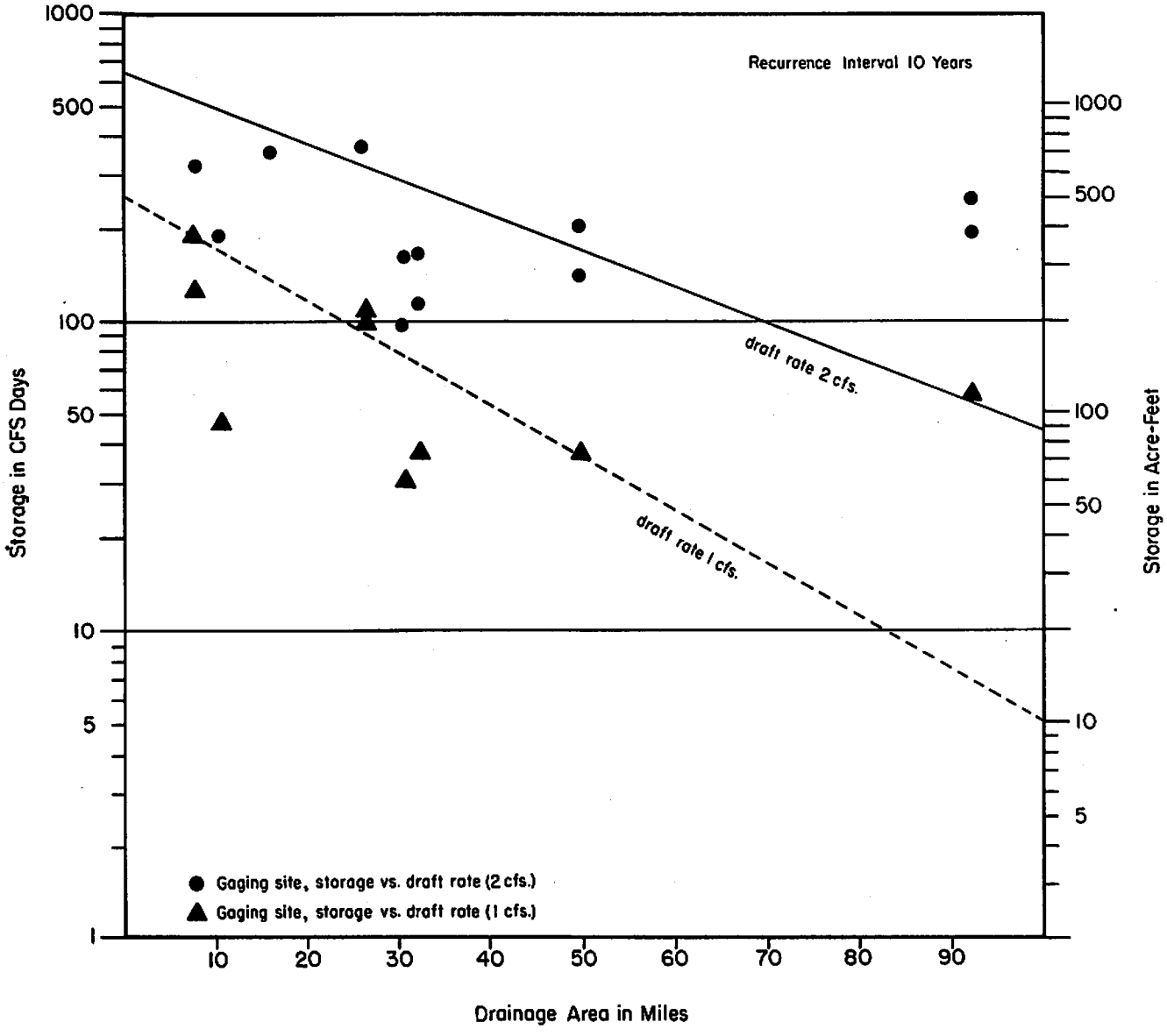

Figure 3. Within-year storage requirements related to drainage areas, and draft rate, for 10-year recurrence interval, low-flow.

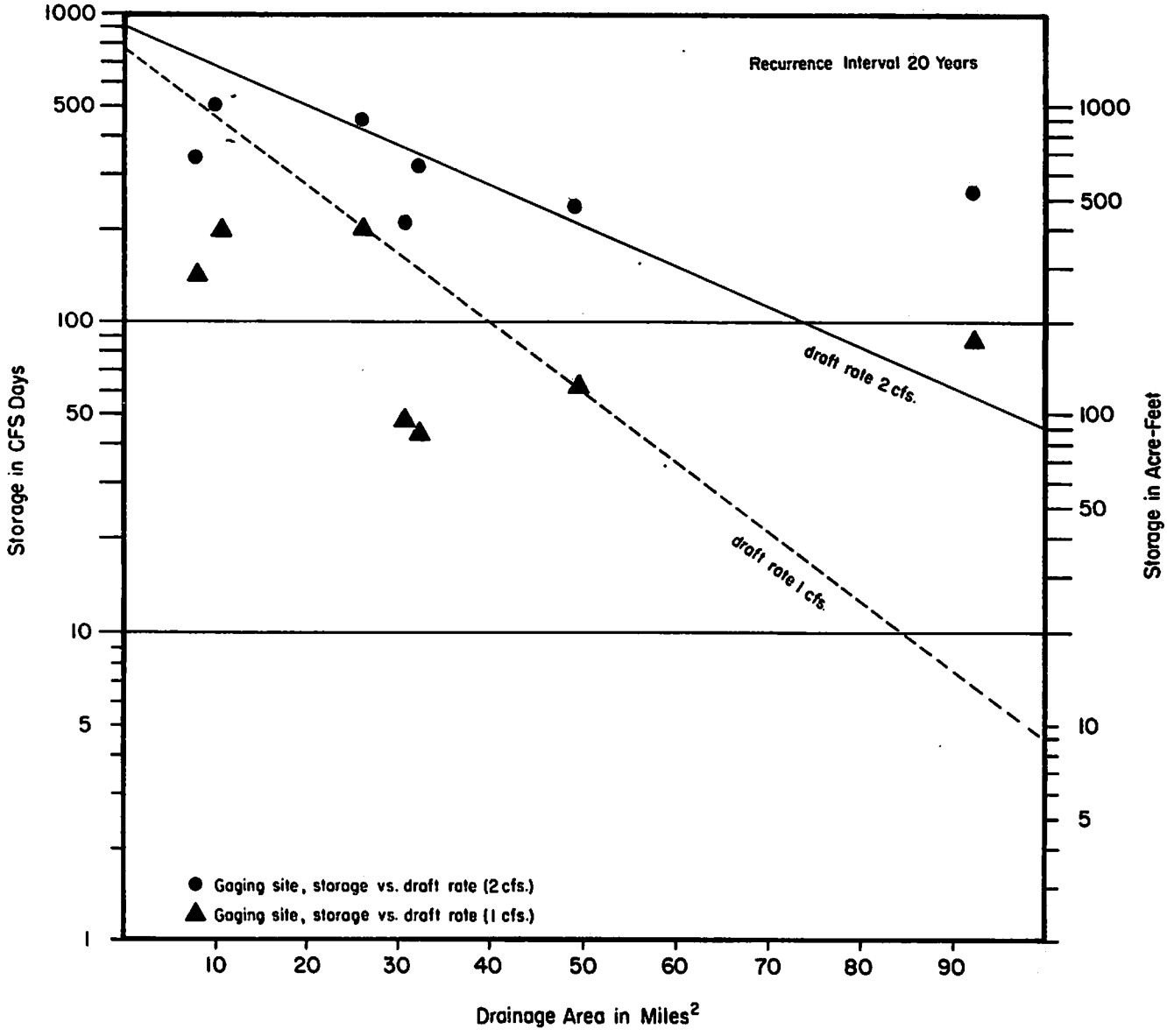

Figure 4. Within-year storage requirements related to drainage area, and draft rate, for 20-year recurrence interval, low-flow.

APPENDIX D

Regional Sediment Storage Requirements vs. Watershed Area

Among the more difficult parameters to determine in the design of a storage impoundment is the amount of space required to store sediment. The service life of an impoundment is determined by the rate that it will fill with sediment. That it will fill with sediment is inevitable.

Several factors influence the rate of sedimentation in a storage reservoir. Among these are: the character of the soils of the contributing watershed; crops and cropping practice; land treatment practices in the watershed; precipitation and rainfall intensity; and the sediment trapping efficiency of the impoundment itself. Obviously, to precisely design an impoundment structure, each of these separate factors would necessarily require evaluation. However, at a reconaissance level, a reasonably accurate, yet time efficient procedure is required. There are several methods available for doing this, but most are time consuming and thus not highly adaptable to regional studies.

For the purpose of this study, a regional sediment storage relation was developed that was based on extant stream sediment data and watershed area. Stream sediment-load data (Schultz et al., 1977) was compared to drainage basin area and used to develop an annual sediment yield vs. basin area relation by numerical regression, as shown in Figure 5. (Note: In the figure, the data point, Lake Panorama, was used for comparative purposes and was derived from an intensive study of sedimentation rates at Lake Panorama. The report on the Panorama study was in progress at the time of this investigation and the information was provided by Oscar Lara of the U.S. Geological Survey). The form of the relation is:

$$S = aA^b \qquad (6)$$

where:

S = annual soil loss in acre-feet/acre

A = drainage basin area in acres

and

a and b are regression coefficients.

The relation developed for the study area and used in calculating sediment storages values is:

$$S = 2.20A^{-0.144} \qquad (7)$$

This relation is considered to be reasonable for the study's level of investigation, and compares quite favorably to one developed by the U.S. Department of Interior and published in their manual for "The Design of Small Dams," 1977. The relation published in this document is:

$$S = 2.40A^{-0.229} \quad (8)$$

The difference in the two relations, about 30%, can probably be related to the highly erodable loess soils of the study region. The relation published by the U.S.D.I. was based on data for less erosive, sandy soils in the southwestern United States.

In calculating sediment storage requirements, all impoundments were considered to have sediment trap efficiencies of 100 percent, i.e., all contributed sediment would be retained by the impoundment.

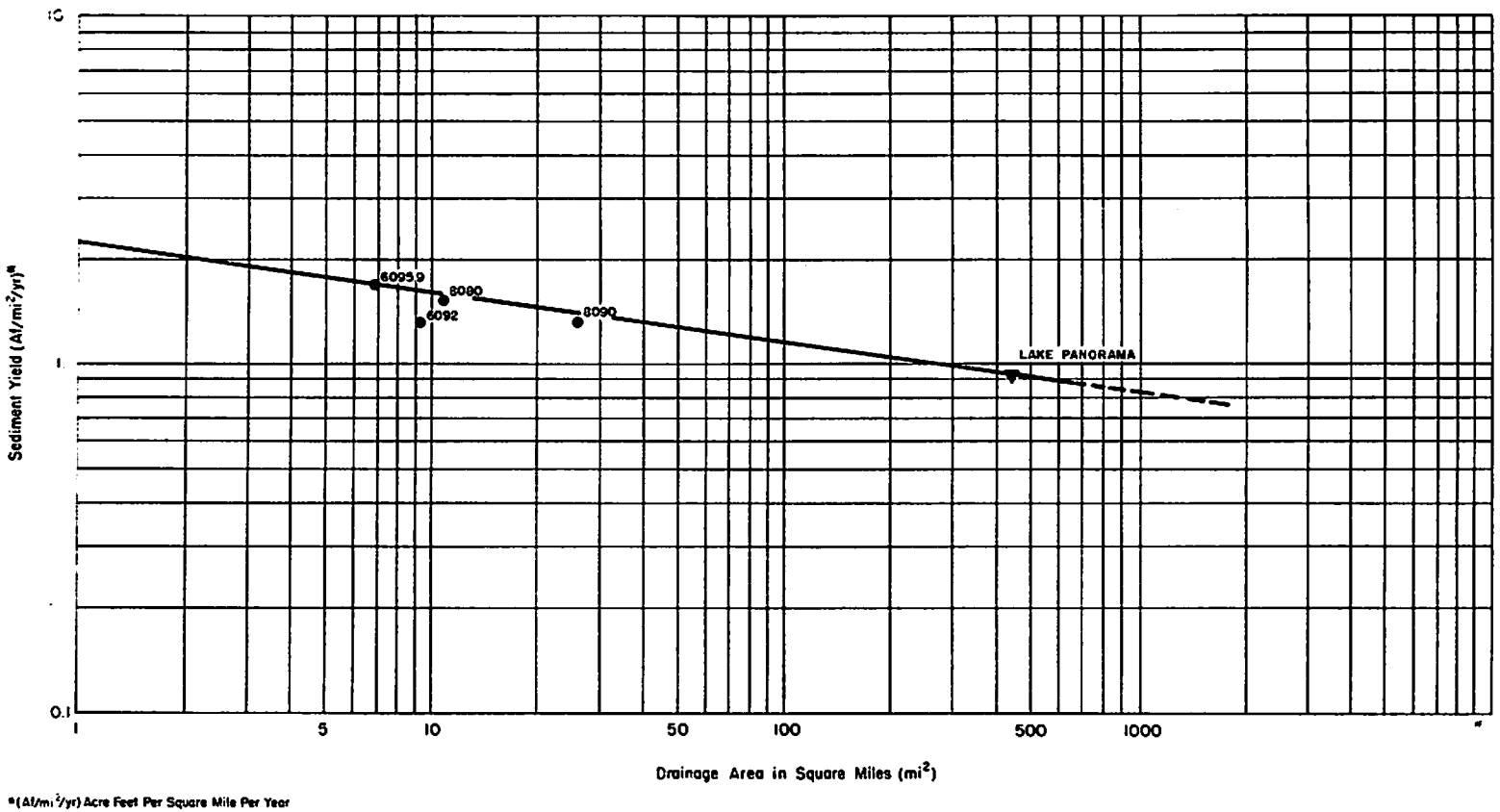

Figure 5. Regional regression relation for sediment yield versus drainage basin area.

APPENDIX E

Scaling of Storage Volumes to Categories of Population Demand

Many of the sites identified and selected in the study had surface areas and total storage volumes many times greater than actually required to supply water to the design populations.

To show this by comparison, for each site, impoundment surface areas were scaled down with respect to population water demands and total storage requirements. The method employed in doing this involved determining the factor storage volume per acre for the particular site. This factor was derived by dividing the gross storage volume (Dawes/Terstriep) by the surface area.

For scaling the population demand, water supply, sediment, and evaporation* storage volumes were summed and divided by the storage volume per acre factor. The result was the number of surface acres in the impoundment related to an actual population demand and its related storage requirements.

*For this study, evaporation losses were based on a 6 inch net evaporation loss per annum. The 6 inch net evaporation loss was derived by subtracting the average annual precipitation, 34 inches (Waite, 1979) from the average annual lake evaporation loss, 40 inches (U.S. Weather Service, 1959).