Problems and Future Development of Water Resources in the Des Moines and Skunk River Basins in Iowa and Minnesota

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DES MOINES AND SKUNK RIVER BASINS

GENERAL DESCRIPTION

Location. The basins of the Des Moines and Skunk Rivers occupy a relatively narrow belt which extends northwest from the mouths on the Mississippi River in the vicinity of Keokuk and Burlington in Iowa, into southwestern Minnesota. Of the 19,070 square miles in the area, approximately 91.6 percent are in Iowa, 7.9 percent in Minnesota, and 0.5 percent in Missouri.

The western edge of the Des Moines River basin constitutes the Mississippi-Missouri divide throughout most of Iowa. Its basin is only 15 to 20 miles wide throughout the lower 150 miles of its length and widens to an average of 60 to 70 miles throughout the rest of its course in Iowa. It falls approximately 1375 feet in the 535 mile length of its main stem. The basin of the Skunk River lies generally parallel to and north of that of the Des Moines, and constitutes somewhat less than one-quarter of the total area; the basin has an average width of 16.4 miles; the river falls 680 feet in 264 miles. The principal left bank tributaries of the Des Moines are the East Fork of the Des Moines, and the Boone River; its right bank tributaries are the Racoon, South Racoon, Middle Racoon, and South Rivers. The Skunk River has two major tributaries, the North Skunk on the left bank and Cedar Creek on the right bank.

Physical Characteristics. The territory drained by the Des Moines and Skunk rivers derives most of its surface characteristics from its glacial origin. Underlying rock structures are exposed in relatively few areas, and the surface consists almost entirely of glacial till, modified to greater or lesser degree by post-glacial erosional forces. From the mouths of the two rivers, north to about the latitude of the City of Des Moines, the plains surface has been altered by a long period of stream erosion; the flood plains of the main streams are broad and flat with considerable areas of bottomlands; and between the river bottoms and the prairies lie broad belts of low hills, carved from the glacial plains by minor tributaries. Northward, the topography assumes a smoother appearance, as the major streams occupy narrow steep-sided valleys, and the prairie becomes the dominant feature of the landscape. And further north, the streams wander across the gently undulating till plain in scarcely perceptible valleys, and there are numerous shallow lakes.

These basins lie in the belt of sub-humid climate which occupies the central portion of the United States. The average annual precipitation varies from 36 inches in the south to 28 inches in the north, of which two-thirds normally occurs during the growing months (April-September), with a normal maximum in June. The temperature varies from a July average of 75° to a January average of 18°; the northern sections are about 4° cooler than the southern in summer and about 10° colder in winter; the maximum temperature ever recorded in the area was 118°, and the minimum was -42°. The growing season averages about 160 days. The combination of hot, humid summers, and cold, relatively dry winters, appears almost ideally suited to the corn belt type of agriculture.

Natural resources in the form of climate and soil have marked these basins for agricultural development. The soil of the northern sections has great fertility; it was formerly covered generally with tall grass; the production is now predominately cash grain. The southern sections were originally in timber; the soils are less productive than those of the northern sections, but are well above the national average. In some areas, particularly in the lower portion of the basins where the land is more rolling, erosion and land destruction have been very serious. Less extensive grain farming and more intensive livestock type of farming is desirable in these areas.

Economic Development. Agriculture is the basic source of income throughout the region, and the remaining economic development is closely allied, as the leading manufacturing industries are devoted to processing farm products, of which the handling of meat is the largest single type. The area is not highly industrialized, although there is considerable diversity of production. The industries of Des Moines, largest city in the area, range from meat-packing and steel production to hosiery and cosmetics. Ottumwa, second city of the area, is best known for its meat-packing plant (one of the nation's largest) and farm implements. Newton is a leading center for domestic washing machines, Fort Dodge manufactures gypsum products, Fort Madison is a center for fountain pens, and Keokuk produces stell products, starch, and other food preparations.

The national expansion of war-industry facilities during the 1941-43 period has brough three new major installations into this region, namely, a Small Arms Ordnance Plant at Ankeny (near Des Moines), a Naval Air Base at Ottumwa, and a Shell Loading Plant at Burlington. The war activity has also caused material expansion of many present establishments which process farm products, such as meat packing plants, canning factories, and food-dehydrating plants. The ultimate effect of the impact of this sudden industrial growth upon an area which is basically agricultural, can only be evaluated after a return to more "normal times" in the post-war period; but it is to be anticipated that in the future manufacturing will occupy a relatively more important position in the economy of eastern Iowa, along with much of the remainder of the Mississippi Valley, than heretofore.

Transportation. In the area of these basins, neither the streams themselves nor their valley, are important factors in transportation. The smoothness of the general topography makes railway and highway construction relatively easy and elaborate networks of both facilities have developed. Freight and passenger traffic through the area has been dominated by movement between Chicago and Omaha; the cities of Des Moines, Fort Dodge and Ottumwa are located at or near trunk-line crossings of the Des Moines River. The area is also crossed by north-south trunk-lines between Minneapolis, St. Paul and Kansas City or St. Louis. Paved highways in general parallel the rail lines. Des Moines is the most significant crossing for rail, highway and air traffic; it is also the principal pipe-line center for the area, being served by both gasoline and natural-gas lines.

Human Occupancy. The total population of the Des Moines-Skunk basin increased slowly from 1920 to 1940. The population of 937,000 in 1940 was an increase of 3.4 percent over 1930, with the largest increase in the urban and the northern rural counties. Based on the 1940 census figures, approximately one-half of the total population was rural. There was a net decrease of farm population furing the 20-year period of approximately 5 percent. Although there are regularly more births than deaths, there have been two currents of migration which have resulted in this decrease in farm population:

(1) the movement from the farms to the cities, and

(2) the net movement out of the area.

Further increases in the population of the area will come through migration induced by continued commercial and industrial expansion of the cities.

Approximately one-third of the population have a "foreign background", i. e., less than two full generations in the United States. Although the main body of the population are of English extraction, there are four nationality groups which give a distinctive cultural background; namely, Scandanavians in the northern half, Germans in the central area, English in the south central, and Dutch in the east central part of the basin. Farmers' organizations are relatively strong throughout the area. The scale of living is distinctly higher in the northern than in the southern section. As the total population may be expected to reach its maximum during the next few decades, it seems probable that water resources will not be necessary for a much larger total population than at present, although continued growth of the cities will create the corresponding problems of water supply and sewage disposal.

Soils and Erosion. The soils of the basin may be classified as: 88 percent upland, 8 percent bottomland, and 4 percent terrace. In 1930 the land use was reported as: 71 percent cropland, 28 percent pasture, 1 percent woods. The upper section of the basin does not constitute a serious erosion problem, as the soils have high infiltration rates, and the surface storage capacity is sufficient to retain a large percentage of the rainfall and to delay the flow of run-off. Provision of adequate drainage to create good agricultural land is an important problem to be influenced by all factors in the land-use program. In some instances, the drainage of peat and muck areas has destroyed the value of natural lakes for wild life and for water storage.

In the lower section of the basin the upland soils are in general more rolling, less permeable, and more erodible. The current method of farming up and down the slopes encourages run-off and erosion, and as a result, damage from floods and siltation is much greater than in the upper area.

The application of an adequate soil conservation program on all farm lands in the area should materially reduce erosion and sedimentation. With few exceptions the permeability of the soils is sufficiently high to permit reduction of 10 to 20 percent in flood run-off and 60 to 80 percent in erosion losses as a result of a good conservation program on the land.

HYDROLOGIC RECORD

Precipitation. In this basin, June is normally the wettest month, when nearly 15% of the annual rainfall is received, and about 73% of the annual rainfall is received during the six warm months from April to September, which distribution is highly favorable to crops. The percent varies from 69 in the lower to 77 in the upper Des Moines-Skunk basin. But extremely great variations in annual rainfall occur as indicated by the following table:

Year	Variation over Basin, in.	Mean, in.	Percent of normal
Wettest, 1881	35-57	46	144
Mean	28-36	33	100
Driest, 1910	14-26	20	63

The ratio of maximum to minimum annual precipitation may go as high as 3 to 1.

The greatest precipitation in 24 hours for stations in the basin having a record of some length was 11.23 in. at Keosauqua. Precipitations approaching this value have occurred at other stations without any definite pattern, although there may be a tendency toward greater amounts in the southern portion.

All of the Des Moines-Skunk Basin has at some time had a drouth of the intensity of only 1.00 in. or less in 100 days or more, except the extreme lower portion. The most prolonged and extreme drouths have been at Algona with only 0.99 in. of precipitation in 155 days ending in March, 1904, and at West Bend with only 0.22 in. in 91 days ending in March, 1931. Considering only the crop season of April to September, the most intense drouths of record were at Perry with only 0.90 in. in 82 days in 1930 and at Esterville with only 0.23 in. in 63 days in 1934. A recent analysis of the duration intensity data for Des Moines for the 61 years for 1878 to 1938, made by the U. S. Weather Bureau office at Des Moines, showed a tendency for the number of consecutive days each year with total precipitation of 1.00 in. or less to be currently 1 day shorter than 61 years ago.

There has been a notable increase in the demand for water during the last generation. In the urban areas, the growth of industries, including present practices in air-conditioning, has caused an increasing use of water.

Increasing Demand for Water. A study by the U. S. Weather Bureau office at Des Moines of the demands for water in the rural areas has indicated that the widespread use of luxurious crops of corn, soybeans, alfalfa, etc., which produce a heavy tonnage of dry matter and require more tons of water per ton of dry matter, has increased the need for water by about 2½ inches of rainfall over about one-third the area of Iowa in the last 70 years as compared with the original prairie grass that produced less tons per acre and required less water per ton of dry matter. There has been a downtrend in annual precipitation in the Des Moines-Skunk Basin of about 1½ inches in the 50 years ending with 1942.

Precipitation Trend in Des Moines-Skunk Basin

Representative stations	Years of record ending 1942	Trend in inches per year, +, rising −, falling	Total change in trend period
Estherville	47	−0.0444	−2.05
Humboldt) Dakota City)	49	−0.0094	−0.41
Carroll	51	−0.0830	−2.07
Des Moines	51	−0.0050	−0.25
Ottumwa	49	−0.0092	−0.44
Keokuk	51	−0.0298	−2.00
Average	50	−0.0301	*−1.49

*Weighted by length of record

Stream Flow. The flow of the Des Moines and Skunk Rivers is characterized by rather wide variations. The maximum, minimum, and average discharge for gaging stations which are being or have been operated in these drainage basins for periods in excess of 5 years, are given in the following table. These figures, some of which are published in Water-Supply Bulletin No. 1 of the Iowa Geological Survey, were obtained from data collected by the U. S. Geological Survey in cooperation with State and other agencies.

River	Gaging Station	Period of Record	Extremes of Discharge, cfs. Maximum	Minimum	Average I charge c.
	Des Moines River Basin:				
West Fork of Des Moines	Jackson, Minn.	1909-13, 1930-41	2,320	0	159
do.	Humboldt	1940-42	3,550	3	-
Des Moines	Fort Dodge	1905-6, 1911-13	12,000	-	-
do.	Kalo	1913-27	18,500	14	1,451
do.	Boone	1920-27, 1933-42	24,500	0	1,252
do.	above Raccoon R. at Des Moines	1893-94, 1897-1927, 1932-42	41,500	0	1,898
do.	below Raccoon R. at Des Moines	1940-42	17,000	80	-
do.	Tracy	1920-27, 1933-35, 1940-42	54,600	95	3,572
do.	Ottumwa	1917-42	58,700	30	3,998
do.	Keosauqua	1903-6, 1910-42	97,000	40	4,715
Heron Lake Outlet	Heron Lake Minn.	1930-33, 1934-40	1,660	0	56.1

River	Gaging Station	Period of Record	Extremes of Discharge, cfs. Maximum	Minimum	Average charge c
Des Moines River Basin:					
East Fork of Des Moines	Hardy	1940-42	3,580	18	-
North Lizard Creek	Clare	1940-42	1,240	.2	-
Boone	Webster City	1940-42	3,060	2.4	-
Raccoon	Jefferson	1940-42	3,660	26	-
do.	Van Meter	1915-42	40,000	10	1,020
do.	Des Moines	1902-3	-	-	-
South Raccoon	Redfield	1940-42	6,380	18	-
North	Norwalk	1940-42	4,350	.2	-
Middle	Indianola	1940-42	8,240	1.3	-
South	Ackworth	1940-42	12,100	.3	-
Skunk River Basin:					
Skunk	Ames	1920-27, 1933-42	3,540	0	108
do.	Coppock	1913-42	25,200	8	1,298
do.	Augusta	1913, 1915-42	44,500	7	1,990
Squaw Creek	Ames	1919-27	3,920	0	110

(note -- Nine additional stations have been operated on tributaries of the Des Moines River since 1940.)

Most of these maximum flows occurred in June or May; however, there is a tendency throughout Iowa for an additional and distinct period of frequent and often large floods in the spring, with occasional flooding in August and September. For several of the stations listed above, references to higher flows occurring outside of the periods of systematic collection of daily discharge records are available. The minimum flows in the Des Moines and Raccoon Rivers occurred in late January 1940, and the minimum in the Skunk River in October 1934. The variation in flow throughout each year reflects in a somewhat general way the character of the occurrence of antecedent precipitation.

The annual runoff data for certain of the above-listed stations during the period of record are as follows:

River	Gaging Station	Drainage Area Sq. Miles	Mean Annual Runoff Sec.-ft. per Sq. Mile	Mean Annual Runoff Depth in Inches
Des Moines River Basin:				
West Fork of Des Moines	Jackson, Minn.	1,170	0.136	1.85
Des Moines	Kalo	4,170	.348	4.73
do.	Boone	5,490	.228	3.10
do.	Above Raccoon R. at Des Moines	6,180	.307	4.17

River	Gaging Station	Drainage Area Sq. Miles	Mean Annual Runoff Sec.-ft. per Sq. Mile	Mean Annual Runoff Depth in Inches
	Des Moines River Basin:			
do.	Tracy	12,500	.288	3.91
do.	Ottumwa	13,200	.303	4.11
do.	Keosauqua	13,900	.339	4.60
Heron Lake Outlet	Heron Lake, Minn.	457	.123	1.67
Raccoon	Van Meter	3,410	.299	4.06
	Skunk River Basin:			
Skunk	Ames	320	0.338	4.59
do.	Coppock	2,890	.449	6.10
do.	Augusta	4,290	.464	6.30
Squaw Creek	Ames	210	.524	7.12

At each of these stations where records were collected furing 1934, the minimum annual runoff of record occurred during that year. The runoff for stations in the Des Moines basin ranged from 0.59 to 0.73 inch for the 1933-34 water year, while that for stations on the Skunk River ranged from 0.48 to 0.51 inch for the same period.

With reference to trends in runoff volume, analysis of some of the available hydrologic data for several drainage basins in Iowa was made in 1941-42 in the office of the U. S. Geological Survey. These studies involved a detailed consideration of significant temperature, rainfall, runoff, and water-loss data during the period of daily discharge records. This material with figures, tables, and maps was largely presented in "Precipitation and Temperature Trends in Iowa with Special Reference to Stream Flow".* In this paper the runoff trend at Keosauqua was demonstrated by the "moving 5-year average" to have decreased rather uniformly from 5.9 inches to 3.2 inches, 1912-1940. Similarly, the runoff trend at Van Meter was demonstrated to have even a more uniform and pronounced downward trend involving a decrease from 5.1 inches to 2.7 inches, 1916-1940. The declining runoff trend was shown to be largely the result of a similar trend in precipitation and associated with the drought years of the last decade.

The following table taken from an earlier planning board report shows the seasonal distribution of floods for these streams:

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* By Lawrence C. Crawford -- a thesis presented to Purdue University in 1942, in partial fulfillment of the requirements for the degree of Professional Civil Engineer.

River	Station	Percent of Floods Coming in Season: Spring	Early Summer	Summer	Fall
Des Moines	Keosauqua	41	41	18	0
Raccoon	Van Meter	26	40	7	27
Skunk	Augusta	31	37	16	16

Damaging floods have occurred on the lower main stem of each of these streams with a frequency of about 4 every 3 years; approximately one out of seven of these floods might be classed as major.

PRESENT WATER PROBLEMS

Trends of Precipitation vs. Demand. A reconciliation of observations on Precipitation and Stream Flow in the two preceeding sections is of interest. At page 7 it is noted that the runoff at Keosauqua has decreased 2.7 inches (from 5.9 inches to 3.2 inches) between 1912 and 1940; a similar decrease of 2.4 inches (from 5.1 inches to 2.7 inches) between 1916 and 1940 was noted at Van Meter. Also at page 4 it was noted that the trend of precipitation had indicated a decline of approximately 1.5 inches in 50 years ending in 1942; and it was further noted that in the last 70 years there has been an increase in the demand for water by vegetation (i. e. present crops vs. original prairie grass) of approximately 2½ inches over about one-third of the area; this might be interpreted as 0.8 inch over the basin area. Thus 1.5 inches decline in precipitation, plus 0.8 inch increase in demand by vegetation represents 2.3 inches decrease in run-off at Keosauqua between 1912 and 1940. Although many other factors have an influence on the water picture, these items as reported by the respective agencies appear to have an interesting relation.

The characteristic indicated by the trend of precipitation decreasing approximately 1.5 inches during the last 50 years may be changed as a longer-time record accumulates. Thus a recent analysis* of precipitation trends in the State of Iowa has indicated an uptrend in the Iowa River basin, immediately northeast of the Iowa-Skunk Basin, with a maximum increase of 5.68 inches at one point, during the same period. Other observations have given indication of a fairly definite prospect of recovery, with the probability that, generally speaking, better weather conditions may be expected with a reversal in the previously recorded long-time trend in the Des Moines-Skunk basin.

According to the best information available, the average rainfall during the growing season is adequate to meet the requirements of the three major types of crops -- namely inter-tilled, small grain, and hay, provided that the rainfall is absorbed and is available for plant use between periods of precipitation. Increased yields of crops through the use of improved varieties, the use of fertilizer and improved cultural practices may be expected. As the yields of crops increase, more water is required for plant growth. Thus, if there is a material increase in crop yields, the rainfall may be a limiting factor to crop production. This can be overcome partly by contouring, additions of organic matter to the soil, and other appropriate conservation measures that will help hold the water where it falls.

Low Flows in Streams. The records of stream flow cited on page 5 show that even at the stations in the lower portion of the basin the flow at times during the 50 years of record has either ceased entirely or become inconsequentially small. During average years the flow at important

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* Reported in correspondence with Chas. D. Reed, Senior Meteorologist, U. S. Weather Bureau, Des Moines, Iowa.

centers, such as Des Moines and Ottumwa, has been so low as to create dangerous conditions; although most of the communities obtain their public water supply from the gound water, there is sufficient use of surface water by portions of the public and by stock, so that stagnant streams present a distinct hazard. The Iowa State Health Department has been alert against epidemics under these conditions, which now develop along extensive stretches of the streams during the late summer and fall of most years.

A conservation program advocated by some Iowa State agencies, contemplates a substantial increase in storage in the headwaters of the Des Moines basin through the further dredging of present lakes and the return of some localities to their original flooded condition. It is possible that, if such work is undertaken in sufficient amount, the amount of low water flow could be increased substantially. However, the significance and extent of such stream-flow improvement requires an engineering and thorough study as to available storage and the usefulness of the water under any plan for control and release. A coordinated program which would lead to a sustained flow in the Des Moines River at Des Moines of at least 200 c.f.s., and in the Raccoon River at Des Moines of at least 100 c.f.s., as compared with the present almost complete stoppage of flow during dry seasons usually occurring in the late summer, would be of great value to the welfare of the entire valley.

Public Water Supply. The following compilation shows the various types of source of water supply for the 187 cities and towns in the basin in Iowa and Minnesota which have public water supplies:

		Population - Iowa					
Source		0 to 2000	2000 to 5000	5000 to 10,000	10,000 to 15,000	over 15,000	Total
Wells	Treated	54	12	5	2	1	74
	Untreated	72	4	2	1	0	79
Surface	Treated	2	2	2	2	3	11
	Untreated	2	0	0	0	0	2
Infiltration Galleries	Treated	1	1	0	0	1	3
	Untreated	0	0	0	0	0	0
		131	19	9	5	5	169

		Population - Minnesota					
		0 to 2000	2000 to 5000	5000 to 10,000	10,000 to 15,000	over 15,000	Total
Wells	Treated	4	2				6
	Untreated	11	0	1			12
		15	2	1			18

The preponderant practice of communities of less than 5,000 population to depend upon wells is apparent. The practice of treating the water supply is quite general even in communities of less than 1,000 population; the method of treatment varies, usually providing for iron removal and commonly, also, chlorination and softening.

In the Iowa portion of the basin, all towns over 1,000 population have public water supplies; only 13 of the 142 communities of more than 500 population do not have a water supply system; whereas, there are 41 towns under 500 population with public water supply systems. The Iowa Department of Health has recommended a water supply and distribution system for all towns with more than 350 population, of which there are 34 in the basin in Iowa not now served. Figures are not available from the portion of the basin in Minnesota; however, the same general situation prevails.

A tabulation by the Iowa State Department of Health has assigned the following classifications to the municipal water supplies as regards dependability and quality in Iowa:

	Dependability	Quality
Class 1	5	16
" 2	119	48
" 3	26	67
" 4	16	37
" 5	2	

Similar information furnished by the Minnesota State Department of Health on municipal water supplies in the Des Moines-Skunk Basin in Minnesota follows:

	Dependability	Quality
Class 1	1	0
" 2	15	9
" 3	2	9
" 4	0	0

The class designations were defined as follows:

Classification as to dependability:

1. Unlimited quantity for any expected condition.
2. Adequate for normal present use.
3. Adequate for normal use except during severe drouth.
4. Inadequate during normal recurring drouths.
5. Inadequate for present normal usage.

Classification as to Mineral Quality:

	Hardness	Iron	Fluoride	Sulfate	Chloride
	(Maximum Concentrations)				
Group 1 (Satisfactory)	200 ppm	0.0 ppm	0.0 ppm	250 ppm	250 ppm
Group 2 (Fair - with treatment would fall in group 1)	200-400 ppm	0.3 ppm	1.0 ppm	250 ppm	250 ppm
Group 3 (Unsatisfactory - but amenable to treatment)	400-600 ppm	over 0.3 ppm	2.0 ppm	250-1000 ppm	250-500 ppm
Group 4 (Unsatisfactory)	over 600 ppm	over 0.3 ppm	over 2.0 ppm	over 1000 ppm	over 500 ppm

The above designations on dependability and quality are admittedly arbitrary and are influenced by local conditions. The quality standards are somewhat lower than those recommended in the recently published U.S.P.H.S. standards for drinking and culinary water for use by interstate carriers for the reason that in many areas it would be impossible to find water which would meet the U.S.P.H.S. recommendations.

The bacterial quality of the water was not taken into consideration in the classification for quality, as almost without exception the waters listed either are satisfactory from a bacteriological standpoint with or without treatment, or could readily be made of satisfactory bacterial quality with proper treatment. In general, the public water supplies in all but very small towns are now effectively supervised by the State officials.

Rural Water Supply. Based on the 1940 census figures, it is estimated that more than 95 percent of the rural population of approximately 475,000 in the basin area, are dependent on underground sources for water supply. It has also been estimated that about 130,000 rural wells are now being utilized.

The rural wells range in depth from about 25 feet to about 1400 feet, but probably average less than 100 feet in depth. In recent years there has been a tendency toward utilizing drilled or jetted cased wells, in preference to dug wells. As most of the water-bearing formations found at the shallow depths in which farm wells are developed, depend for recharge on sources in the immediate vicinity, the water levels often fluctuate in response to precipitation, to changes in stream flow, and to changes in lake and pond water levels. During prolonged periods of drought, many of these shallow wells have failed due to the water level falling below the bottom of the well. To ascertain the seasonal changes in level of ground water, as well as changes in shorter and longer periods, the Iowa Geological Survey, in cooperation with the U. S. Geological Survey, is measuring periodically and systematically the water level in about 80 observation wells in this basin, as part of a state-wide program. However, the observation wells now in operation are not considered adequate in number for a complete picture of existing conditions.

In general, with normal rainfall, the water-level in shallow wells shows a definite rise during the late winter and spring, a decline during the growing seasons, followed by a slow rise in the late fall. Low levels were experienced in shallow wells following the seasons of 1934, 1936 and 1939. As a result of copious rains in the fall of 1941, and snow fall in the winter of 1942, these water levels stood substantially higher in the spring of 1942 than for many years previous. Recharge to the shallow ground water is largely dependent upon precipitation, and any program that increases the amount of infiltration and decreases run-off from the land surface will be beneficial in maintaining a uniform water table.

Some well owners have constructed artificial ponds upstream from their wells, with the thought that such ponds would have a beneficial effect on the wells. Sufficient evidence is not available to draw conclusions regarding the effect of such ponds, as other factors may have been active in the cases where wells improved after the ponds were built.

The safety of well water for domestic use depends primarily on the type of well construction and location with reference to sources of pollution; but wells which are well located and sealed against the inflow of surface water, have in general been satisfactory from the standpoint of health. One of the exceptions is the high fluorine content in some aquifers, particularly: (1) in the area northwest of Ft. Dodge, and (2) in an area north of Des Moines.

There has been some mineralogical and bacteriological contamination from wells drilled for the purpose of draining mines or poorly drained land surfaces; lately it has been considered feasible to locate and plug all abandoned wells which are potential sources of contamination through underground water circulation, but legislation will probably be necessary to eliminate this danger.

Pollution. Significant progress has been made toward controlling the pollution of streams in both the Des Moines and the Skunk River basins. Under the supervision of the Iowa health officials the towns and cities have very generally installed sewage disposal plants, and industries have cooperated widely in treating or controlling objectionable effluents. In some instances industrial disposal plants are currently overloaded, due to increase in plant production under the war effort and inability to obtain equipment for improvements under existing limitations. But one important present source of pollution is the uncontrolled drainage from stock farm areas and the access of stock to the banks of the streams.

The present program of the Iowa officials is pointed toward controlling pollution of all streams in the basin to a point that the water will support fish life, and also be suitable for domestic water supply, although extensive treatment may be necessary. Even though few public water supplies are now drawn from the streams, public sentiment will undoubtedly support control to this extent. With present silt loads and the uncontrolled farm pollution, some treatment of water for public supply is necessary in all cases, although the degree of necessary treatment will vary considerably throughout the basin because of differences in dilution available and other local conditions.

The accompanying map reflects the present status of sewage disposal in this basin.* It will be noted that of the 108 sewered communities, 89 are giving complete treatment and 5 primary treatment. Several towns with a population of less than 500 now have complete treatment.

Under a joint policy adopted by the Upper Mississippi River Basin Health Commissions (Iowa, Minnesota, Wisconsin, Illinois, Missouri), a minimum of primary treatment (settling and sludge disposal) is recommended in all cases regardless of size of community or dilution available.

The Iowa State Department of Health recommends that complete treatment is needed in 10 communities now without treatment plants, the largest of which is Ottumwa (population 32,000, with an equivalent population of 280,000 due to industrial wastes). Partial treatment is recommended for 4 towns and additional treatment for 18 other now having treatment plants; 29 industrial plants need treatment.

In the basin in Minnesota, there are 4 sewered communities for which complete treatment is recommended and 10 industrial establishments requiring treatment.

A source of uncontrolled pollution which has a considerable effect on the streams of the basin is the surface wash from barnyards. Hog raising and cattle feeding are carreid out on a tremendous scale throughout the basin, the livestock population being estimated as six to eight times the human population. Much of this livestock is concentrated in relatively small areas a portion of the time, and the run-off, particularly in spring, carries with it a tremendous organic load from these feed yards. It has been proposed that soil conservation practices might be applied to controlling the run-off from the feed and livestock concentration years in connection with the general erosion control work, with a view toward reducing the amount of organic materials reaching the streams from these sources.

Floods and Their Control in Des Moines River. Approximately 80 percent of all flood damage that occurs in the Des Moines River Basin is sustained by agricultural interests. Of the 136,500 acres of bottom lands along the main streams of the Des Moines River system about 91,500 are in cultivation. This represents only about 1½ percent of all

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* The minor portion of the basin in Missouri (approximately 90 square miles) is omitted.

lands under cultivation in the basin. Thus, although the bottom lands along the major streams may be the highest type of farming land, it is apparent that they contribute but a small percentage of the basin's agricultural products and that no particular regional significance can be placed upon protecting these lands from floods. It is felt that the benefits to justify flood remedial works must arise principally from the savings in actual flood losses caused by inundation.

Flood Characteristics. Floods occur frequently throughout most of the basin, especially along the main stem downstream from Des Moines. In this reach 44 damaging floods occurred in a 33-year period (not continuous) from 1903 to 1940. Of these, 35 occurred in the growing season and six may be classed as major floods. At Des Moines, where flood frequencies are representative of the upper basin, 15 floods occurred in a 20-year period. Of these, 10 occurred during the growing season.

Floods may be caused by short intense rains of several hours or by prolonged periods of precipitation lasting for days. Occasionally early spring floods have been caused by ice gorges. Late spring floods in May and June occur most frequently, but fall floods are not uncommon.

With the exception of the headwaters area, tributary run-off is quite flashy. As it enters the main stem it is moderated by the large volumes of natural valley storage and moves downstream as a relatively uniform rise lasting from several days to two weeks or more. However, intense rainfall on the lower watershed may be reflected in a sharp rise and fall of the main stream. Floods along the Des Moines may originate in the upper basin; in the Raccoon watershed; downstream from Des Moines in the North, Middle and South River basins; generally over the entire basin; or by combinations of the above.

Flood Areas and Damages. The flood plains of the Des Moines River basin are extensively cultivated. Along the main stream below Des Moines approximately 80 percent of the bottom land area is under cultivation while elsewhere the total area cropped aggregates 54 percent. That area not in cultivation is devoted principally to pasture. Bottom lands along the main stem vary in width from 3 miles just below Des Moines to narrow gorges at Madrid and along the lower reaches in Van Buren County.

Damages are concentrated largely along the Des Moines River from its mouth to Des Moines where 65 percent of the total for the watershed occurs. Along the upper reaches of the Des Moines River and along tributaries, with exception of the South River, flood losses are spread out over long reaches.

The flood plain areas and estimated direct average annual flood damages are given in the following table:

FLOOD AREAS AND AVERAGE ANNUAL DAMAGES

Reach			Flood Plain Areas----Acres		Average Annual Direct Damages		
Stream	From	To	Cultivated	Total	Crop	Property	Total
Des Moines	Mouth*	Red Rock*	40,200	48,700	$131,250	$18,160	$149,410
Des Moines R	City of Ottumwa		-	-	-	39,670	39,670
Des Moines R	Red Rock	Des Moines	15,400	21,000	51,800	5,820	57,620
Des Moines R	City of Des Moines		-	-	-	30,260	30,260
Des Moines R	Des Moines	Madrid	3,600	6,300	13,900	790	14,690
Des Moines R	Madrid	Upstream	3,200	4,700	19,060	1,710	20,760
East Fork R	Entire Stream		2,200	8,000	14,400	2,740	17,140
Raccoon	"	"	2,250	5,800	6,410	600	7,010
S. Raccoon	"	"	2,200	5,050	6,440	470	6,910
Middle Raccoon	"	"	300	400	490	160	650
Busby Creek	"	"	400	1,650	1,200	100	1,300
Boone R	"	"	1,300	3,600	6,150	1,560	7,710
Beaver Creek	"	"	2,250	7,200	4,400	600	5,000
North R	"	"	5,200	8,700	15,000	1,600	16,600
Middle R	"	"	3,000	4,100	12,000	400	12,400
South R	"	"	10,000	13,300	34,400	5,000	39,800
			91,500	136,900	$316,900	$109,640	$426,540

* Does not include Ottumwa

Existing Improvements. Existing improvements for flood control consist of:

(a) The Des Moines and Mississippi Levee District No. 1 is located on the south bank of the Des Moines River at its mouth. Improvements consist of 21.4 miles of levess protecting 19,000 acres.

(b) The Parsons Levee District is on the north bank of Des Moines River one-half mile above its mouth. Improvements consist of 3 miles of levees protecting 700 acres.

(c) A number of small private levee systems have been constructed along the lower Des Moines River. In total they protect, to varying degrees, about 3500 acres.

(d) Five and one-half miles of levees have been constructed at Des Moines. Also some ri-rapping and low concrete retaining walls have been constructed. Present protection is inadequate for major floods.

(e) Six miles of levee afford limited protection to Ottumwa. Backwater through sewer outlets causes inundation and the existing levees act principally to prevent cross-current.

(f) The South River has been straightened for the greater part of its length.

Flood Protection Possibilities. Major structure for control of floods have been investigated in detail in the Des Moines River Basin. Flood protection by means of land treatment and run-off retardation measures and by means of headwater reservoirs on small tributary streams has not been studied.

The concentration of flood damages along the Des Moines River from Des Moines to its mouth makes this reach the natural focus for reservoir protection. Six reservoirs have been investigated in detail primarily for reduction of floods in the lower Des Moines River. These reservoirs are Howell and Red Rock on the Des Moines River below Des Moines, and Van Meter and Minburn on the Raccoon River. Of these, the Red Rock, Howell,a dn Madrid projects appear to be economically feasible. Red Rock and Howell are alternates and Red Rock apparently is better and more desirable. The Madrid project, although economically justified by a small margin, would not be economically feasible if Red Rock is constructed, for a large portion of flood control benefits for Madrid would accrue in the flood plains downstream from Red Rock. Red Rock is justified by a much wider margin than Madrid and has several other advantages which definitely make it a more desirable and logical project than Madrid. Thus Red Rock project appears to be the only major reservoir for inclusion in a comprehensive plan for flood control.

The Red Rock project would provide no control of floods at Des Moines, in fact, backwater from the reservoir could conceivably aggravate flood conditions there. Investigation indicate that enlargement of the present floodway by means of levees, walls, and other construction to protect against a flood of 120,000 c.f.s. (40 percent greater than the largest of record) is economically justified and a proper part of the comprehensive plan. This project would require structures on both banks of the Des Moines and Raccoon Rivers within the city limits.

If the Red Rock project is constructed, Ottumwa will receive almost complete flood protection. If Red Rock is not built, construction of a floodway here would have a high ratio of economic justification.

Levees are not feasible for protection of large bottom land areas along the lower Des Moines River. A few small scattered pockets might be leveed economically but these opportunities are not important. Construction of Red Rock would eliminate the need for such levees.

Of the projects studied and reviewed briefly above, the Red Rock reservoir and local flood protection works at Des Moines appear most suited to a comprehensive plan of development. They would practically eliminate floods on the Des Moines River downstream from Des Moines. Flood losses along main reaches of the tributary streams and along the main stem upstream from Des Moines aggregate $150,000 or 35 percent of the watershed total. Major structures apparently are not justified for control of floods along these reaches.

Red Rock Reservoir. The Red Rock reservoir site is on the Des Moines River near the town of Red Rock, about 50 miles below Des Moines. The proposed project provides for flood control and hydroelectric power development with possible important recreational opportunities associated with the maintenance of a permanent power pool. The contemplated storage capacity is 1,200,000 acre feet of which 800,000 acre feet representing 1-1/3 inches of run-off from the watershed controlled are for flood control control and 400,000 acre feet are for power. At full reservoir the area inundated by the reservoir would be 50,000 acres while the normal power pool would cover 23,600 acres.

Although the reservoir would eliminate flood losses almost entirely on the lower Des Moines River, about 65 percent of all flood control benefits would be derived from reduction of flood damages along the Mississippi River. As the Red Rock project would be effective in reduction of Mississippi River floods only as one of a system of Upper Mississippi River reservoirs, it appears that the Red Rock project should be constructed only if and when a system of reservoirs for the Upper Mississippi River is adopted. Otherwise, as a reservoir project by itself, it is not economically feasible.

Madrid Reservoir. Although apparently not as desirable as Red Rock and not a unit in the best plan of development a brief review of the Madrid Reservoir characteristics are given. The reservoir site is on the Des Moines River near the town of Madrid. The reservoir, which would control an area of 5,750 square miles, is considered as a flood control project only. The contemplated capacity of 325,000 acre feet represents about 1.1 inches of run-off from the drainage area controlled. The reservoir would protect Des Moines against a flood 50 percent greater than the largest of record. The greater portion of benefits would be derived from reduction of lower Des Moines and Mississippi River floods. The total benefits for this project would barely exceed the cost.

Land Treatment Measures. No studies have been made of the need for and probable effects on floods of land treatment and rainfall run-off retardation measures. However, much of the watershed is quite flat and erosion is serious only locally.

The damage surveys conducted by the Corps of Engineers were in great detail for the main streams. The damage surveyors interviewed personally all farmers, going upstream as far as flood damages in substantial proportion were reported. It was their experience that as they approached a stream's headwaters, floods caused occasional damage but created little concern. From this it is believed that flood damages on headwater streams and small tributaries are of small magnitude and do not present a serious problem.

In the upper basin above Des Moines the land is especially flat and drainage is not well developed. The tributaries entering the Des Moines River below Des Moines are in a region of better developed drainage and more erosion is in evidence. Land treatment measures would be much more effective in this area.

It is not believed that land treatment measures would provide very substantial benefits for flood control, although they might well be justified by benefits to the land in place. An exception may be the South River watershed.

Small Tributary Reservoirs. Although small reservoirs have not been investigated for flood control, it is not believed that they could be justified in very great part for this purpose. In the flat topography of the watershed favorable sites are not too numerous and the lack of concentrated damage on tributary streams is not favorable to small reservoir control. There is a great need for small lakes for recreation in this area and it is felt that small reservoirs will have to find justification primarily in recreation and water supply benefits, with flood control as an incidental reservoir use. There may be some possibilities for small flood control reservoirs in the South River basin.

Flood Control in the Skunk River. Existing improvements include:

(a) Green Bay Levee and Drainage District is located in Skunk River and Mississippi River bottomland; the area is 14,800 acres. This district has a levee on the right bank of Skunk River starting at the mouth and extending 7.5 miles upstream.

(b) The left bank of Skunk River is leveed for a distance of about three miles starting at a point above five miles upstream from the mouth; the area protected is about 1,500 acres.

(c) About 76 miles of channel straightening has been done on the Skunk River in Story, Polk, Jasper, Marion and Mahaska Counties. Additional straightening has been done on the main sten of Skunk River in Hamilton County, on North Skunk River in Jasper County and on Cedar Creek in Jefferson and Wapello Counties.

Flood Damage. As no cities are located in Skunk River bottomland, urban flood damage is not a problem.

There are about 30,000 acrea of bottomland in Kahaska, Keokuk and Washington Counties which would be benefited by channel improvements. The bottomland area is not sufficiently wide to pay for a levee system. The channel improvement would not provide complete protection but the flooding frequency would be reduced and the length of time of overflow would be lessened by such improvement.

Reservoirs. Studies by the Corps of Engineers have concluded that reservoirs built for the reduction of Skunk River flood damage would not be as economical as flood protection by channel improvement. A reservoir damsite located 10 miles above the mouth of Skunk River was studied in connection with Mississippi River flood reduction. No justification was found for the construction of such a reservoir.

Navigation. There has been no commercial navigation on the streams of this basin since pioneer times. Investigations have been made of the feasibility of improving the Des Moines River for navigation, but the reports have been unfavorable. As the present and predictable heavy traffic movements in the area are not along the direction of the basin axis, there is not important need for the development of facilities for navigation.

Hydroelectric Power. Only a limited number of hydroelectric developments are operated in this basin, and these are small in capacity and of marginal value. The general trend in number, capacity, and output of such projects has been downward during recent years. Investigations of undeveloped sites have indicated that similar blocks of power could be produced in the same area more cheaply by modern stream plants. It, therefore, appears that the possibilities of hydroelectric projects exclusively for power generation, are not an important aspect of the development plan for this basin. However, if any high dams are built on the main stem of the Des Moines River as has been proposed, the structures should be so designed that the maximum benefit from the water resources of the basin may be obtained, and to this end penstocks or similar facilities adapted to possible future use in the development of hydroelectric power should be installed in the dams.

Recreation and Wildlife. There is deep local and state interest in the improvement of existing recreational facilities in this basin area, and the creation of new facilities. The importance of water conservation and flow regulation of streams has been recognized by the state agencies.

In 1899 Iowa possessed 109 natural lakes containing 61,000 acres of water; in 1942 the state had 65 natural lakes, containing 41,000 acres, of which 21 lakes containing 14,000 acres were located in the Des Moines-Skunk basin, all in the upper portion of the area. The lower portion of the basin does not contain any natural lakes. Seven a rtificial lakes, containing 770 acres of water, have been built in recent years in the headwaters of tributary streams mostly in the lower part of the watershed.

In addition to the many natural lakes the upper basin originally contained thousands of acres of marsh land, many of which have been drained and which contributed materially to the upstream water storage, and produced fishing, hunting, trapping and other forms of outdoor recreation.

The manner in which much of the privately-owned land was used greatly accelerated soil erosion, and resulted in heavy silt deposits in the lakes and marshes. Investigations made recently in 18 natural lakes indicate an average depth of water of $3\frac{1}{2}$ ft., and an average depth of silt of about $11\frac{1}{2}$ ft. The recreational use of the lakes in this basin has declined greatly in recent decades because of this silting and filling.

The Iowa State Conservation Commission has a plan for improving 30 of the natural lakes in the state by dredging. Fifteen lakes in this basin are included in this tentative program. The plans call for dredging 2,444 acres to an average depth of 10 feet with shore reprap, outlet control structures, and other improvements included.

Dredging operations have been completed on two lakes in this basin, and dredges are operating on two others. Approximately 440 acres have been deepened in these four lakes to an average depth of 10 feet. This program, as funds are made available, will go far toward the rehabilitation of these lakes, making them again productive of fish, game and fur, and improving them for other recreational uses.

Acquisition of the s hore line around the natural lakes is part of the state program. Access is provided by creating new shore line with dredged material. This program provides public access to these recreational area, and assists in controlling the pollution from livestock. All articial lakes in the lower basin have state-owned shores, and do not have the access problem.

The recreational use of streams and their ability to produce fish have, as the lakes, been seriously affected by erosion, pollution, and drainage. Straightening of the streams has destroyed the recreational value in some places. Programs that will reduce the amount of silt going into the streams, stabilize stream banks, eliminate pollution, and stabilize stream flow, will greatly improve them for wildlife and recreation. Public access to streams is also a part of the state's program, and some progress has been made in acquiring shore line for this purpose.

FUTURE DEVELOPMENT

The future development of this basin area can be visualized as a gradually expanding agricultural economcy based on a program of balanced production of inter-tilled, small grain, hay, and pasture crops in accordance with the capability of the land and livestock needs. And superimposed on the strictly agricultural production will be a steady expansion of manufacturing production based largely on processing products from the farms and making equipment needed on the farms. The current increased activity in manufacturing as compared to the pre-war rate, may likely lead to continuance of this stepped-up-rate, and thereby give to the cities a relatively greater importance in the over-all economy of the region than heretofore.

Water facilities and characteristics will have an increasing influence on such expected growths as regards various elements in life of the population such as industry, farming, health and recreation. There is a growing consciousness in the area of the value of water resources, and consequently the need for conserving and utilizing all supplies. The collection of fundamental data regarding water has expanded greatly in the past 10 years under the guidance of federal and state officials; there is need for some further expansion of this work, but there is also need of thorough studying and interpreting of the data already collected and those steadily accumulating.

The following proposals regarding the several functional uses of water are presented as important elements which would contribute to attaining the visualized development of the area.

Land Use. The future of agriculture in this area will depend on the use that is made of the land in the area. The productivity of the soil can be maintained, efficient production and high crop yields assured and erosion reduced to a minimum with the adoption of crop rotations, contour farming and other treatments suited to the land. Soil conservation districts will aid materially in bringing about the desired soil conservation and land use program in the basins. A program for reforestation of submarginal lands and planting trees along stream banks should be undertaken. Land use in accordance with the capability of the land, together with conservation practices which will produce on-site benefits, will contribute to flood control and reduce sedimentation.

Stream Flow Stabilization. Remedial measures directed toward stabilizing low water stream flow is considered to be a primary feature in the water planning program for this basin. Under present conditions damaging floods often occur after heavy rainfall, and during dry periods the stream discharge is sometimes insufficient to meet the demands within the basin; both extremes are costly and probably indicative of the need for a coordinated plan of water use. The terrain of the headwater areas, which include many former lake sites, offers some opportunity for developing storage by the construction of appropriate dam projects which possibly could be operated for the dual purpose of retention of some excess runoff and release of the same from storage to augment low flow. Such projects would also have some substantial recreational value. There is obviously sufficient precipitation in this area to provide adequate water supplied for all purposes, but a proper balance must be maintained within the agricultural and urban areas to provide sufficient supplies for the various purposes. Any approach to stabilization of low water flow would benefit all interests. Although current work of the Iowa Conservation Commission in dredging silt from existing lakes offers a primary step, there should be initiated a thorough factual survey of the headwater area with the objective of determining the potential possibilities of an augmented program of dredging present lakes and restoring some former lake sites to a flooded condition for storage purposes. Such a program would involve extensive readjustment of present occupancy of the drained districts which might be flooded and should be adequately considered from this standpoint. In any event, sustained flows in the Des Moines River at Des Moines, of not less than 200 cubic feet per second and in the Raccoon River at Des Moines of not less than 100 cubic feet per second are desirable objectives for a comprehensive water planning program in this basin.

Although construction of a dam at the Madrid site primarily for flood control has not been found justified, a further study should be made of the benefits which would accrue from a moderate storage at this location intended primarily for conservation and recreation purposes; storage at this point could supplement headwater storage for accomplishing stabilization of stream flow at both Des Moines and Ottumwa, the two largest cities in the basin.

Pollution Control. The present program of the Iowa and Minnesota State Departments of Health in recommending treatment of all sewage from municipalities and wastes from all industrial establishments to a point that the water in the carrying streams will support fish life and be suitable for public water supply, should be carried out as soon as conditions will permit. The full program would involve --

In Iowa:

- Complete treatment plants for 10 communities.
- Partial treatment plants for 4 communities.
- Additional treatment to present facilities for 18 communities.
- Treatment of industrial wastes at 29 localities.
- A study and demonstration program of the application of soil conservation practices in reducing as much as possible the carrying of organic accumulations from feed and stock concentration yards into the stream with the surface run-off.

In Minnesota:

- Treatment plants for 4 communities.
- Treatment of industrial wastes at 10 localities.

Such new treatment facilities should be adequate to meet the proposed standard under present conditions of the flow in the larger streams becoming very low (and in cases almost stopping) during a dry, hot summer. If the proposed degree of stabilizing stream flow is accomplished, then the purity of the stream water will be raised above the standard suggested, due to the effect of greater dilution than now available at these times of low flow.

Domestic Water Supply. As all but a few of the communities in the basin draw their public water supplies from wells, the probelm of insuring quality and quantity is closely related to that of ground water values. Prospects for reducing the decline in level of ground water during periods of drought, are discussed under that function. But without waiting for any such improvemtn, all communities whose water supply is rated by the Iowa and Minnesota Departments of Health as below Class 2 for dependability or below Class 2 for quality (per table p. 11) should initiate steps to make their supply reliable during at least a moderate dourth, and the necessary treating and softening plants should be added. This program would involve --

More reliable supply for 18 communities.
Treating and softening plants for 73 communities.

All communities having public water supplies drawn from streams or other surface source should of course have treating and softening plants to meet similar standards for quality. The proposed project of impounding an additional supply of water by the City of Des Moines is not adverse to the general basin plan.

Ground Water Control. Since ground water is one of the great natural resources, paramount to the welfare of the area, its development and use should be protected by a reasonable degree of control. There has been a significant rise in the level of the water in shallow wells as the result of above normal precipitation in 1941 and 1942. However, the deeper water bearing beds, some of which occur more than 2000 feet below the land surface, are not so readily affected by local precipitation within the area. Recharge to the deeper water-bearing beds takes place largely outside the basin area and then percolates through permeable beds into the area. Overdevelopment of these water-bearing beds and contamination of them through improper well construction would adversely affect them as a source of water supply for the area.

Locally some recharge to the shallow ground water may be expected from an increase in the headwater storage of the principal streams and the maintenance of reasonable minimum flows. The extent of the recharge, however, is dependent upon geologic and hydrologic factors prevailing at the locality.

The following steps intended to prevent abuse of the ground-water resources should be initiated:

Sound legislation to control the drilling of water supply and recharge wells, and to regulate the beneficial use of ground water.

Preparation of a report outlining the factors to be considered in planning, constructing, and caring for farm wells.

Flood Control. The Red Rock Reservoir combined with a floodway at Des Moines would eliminate 65% of the flood damages along the main streams of the Des Moines River system. There structures appear to fit favorably the best plan of watershed development. It is not believed that additional major flood control structures can be justified for flood control.

The Red Rock project should be constructed only as a part of a system of Upper Mississippi River reservoirs is adopted for construction.

Detailed study should be made of the effects of population displacement and land retirement related to construction of the proposed Red Rock project.

The 35 percent of flood damages along the major streams of the Des Moines River basin for which flood protection is not contemplated is spread out over long reaches and, as a whole, does not present a serious problem.

The benefits through reduction in frequency and severity of floods to be derived from further channel improvements along the Skunk River should be studied.

Land Treatment and small headwater reservoirs for flood control in this basin appear to have limited possibilities. The South River watershed apparently offers the most favorable opportunities for these measures.

Recreation and Wildlife. As discussed in the section on Stream Flow Stabilization, the Iowa State Conservation Commission is engaged on a program of dredging and improving the natural lakes and restoring some drained lakes and marshes in the upper portion of the basin. This program should be carried on energetically. And further, as suggested in the above reference, a factual study should be made of the possibilities and results that could be accomplished to help stabilize stream flow and aid flood control by storage of flood water in dredged and restored lakes and marshes in amounts and at times when it would not to any great extent adversely affect wildlife and recreation.

Among the proposals of the Conservation Commission for the improvement of wildlife and recreation facilities are:

1. Reduction of silt going into the lakes and streams by stimulating the adoption of land use practices that will reduce erosion.

2. Elimination of pollution as rapidly as possible.

3. Stabilization of lake levels by outlet control dams so con-

structed with gates that flood waters could be stored and released at times and in amounts not greatly detrimental to wildlife and recreation.

4. Stabilization of stream flow by every means found practical.

5. Acquisition by the State of shore line along all lakes and streams for public access, and elimination of stock pollution.

6. Coordination of interstate activities in the storage and release of water which might affect importantly the portion of the stream in the down-stream state.

7. Construction and development of artificial lakes at suitable sites to provide recreation and aid in stabilization of stream flow and flood control.

Hydrologic Data. The present excellent program of Iowa officials in collecting hydrologica data should be continued and extended in the following features:

1. Measurements of precipitation should be continued.

2. Gaging of streams and lakes should be continued.

3. Program for observation wells should be continued and expanded.

4. The program of collecting subsurface geologic data as it pertains to ground water and the quantity of water available from the various aquifers should be continued and expanded.

5. System of obtaining and analyzing samples of ground water should be made systematic and permanent.

6. Study of sources, extent, and control of the deposition of sediment in lakes and streams should be inaugurated.

7. Further effort should be given to interpreting all available meteorologic and hydrologic data.

The matter of studying the deposition of sediment will become of growing importance as it is related to efforts toward better practices in land use, to the destruction of natural values by the silting of lakes, and to water quality in the streams as affecting human use of the water and influencing fish life. Preservation of stream banks and need for reforestation of adjacent strips are related factors. Federal cooperation in such a study of silting should be developed.

SUMMARY OF WATER PLAN

The three most important needs for improvement in water resources of this basin are:

1. More water in soil for crop production.

2. More water in ground for maintaining supply to shallow wells.

3. Greater sustained flow in streams during dry weather.

Improvement in soil moisture for crops and supply of ground water for wells which are depended upon largely for domestic supplies, both rural and urban, will depend principally upon better land practices. Extensive adoption of soil conservation practices, such as crop rotation, contour farming and other suitable treatments, is indicated as a principal objective of future planning throughout the basin. In addition to the on-site benefits of better soil conditions and reduction in erosion, there would result substantial down-stream benefits from reduction in flood flows and less sedimentation.

Attainment of better sustained flows in the streams, during dry weather (item 3 above) is probably one of the most pressing needs of the area. Although the possibilities of controlled headwater storage in the undulating terrain of this region may be limited, there has been no factual survey in this field. Such a survey should be undertaken. The organization of this investigation should be developed comprehensively, as several Federal agencies and a number of departments of both Minnesota and Iowa, would be definitely concerned. As regards a stabilized flow in the lower Des Moines River, the benefits which would accrue from a moderate storage at the Madrid dam site, intended primarily for conservation purposes, should be investigated.

The present programs of the state Health Departments of both Iowa and Minnesota are pointed toward treatment of municipal and industrial waters to a point that water in the carrying streams will support fish life and be suitable for public water supply. These programs will involve:

Complete or partial treatment plants in 18 communities.
Additional treatment to present facilities for 18 communities.
Treatment of industrial wastes at 39 localities.

These improvements should be carried out as rapidly as conditions will permit.

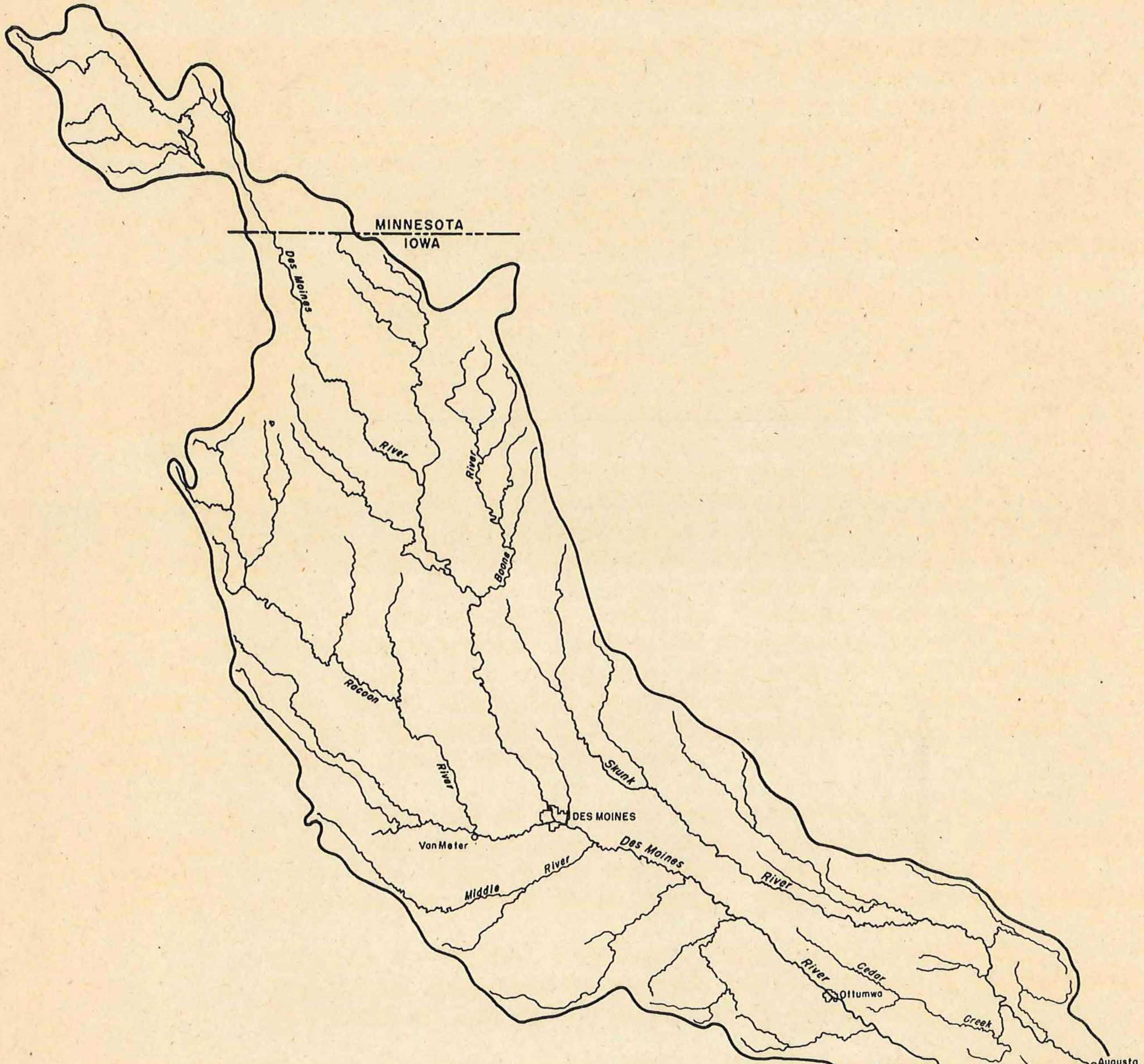
Similar programs for insuring reasonable standards of quality and quantity of municipal water supplies, which should also be carried out as conditions permit, involve:

More reliable supply for 18 communities.
Treating and softening plants for 73 communities.

In the function of flood control in this basin, the construction of the Red Rock project as a unit in a system of Upper Mississippi River reservoirs appears justified. This project, together with a floodway at Des Moines, would eliminate 65% of the flood damages along the main stem of the Des Moines River. The benefits from further channel improvements along the Skunk River should be studied.

The program of the Iowa State Conservation Commission for dredging a number of the natural lakes and restoring some of the drained marshes in the area should be carried on actively. The continued cooperation of this agency with other state agencies in reducing siltation, stabilizing lake levels, and aiding toward large sustained flow in streams, will be beneficial to the many individuals concerned with water-use. The State's objective in obtaining control of the shore line of lakes and streams offers important benefits to the public.

Both Iowa and Minnesota have established commendable services in collecting date on precipitation, stream flow, and observation wells, throughout this basin area; such services should be continued and extended. Continuing studies of the quatity of ground water, and control of over-pumping and contamination of aquifers, are important functions in protecting water resources among the investigations which have been indicated as badly needed in the proposed comprehensive survey of measures for improving the sustained flow in streams during dry weather. Another needed investigation of growing importance is a study of the sources, extent, and control of sedimintation in lakes and streams.



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STREAM POLLUTION SOURCES
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