NEBRASKA SOIL AND WATER
CONSERVATION COMMISSION

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Big Blue River Basin Appendix

SEPTEMBER 1968

FLOOD CONTROL SECTION PREPARED BY
THE U.S. ARMY CORPS OF ENGINEERS

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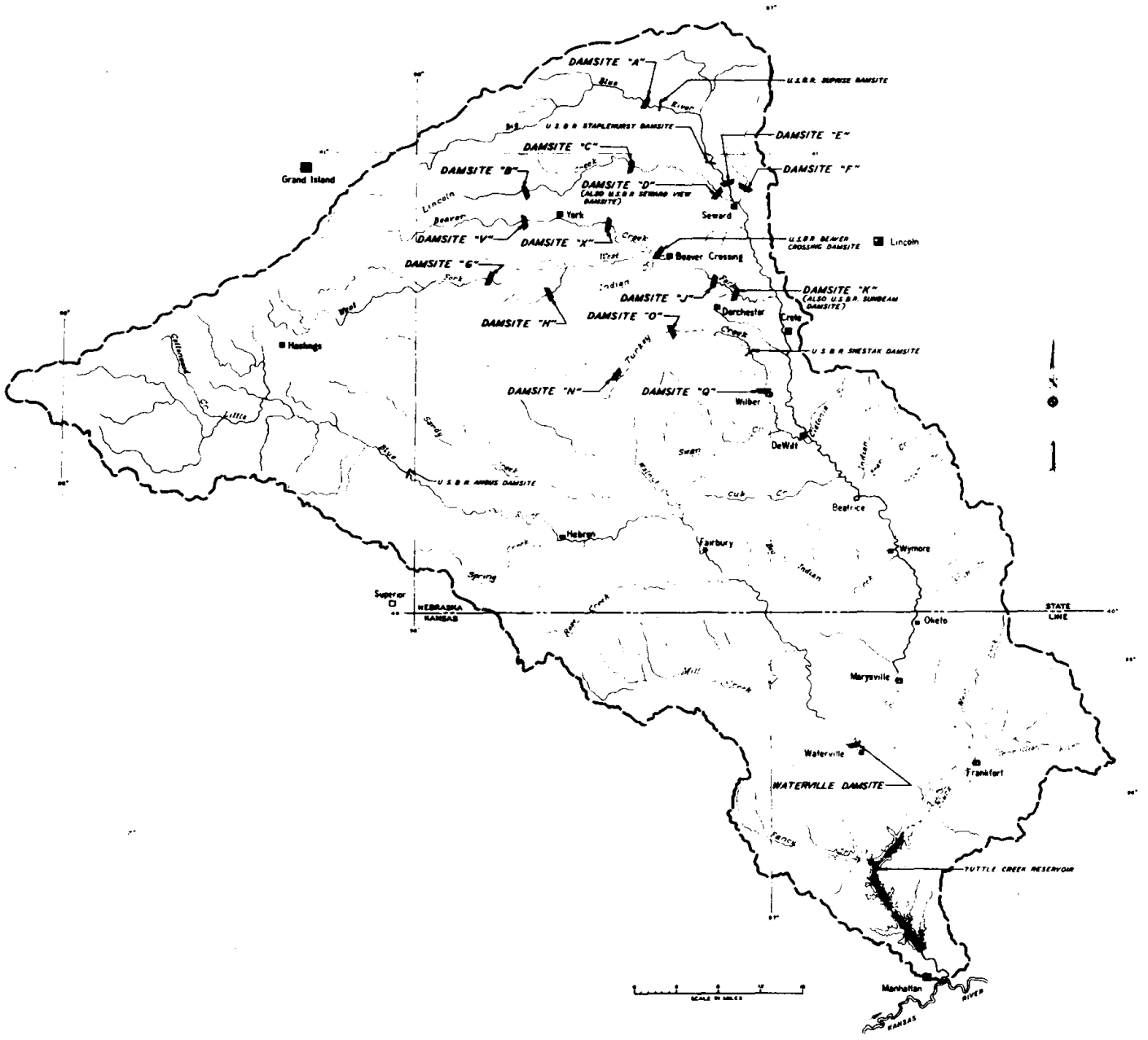

BIG BLUE RIVER BASIN

NEBRASKA AND KANSAS

POTENTIAL RESERVOIR SITES
REFERENCE MAP

Sheet 1 of 1 Scale: as shown

U.S. ARMY ENGINEER DISTRICT
KANSAS CITY

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AUGUST 1966

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DEPARTMENT OF THE ARMY
Kansas City District, Corps of Engineers
700 Federal Building
Kansas City, Missouri 64106

Preliminary Statement on the Investigation in the Big Blue River Basin, Nebraska and Kansas

September 1966

1. The authority for this investigation is provided in a resolution of the Committee on Public Works, United States Senate, which was sponsored jointly by Senators Roman L. Hruska and Carl T. Curtis and was adopted on 2 October 1961 as follows:

> "Resolved by the Committee on Public Works of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the reports of the Chief of Engineers on the Kansas River and tributaries, Colorado, Nebraska, and Kansas, published as House Document No. 642, Eighty-first Congress, second session, and other reports, with a view to determining whether the recommendations contained therein should be modified in any way at the present time, with particular reference to the advisability of constructing additional improvements in the interest of flood control and allied purposes in the Big Blue River Basin in Nebraska and Kansas."

2. The investigation is of survey scope and deals with the determination of needs for flood control, irrigation, water supply, water quality, recreation and fish and wildlife, and related water and land resource development.

3. The Big Blue River rises in the plains of south-central Nebraska and flows on a southeasterly course to its mouth at Kansas River mile 147.5, near Manhattan, Kansas. The basin has a drainage area of 9,600 square miles, of which 7,200 square miles are in Nebraska and 2,400 miles are in Kansas. The Little Blue River is the principal tributary of the Big Blue River, joining that stream near Blue Rapids, Kansas. The confluence of these two streams is now located in the Tuttle Creek Reservoir. The economy of the basin is predominantly agricultural and the major products are small grains and livestock. The cities and towns throughout the basin serve primarily as marketing and distribution centers for the surrounding agricultural regions, and many of them lie wholly or partly within the flood plain areas. The 1960 basin population was approximately 226,000, of which 83,000 resided in towns of cities having populations of 1,000 or more. The topography ranges from broad, gently-rolling plains in the western portion of the basin to more broken and hilly terrain in

the southern portion. Mean sea level elevations range from 990 feet at the mouth of the Big Blue River to approximately 2,200 feet near the headwaters of the Little Blue River.

4. Water resources development in the Big Blue River basin at the present includes:

a. Existing flood control projects.

(1) Tuttle Creek Reservoir. The dam of this multiple-purpose project is located on the Big Blue River about 12 miles upstream from its mouth. The project controls the drainage from 9,556 square miles, or more than 99 percent of the Big Blue River basin. The flood plains of the Big Blue River below the dam are completely protected from Big Blue River floods by this project, and Kansas River backwater flooding in this area is or will be minimized by other existing and authorized projects in the Kansas River basin. The Tuttle Creek project, a key unit of the Kansas River flood control program, was dedicated in June 1963.

(2) Seward, Nebraska, local protection project. The local protection project at Seward, Nebraska, consists of levees and a channel cutoff. This project, completed in 1953, protects major developments in the city from recurring floods on Lincoln Creek and on the Big Blue River.

(3) Manhattan, Kansas. The Manhattan local protection project, which is designed primarily to protect the city from Kansas River floods, includes a tieback levee extending along the right bank of the Big Blue River. The project was placed in operation in 1964.

(4) Frankfort, Kansas. The Frankfort local protection project, completed in 1963, is designed to protect the city from floods on the Black Vermillion River and Timber Creek. The Black Vermillion River is a left bank tributary joining the Big Blue River within the Tuttle Creek Reservoir. The project includes levees, channel realinements and improvements, replacement of one railroad bridge and alteration of another, raising of railroad tracks, and sidehill cutoff diversion ditches.

b. Flood control projects under construction.

(1) Marysville, Kansas. This project, for which construction funds are now available, will include a levee, and channel improvements. It is scheduled to be under construction this year and will protect the city from flooding on the Big Blue River.

(2) Fairbury, Nebraska. This project was developed under the continuing authority provided in Section 205 of the 1948 Flood Control Act, as amended. The protection works will include levees and a short floodwall to protect Fairbury from floods on the Little Blue River.

c. The Flood Control Act of 1954 authorized local protection works at Beatrice, Nebraska. As conceived in that document, the project would include new levees, raising existing levees, channel improvements, floodwalls, and bridge alterations. The project, which would protect the city from floods on the Big Blue River and on Indian Creek will be re-evaluated during the current investigations.

d. Bureau of Reclamation Studies.

(1) The Bureau of Reclamation has conducted a feasibility study of the Angus Reservoir on the Little Blue River. The Angus project would include storage for irrigating lands in the Little Blue Valley, but irrigation would be deferred and its immediate primary purpose would be for flood control along the Little Blue and Big Blue Rivers and along the Kansas River when operated in conjunction with Tuttle Creek Reservoir.

(2) The Bureau has also completed a reconnaissance report of the entire Big Blue River basin. This report outlines a plan for development which would include a system of four reservoirs, each of which would provide for irrigation, flood control, and recreation and fish and wildlife. The studies did not include an inventory of needs outside the basin for water supply or water quality control which might be satisfied by providing conservation storage in the proposed reservoirs.

e. The Soil Conservation Service, Lincoln, Nebraska, has completed work plans for 10 watersheds in the Big Blue River basin in Nebraska. One pilot watershed project, the Little Indian Creek Watershed in Gage County, has been completed. A preliminary investigation covering the Big Blue River in Nebraska, with a view to determining the extent of additional watershed development necessary to realize the full utilization of the soil and water resources, is in progress. The extent of watershed development in the Big Blue Basin in Kansas is considerably less than that of Nebraska. There is one completed pilot project, the Snipe Creek watershed in Marshall County. Work plans have been completed for the Upper Black Vermillion, North Black Vermillion, and Irish Creek Watersheds in Marshall, Nemaha, and Pottawatomie counties, immediately upstream from the Tuttle Creek Reservoir.

f. Public Law 86-489, June 1960, granted to the States of Kansas and Nebraska the right to negotiate and enter into a compact relating to the interests of such States in the water of the Big Blue River and all its tributaries. A commission, with a representative of the Corps of Engineers as Chairman, was organized with representatives from both States. This commission is to be assisted in the preparation of the compact by various committees having representatives from the Federal Power Commission, the Departments of Justice, Commerce, Agriculture, Interior, and Health, Education and Welfare, and interested State agencies as required. Engineering studies are continuing, but no specific recommendations have been made as to the apportionment of waters of the Big Blue River at this time.

5. Based on preliminary investigations made thus far, water resource problems in the basin appear to be essentially as follows:

a. Flood problem.

(1) Streamflow records indicate that floods have occurred in 35 of the 64 years of the period 1902 through 1965. The latest flood, in June 1965, caused about $180,000 damage, mostly along the main stem below Seward, Nebraska, and above the Kansas-Nebraska line. A flood in June 1963 approached record stages in the upper basin, particularly at Seward. The local protection works at Seward prevented severe damage to the city, but considerable losses were sustained in unprotected areas near Seward and elsewhere along the upper Big Blue River and certain tributaries. The record 1951 flood caused $17,390,000 damage in the basin, including $16,032,000 damage on 139,000 acres of rural flooded area. Only a small proportion of this flooded acreage would be affected by existing and currently authorized projects. Widely spaced intense rainfall often causes severe but localized flooding in many areas throughout the basin. The Tuttle Creek Reservoir provides flood protection to only the lower few miles of the river valley. The existing and authorized local protection projects do not protect the agricultural flood plains of the Big Blue River and its tributaries.

(2) The 1,933,000 acre-feet of flood control storage in the Tuttle Creek Reservoir is approximately 831,000 acre-feet less than the desirable 2,764,000 acre-feet. Studies indicate that critical transpositions of the 1951 storms over the Big Blue basin would result in flood runoff which the Tuttle Creek Reservoir could not completely control and which would cause discharges in excess of design capacity at the Kansas Citys and elsewhere. The resulting flood would cause damage approximating $1 billion at the Kansas Citys alone, and this damage could be prevented by reduction of the Tuttle Creek spillway discharge. Therefore, backup storage for flood control is considered desirable in the Big Blue River basin. Incremental benefits for this storage could amount to about $3 million annually.

b. Water supply. Studies conducted by the Federal Water Pollution Control Administration (FWPCA) for the Big Blue River indicate that existing sources of water will be sufficient to meet municipal and industrial needs in the basin during the foreseeable future. However, the study area for these investigations did not include the Kansas River below Manhattan. Impoundments in the Big Blue River basin could be effective in providing additional water supply for several cities including Manhattan, Topeka, Lawrence, and others in the lower Kansas River. The amount and value of such potential storage has yet to be determined, but it is believed to be relatively high. Water supply for irrigation has been studied by the Bureau of Reclamation and there appears to be a potential future need in the basin.

c. Water quality. Studies made by the FWPCA indicate that significant waste discharges are made into the Big Blue River and its tributaries at Beatrice, Crete, Fairbury, Hastings, Seward, and York,

Nebraska, and at Marysville, Kansas. With the exception of Hastings and York, streamflows at these points are presently adequate to assimilate wastes. Hastings is located near the extreme edge of the drainage basin and there is no feasible way of providing additional flow for dilution purposes in that location. The water quality problem at York could be alleviated by releases from a reservoir upstream on Beaver Creek. Current discussions with representatives of the FWPCA indicate a justifiable need in the Kansas River for additional flows to dilute increasing industrial pollution. It appears that storage in the Big and Little Blue River basins could be justified for water quality control.

d. Other problems. Preliminary studies have disclosed that no great need exists for bank stabilization in the Big Blue River basin. Investigations also indicate that providing additional flows for navigation in the lower Missouri and Mississippi Rivers would not be feasible at this time. Water based recreational opportunities in the region are not adequate to serve increasing needs. While the Tuttle Creek Reservoir provides much needed relief, additional facilities will be necessary to meet the anticipated continued increase in demand for water based recreation.

6. In formulating a plan for water resources development in the Big Blue River basin, flood control and the potential of damsites to develop sustained yields during critical drouth periods were considered to be of primary importance. At the beginning of investigations, about 21 individual sites were selected for study. Field reconnaissance plus increasingly detailed economic evaluations have reduced that number to 7 sites currently under scrutiny. Of these 5 are the same as, or reasonably close to, those studied by the Bureau of Reclamation: namely, Angus, Seward View, Surprise, Shestak, and Beaver Crossing. The FWPCA studies indicate a local need for water quality control at York, Nebraska. This need could be served by the potential York Reservoir upstream on Beaver Creek. The other site under detailed study is the Waterville Reservoir near Waterville, Kansas, on the Little Blue River. This reservoir could control a substantial area above the Tuttle Creek Reservoir and would be very effective as a flood control reservoir by providing backup storage. It would also be highly effective for conservation purposes. Since the chief source of benefits is from flood control, much of which stems from Tuttle Creek Reservoir backup, the addition or deletion of a reservoir from the system could affect the economic justification of other units in the system.

7. Present studies indicate that all reservoirs currently under consideration, except the York Reservoir and possibly the Angus or Waterville Reservoir, may be included in final recommendations. However, the final apportionment of storage volumes between plan elements will depend on even more detailed economic studies. These studies will be directed to defining the optimum plan, based on maximization of net benefits for serving all identifiable water resources needed. Of considerable importance in these studies will be the physical site

limitations, yield-storage-cost relationships, willingness of beneficiaries to participate in irrigation, recreation, and water supply projects, and the capability of the site to control storm runoff. The interplay between these functions cannot be pinpointed at this time.

8. Furthermore, it may be that the plan which may be proposed in response to the Congressional resolution may not serve all the local desires. For example, a small reservoir providing only local water supply and recreation might be desirable even though it could not be recommended as a Federal project. In anticipation of local or State interest in potential projects which have been, or will be, eliminated in the process of Federal project formulation, all of the 21 sites considered are shown on the inclosed table 1 and basin map.

Table 1.--Big Blue River basin potential reservoirs

Preliminary reservoir site designation	Stream	Drainage area sq. mi.	Total storage ac.-ft.	Purposes(1)	Remarks(2)	Under detailed study
A	No. Br. Big Blue	314	90,300	FC	FCD	
B	Lincoln Creek	162	63,200	FC	FCD	
C	Lincoln Creek	327	308,900	FC, R, UC	Better site downstream	
D-Seward View	Lincoln Creek	445	227,300	FC, Irr, R	Bu Rec	X
E	Big Blue	648	227,000	FC	FCD	
F	Plum Creek	86	64,800	FC, UC	Low BCR	
G	West Fork Big Blue	354	87,900	FC	FCD	
H	West Fork Big Blue	587	221,000	FC, R, UC	Better site downstream	
J	West Fork Big Blue	1,220	686,600	FC, UC	Better site @ Beaver Cr.	
K-Sunbeam	West Fork Big Blue	1,330	195,800	FC, Irr, R.	Bu Rec, Low BCR, Reloc	
N	Turkey Creek	197	150,400	FC, R, UC	Better site downstream	
O	Turkey Creek	315	282,500	FC, R, UC	Better site downstream	
Q	Turkey Creek	457	193,700	FC, R, UC	Better site @ Shestak	
V-York	Beaver Creek	172	64,700	FC, WQ, R		X
X	Beaver Creek	261	147,900	FC, UC	Better site @ Beaver Cr.	
Angus	Little Blue River	1,098	440,000	FC, Irr, R	Bu Rec	X
Staplehurst	Big Blue River	626	100,000	FC, Irr, R	Bu Rec, Reloc	
Shestak	Turkey Creek	415	180,500	FC, Irr, R	Bu Rec	X
Surprise	No. Br. Big Blue	337	176,700	FC, Irr, R	Bu Rec	X
Beaver Crossing	West Fork Big Blue	1,154	534,500	FC, Irr, R	Bu Rec	X
Waterville	Little Blue River	3,364	1,192,200	FC, WQ, R,		X

(1) Purposes:
- FC - Flood control
- Irr - Irrigation
- WQ - Water quality control
- R - Recreation & Fish & Wildlife
- UC - Unallocated conservation storage
- Nav - Navigation

(2) Remarks:
- FCD - Flood control deficiency at max. site development
- Reloc - Relocation problems
- BCR - Benefit cost ratio
- Bu Rec - Also recommended or studied by Bureau of Reclamation in Feasibility

9. Current efforts are centered around detailed analysis of the flood problems and potential benefits, downstream needs for water supply, water quality control, recreation and fish and wildlife, and irrigation. Much of the data shown in the Bureau reports, including design, storage allocation, and cost estimates are subject to additional refinement to reflect the other conservation purposes that would be included in the Corps plan.

10. Present studies point up the need for 5 of the 6 additional reservoirs as shown in the following table 2. The reservoir near York on Beaver Creek does not appear feasible at this time and it appears unlikely that both Angus and Waterville could be justified. All elements must return benefits in excess of costs.

Table 2.--Big Blue River basin probable reservoirs

Reservoir	Stream location	Purposes	Total storage (ac.-ft.)	Surface area cons. pool (acres)	Approximate cost
Waterville	Little Blue R.	F.C., WQ, Rec, F&W	*	*	*
or Angus	Little Blue R.	F.C., Irr. Rec.	440,000	5,080	$27,320,000
Beaver Crossing	W. Fork, Big Blue River	F.C. Irr. WQ, Rec. F&W	534,500	8,000	27,300,000
Seward View	Lincoln Creek	"	227,300	4,500	16,500,000
Surprise	No. Branch, Big Blue R.	"	176,700	4,100	16,600,000
Shestak	Turkey Creek	"	180,500	4,300	13,000,000

*Not yet determined

11. Delineation of the recommendations will have to await completion of the detailed plan formulation studies. It is anticipated that these investigations will be sufficiently advanced so as to make final plan selection possible by about July 1967.

WATER QUALITY SECTION PREPARED BY
THE NEBRASKA DEPARTMENT OF HEALTH

Surface Water Quality

The quality of the surface water in the Big Blue River Basin varies greatly during the year. Studies conducted by the Nebraska State Department of Health indicate that the best quality of water exists in the late winter and early spring before the spring run-off occurs. The Big Blue River may rank as the most polluted interstate river in Nebraska if we consider silt as a pollutant. From October 1, 1961 until September 30, 1962, the U. S. Geological Survey[1] made daily measurements of the suspended sediment (silt) in the Big Blue River near

[1]Geological Survey Water-Supply Paper 1943, Quality of Surface Waters of the United States 1962, pp. 311-312.

Crete. During this year of study, 535,938 tons of suspended sediment moved down the river. Figure 1, shows the monthly variation in suspended sediment at Crete. The yearly discharge at Crete was 139,631 cfs. In addition to the high load of suspended solids, the Big Blue River receives municipal and industrial wastes from every community located along the river. Since many of the existing waste water treatment plants need upgrading within the next five years, it is difficult to predict how much additional municipal and industrial waste water can, in the future, be discharged into the Big Blue River and maintain Water Quality Standards.

In discussing the water quality of the Big Blue River, there are several factors which must be kept in mind. First, from the historical viewpoint, there were at least 20 low head dams on the Big Blue River.

At the present time, only the following are holding water: Crete, Wilber, DeWitt, Homesville, and Barneston. All of these dams, except the Crete dam, are used to generate electric power. These impoundments, in general, help to improve the water quality because they act like waste water retention ponds. These impoundments contain a high plankton population which utilize many of the pollutants as food. This is evidenced by the fact that below most of the dams there is a reduced phosphate content and an increased amount of dissolved oxygen. It is interesting to note that the river does not show a major increase in pollutants at the Kansas State Line, in spite of the fact that a large amount of waste water is discharged into the river between Crete and the Kansas line.

Secondly, we must keep in mind that Marysville, Kansas, obtains its drinking water from the Big Blue River. At present, the quality of the water meets the Kansas State Health Department requirements for a raw drinking water supply. However, it must be kept in mind that the amount of waste water--municipal, industrial, agricultural, and return irrigation flows, are increasing every year and, in the future, there will have to be an upgrading of the waste water effluents.

Lastly, south of Marysville, Kansas, the Big Blue River flows into Tuttle Creek Reservoir. At the present time, we do not know what effect the Blue River is having upon the water quality in the reservoir. Data collected by the Nebraska State Department of Health[2] indicate

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[2] Rapp, William F. and Francl E. Krebs 1966, Water Quality of Nebraska Surface Streams, Surface Water Quality Report #1, page 15

that both the phosphate and nitrogen concentrations are high enough to cause eutrophication at least in the upper reaches of the reservoir. These studies also indicate the concentration of orthophosphate in the Big Blue River varies from 0.3 ppm to 2.9 ppm. The modal concentration is 1.2 ppm at Barnston. Sawyer[2] has stated that concentrations in

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[2]Sawyer, C. N., 1952 Some New Aspects of Phosphates in Relation to Lake Fertilization. Sewage and Industrial Wastes, vol. 24, pp. 768-776.

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excess of 0.01 mg/l of inorganic phosphorus can be expected to produce algae blooms of such density as to cause nuisance. All of the orthophate analysis to date at the Barnston station have exceeded this level.

Table 1 shows the chemical water quality of the Big Blue River at Crete and Barnston based upon a large series of analysis by the Nebraska State Department of Health. For each analysis, the maximum, minnum and modal concentrations are given. The mode has been used in the interpretation of the analysis rather than the arithmetic mean because the standard deviation of the arithmetic mean was so great that there was little reliability. Therefore, the mode which is the value that occurs most frequently was used as it appeared to represent the most reliable value. A study of the data in Table 1 shows that there is very little change in the concentrations of chemical ions in the Big Blue River between Crete and Barnston.

The Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) are commonly used as measurements of pollution. The BOD analysis measures the ability of the microorganisms to breakdown organic matter by biochemical oxidation and the COD analysis measures the ability of the available dissolved oxygen in the stream to break down the organic matter by chemical oxidation. Table 2 shows the BOD and COD concentrations in the Big Blue River at Crete and Barnston. A study of this data indicates that there is very little increase in either BOD or COD between Crete and Barnston, in spite of the large amount of municipal and industrial wastes discharged into the stream.

Because of the high dissolved oxygen content usually found in the river, plus the reaeration which occurs when water spills over the dams, there appears to be an adequate concentration of oxygen present to carry out the necessary oxidation reactions.

Since both sanitary and industrial wastes are discharged into the Big Blue River, anothe r indicator of water quality is the coliform bacteria count. Between April and September 1965, Krebs and Rapp[1] made a detail study of the M. P. N. Coliform in the Big

[1] Rapp, William F. & Francl E. Krebs, 1966. A Study of Water Quality in the Big Blue River based upon M. P. N. Coliform Counts. Surface Water Quality Studies #2. Lincoln, Nebraska.

Blue River. Their work shows a correlation between flow and M. P. N. Coliform count; and that in general, the highest M. P. N. Coliform counts occur at, or just prior to, peak flows. The M. P. N. Coliform analysis is a measurement of a group of organisms which include all

of the aerobic and facultative anaerobic Gram-negative nonspore-forming bacilli which ferment lactose with a gas formation within 48 hours at 35 degrees Centegrade. The interpretation of the M. P. N. Coliform count is difficult since many of the species of bacteria are common soil organisms. All sampling stations averaged M. P. N. Coliform count exceeded 25,000 and were often over 100,000.

The measurement of fecal coliform has, in recent years, been perfected to where it can be done on a routine basis and provides a more realistic indication of pollution by excreta wastes. Between February 26 and March 5, 1968, the fecal coliform count was run on a series of samples collected from the Big Blue River and its two principal tributaries. This period was chosen because earlier studies had shown that the suspended sediment load is minimal at this time of year. Figure 2 graphically shows the concentration of fecal coliform in the Big Blue River and its two principal tributaries. Many municipalities are contributing a heavy load of fecal coliform, but the river, at present, has the ability to destroy the majority of them by the time it reaches the Kansas line.

Summary

It would appear that at the present time, suspended sediment (silt) is the number one pollutant in the Big Blue River. A large amount of municipal, industrial, and agricultural wastes are, at present, being discharged into the river. At present, it appears that the river is able to assimulate most of these wastes. However, it is doubtful that the river is capable of handling any large addition waste discharge, especially under low flow condition and high

irrigation demands. Lastly, it must always be kept in mind that the Big Blue River is the water supply for Marysville, Kansas and the principal source of water for Tuttle Creek Reservoir.

Pollution Abatement

In the near future there may be inadequate streamflow in the upper reach of the West Blue River to meet the dilution requirements for the Hastings Sewage Treatment Plant and also for the York Sewage Treatment Plant. However, before any impoundments or transbasin diversion are considered, economic studies should be made to determine the feasibility of tertiary treatment of sewage plant effluents as compared to supplimentary stream flow by storage or transbasin diversion.

Until additional studies are made to determine the loading capabilities of the Big Blue River, caution should be used in the construction of additional waste water treatment plants which will discharge into the river. In many cases where there are increases in waste water loadings, tertiary treatment will be needed.

At the present time, in the Big Blue River, no part of the flow has been reserved for dilution of waste waters. Tertiary treatment of municipal and industrial wastes may, in the future, be necessary if we have reduced flows. In some of the larger communities, in addition to tertiary treatment, phorphous and nitrogen removal may be necessary. At the present time, the Nebraska law does not recognize the use of water for sewage dilution.

At the present time, very little is being done relative to the control of agricultural pollution; the major one being silt, followed by feedlots and irrigation return flows. At the present time, much thought and discussion is occuring on this subject. There is ample evidence that agricultural pollution has a serious effect upon water

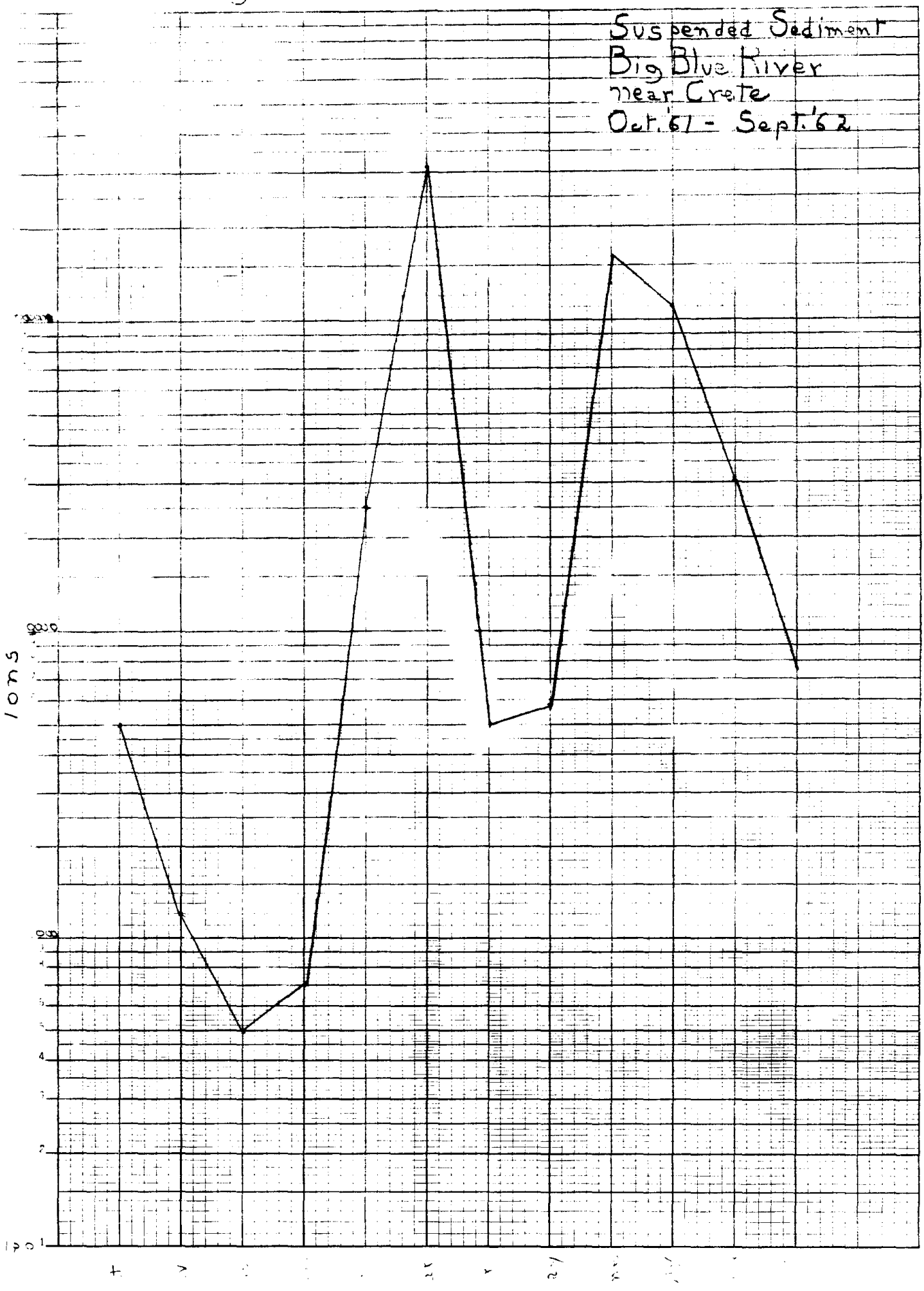
Table 2

BOD and COD Concentrations in the Big Blue River.
(expressed as mg/l)

Station	BOD			COD		
	Minim	Modal	Maxium	Minim	Modal	Maxium
Crete River Mile 180.8	3.3	4.8	16.8	4	43	152
Barnston River Mile 181.9	3.0	~~43.5~~ 4.35	14.7	8	35	156

quality and that there is a need to control this type of pollution. Unfortunately, modern technology has not advanced to the point whereby economical methods of control and treatment have been developed.

Fig. 1


Suspended Sediment
Big Blue River
near Crete
Oct. '61 - Sept. '62
tons

IRRIGATION WATER MANAGEMENT SECTION PREPARED BY
THE AGRICULTURAL EXTENSION SERVICE

IRRIGATION WATER MANAGEMENT

A Report of the Blue River Basin

Deon D. Axthelm[1] and Paul E. Fischbach[2]

The variability and scope of irrigation practices in the Blue River Basin and lack of time, personnel and funds prohibited the gathering of actual data on specific management items. However, using research data and certain estimates known about irrigation management practices in the area allows discussion of potential water saving.

Land shaping practices have been neglected in this report in anticipation of this information being available in other sections.

Crop irrigation is a consumptive and a necessary use of water in Nebraska. Agriculture is the largest consumer of water. Therefore, all management factors mentioned in this paper, if economically feasible, should be put into use to conserve water resources.

Three sections of the report discuss irrigation water relation to:

WATER LOSSES

- Runoff, surface irrigation
- Runoff, sprinkler irrigation
- Evaporation
- Deep Percolation

WATER USES

POTENTIAL WATER SAVING

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WATER LOSSES

A. Runoff losses - surface irrigation

Research or survey data on specific farms for the area of the Blue River Basin is not available. However, tests on demonstration farms and fields on fine textured upland soils of this area and other areas resulted in the following runoff losses.

Table 1 - Runoff Losses on Demonstration Fields

1960	22 - 37%
1961	28%
1965	40%

Soil compaction, soil saturation, soil texture and percent of slope were factors in the variation of runoff.

Irrigation practices used by surface irrigators can be classified into four categories. Table 2 estimates the percent of runoff according to the irrigation management practice used and the percent of irrigators in the Blue River Basin using a particular practice.

Table 2

Irrigation Management Practice	Estimates % Water Runoff	Estimates % Irrigators Using Method
1. Large stream size at start with later cutback stream adjustment	10-20	10
2. Maximum non-erosive stream, no cutback	30-35	36
3. Small stream; or stream shut off at end of run, or blocked row ends	5-10	45
4. Maximum non-erosive stream using a recovery or return system	0	9

Practice 1 offers an opportunity to effect a water saving coupled with good soil moisture patterns. Few irrigators have or will adopt this particular practice because of the extra amount of labor involved in readjusting stream size following the initial adjustment.

Practice 2 involves running a full furrow stream of water at the maximum non-erosive level and continuing at that rate of flow for the desired time. Runoff is excessive but water distribution is nearly uniform within the field. Low cost of irrigation water and high labor costs encourages this practice.

Practice 3 usually results in poor distribution of water within the field and yields are reduced. Over or under irrigation of crops results in portions of the field in which water leaches nutrients below plant root depth or limits amount of available soil moisture within the root zone. Although widely used, this practice reduces crop yields. Deep percolation can result in additional needs

for subsurface drainage works in areas requiring such drainage.

Practice 4. The Soil Conservation Service reports 9% of the irrigators using some form of recovery system. It may be that not all fields of the reported 9% have reuse systems. The systems may be a manually operated type or the very recent innovation, the automatic irrigation and reuse system. Practice 4 permits use of the maximum non-erosive stream, reduces labor and applies water to the soil efficiently. The automatic system involves extra capital outlay, but may ultimately result in more profitable use of the irrigators time for other production enterprises. In effect, practice 4 trades capital for labor while reducing irrigation runoff to zero.

When the economics of a particular form do not justify such a system, community or neighborhood cooperative systems of water recovery could be considered.

It appears that recovery systems for irrigation water runoff and in particular reuse systems offer the possibility of substantial water savings. Considering past experience and without imposed controls, (limitations of runoff or other measures) it is probable that it will take 7-10 years before one-half of the present acreage will be serviced by recovery or reuse systems.

B. Runoff Losses - sprinkler irrigation

Sprinkler systems are estimated to number about 500 in the Big Blue Basin and 125 in the Little Blue Basin. No record of the acreage by sprinkler system is available. However, many sprinkler systems are used in conjunction with surface systems. If 40 acres is arbitrarily assigned per sprinkler system there would be 25,000 acres irrigated by this method.

Sprinkler irrigation runoff should be below the 5% level if they are properly designed and operated. Design in the Big Blue Basin is generally adequate with a few designs erring on the side of high application rates. Survey data on runoff are not available and probably would be inaccurate if available, because of variation in soil, slope and crop conditions at various times of the year. Observation indicates a generally satisfactory situation. There is a need for more education concerning correct water application rates for sprinkler operation. Educational programs should be directed at users and also retailers of equipment.

C. Evaporation Losses

Evaporation losses are incurred through spraying of water, transporting by lined or unlined ditches and from soil and water surfaces. Evaporation may vary from 5 to 25% of the applied water depending on the method of irrigation, air temperatures, wind, the length of application period, crop canopy and humidity.

Irrigation by pipe systems are a means of reducing evaporation from free water surfaces. A large number of pipe conveyance systems are in evidence in the Blue River Basin. It is anticipated that the use of closed conduit systems to the point of field use will increase with an increasing trend toward underground piping systems and the use of gated pipe. Acceptance of gated pipe systems remains

high. Maintaining good farm incomes will be the largest factor in increasing the use of this water evaporation saving method.

Irrigation evaporation losses under highly controlled research conditions at the North Platte Experiment Station can be deduced from their efficiency studies of 1961. These studies showed an irrigation efficiency of 82.5% for sprinklers and 74.4% for the surface method. The difference in efficiency between methods was attributed to surface runoff, leaving evaporation at approximately 17%. There was no measurable deep percolation.

One water conserving practice in the field is to limit the time of exposure of the water to the atmosphere. Exposure time can be limited by knowledge of the moisture conditions and irrigating at the correct time. This can be accomplished by use of soil moisture sensing devices to schedule irrigation. A field trial using such instruments showed that 4 inches of water per irrigation was sufficient where previously the irrigator had been using 12 inches per irrigation. It is estimated that only 2% of the irrigators use such equipment.

Gross evaporation from free water surfaces is shown to range from 44" to 52" with a net loss of 15" to 25" annually in the Blue River Basin. Water impoundments for irrigation purposes whether for collection of rainfall or irrigation runoff and subsequent reuse should be made as deep as practical with as little surface area as possible to minimize evaporation potentials. No field application of hexadecanol or similar fatty alcohols has been made to suppress evaporation. The cost of suppressants in relation to the availability of other sources of water is the most probable limiting causes.

Evaporation from soil surfaces can also be partially arrested by tillage methods. The minimum tillage method of crop production can result in a soil moisture saving by exposing less moist soil to the atmosphere than is common with conventional tillage methods. No data is available on losses. Immediate research should be accomplished to test this theory.

Tillage practices designed to keep residue on the surface and to reduce compaction will increase infiltration rates and retard evaporation of water from the soil surface.

D. Deep percolation losses

Deep percolation of water in soils is not a water loss to the River Basin. Excess percolation is an economic loss to the individual irrigator. The losses are economic as related to the potential application of the original volume of water to a larger area. Water wasted in deep percolation could be used to irrigate a large acreage. The original cost of water delivery per acre is also increased.

An additional loss is plant nutrients that are moved below plant root zones. An additional hazard exits when perched water tables may rise because of deep percolation and cause water logging of plant root zones.

Soil additives may also constitute a potential hazard in ground water pollution. There is a need for additional research on the

specific minerals or compounds and the rates at which they may enter ground waters.

Conflicting with the danger of ground water pollution, is the need for application of additional irrigation water beyond plant growth needs to avoid the accumulation of excessive amounts of salts in the root zone. The minerals applied in irrigation water will accumulate unless the soil is periodically flushed of salts.

Although the total mineral content varies from a low to high salinity hazard from farm to farm in the Blue River Basin, the average would be in the medium range. This calls for a leaching requirement of 10-15 percent additional water above crop requirement. This may be provided by precipitation most years but added irrigation water may be needed for this purpose. This would occur when rainfall plus irrigation is only equal to or less than the water needed for crop requirement plus the 15% leaching requirement.

An alkali hazard may also exist in localized areas such as central Saline County. Chemical amendments with additional leaching may be needed to counteract this problem. On these farms it may be necessary to apply 30% more irrigation water to meet leaching needs.

WATER USES

Most row crops will use from 23-31" net water from planting time through harvest in the evapotranspiration process. This requirement would be supplied partly by effective rainfall and the remainder by irrigation water.

Research by the Agronomy Department, University of Nebraska, showed an increase of crop consumptive use of approximately 1" of additional water when adequate fertilizer was applied for maximum yields of corn, grain sorghum and wheat. This increased crop consumptive water use, however, is more than offset by the increased efficiency of soil water in producing grain as shown in Table 3.

Table 3

MEAN CWT PRODUCTION PER INCH OF WATER CONSUMPTIVELY BY CROP

	No Fertilizer	Fertilizer Applied	% Yield Increase
Corn	2.98 cwt.	4.26 cwt.	43
Grain Sorghum	2.99	3.81	28
Wheat	1.41	1.58	12

Good fertilizer practices means more cwt of grain from the water applied and is therefore a good practice for gaining the most benefit from our water resources. The research on which Table 3 is based also showed that additional water was needed when the crop was adequately fertilized. One additional inch of water, for example, was required to increase the yield of corn from an average of 91 bushels to 133 bushels per acre. Nebraska agricultural statistics show that in 1965 average yields of irrigated corn were 96 bushels in the East and South regions.

If we assume that 95% or 603,980 irrigated acres of corn and sorghum for grain in the Blue River Basin are not reaching yields of at least 130 bu. per acre, but have the possibility to do so with fertilization, then additional water will be consumed. This demand may be translated from 1" per acre into 50,331 additional acre feet of water potentially needed annually for the area. This estimate is conservative because a few irrigators are already reaching 180-200 bushels of corn per acre. No data on water use by the additional yield increment is available. It may be possible that in the next 10 years the need could expand. It would be a matter of conjecture whether an increased amount of water will be consumed by the higher crop yields or whether advances in technology and genetics will increase efficiency of the water consumed.

Alfalfa is grown on approximately 22,146 acres in the Basin. According to estimates, yields are about 5.0+ T per acre representing a current need for about 25 inches of water per acre. If yields were improved to the 6-8 T level an additional 5-15 inches of water per acre would be needed. Assuming all alfalfa acres were to increase to approximately a 7 T yield, a need for 10 additional inches of water per acre might reasonably be expected. Translated, this could mean a demand for 18,455 additional acre feet for the growing of top yielding alfalfa crop.

Water uses on remaining irrigated crop acreages of silage crops, sugar beets, soybeans, etc. can be expected to increase slightly as varieties and yields improve. No evidence, however, has been obtained to enable estimation of added water needs for those acreages.

POTENTIAL WATER SAVING - DISCUSSION

Although good irrigation management practices are at a moderate level of use in the Blue River Basin additional water saving can be achieved on many irrigated farms. It is important that correct irrigation land levelling practices be continued. However, the use and improvement of the following irrigation management practices will assist in additional water saving.

1. Pipe conveyance of water from supply to field distribution point.

2. Soil moisture sensing devices for irrigated fields.

3. Irrigation water runoff-recovery and reuse systems for all.

4. Adequate design of sumps and reservoirs to minimize evaporation.

5. Tillage practices which minimize soil evaporation and reduce compaction.

The irrigation water runoff recovery and reuse system at this time appear to offer the greatest and most feasible potential for total basin wide saving of the available water supply. For this reason the following estimates are offered for consideration. Table 4 estimates are based on the goal of 90% farm irrigation efficiency and these assumptions: (a) recovery and reuse systems for surface irrigation and use of sprinklers will reduce irrigation runoff to

zero. (b) closed piping systems will be used, (c) irrigation water loss under recommended reuse system practices will not exceed 10% of delivery to the field, (d) annual irrigation water need as computed by the U. S. Bureau of Reclamation .85 feet per acre + .085 (10%) = .935 ft. per acre annual water need, (e) table 2 estimates are near actual figures, (f) sprinkler irrigation accounts for 25,000 acres of the 712,733 irrigated crop acres as reported by the Economic Research Service leaving 687,733 acres irrigated by surface methods, (g) irrigators using a specific management practice in table 2 have equal irrigated acreages.

Table 4

Potential Annual Irrigation Water Saving with Reuse System

Compared to Estimated Present Use, Blue River Basin*

Irrigation Management Practice(Table 2)	Acreage	Acre Feet of Irrigation Water, Annual		
		Present Use	Future Need	Potential Saving
1	68,773	77,163	64,303	12,860
2	247,584	312,451	231,491	80,960
3	309,480	318,455	289,364	29,091
4	61,896	57,873	57,873	0
TOTAL	687,733	765,942	643,031	122,911

* Based upon farm irrigation efficiency. Runoff water may not be lost entirely to the basin because of seepage or redistribution of runoff water at some point downstream.

The saving of water by better management could more than offset the estimated additional 50,331 acre feet for grain and 18,455 acre feet for alfalfa which may be needed in the near future for top production.

RECREATION, FISH AND WILDLIFE SECTION PREPARED BY
THE NEBRASKA GAME AND PARKS COMMISSION

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I. INTRODUCTION

Outdoor recreation has recently received much needed recognition as an important element in social progress. This awareness has stimulated the inclusion of recreational benefits in most resource planning and development projects. In view of the fact that many outdoor-recreation activities are water oriented and demand for these activities is increasing rapidly, water resource development programs provide an excellent opportunity to satisfy a substantial part of the burgeoning recreational demand. In addition to the actual use of water for outdoor recreation, it also enhances use of adjacent land for other activities.

The primary emphasis of this study is on those outdoor-recreation activities most commonly associated with water resources. These activities include swimming, boating and water-skiing, camping, picnicking, hunting and fishing. Recreational activities other than those oriented to water, however, do satisfy part of the demand. Thus it is necessary to consider all phases of outdoor recreation in the Blue River Basins in an attempt to determine how the demands are being and can be satisfied.

This report is an attempt to draw together all the available information on the recreational aspects of the Blue Basin. Each major activity is considered as to the present status of recreational opportunity being provided, and what future needs will be in view of rapid population and socio-economic changes. Except for those developments provided by the private sector, information is sufficient to make reasonable estimates of supply, demand, and need. Estimation techniques and sources of data are described under section 1, Demand.

An evaluation of the fish and wildlife resource and its use is considered separately from the "simple pleasurers" of driving, walking, picnicking and sightseeing, and those activities requiring high-density development such as outdoor games and sports

and swimming. Although it is obvious that a high degree of interdependence exists among all outdoor activities, the infinite variety of factors effecting the maintenance and use of the fish and wildlife resources necessitates separate and additional discussion.

The combined area of the Big and Little Blue River Basins is some 7,231 square miles or 4,628,200 acres. The Blue Basin drains all of Clay, York, Fillmore, Jefferson, and Thayer counties and parts of 14 other counties in Nebraska. Both river systems arise in the loess plains of south-central Nebraska and flow east and south to a convergence in Marshall County, Kansas. For purposes of this study, only that area of the basin within Nebraska has been considered.

The economy of the Blue River Basin is intimately tied to agriculture. Approximately 95 per cent of the area is considered agricultural lands of mostly diversified family-sized units. Corn, wheat, sorghum and livestock contribute most to the basin's agricultural economy. Deep well irrigation is well established and is a prime factor in the economic growth and stability of the area.

Less than five percent of the land is in forest which is limited almost entirely to the major stream courses. This fact alone suggests the critical lack of basic recreational resources that exist within the Blue River Basin.

The 1960 population, estimated by counties from the U. S. Census of Population, was 165,665 or a population density of 23 persons per square mile. The statewide population for Nebraska was 19 persons per square mile. Like the rest of rural Nebraska, the rural farm population is undergoing a slow, but a steady, decline. An increase in rural non-farm and urban populations, however, have combined to hold the overall population at a relatively static level. (See Table I). The rural to urban shift in in-basin population is expected to continue. Overall population growth however, is expected to accelerate with the current trend in industrial decentralization. Industry

should assume an increasingly important status in the rural economy.

TABLE 1: POPULATION DISTRIBUTION BY RESIDENCE: BLUE RIVER BASIN

Place of Residence	Population			% Population		
	1950	1960	1980*	1950	1960	1980
URBAN	53,898	55,619	71,200	30.9	33.6	40.5
RURAL NON-FARM	54,557	60,299	66,400	31.2	36.4	37.8
RURAL FARM	66,375	49,747	38,100	37.9	30.0	21.7
TOTAL	174,830	165,665	175,700			

* 1980 population estimates supplied by the Soil Conservation Service.

II OUTDOOR RECREATION

A. Supply:

The supply of outdoor recreation resources in the Blue River Basin is critically short. Public areas designated for outdoor recreation include only 0.14 per cent of the total land area. This amount of land must not only serve over 165,000 people living within the Basin but must also serve the many visiting people from the metropolitan area of eastern Nebraska and the nation.

Not only is the problem one of number of acres but of effective acres. This location at considerable distances from major population centers limits the benefit to a large number of people who would otherwise use the area. Also, each recreation area has its own unique set of conditions which may limit certain types of outdoor recreational activities. In addition, it is doubtful that more intensive use can be realized without destroying the quality of the outdoor experience.

Ideally, a balance of all types of opportunity should be available. However, real limitations are presented simply on the basis of lack of suitable land and water areas in public ownership.

The supply of recreation areas includes those areas under federal, state, or municipal ownership that are available for recreational use. Recreational supply data will be discussed as to the amount of land area and its principal use under each ownerhsip category.

1. Municipalities:

An inventory of outdoor recreation facilities being provided by municipalities is presently underway in Nebraska. In the Blue River Basin, data for 32 of 148 communities are available on the number, size, and principal use of outdoor recreation areas under the ownership of municipalities (See Table II). For the purpose of this report, it is assumed that other municipalities upon which an inventory has not been made do not significantly differ in the amount and types of outdoor recreation facilities provided. Pending completion of the inventory, this is the best information available. The Nebraska Department of Health provided information on Quasi-public and municipal swimming pools.

Data were tabulated by population class of the community to conform to the Nebraska Comprehensive Outdoor Recreation Plan.[1] These classes are villages (Less than 1,000 population, Class II cities (1,000 to 5,000 population) and Class I cities (5,000 to 25,000 population).

The state comprehensive outdoor recreation plan[2] also provides minimum standards for each size community. Villages should have at least 25 acres of recreational lands for each 1,000 population; Class II cities at least 20 acres per 1,000 population; and Class I cities at least 15 acres per 1,000 population.

Population data for 1960 were used to determine the acres of recreational land needed by each community. For most communities in theBlue River Basin, the resultant

[1]Nebraska Game, Forestation and Parks Commission, 1965. Outdoor Recreation for Nebraska.

TABLE II: SUMMARY OF MUNICIPALLY OWNED OR ADMINISTERED RECREATION AREAS IN THE BLUE RIVER BASIN

	Villages	Class II Cities	Class I Cities	Total
Number of municipalities in Basin	129	16	3	148
Number of municipalities in inventory	23	9	2	34
Number of municipal recreation areas in inventory	25	25	20	70
Number of acres of municipal recreational land in inventory	68.6	317.3	256	642
Projected number of acres of municipal recreation land[3]	387	565	339	1,291
Average number of acres per community	2.98	35.3	85	
% with no lands	22%	0%	0%	
% with deficiency	86%	67.7%	100.0%	
Most common uses of municipal lands (rating 1-3)				
GAMES & SPORTS	1	1	1	1
PICNICKING	2	2	2	2
SWIMMING	3	3	3	3

[3]Projected acres obtained by multiplying 2.98 (average acres/community inventoried) by total number of communities in basin.

ratio of land area to population should provide a slightly conservative approximation of conditions as they exist in 1966.

a. Villages:

The inventory of 23 of 129 villages within the Blue River Basin provided information on 25 recreation areas. Five or 22 per cent of 23 villages do not own or administer recreational lands (See Table II).

Thirteen per cent of the sampled villages have sufficient lands to meet the minimum requirements of 25 acres per 1,000 population. Again assuming the sample is representative, approximately 17 of 129 villages have sufficient lands and 112 or 87 per cent of the total number of villages are presently deficient.

Most of the areas administered by villages are quite small, ranging in size from one-fourth to nine acres. Seventy per cent are less than five acres. Assuming that the sample is representative of all villages in the Basin, approximately 387 acres of municipal lands are owned or administered by 129 villages and available for outdoor recreation.

Picnic facilities and play fields are the only significant facilities provided by villages. Sixty per cent of the villages inventoried have them. Only three (13%) villages provide swimming pools.

b. Class II Cities:

An inventory of recreation facilities has been made in nine of 16 Class II cities. All have recreational lands under their administration, which vary in size from two to 108 acres with an average of 35.3 acres per community. If the sample is considered representative, approximately 565 acres of municipal recreational lands are presently owned by cities of this category.

Thirty-three per cent of the sample cities have sufficient lands to meet the minimum standard of 20 acres per 1,000 population. This would indicate that approximately five of 16 cities of the second class have sufficient land to meet minimum needs.

All cities of this category have picnic and play field areas. Eighty-eight per cent have swimming pools, and 38 per cent have some fishing water and ice skating facilities. Two communities have camping facilities.

c. Class I Cities:

There are four cities within the Blue River Basin that have a population exceeding 5,000. An inventory is complete on Hastings (pop. 21,412); Beatrice (pop. 12,132), and York (pop. 6,183). No information is available from Fairbury (pop. 5,572).

Hastings owns ten areas for a total of 152 acres. For a city of this size, 169 additional acres are needed to meet minimum needs. Beatrice owns or administers 104 acres, and has a deficiency of 78 acres. York has four areas totaling 33.5 acres and has a deficiency of 59 acres. All Class I cities have at least one public or quasi-public swimming pool.

Picnic facilities and play fields were again the most common facilities provided. Swimming and ice skating were also popular activities.

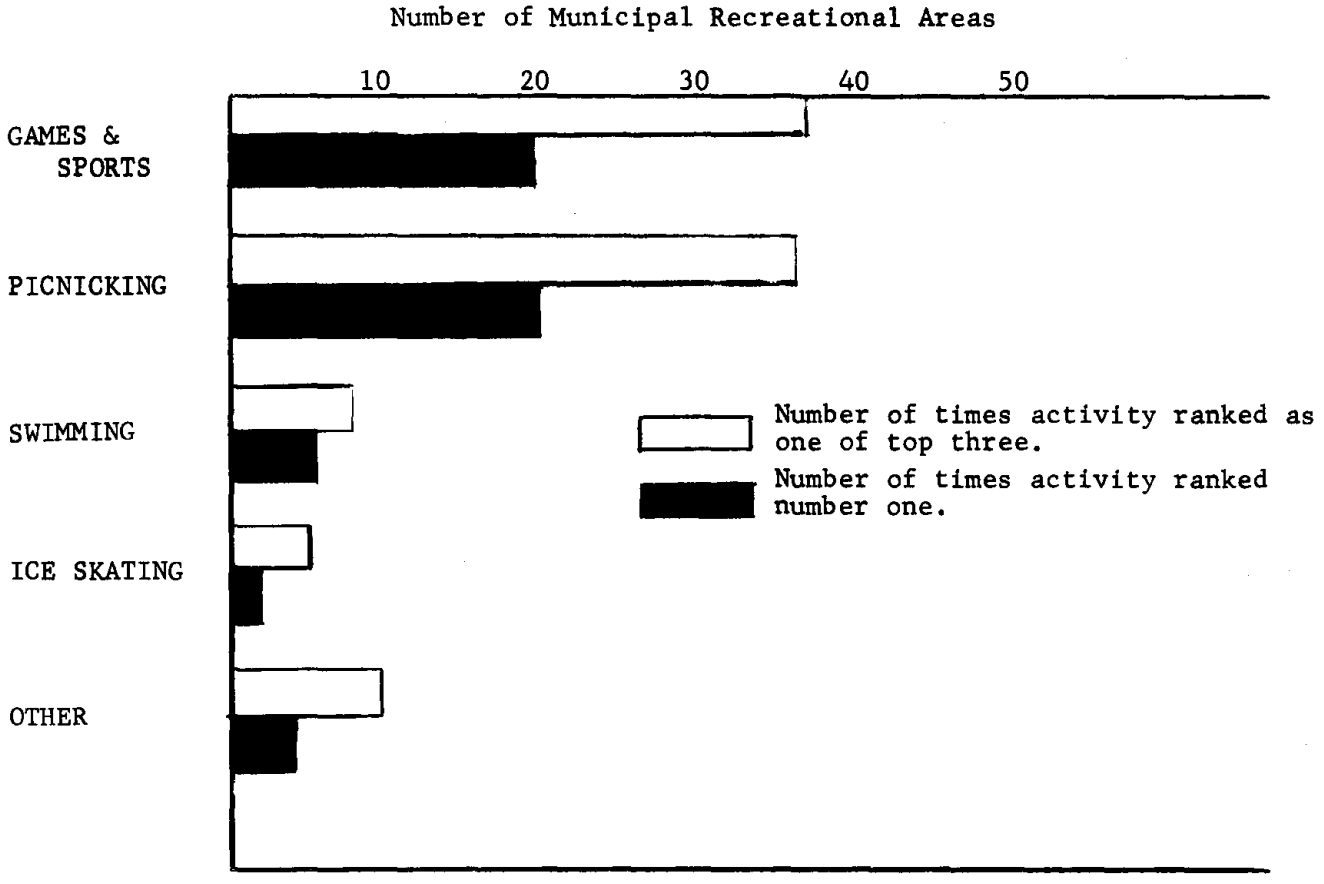
SUMMARY:

In all classes of municipalities in the Blue River Basin, inventory data based on the types of activities provided on recreational lands indicated that participation in games and sports and picnicking are by far the dominant activities (Figure 1). Swimming and ice skating were next in importance. Other activities account for only a small portion of the outdoor recreation opportunity provided by municipalities in the Blue River Basin.

An estimated 1,291 acres of outdoor recreation lands are owned or administered by municipalities in the Blue Basin. Approximately 387 acres are controlled by villages, 565 acres by cities of the second class and 339 acres by cities of the first class. Twenty-one villages and cities have public or quasi-public swimming pools totaling 148,908 square feet of surface area.

The provision of certain types of facilities can be correlated to the size of the cities and is related to economics. Most small towns do not have adequate funds for

FIGURE 1. ACTIVITIES PARTICIPATED IN BY MOST PEOPLE OF 56 MUNICIPAL RECREATION AREAS



providing high cost facilities such as swimming pools. However, most villages can provide at least one small park or play field.

2. State:

Within the Blue River Basin, the Nebraska Game, Forestation and Parks Commission owns ten areas totaling 874 acres. Included are two recreation areas, four special use areas, and four wayside areas (See Table III).

a. State Wayside Areas:

State Wayside Areas are those areas located at strategic intervals adjacent to main highways to provide safe rest and picnic stops for travelers. They are selected for scenic or historical interest when possible, equipped with safe entrance and exit

TABLE III: CLASSIFICATION OF STATE OWNED NON-URBAN LANDS IN BLUE BASIN

	Acres Recreational Land Class*			Type Area (Acres)		
	I	II	III	Land	Wetlands	Water
American Legion SWA	7			7		
Blue River SWA	14			14		
Blue Valley SWA	9			9		
Cross Trails SWA	7			7		
Alexandria SRA		95	345	408		32
Crystal Lake SRA		63		33		30
Shady Trail SUA			7	5		2
Blue Bluffs SUA			7	4		3
Pintail Marsh SUA			280		280	
Smartweed Marsh SUA			40		40	
TOTAL	37	158	679	487	320	67

* Class I Areas - High Density Recreation
Class II Areas - General Outdoor Recreation Areas
Class III Areas- Natural Environment Areas

lanes, and developed with such facilities as are appropriate to their purpose. The number of state wayside areas depends upon major routes of traffic movement. Area population is not necessarily a factor in their location.

Within the Blue River Basins, the state owns four wayside areas totaling 37 acres. Location and primary purpose of wayside areas demand development for high density use. The primary developments are picnicking and camping facilities.

b. State Recreation Areas:

State Recreation Areas are defined as those areas with a primary value for day-use, but with secondary overnight-use facilities. Two of these areas, totaling 503 acres are located within the Blue River Basin watershed. In breaking land-use down

to specific activities, these areas provide a total of 15 acres camping grounds, 20 acres of picnic grounds, nine acres of ice skating area, and two acres of play field. About two-fifths of the land area in this category has been classified as general outdoor recreation and three-fifths as natural environment.

Both Crystal Lake and Alexandria State Recreation Areas provide opportunities for camping, picnicking, fishing, and non-power boating. Both areas are open to hunting after October 1st each year. The only land managed specifically for game, however, is on the Alexandria area.

c. State Special Use Areas:

These areas are defined as those areas which are primarily of hunting, fishing, or other wildlife values. To date, there are four special use areas totaling 334 acres within the Blue River Basin. All are classed as natural environment areas.

The seven-acre Blue Bluffs and the seven-acre Shady Trails Special Use Areas have picnicking and primitive camping facilities. Their primary use, however, is to provide public fishing access to the Big Blue River.

Both Smartweed and Pintail Marsh Special Use Areas are rainwater basins, managed primarily for the production and harvest of wildlife. No day use facilities are provided.

SUMMARY:

In all classes of state owned lands in the Blue River Basin, 37 acres are managed for high density recreation (Class I), 158 acres for general outdoor recreation (Class II), and 679 acres for natural environment areas (Class III), for a total of 875 acres or .019 per cent of the Blue Basin's total land area.

State Wayside Areas provide only picnicking and camping facilities. Their

primary purpose is to serve the traveling public. State Recreation Areas provide a broad spectrum of activities with camping and picnicking being the most dominant. They also provide ice skating, boating, play field, hunting, and fishing opportunities depending upon the area's resources.

Special Use Areas in the Blue River Basin provide a rather limited opportunity for outdoor recreation other than hunting and fishing.

3. Federal:

Similar to the state-wide situation in Nebraska, there is little federal ownership of land in the Blue Basin, and a still smaller portion upon which outdoor recreation opportunity, other than hunting, is available. The only federally owned high density development in the Blue Basin is Homestead National Monument. Interpretive facilities provide historically significant information on the development of the Nebraska Territory.

In an area roughly synonymous with the Little Blue Basin, the Bureau of Sport Fisheries and Wildlife, U. S. Department of Interior, has purchased and manages 21 rainwater basin areas totaling 6,250 acres of land and water for waterfowl production. Other than their unique value for nature enthusiasts, primary recreational use is for waterfowl and upland game hunting. Severe seasonal and annual fluctuation in water levels, and their shallow nature prevent boating, swimming, and other water-based activities.

4. Private:

An inventory of recreational opportunity on private lands has not been attempted. It is assumed, however, that the private sector provides little recreational opportunity to the general public, other than hunting and fishing. This assumption is based on the idea that private exploitation of outdoor recreation is closely related to resources of

high esthetic quality. Unfortunately, existing resources of this nature are rather limited in this portion of the state. Not only are large developments economically infeasible for the private sector, current resource related activities do not lend themselves to profit motives.

B. DEMAND:

1. Factors Affecting Demand:

Under the influence of many and varied factors, the demand for outdoor recreation is on the rise. Americans are seeking recreation as never before. There are more people, they want to do more, and have the time and money with which to do it. The Outdoor Recreation Resources Review Commission (ORRRC) estimates that the national population will double by the year 2000 and the demand for recreation will triple.

According to the data published in ORRRC Report 20, the activities most participated in are the simple pleasures, i.e., pleasure driving and walking. Together, they account for 42 per cent of the total activity. Following closely are playing games, picnicking, swimming, sightseeing, and fishing. Other activities requiring special skills and equipment such as scuba diving and horseback riding rank much lower in frequency. However, most of these activities rank very high in intensity of personal involvement.

Factors other than the effect of population growth, must be considered in recreation demand. Age, obviously, plays an important role in personal selection of recreational activity. The older people get, the less they participate, especially in the more active pursuits. Income, education, and occupation have discernable effects upon participation rates. Participation increases as income and education levels rise. Professional people participate more than the unskilled.

Place of residence plays an important part in recreational demand, both from

the standpoint of total participation, and types of activities participated in. Urban residents generally participate in less total recreational activity than do rural and suburban residents. Rural and suburban people pursue camping, fishing, and particularly hunting. Based on participation, city people seem to favor picnicking, driving, and swimming.

In the Blue Basin, the factors ffecting demand, although similar to the regional picture, are modified slightly to fit area social and economic considerations. The most important modifying influnces affecting Basin demand are place of residence and the critical lack of certain types of quality resources.

Less than 25% of the Basin population is centered in cities over 5,000 population. Therefore, the opportunity to be out-of-doors with little time and effort in available to all persons. However, the lack of quality recreational resources, primarily quality scenic and water resources, does not permit many people to pursue certain activities.

This points up the factor of latent demand. There is little question that the availability of an improved recreation resource would greatly increase participation in related activities. Perhaps present participation rates in an activity as a measure of demand may be in error altogether.

2. Estimation Procedure:

The first data needed for calculating area demand were population projections (age 12 and over). The projections for the in-Basin population were obtained from the Economic Research Service, U.S.D.A. Those for cities outside the Basin (Columbus, Fremont, Grand Island, Kearney, Lincoln, and Omaha) were furnished by the Nebraska Soil and Water Conservation Commission. It was assumed that the age structure of the 1980 population would not greatly change. Therefore, the same percentage of the population (age 12 and over) derived from the 1960 census data was used for 1980 projections. To satisfy the out-of-Basin population recreational demand felt within the

ational facilities and the amount of land lying in the Basin which is within 1½ hours driving time (two hours from Omaha) from the respective cities i.e., the area of influence. The driving time factor is consistent with that expressed in the Nebraska Comprehensive Outdoor Recreation Plan. Multiplying the estimated percentages by the projected population indicated the demand of those cities outside the basin which is to be satisfied within the Basin (See Table IV). For this study, rural populations and populations for cities under 10,000 outside the Basin, but within the area of influence, were not included.

The most useable expression of recreational demand is activity days. To find the seasonal Blue Basin activity day demand for major outdoor recreational pursuits, participation rates for the North Central Region[4] taken from Outdoor Recreation Resource Review Commission Reports 19 and 26 were used. The seasonal rates per population group (in SMSA urban, not in SMSA rural, not in SMSA rural non-farm, not in SMSA urban) were multiplied by preference factors.[5] The product was then added to the seasonal rates giving the rates adjusted for preference. The "preference factor" considers the percentage of the population which doesn't participate, but would if not for one or more of six reasons. The reasons given were crowded, inadequare, or distant facilities; and the lack of equipment, money, or time.

The adjusted rate for preference was then multiplied by the "socio-economic adjustment factor"[6] i.e., the influence of income, education, occupation, residence, age-sex, and leisure.

By adding this product to the "adjusted" rate for preference, the "projected per capita participation rate," was derived. The projected participation rate was then multiplied by the number of persons within the respective population groups,

[4]ORRRC Report 19, pages 122 - 179.
[5]Ibid., Pages 179 and 303.
[6]ORRRC Report 26, page 28, Table 11.

TABLE IV: TOTAL POPULATION (1960, 1980) AFFECTING RECREATION DEMAND IN BLUE BASIN

	1960 Pop. 12 & over	1980 Pop. 12 & over	% Demand Satisfied in Basin	1960 Pop. Satisfying Demand in Basin	1980 Pop. Satisfying Demand in Basin
OUTSIDE BASIN					
Omaha SMSA	352,560	539,000	5%	17,628	26,950
Lincoln SMSA	119,559	161,700	15%	17,934	24,255
GRAND ISLAND	19,821	27,720	10%	1,982	2,772
Fremont	15,167	20,020	3%	455	601
Kearney	10,942	14,630	3%	328	439
Columbus	9,607	12,320	10%	961	1,232
Sub-Total	527,656	775,390		39,288	57,249
BLUE BASIN					
Rural Farm	38,305	29,337	100%	38,305	29,337
Rural Non-Farm	46,430	51,128	100%	46,430	51,128
Urban	42,827	54,824	100%	54,827	54,824
Sub-Total	127,562	135,289		127,562	135,289
TOTAL	655,218	910,679		166,850	183,811

resulting in the number of activity days for each recreational activity for 1960 and 1980 during the peak season of use. Table V illustrates the total seasonal activity day demand for 1960 and 1980 ranked in order of greatest demand. A detailed summary of derivation methods, ORRRC rates, and activity day demand are given in APPENDIX A.

a. Participation:

According to the ORRRC rates for the North Central region, the demand for the simple pleasures (driving and sightseeing, walking, picnicking) will continue to be of great quantitative importance as common recreational activities. Active pursuits ranking especially high are swimming, and playing outdoor games and sports. Also

TABLE V: 1960 AND 1980 ACTIVITY DAY DEMAND

ACTIVITY	SEASONAL ACTIVITY DAY DEMAND 1960	1980	ACTIVITY
Driving and Sightseeing	1,219,364	1,743,913	Driving and Sightseeing
Swimming	732,686	1,054,281	Swimming
Playing Outdoor Games & Sports	683,782	1,045,551	Playing Outdoor Games & Sports
Walking for Pleasure	563,246	797,696	Walking for Pleasure
Bicycling	337,340	466,659	Picnicking
Picnicking	334,822	403,496	Bicycling
Viewing Outdoor Games & Sports	261,311	379,422	Boating
Boating	224,647	374,497	Viewing Outdoor Games & Sports
Ice Skating	159,423	355,331	Ice Skating
Nature Walks	123,637	175,218	Nature Walks
Horseback Riding	94,186	120,474	Camping
Camping	65,959	102,628	Sledding
Sledding	40,786	88,350	Horseback Riding
Attending Outdoor Concerts	37,202	66,050	Water-Skiing
Water-Skiing	31,306	58,604	Attending Outdoor Concerts
TOTAL	4,909,697	7,232,170	

ranking high are bicycling, boating, and ice skating. The demand for water-skiing and sledding, although ranking low in comparison to other activities, shows the greatest projected increase in demand. The calculated demand for sledding is to increase 60.3 per cent and water-skiing, 52.4 per cent. Of the more common recreation activities, only ice skating shows an increased demand of this magnitude.

It should be understood, however, that present and future demand derived by this method is only as good as the relationship of the factors affecting Blue River

Basin demand to those determined for the North Central region by ORRRC.

b. Design Load:

Methods developed for the Missouri River Basin Recreation Task Force were used in an attempt to calculate outdoor recreational requirements for land and water. First, the activity day demand was converted to design load (See APPENDIX B). The design load is the approximate amount of activity a site can reasonably accommodate at any given time. Calculation of design load required that the percentage of weekly use occurring on a normal Sunday, the turnover rates, and the length of season be estimated. The design load was then applied to standards used by the Missouri River Basin Recreation Task Force for boating, water-skiing, swimming, camping and picnicking, i.e., those activities requiring specific land and water areas (See Table VI). Many of the other outdoor activities can be associated with and are complementary to resource-oriented recreation and require additional non-urban lands.

By using these standards, the acre demand for boating, water-skiing, swimming (pools and beaches), camping, picnicking was derived for the Blue River Basin for years 1960 and 1980 (See Table VII).

The 1960 acre demand for water for boating, water-skiing (excluding a 300 ft. zone around shoreline), and swimming (beach) was 5,792 acres. By 1980, the demand will increase by 44.3 per cent to 10,404 acres.

The combined acre demand in 1960 for land area for camping and picnicking was 386 acres and, by 1980, 873 acres will be demanded. This excludes the space necessary for roads, toilets, play fields, and other miscellaneous use coincident with camp and picnic ground development.

TABLE VI: MISSOURI RIVER BASIN TASK FORCE STANDARDS FOR DESIGN LOAD CALCULATION

Activity	% of weekly demand occuring on an average Sunday	Daily Turnover Rate/Unit	Length of Seasons (Weeks)	Calculated Design Load (in Activity Days) 1960	1980
Boating	60%	1.5	14	6,419	10,841
Water-Skiing	60%	1.5	14	895	1,886
SWIMMING					
Pools	60%	1.5	14	20,933	30,122
Beaches	60%	1.5	14		
Camping	50%	1.0	14	2,356	8,605
Picnicking	60%	1.5	14	9,556	13,332
TOTAL				40,159	64,786

TABLE VII: BLUE RIVER BASIN: 1960 AND 1980 ACRE DEMAND

Activity	Unit Use Standards	Acre Demand 1960	Acre Demand 1980
Boating*	3 persons/Boat 2 acres/Boat	4,279	7,227
Water-Skiing*	3 persons/Boat 5 acres/Boat	1,491	3,144
Swimming:**			
Pools	80% of total occasion 25 ft.^{2}/Swimmer	9.3 (405,945 ft.^{2})	13.4 (584,910 ft.^{2})
Beaches	20% of total occasions 150 ft.^{2} water/swimmer 75 ft.^{2} beach/swimmer	22.0	33.0
Camping	4 persons/Unit 4 sites/Acre	147	538
Picnicking	4 persons/Unit 10 units/Site	239	333
TOTAL		6,187.3	11,288.4

* These figures exclude the 300 ft. band around the shore zoned against these uses except at access points (SCS).

** Percentage of total occasions for pools and beaches is that used by the Missouri River Basin Task Force. The 25 ft.^{2}/swimmer for swimming pools is the Nebraska Game, Foresation and Parks Commission estimate. The area/swimmer for beach swimming was supplied by the SCS.

C. Needs:

1. General:

A comparison of the existing supply and the calculated demand show a great need for outdoor recreation facilities. The supply and demand given includes both urban and non-urban lands. A measure of quantity, however, does not tell the complete story. Quality or physical character of the resource is a value that must not be forgotten.

The location of outdoor recreation sites depends largely upon the activities desired. In this regard, the concept of mobility must be considered as people will travel a greater distance for some outdoor experiences than for others. As an example, people, in general, will travel farther for quality hunting, fishing, and boating than for picnicking. Therefore, recreation areas, especially high density use areas, should be accessible to the greatest number of people possible. For the Blue Basin, location of recreational lands near Interstate 80 would be most desirable due to the shortened driving time from the state's population centers.

Quality water begets quality recreational experience. For all practical purposes, no water is available in the Blue River Basin to meet the huge demand for boating and water-skiing. To meet this demand, sizeable reservoirs could be developed in the Blue Basin and, fortunately, several of the most favorable sites are located in the eastern and northeastern portion of the Basin, i.e., that portion nearest the greatest population. The water confined by the dams, however, might be less than optimum quality for all water-based activities. The high proportion of cultivated land above suitable impoundment sites presents the problem of silt laden run-off. Also, certain basin soils have a tendency to remain in suspension; thus, creating a turbidity problem which may greatly reduce water quality. Additional pollution from agricultural pesticides and fertilizers and municipal sewage may create problems. Problems caused by silt and chemical pollution have quite subtle limnological effects

not easily measured and not well understood. None-the-less, water quality and thus recreation benefits, are lowered by these factors.

Regardless of the problems involved in providing water quality control on large reservoirs, they do provide the best opportunity for power boating and water-skiing. In addition, they usually have sufficient lands adjacent to water to provide for a multitude of land based activities.

Although certain activities, such as power boating and water-skiing, are limited on small reservoirs, small watershed projects could provide more opportunity for most activities simply due to a wider distribution. Most demand is local and, ideally, local demand should be satisfied first. Furthermore, these small impoundments can provide a well balanced recreational experience and, in general, a higher quality of water.

Land based recreation activities also require quality resources even for the most intensive uses. Wherever possible, recreational development of land facilities should coincide with water resource development projects. This not only would provide an opportunity to satisfy most of the recreational needs of the most people, but would supply a basic and demanded resource in an area that has no outstanding recreational attraction.

2. Municipal:

According to standards prescribed in the Nebraska Comprehensive Outdoor Recreation Plan,[7] municipalities within the Blue Basin are far short of the needed amount of recreational lands. Only 25 of 151, or 16 per cent, of all communities meet the standards of 25, 20, and 15 acres per 1,000 population for villages, Class II, and Class I cities respectively. In addition, this insufficiency, if not met, will create a greater demand for non-urban facilities.

[7]Nebraska Game, Forestation, and Parks Commission, 1965. Outdoor Recreation for Nebraska.

Most municipalities provide only picnic and play field facilities. Therefore, as well as a basic need for additional lands, the provision of facilities for other activities is needed.

There are 148,908 square feet of public or quasi-public swimming pool space provided within the Blue Basin. Therefore, the deficiency in 1960 was approximately 257,000 square feet. By 1980, 436,000 square feet of pool space will be needed.

In the future, the need is expected to increase at a rate greater than population growth. Most municipalities will grow with the continuing shift of the population from the farm to towns and cities. This will increase the importance of municipal recreation areas.

3. Non-Urban:

Non-Urban recreational lands and waters are likewise insufficient to meet current needs. There is a deficiency of land for all recreational categories. The needs for each activity are broken down as to what the average maximum use would be for a normal Sunday during the peak season, i.e., design load. For 1980, estimates of needs are also given. No attempt was made, however, to estimate how much land and water might be added by such things as Corps of Engineers or Bureau of Reclamation projects authorized but not now under construction, and State and local agency construction comtemplated. Thus, the 1980 calculated need may be liberal. The demand and supply calculation are given as acre demand converted to acre needs for 1960 and 1980 and summarized in Table VIII.

These calculations indicate that about 5,792 surface acres of water were needed to meet the 1960 demand for boating, water-skiing, and swimming. By 1980, 10,404 acres will be needed. Again, it must be emphasized that this acreage includes only that surface acreage suitable for these activities. For boating and water-skiing this would include only that water which is of sufficient depth and free of obstacles.

TABLE VIII: SUMMARY OF ACRE NEEDS FOR NON-URBAN LANDS AND WATERS (1960 AND 1980)

Activity	Supply	1960 Demand	1960 Need	1980 Demand	1980 Need
Boating	None	4,279	4,279	7,227	7,227
Water-Skiing	None	1,491	1,491	3,144	3,144
Swimming	None	22.0	22.0	33.0	33.0
Camping	28	147	119	538	510
Picnicking*	47	120	73	167	120
TOTAL	75	6,257	5,984	11,109	11,034

* Approximately 50 per cent of the picnicking need should be met by municipalities. The calculated demand and need represented here is only that related to non-urban lands.

In addition to acres of water, such related land-based facilities as launching ramps and parking areas are necessary. Obviously, the magnitude of need for this additional land requirement is very substantial. For swimming, the more critical land needs are for such facilities as beaches, change houses, and parking areas.

Picnicking and camping are activities not directly dependent on water, although they are greatly enhanced by it. Land is the necessary resource, with water being complementary. Total land need for camping and picnicking is 192 acres for 1960 and 630 acres for 1980. These must be acres in addition to those already available. An inventory of non-urban lands indicates that expansion of existing facilities would be something less than desireable since further development of these areas would erode the value of the outdoor experience. Essentially, we would be providing for municipal type of recreation and destroying the natural setting which is the basic attraction of non-urban lands.

D. Conclusions and Recommendations:

This section will sketch in general terms the major items that should be considered by action agencies when formulating detailed management plans.

One of the most dominant features of the Basin influencing recreational demand, is unequal population pressure. Approximately 34 per cent of the Basin's population is centered in Adams County, located on the extreme western edge of the Basin, and Gage County, located on the extreme southeastern edge of the Basin. Saline, Seward, and York counties have moderate population densities, but the recreation demand in these counties is considerable due to the close proximity to the states population centers and Interstate 80.

User pressure on these portions of the Basin makes it important that their recreation needs receive prime consideration. Short-term use facilities, especially camping and picnicking facilities associated with water, could help a great deal in providing for the needs of the higher proportion of urban residents in Adams and Gage counties and the increase in demand associated with Interstate 80 in Seward, Saline, and York counties. Local agencies -- municipal and county -- should be encouraged to provide these facilities wherever possible. Financial assistance is available, usually on a matching basis, from several federal agencies (See APPENDIX B).

The state government, cooperating with federal agencies, will be required to contribute heavily to the more extensive acquisition and development projects. Unfortunately, the need is so great that the state cannot begin to provide and maintain facilities to meet all the demand. If the demand is to be met, local governments must play a larger role. The state can provide more and better facilities if maintenance is assumed by local governments.

Although many local governmental units may be reluctant to undergo the expense of providing recreational facilities, they can provide a great service to the public by giving careful consideration to planning and zoning. In the Blue Basin, the prevention of industrial, residential, and possibly agricultural development within the flood plains of the rivers would help to insure that one of the Basin's better recre-

ational resources is not lost. For much of the Basin, the wooded flood plains are the only existing areas where quality outdoor recreation sites can be found. The flood plain can provide quality outdoor experience without extensive and costly development. It is a mistake to rely exclusively on extensive water resource development such as the reservoirs to serve the recreating public, when valuable existing resources go unnoticed, unused, and are often destroyed.

Additional zoning restrictions could be placed on residential development above multi-purpose small watershed developments that are to be used for recreational purposes. A small amount of sewage can greatly reduce the water quality in small impoundments which have little or no overflow. Enrichment caused by waste accumulation may not only become unsanitary, it encourages growth of undesirable aquatic vegetation. Residential restrictions may extend the usefulness of a small watershed impoundment for many years.

Proposed watershed development projects will provide additional recreational opportunity in the Blue Basin. The Nebraska Game, Forestation and Parks Commission will participate wherever possible in the acquisition and development of these sites that are of exceptional value. One 150 acre reservoir and adjacent lands will be purchased within the Mud Creek Watershed in Gage County. It will be developed as a State Recreation Area as a pilot project in cooperation with S.C.S. and the local watershed district. This site will do much to alleviate the needs for this area.

The completion of the proposed Angus reservoir would provide a considerable amount of recreational opportunity. The use of ~~these~~ this reservoirs for irrigation purposes, however, will seriously reduce ~~their~~ its recreational value. Severe periodic fluctuation of water levels greatly affects the use of the shoreline for a multitude of purposes and makes fishery management difficult. The proposed Suprise, Shestak, Seward View and Beaver Crossing reservoirs, planned as a part of the Bureau of Reclamation Sunbeam unit, may offer opportunities for higher quality recreation if suffi-

cient land treatment is affected in the respective watersheds.

III. HUNTING AND FISHING

The fish and wildlife resource of the Blue River Basin is considered separately from the other major outdoor recreational activities. Close examination of data presented in ORRRC Study Report 20[8] makes it clear that many outdoor activities are interrelated and that a substantial, if not principal, portion of several recreational activities is closely related or is subordinate to the more traditional outdoor activities of hunting and fishing. The ORRRC Report 20 shows that 46 per cent of all persons over age 17 participate or wish to participate in hunting and fishing and, in many instances, other activities, such as boating, camping, and picnicking, are secondary. Misinterpretation of ORRRC data has led many people to believe that driving for pleasure, picnicking, and other passive pleasures have displaced hunting and fishing as key values in outdoor recreation. It is therefore necessary to re-emphasize the hunting and fishing aspect of outdoor recreation and not lose sight of these activities in recreational planning as a part of resource development in the Blue River Basin.

Under pressure of a growing population, with it's inevitable demands on lands and waters, a shrinkage in the capacity of the basin to produce certain forms of fish and wildlife is unavoidable. Improved planning and more intensive management of existing public lands and waters can increase production on some of these areas. However, only less than one per cent of the Basin's land area is in public ownership, and much less is available for accelerated wildlife management practices. It is evident that the lands and water presently in public ownership cannot be of significant importance in meeting the total demand for hunting and fishing. With limited funds available for acquisition of public lands and waters, a large percentage of present and future fish and wildlife production and harvest will have to come, as in the past, from the private sector.

[8]ORRRC Report 20, page 32.

Basin development will inevitably effect fish and game resources -- in some cases improving and in other cases damaging. In view of the importance of fishing and hunting in outdoor recreation, more consideration should be given to wildlife conservation in the planning and construction of land and water-use projects. There is no longer room for displacement of wildlife. It is a direct and irreplaceable loss.

A. Supply:

1. Fish:

The fisheries resource in the Blue Basin is entirely warm-water. A few lakes provide good catches of Largemouth Bass, Crappie, and Channel Catfish, but, these are few. Most of the current fishing pressure is related to the streams and the Big and Little Blue Rivers provide one of the best catfishing resources in the state. Thus, the streams of the Basin are very significant. Carp, Channel Catfish, Flathead Catfish, and Bullhead are the most important species.

a. Public Fishing Waters:

The city of Hastings owns a 72 acre lake as part of their parks and recreation system. Although this lake is heavily used for power boating and water-skiing, it receives a significant amount of fishing pressure from local residents.

The State manages lakes for public fishing on the Crystal Lake and Alexandria State Recreation Areas. The Crystal Lake area has three lakes totaling 30 acres. Only one small lake of six acres provides good fishing for Channel Catfish, Flathead Catfish, Bass, and Crappie. Another lake is stocked as a Carp lake and the third lake is used primarily for boating.

On the Alexandria area, three lakes are managed for fishing. An eight acre lake provides rough fish angling. Another lake of 12 acres has good Crappie, Bass, and Channel Catfish populations. The third lake of 25 acres has recently been

drained and restocked with Bass and Channel Catfish and should provide excellent populations of sport fish in a few years.

The state also operates two special use areas as access points to the Big Blue River. Both the Blue Bluffs and Shady Trails Special Use Areas are located at abandoned power sites and should offer excellent river fishing opportunity. This is especially so at the Blue Bluffs area where the old dam is still intact. Restoration of the dam at Shady Trails would probably increase the fishing pressure at this point.

b. Private Fishing Waters:

There are many small lakes and farm ponds in the Blue Basin. However, the Nebraska Game Commission estimates that only about 40 per cent of the farm ponds and 20 per cent of the grade control structures have fisheries potential because most are too small, shallow, turbid, or are used for other purposes not compatible with fisheries management. Also, many are not open to the public. None-the-less, farm ponds can and do provide an important source of fishing opportunity to local residents.

The rivers and streams of the basin, mainly the Big Blue and Little Blue, are privately owned. Where access is permitted, fishing pressure is heavy. Excellent populations of Channel Catfish and Flathead Catfish provide good fishing opportunity to thousands of fishermen a year.

2. Game:

The game resources contained within the Blue River Basins include pheasants, quail, deer, cottontail rabbits, squirrel, and waterfowl. Other abundant, but little used game resources include the coyote, fox, mink, raccoon, muskrat, and beaver. With the exception of Alexandria (350 acres), Pintail Marsh (280 acres), and Smartweed Marsh (40 acres), State Special Use Areas, and 6,250 acres of wetlands purchased by

the Bureau of Sport Fisheries and Wildlife, the bulk of game production and harvest occurs on private lands. Within the Blue River Basins, approximately 2,420 acres of private land is made available through the Cropland Adjustment Program (C.A.P.).

a. Waterfowl:

The importance of the Blue River watershed to waterfowl resources is considerable to the State of Nebraska, as the unique "rainwater basin" area, lies almost entirely within its boundaries. However, production of ducks in this area varies considerably with the amount of surface water available. When dry years occur in the northern production areas of the U. S. and Canada, and when conditions are favorable in the Nebraska part of the breeding range, production within this area takes on added importance.

Breeding populations in favorable years have been calculated to approximate 25,000 breeding ducks, mostly mallards and blue winged teal. This is a minimum figure based on systematic aerial surveys. However, two smaller more intensive studies indicate that more than 50 per cent of the birds present were not observed on the aerial surveys.

Waterfowl use of this area includes nesting and feeding, and resting areas during fall and spring migration. It also provides a much needed hunting opportunity. The duck harvest in the Big Blue River Basin based on the nine-year average from 1956 to 1964, a period encompassing drowth years, reduced populations and restrictive regulations, is 29,050 per anum. No harvest information is available for the Little Blue River Basin where better waterfowl hunting opportunity exists. For the Little Blue Basin, annual harvest would be much greater.

The importance of goose hunting within the Basin is considerable, but available data is not sufficient to allow calculation of actual harvest.

the east of Nebraska, concentrations of migrating waterfowl draw thousands of sight-seers and photography enthusiasts. All indications are that this use of waterfowl will continue to increase in Nebraska and the Blue Basin as birdwatchers, nature enthusiasts, etc, continue to grow in numbers and intensity of interest.

b. Other Game:

Much of the states better quail and pheasant range is found within the Blue Basin. In 1964, an estimated 201,000 cock pheasants were taken and 66,400 bobwhite quail were bagged. The probable limiting factor for increased populations of these animals is insufficient nesting cover. Cottontail rabbits and squirrel are locally abundant wherever adequate habitat is available.

Large populations of mourning doves occur in this region of the state. This game specie$is currently protected by legislation. Therefore, this bird of great game potential is being lost from the hunters bag.

Both deer and deer hunting are relatively new to this area. Observations of deer were rare less than ten years ago, but numbers have increased substantially in the past three or four years. In 1965, the Blue drainage contributed 300 deer to the harvest, of which 90 per cent were whitetails. With expected increases in deer numbers during the next few years, the potential harvest should be much greater.

Except for organized coyote hunts, there has been little use of other predators and furbearers for sporting purposes.

B. Demand:

The demand for fishing and hunting, like other outdoor activities, is expected to increase tremendously. The magnitude of this demand can be appreciated from statistics provided by the 1960 National Survey of Fishing and Hunting published by the Bureau of Sport Fisheries and Wildlife, U. S. Department of Interior.[9] The

[9]Bureau of Sport Fisheries and Wildlife, U.S. Dept. of the Interior, Circular 1[illegible]

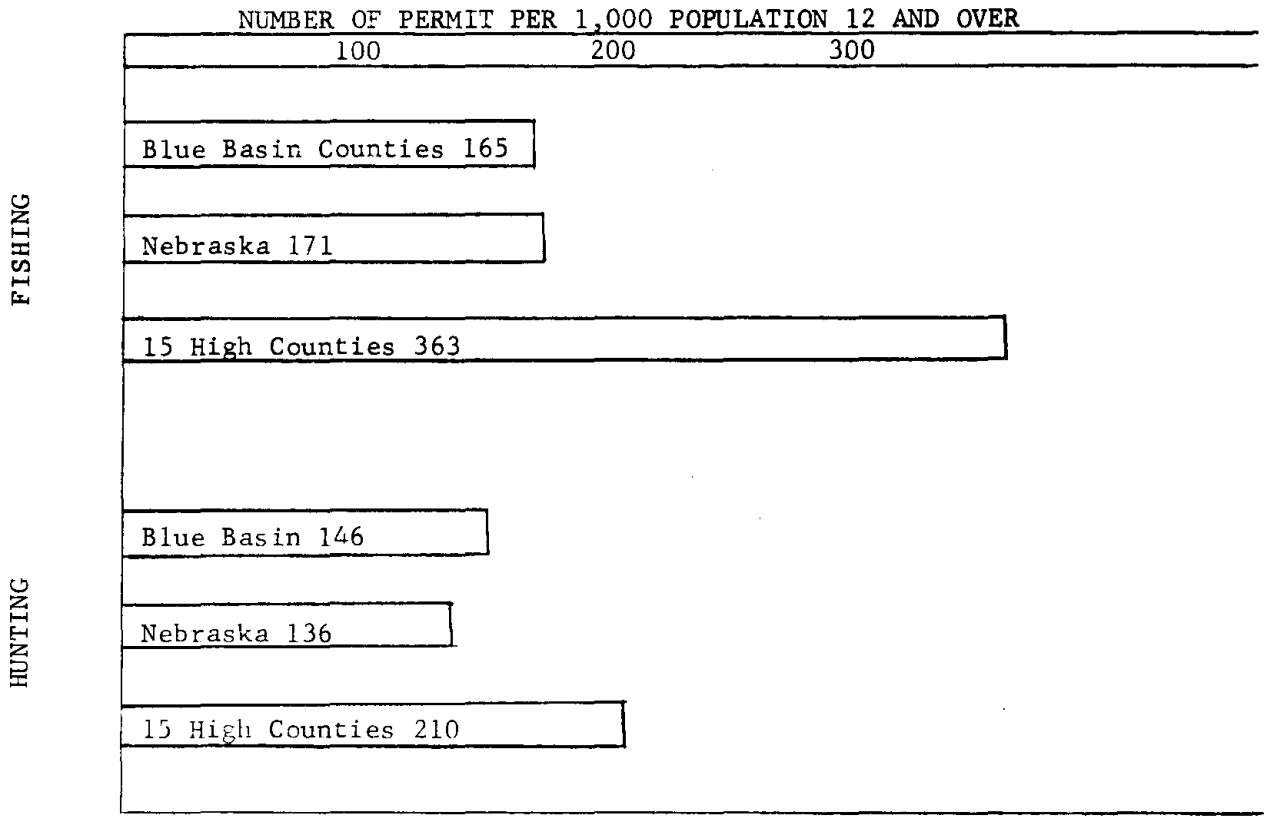
survey states that two out of every five persons over 12 years old, or approximately 50 million people, went hunting, fishing, or both, in 1960. Forty-five million people fished, including many who also hunted. Roughly twenty million people hunted, and most who hunted also fished.

In Nebraska, the demand picture is very similar. Of every seven persons 12 years of age and over, two purchased hunting and/or fishing permits in 1960. This is a conservative figure for hunting and fishing demand, as persons less than 16 years old and landowners who hunt or fish on their own land are not required to purchase permits. The per cent of persons 12 and over in Nebraska who hunt and/or fish is probably quite comparable to the nationwide average.

For the Blue Basin, two of every eight persons hunt and/or fish. This is again a conservative figure due to the reasons given above for the State of Nebraska. In addition to the high resident hunting and fishing pressure exerted upon the resources of the Blue Basin, the Basin is used by a large number of out-of-basin Nebraska residents and many out-of-state people, especially hunters. Although the use of fish and wildlife resources as shown by hunting and fishing permit sales is below the state average, this is an indication of the available supply of sport fish and game. The number of people purchasing hunting permits is slightly above the state average. Fishing permit sales, however, are slightly below the state average. The quality of hunting is fairly good; fishing, except that in streams is rather poor.

This again demonstrates the factor of latent demand. This is the demand which is demonstrated to occur if optimum conditions for an activity are available. Ideally, it is the demand that should be met. Figure 2 shows demand as determined from hunting and fishing license sales for the state, the Blue Basin, and the 15 counties which had the highest per capita permit sales during 1965. For hunting, the data represents the number of permits sold by place of residence. For fishing, the number of permits sold in that county was used.

FIGURE 2: 1965 RESIDENT FISHING PERMIT SALES AND NUMBER OF RESIDENTS PURCHASING HUNTING PERMITS PER 1,000 POPULATION 12 YEARS OF AGE AND OLDER



The sale of fishing permits by county, although not an accurate measure of resident demand, does show that fishing demand within those counties having good quality water and excellent fishing opportunity exceeds the state average by 53 per cent and the Blue Basin by 55 per cent. The 15 high counties are those having large reservoirs or a large number of natural lakes.

Those counties with the highest per cent of residents holding hunting permits are those counties having good mixed-bag hunting opportunity and relatively low human populations. There are 35 per cent more hunters per 1,000 population in the 15 high counties than in the state as a whole and 30 per cent more than in the Blue Basin counties. Again, use of wildlife resources is related to opportunity.

There is little use of the fishery resource of the Blue Basin by non-residents, simply because much better opportunity can be found elsewhere. Non-resident use of

the game resource, however, is quite high. A non-resident hunter survey conducted in 1964 by the Nebraska Game, Forestation and Parks Commission stated that the average out-of-state hunter travels 113 miles into the state from his point of entry and averages 3.24 days of hunting activity. Approximately 37 per cent of 26,210 non-resident hunters were from Missouri, Kansas, and Oklahoma. The Blue River Basin probably absorbed the hunting pressure of a large percentage of the non-residents from these states.

The seasonal demand in activity days for fishing derived from the ORRRC calculation method was 375,230 activity days in 1960 and 464,946 activity days in 1980. For hunting, the seasonal demand was 308,896 activity days in 1960, and by 1980, 326,645 activity days will be demanded. The annual demand in activity days for fishing was 847,384 activity days in 1960 and 1,195,303 activity days in 1980. For hunting, the annual demand was 411,861 activity days in 1960 and 435,527 activity days in 1980.

Using data presented in the National Survey of Fishing and Hunting for the West-North-Central Region,[10] annual demand was found to be quite simular to ORRRC demand. According to this study, 28 per cent of the west-north-central population 12 and over fish, and 17 per cent hunt. These people spent an average of 18.4 days fishing and 13.2 days hunting. Calculated annual Blue Basin demand for fishing in 1960 and 1980 is 859,611 and 946,993 activity days, respectively. For hunting, the 1960 and 1980 demand is 374,405 and 412,474 activity days, respectively. The comparison of the calculated annual activity day demand from the two methods for 1960 and 1980 is given in tabular form (See Table IX).

C. Need:

1. Fishing:

The potential for increasing the production of sport fishes has been identified in the Nebraska Comprehensive Outdoor Recreation Plan and is applicable to the Blue River Basin. Basically, the needs can be categorized into four areas: (1) creation

[10]Bureau of Sport Fisheries and Wildlife, U.S. Dept. of Interior, Circular 120.

TABLE IX: COMPARISON OF ACTIVITY DAY DEMAND DERIVED FROM ORRRC AND NATIONAL SURVEY OF FISHING AND HUNTING FOR THE BLUE RIVER BASIN

	ANNUAL DEMAND IN ACTIVITY DAYS	
	ORRRC	National Survey Fishing and Hunting
FISHING:		
1960	847,384	859,611
1980	1,195,303	946,993
HUNTING:		
1960	411,861	374,405
1980	435,527	412,474

of new waters, (2) improved management of existing waters, (3) watershed management, and (4) development of tools to provide greater use of private waters. Of these, creation of new waters offers the greatest potential in satisfying both present and projected needs for angling.

The total public fishing water in the Blue Basin at this time is less than 150 acres. Obviously, many additional acres are needed. Although the needs for fishing water derived from ORRRC data is thought to be quite conservative, it will be used to maintain consistency with the rest of the report. Ideally, the conversion of activity day demand to an acre need should be based on the quality and quantity of the available fish populations. This, however, is impossible to predict due to the variable nature of these populations. A conversion based on space requirements is not good for the same reason. None-the-less, a 40 activity day occasions per acre average has been estimated for impounded waters in Nebraska. Based on this conversion factor, the approximate acreage needed for fishing, within the Basin for 1960 was 9,230 acres. For 1980, 11,500 acres will be required. Unless extensive water development is undertaken, almost all of this demand will go unsatisfied.

Potential reservoirs and small watershed projects could satisfy much of the existing and future needs. Recreation, including fishing and other water-oriented activities, should be a primary motivating force in development of these projects. Those small watershed projects having significant fishery and recreation potential should be made available for use by the public.

2. Hunting:

As previously mentioned, a very small portion of the total land area is in public ownership and only about 0.15 per cent of all public land is available for game management and harvest. Obviously, private lands supply the hunting opportunity in the Blue Basin, and the status of game population depends largely upon the landowner's manipulation of the land and its plant life. The potential for meeting the future demand for hunting must be closely aligned with improvement of landowner-sportsman relations, and the development of incentive programs, such as the C.A.P. program, whereby the landowner can produce more game. Much valuable game habitat has been provided by the federal cropland retirement programs.

The potential for increasing the supply of upland game in the Blue River Basin is unlimited. However, the financial burden would be too great to attain maximum populations. Several inexpensive techniques, however, could be used. Delayed mowing of grassed waterways could provide good nesting cover for game birds. Agriculturally undesirable weeds and woody vegetation could be left on non-agricultural land. This type of cover is essential for maintaining populations of deer, squirrels and quail. With proper management techniques, roadside ditches, railroad right-of-ways, and other non-agricultural land would provide sufficient game.

The protection of mourning doves is a great loss to Nebraska sportsman. When the killing of doves is legalized, they will provide an excellent supply of high quality sport.

All game species except deer and turkeys are at maximum numbers for the present habitat available. The whitetail deer has made a strong comeback and has spread throughout most of the drainage. However, maximum population levels for the habitat available have not occurred and may never be reached. Economic tolerance of private landowners will probably be the limiting factor. Rio Grande and Merriam's turkeys have recently been introduced into the area but are still confined to the area of the release sites. It is too early to evaluate the potential production and adaptation of these fine birds.

At the present time the Prairie Chicken population is not large enough to be hunted. The loss of grassland has greatly reduced their numbers and it is very doubtful that they will make a substantial recovery with the present agricultural practices.

Waterfowl have in past years been a heavily used game resource. The general trend in the population, however, seems to be irreversibly downward due to a continuing loss of breeding habitat. In years of good water conditions, the rain-basin area supports good populations of breeding ducks and provides excellent waterfowl hunting. These wetlands, like those all across the waterfowl breeding range, are being drained. In view of this fact, a program to save wetlands was authorized by Congress in 1958. It is financed by receipts from the sale of migratory bird hunting stamps. Sportsmen throughout the nation are sponsoring the program through purchase of these stamps. Added acquisition of wetland areas, and the removal of incentives to drain these wetlands could do much to alleviate the shortage of nesting habitat for waterfowl. The practice of making incentive payments to farmers for drainage seriously accelerates the loss of this type of wildlife habitat; habitat that in many cases is the only wildlife cover of consequence in large blocks of land. It would appear that ACP "Water Bank" incentive payments could be made to landowners to preserve the rain basin wetlands as complimentary to water conservation, ground water recharge, and flood control development, as well as maintainance of wildlife habitat. It seems irrational to drain and fill these natural catch basins, and then build flood control structures

that serve essentially the same purpose. A program of coordinated planning within each watershed should be initiated to consider this aspect in the overall development plan. It may be worthwhile to consider treating causes for need in flood control rather than to continue treating symptoms by expensive watershed developments. Emphasis on land treatment practices to help stabilize soil and water, and de-emphasis on drainage and filling of rain basin areas seems to be one logical route in future planning. Are we to continue to satisfy the needs of the local individual at the expense of the downstream residents within and outside the watershed?

IV. ECONOMIC VALUES

There are those who challenge the economic system of allocating resources on the basis that the chief values of outdoor recreation and wildlife conservation are social and cultural and thereby esthetic in nature. They feel that measuring this value in dollars is comparable to measuring the value of education in dollars. Such resources are said to be priceless. The logical contention is that the economic approach doesn't give due consideration to the consequences of not providing a suitable environment for man. Whether or not recreation should be considered one of that order of services which must be provided for its benefit to the public without a monetary accounting of immediate benefits, it can and does make sound fiscal sense. Recreation is often a wise economic use of land, increasing values beyond its cost. In some undeveloped areas, it may mean economic rebirth; and throughout the nation it provides a major market for goods and services.

Another example is the economic benefit accruing to an area when local people satisfy recreation demands at home rather than traveling outside to other areas. We might expect that provision of quality recreational opportunity within a "local" area where none existed previously would not only result in economic benefits to the locality due to "holding" of its people and their money, but expenditures would probably shift between various expenditure categories and participation habits would

change. Persons who formerly drove considerable distances to accomplish recreation might now spend less money on travel and more on equipment. They might sightsee less and participate more.

For this report, the total values were computed by multiplying total annual activity days (See APPENDIX C) by the developed fair market value per activity day as presented in Table X. No attempt was made to judge the market values of the other outdoor activities not listed in this table.

TABLE X: ESTIMATED VALUES FOR OUTDOOR RECREATION FOR THE BLUE RIVER BASIN (1960 and 1980)

Activity	Value per Activity Day (Dollars)	Annual Value (Dollars) 1960	1980
Fishing	1.00*	$ 847,384	$1,195,303
Hunting	1.00*	411,861	435,527
Boating	.70	260,958	395,561
Water-Skiing	.70	31,836	61,126
Picnicking	.50	81,529	383,485
Camping	.50	71,719	114,441
Swimming	.50	466,038	694,707
TOTAL Annual User Value		$2,139,489	$3,280,150

* Panel on Recreational Values, Interagency Committee on Water Resources.[11]

Once again it must be stressed that the difficulties arising in making these determinations are evident in people's reluctance to place values on recreation. The values that have been assessed for boating, water-skiing, and picnicking are based primarily on judgment. Swimming and camping values were based on going rates at municipal and private pools and campgrounds.

[11] Report of the Panel on Recreational Values, Recreation Aspects of Fish and Wildlife. Interagency Committee on Water Resources, May 24, 1960.

V. MITIGATION FOR FISH AND WILDLIFE LOSSES

The major governmental water resource development agencies have installed all those adopted mitigation practices that have been requested by the Bureau of Sport Fisheries and Wildlife for recent projects in Nebraska. These practices have been planned in consultation with the Game Commission and in all cases the state has concurred with the reports of the Bureau.

It should be realized, however, and the degree of success is tempered by the fact that these recommendations were based on: (1) the best estimates available at the time, (2) estimated productivity of the development, (3) willingness of the developing agency to adopt recommendations. The recommendations were not based on mitigation in kind. It is the general desire of most game and fisheries management agencies that habitat losses be mitigated in kind, i.e. pheasant habitat be replaced by pheasant habitat; deer habitat by deer habitat; waterfowl habitat by waterfowl habitat. This has not been done in the past.

It is an established ecological fact that various inter-relationships exist between organisms. The environment of one organism cannot be altered without affecting in some degree the other organisms present, including man. And regardless of the scope of water resource development projects, the environment will be affected. An inventory of the environmental factors should be made by professional ecologists and a determination made of the ecological effects that a project might have prior to embarking on new programs. Ideally, ecological studies should be conducted on a basin basis by an organization whose interests are academic and whose motives cannot be questioned.

APPENDIX A: CALCULATED SEASONAL ACTIVITY DAY DEMAND FOR MAJOR OUTDOOR RECREATION ACTIVITIES IN BLUE RIVER BASIN

ACTIVITY	1960 ADJUSTED PARTIC. RATES (Days per person) 12 and Over: SMSA	NOT SMSA URBAN	NOT SMSA RURAL FARM	NOT SMSA RURAL NON-FARM		SOCIO-ECONOMIC COMPOSITE FACTOR		1980 ADJUSTED PARTICIPATION RATES (Days per person) 12 and Over: SMSA	NOT SMSA URBAN	NOT SMSA RURAL FARM	NOT SMSA RURAL NON-FARM		SEASONAL RECREATIONAL DEMAND (All Residence Classes.) ACTIVITY DAYS: 1960	1980
Viewing Outdoor Concerts	.3636	.3131	.1919	.0505	MULTIPLY ADJUSTED RATE (1960) BY SOCIO-ECONOMIC COMPOSITE FACTOR	28.6%	=	.4676	.4026	.2468	.0649	MULTIPLY 1960 AND 1980 ADJUSTED PARTICIPATION RATES BY POPULATION (1960 & 1980) 12 and Over	37,202	58,604
Viewing Outdoor Games & Sports	1.7372	2.0099	1.0908	1.4039		11.0%	=	1.9283	2.2310	1.2108	1.5583		261,311	347,497
Bicycling	.9292	3.8077	.9292	1.9695		-----	=	.9292	3.8077	.9292	1.9695		337,340	403,496
Boating	1.8096	2.1424	.6448	.7800		35.9%	=	2.4457	2.9115	.8763	1.0600		224,647	379,442
Camping	.5814	.2550	.1428	.6018		44.2%	=	.8384	.3667	.2059	.8678		65,959	120,474
Driving For Pleasure	9.8677	9.8172	4.4238	5.2116		17.1%	=	11.5551	11.4959	5.1803	6.1028		1,219,364	1,743,913
Picnicking	2.8078	1.9594	1.7574	1.6463		14.1%	=	3.2037	2.2357	1.4925	2.4445		334,822	466,659
Playing Outdoor Games	5.4463	4.5265	1.5154	3.7978		32.6%	=	7.2218	6.0021	2.0094	5.0359		638,782	1,045,551
Swimming	5.5120	4.9192	2.3088	4.7216		33.7%	=	7.3695	6.1843	2.0261	5.0777		732,686	1,054,281
Water-Skiing	.4095	.1680	.0420	.1575		62.6%	=	.6658	.2731	.0683	.2561		31,306	66,050
Nature Walks	.7878	.7878	.3636	.9696		18.6%	=	.9343	.9343	.4312	1.1499		123,637	175,218
Ice Skating	1.2733	1.5301	.1605	.7918		45.4%	=	1.8514	2.2248	.2334	1.1513		159,423	355,331
Sledding	.2346	.3162	.0918	.3060		16.0%	=	.2721	.3668	.1065	.9185		40,786	102,628
Horseback Riding	.0306	.0306	1.5402	.7038		13.3%	=	.0347	.0347	1.6033	.7327		94,186	88,350
Walking	3.6057	4.8985	1.3635	3.3330		14.9%	=	4.7264	5.6284	1.5667	3.8296		563,246	797,696

APPENDIX B

To figure both present and projected design load capacity the formula developed for the Missouri River Basin Comprehensive Study was used. The formula and sample calculation for camping is given as follows:

$$DL = \frac{\frac{CD}{14} \times 60\%}{1.5}$$

DL = Design Load

CD = Calculated Demand (65,959 activity days in 1960)

14 = Number of weeks in normal recreation season

60% = % of weekly demand which would occur on a normal summer Sunday

1.0 = Estimated Turnover

APPENDIX C: CALCULATED ANNUAL ACTIVITY DAY DEMAND FOR MAJOR OUTDOOR RECREATION ACTIVITIES IN BLUE RIVER BASIN

ACTIVITY	1960 ADJUSTED PARTIC. RATES (Days per person) 12 and Over						1980 ADJUSTED PARTICIPATION RATES (Days per person) 12 and Over				ANNUAL RECREATIONAL DEMAND (All Residence Classes) ACTIVITY DAYS	
	SMSA	NOT SMSA URBAN	NOT SMSA RURAL FARM	NOT SMSA RURAL NON-FARM	SOCIO-ECO-NOMIC FACTOR		SMSA	NOT SMSA URBAN	NOT SMSA RURAL FARM	NOT SMSA RURAL NON-FARM	1960	1980
Viewing Outdoor Concerts	.4444	.3939	.3232	.0909	28.6%	=	.5715	.5066	.4156	.1169	55,745	77,986
Viewing Outdoor Games & Sports	4.5114	4.7383	2.6986	2.9870	11.0%	=	5.0077	5.2595	2.9954	3.3156	68,325	831,005
Bicycling	4.0703	5.7570	2.7371	5.8176	-----	=	4.0703	5.7570	2.7371	5.8176	730,554	933,353
Boating	2.5680	2.6857	.9630	1.8404	35.9%	=	3.4899	3.6499	1.3087	2.5011	372,797	565,087
Camping	.8424	.9776	.3536	.9048	44.2%	=	1.2147	1.4097	.5099	1.3047	143,438	228,881
Driving for Pleasure	26.2196	27.8255	9.9586	17.9881	17.1%	=	30.7032	32.5837	11.6615	21.0641	3,797,817	2,098,370
Picnicking	4.1208	3.9895	2.5553	2.8482	14.1%	=	4.7018	4.5520	2.9156	3.2498	613,057	766,969
Playing Outdoor Games	17.3000	14.2700	7.7125	13.3875	32.6%	=	17.8640	18.9220	10.2268	17.7518	2,377,772	3,263,512
Swimming	6.3176	5.9466	2.6394	5.4696	33.7%	=	8.4466	7.9506	3.5289	7.3129	932,077	1,389,414
Water-Skiing	.4558	.2120	.0636	.3074	62.6%	=	.7411	.3447	.1034	.4998	45,480	87,323
Nature Walks	2.7876	1.5958	1.7271	2.2725	18.6%	=	3.3061	1.8926	2.0483	2.6952	365,358	481,231
Ice Skating	1.3090	1.5840	.2420	.8250	45.4%	=	1.9033	2.3031	.3519	1.1996	187,983	256,883
Sledding	.2448	.3468	.1632	.4386	16.0%	=	.2840	.4023	.1893	.5088	55,523	70,372
Horseback Riding	.3161	.5232	3.0956	1.5042	13.3%	=	.3581	.5928	3.5073	1.7043	230,136	244,120
Walking	19.5031	12.1604	5.8782	10.0798	14.9%	=	22.4091	13.9723	6.7541	3.4814	2,107,279	2,366,242
Hunting	.8560	2.1400	4.2479	1.9795	1.0%	=	.9416	2.3540	4.6727	2.1775	411,866	435,527
Fishing	4.0920	6.3250	3.8170	5.2580	2.3%	=	5.0332	7.7798	4.6949	6.4673	847,384	1,195,303

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GEOLOGY AND GROUND WATER SECTION PREPARED BY
THE CONSERVATION AND SURVEY DIVISION, U OF N

GEOLOGY AND GROUND WATER RESOURCES
BIG BLUE RIVER BASIN
(Conservation and Survey Division, University of Nebraska)

The Big and Little Blue River basins comprise one of the most thoroughly investigated areas of significant size in the country as a result of the ground water and subsurface investigations of the Conservation and Survey Division of the University of Nebraska in cooperation with the Water Resources Division of the U. S. Geological Survey over a period of years. These investigations are especially useful because of the large amount of basic data available as a result of the systematic test drilling program and the ground water level observation program of this cooperative survey, and because this basic data has been converted to hydrologic information that is susceptible to careful analysis.

The Big and Little Blue River basins are truly a single hydrologic unit from the ground water standpoint, but the collective data is presented in two segments to conform to the general practice of defining basins on the more easily identifiable surface features that control runoff reflected in surface water. This arbitrary division (from the ground water standpoint) presents some real difficulties in evaluation of the ground water resources and also encumbers reports on each of the separate surface water basins with material which must be common to both and therefore is repetitive, in large degree.

Geology of the Big Blue River Basin

The geologic features that are directly related to the hydrology of the basin are illustrated in Figures 1-5. The geologic materials are classified in two groups: the bedrock formations which are older and exhibit varying degrees of cementation and the mantlerock formations which are younger and are generally unconsolidated.

The bedrock formations were generally tilted to the west and northwest throughout the basin and their upper surface was eroded by streams that flowed eastward and southeastward through the area during several periods of erosion that preceded the deposition of the mantlerock materials upon the eroded surface of the bedrock formations. Figure 1 illustrates the configuration of the generally buried bedrock surface which indicates a drainage pattern that is unrelated to the surface drainage of the region, for the most part, and controls the thickness of the mantlerock formations. The buried valleys have west-to-east trends in general and many of these valleys cut across the present drainage system. Bedrock formations outcrop only in the lower part of the Big Blue River basin at a few localities in southeastern Seward and east-central Saline counties along the west side of Big Blue River valley near Milford, on the southwest side of the Turkey Creek valley near Pleasant Hill, and on the north side of the Swan Creek valley near Western where the bedrock material is the Greenhorn limestone of Cretaceous age. In addition, more extensive areas of bedrock formation outcrops occur along the valley sides of the Big

Blue River valley from Beatrice to the Kansas-Nebraska line and on the south side of the Big Indian Creek valley in southwestern Gage County where the bedrock materials are mostly limestones and shales of Permian age and also include some outcrops of Dakota Group sandstones and shales of Cretaceous age, largely in the Beatrice vicinity.

The general nature of the bedrock materials throughout the basin is illustrated in Figure 2 in which the geologic formations are grouped in relation to their general permeability and their ground water characteristics. Permian limestones and shales constitute the bedrock formations in the southeastern part of the basin at the lower elevations. These formations are generally comparatively impervious and yield little or no water to wells except in unusual situations where their upper surface may be cracked or creviced. Deeper drilling into this succession of limestones and shales may encounter some zones of permeability that may yield water to wells, but this water is almost always too highly mineralized for most uses, especially if it is developed at depths of 300 feet or more. Still deeper drilling, involving depths of over 1000 feet, often encounter zones of higher permeability in dolomites and sandstones of Lower Pennsylvanian, Devonian, Silurian, Ordovician and Upper Cambrian age with ground water of slightly better quality but generally exceeding 2000 parts per million of total dissolved solids. No wells have been developed in these lower geologic formations because of the high cost of drilling and the generally poor quality of the water.

The Cretaceous formations, which form the bedrock materials throughout most of the basin, rest upon an eroded surface of the Permian limestones and shales and consist of the Dakota Group of sandstones and shales with an aggregate thickness of 300 to 400 feet or more where their upper surface is not reduced by erosion, overlain by 50 to 70 feet of Graneros shale, about 30 feet of Greenhorn limestone, about 170 feet of Carlile shale, from 250 to about 400 feet of Niobrara chalky shale, and less than 100 feet of Pierre shale. Because of the northwest dip of these Cretaceous formations and the southeast slope of the erosion surface at their top they occur as successive bands from oldest (Dakota Group) to youngest (Pierre shale) from southeast to northwest across the basin. The areas where the Dakota Group of sandstones and shales form the bedrock formation are indicated in Figure 2 and all of the younger Cretaceous formations are grouped together because they are generally comparatively impervious and do not yield water to wells except under fractured conditions. Small amounts of ground water may be secured in the upper part of the Greenhorn limestone, if it is cracked or creviced, and some larger supplies are occasionally secured in the lower part of the Niobrara formations if it is also cracked or creviced.

The Dakota Group of sandstones and shales is the source of domestic and stock water supplies in the southeastern half of the basin where the bedrock formations are comparatively high and the overlying mantlerock does not provide a suitable source of water. However, the Dakota Group is highly variable

in character and also variable in water quality. Where its upper part includes permeable sandstones that are available to recharge and flushing from meteoric water sources the water quality is generally good, although it may be comparatively high in boron and fluorides. If the upper half of the formation consists of clay shales with little or no sandstone and it becomes necessary to drill into the lower part of the formation to secure permeable zones, water quality is generally too poor for most uses and may be high in sodium chloride and other salts. In some local areas, such as the Blue River valley, between Wilber and DeWitt, the mantlerock sands and gravels occur in channels eroded into the lower sandstones of the Dakota Group and poor quality water is free to move up into the mantlerock sands and gravels, especially under high development, and water quality is poor, even in the mantlerock formations. There is a strong tendency for progressive westward increase in mineralization in the Dakota Group of sandstones and shales. Therefore deeper drilling into the Cretaceous bedrock formations for supplementary water supplies for irrigation purposes in the western half of the basin is discouraged. Occasionally, permeabilities in the Dakota Group of sandstones and shales in the eastern half of the basin are high enough to permit the development of several hundred gallons per minute from wells, but water quality must be checked to be sure that continued use of this ground water will not have a damaging effect on soils and crops.

The bedrock formation in the extreme western part of the basin is the Ogallala formation of Pliocene age which often

contains zones of comparatively good permeability and is a source of good quality water. Wells in this area may develop water supplies from permeable zones in the mantlerock and in the Ogallala formation, but the Ogallala formation here is not an important source of water.

The depth below land surface where bedrock formations may be encountered in drilling is illustrated in Figure 3 which is a mantlerock thickness map prepared by superimposing the bedrock topography on the surface topography and isopaching thicknesses in increments of 100 feet. Maximum mantle rock thicknesses occur where relatively high surface topography occurs above relatively low bedrock topography and generally larger supplies of good quality ground water can be secured in these areas except where the mantlerock fill is largely fine-textured.

The most important sources of good quality water in the basin are developed from the mantlerock formations of Quaternary age which are illustrated in Figure 4. The Quaternary deposits include the Pleistocene and Recent sediments that are relatively unconsolidated and include zones of sand and gravel of high permeability. Most of these deposits are Pleistocene in age with minor thickness of Recent sediments along stream valleys. These deposits are complex in nature and reflect a varied history of erosion and sedimentation related to the advance and retreat of continental ice sheets which generally were more extensive in areas east and northeast of the basin. There were four major advances and retreats of the continental ice sheets known as the Nebraskan, Kansan, Illinoian and Wisconsinan, and each of these major glaciations were complexes of more than a single

advance and retreat. Our stratigraphic studies indicate that there were probably two minor advances and retreats of the ice in Nebraskan time, three in Kansan time, three in Illinoian time, and three in Wisconsinan time. As the continental ice sheets advanced sea levels were lowered, stream gradients were increased, and erosion was a dominant factor with deposition of sediments generally related to times of glacial retreat under conditions of progressive rise in sea level and lower stream gradients.

The Nebraskan glaciation reached only into the easternmost part of the basin, the Kansan glaciation extended into the eastern two-thirds of the basin with progressively thinner deposits of till (boulder clays) preserved in parts of the subsurface westward and exposures of till generally limited to areas on the east side of the Big Blue River valley in Butler, Seward and Saline counties, and more extensively on side slopes in Gage County. None of the Illinoian and Wisconsinan glaciation reached into the basin but the advances and retreats of these continental ice sheets are reflected in the deposits that underlie the basin.

The mantlerock deposits are mapped in Figure 4 in relation to their permeability characteristics. No attempt has been made to indicate areas where Nebraskan till is represented in the subsurface because the tills of Kansan age generally occur above the tills of Nebraskan age and both are relatively impermeable. However, areas where significant deposits of late Nebraskan age or early Kansan age sands and gravels occur between

these tills or below the upper tills of Kansan age are delineated because they often provide sources for significant supplies of ground water and these deposits are also indicated west of the till areas where they also provide important sources of ground water. These deposits occur below valley level and also below the water table so that they are saturated and all of their thickness is effective in yielding ground water. The early Nebraskan age deposits are generally fine textured and are not important sources of ground water.

Except for the early Kansan age sands and gravels most of the Kansan deposits are fine textured whether they consist of till or alluvial silts. The terrace deposits of Illinoian age, on the other hand, are generally the most permeable deposits of the basin and generally yield large amounts of ground water to wells. They often consist of as many as three sequences of sand and gravel, often separated by silts and generally mantled by silt or loess of late Illinoian age. In many areas the higher sands and gravels (Illinoian) occur in channels that cut into the lower sands and gravels and the combined thickness of permeable materials will provide large ground water supplies.

Some terrace deposits of early to medial Wisconsinan age occur in the extreme western edge of the basin but these deposits occur at comparatively high elevations in relation to the water table and are not important sources of ground water because they are often only partially water-saturated or may be dry. Most of the upland areas are mantled with loess of medial to late Wisconsinan age in which the soils are developed. Also, deposits

of Late Wisconsinan to Recent sediments of variable thickness underlie most of the valley lowlands and occur under the terrace levels adjacent to the principal valleys. These deposits are generally fine textured and often serve as barriers to the free interchange of water between the stream flow and the ground water.

The relationship of these mantlerock deposits to each other and to the bedrock formations is indicated in the geologic profile sections illustrated in Figure 5. It should be realized that it is necessary to exaggerate the vertical scale of these profile sections in order to illustrate significant differences in sediments. This tends to greatly exaggerate the slope of surfaces and also exaggerates the slope of the water table.

The transmissibility of the water-saturated materials which overlie the Cretaceous and Permian bedrock throughout the basin is shown in Figure 6 which is based on an evaluation of the test hole records. Areas of less than 20,000 Meinzer units are shown, those with 20,000 to 50,000 Meinzer units of transmissibility are delineated and areas of more than 50,000 Meinzer units are separated in increments of 50,000. In some of the areas included within the 200,000 Meinzer unit boundaries the calculated transmissibility exceeds 250,000. The transmissibility map may be translated in terms of water-producing capacity of most of the irrigation wells drilled in these areas. Areas of less than 20,000 units are expected to be capable of yielding less than 200 gallons per minute to wells (often much less), 20,000 to 50,000 unit areas may vary from 200 to 500

gallons per minute and so forth with areas of more than 200,000 units having capabilities of yielding more than 2000 gallons per minute. These yield estimates assume that all of the favorable water-bearing material is available to the well, that approximately 100 feet of water occurs in the well, and that the drawdown of the well while pumping is about 30 feet. Obviously higher drawdowns while pumping will give higher yields (within limits) and lesser drawdowns will give lower yields. Also, higher yields in relation to drawdown may be secured in wells with more than 100 feet of water and smaller yields will result in wells with less than 100 feet of water. Areas where wells may be installed to irrigate 100 acres or more of land per well would generally be included in the areas of more than 100,000 Meinzer units. Also it is probable that areas of less than 50,000 units are generally not favorable for significant ground water use for irrigation purposes.

The configuration of the water table (top of zone of saturation) is shown in Figure 7. The ground water is moving slowly down the hydraulic gradients indicated by the contours and at right angles to the contour lines. However, the lateral movement of ground water under natural conditions is very slow (probably only a few hundred feet per year). Under these conditions it is unreasonable to expect that ground water will be able to move in quickly and replace the amount withdrawn if this withdrawal is significant. Moreover, almost all areas have more ground water moving out of the area than is moving into the area. This presents a situation in which the

limitations of ground water withdrawal without exceeding recharge are regulated by the amount of local recharge that can be anticipated from precipitation sources. If average annual consumptive use of ground water exceeds the local recharge the amount of ground water in storage will be progressively reduced and ground water levels will lower.

The amount of ground water in storage in permeable materials above the Cretaceous and Permian bedrock is shown in Figure 8. This represents the amount of water that is available in permeable materials and does not include ground water in fine textured materials that is essentially unavailable.

Ground water quality is important because of its effect on the utilization of the ground water supply. The total dissolved solid content of the ground water, based on chemical analyses made by the U. S. Geological Survey, the Conservation and Survey Division, the Agricultural College, and the State Health Department, is illustrated in Figure 9. It may be noted that the areas of lower mineralizations are generally associated with the areas of greater transmissibility of the water-bearing materials. Areas of higher mineralization are generally associated with areas where wells need to penetrate bedrock formations to secure supplies, or where the mantlerock formations have low transmissibility. As noted before, the poorer quality water in the Blue River valley between Wilber and DeWitt is probably the result of poor quality water from the lower part of the Dakota Group sandstones moving up into sands and gravels that are channelled into this formation. Mineralizations within

the more than 1000 parts per million areas may be much larger but it is not practical to subdivide these areas because of their great variability. Figure 10 illustrates the concentrations of bicarbonate in the ground water and the parts per million of sodium in the ground water supplies is illustrated in Figure 11.

The degree of ground water utilization for irrigation use is reflected in Figure 12 which is an irrigation well concentration map which has been prepared by contouring the average number of irrigation wells per township at each township corner. The greatest concentration of wells is indicated in much of Hamilton County, western and northwestern York County, southwestern Polk County, northeastern Clay County, and southwestern Fillmore County (an area extending southwestward into the Little Blue River basin). If we assume that each well is consumptively utilizing an average of 100 acre-feet of water per year, it appears that areas with more than 60 wells per township are utilizing 3 times or more water than can be expected to be supplied from local recharge from precipitation sources and have a development of more than three times local recharge. The concentration of more than 120 wells per township in east-central Hamilton and extreme west-central York County would have a development of more than 6 times average annual recharge.

A total of 55 observation wells were measured by the U. S. Geological Survey and the Conservation and Survey Division in the fall of 1965 in the Big Blue River basin. 47 of these wells were measured periodically with steel tape and 8 wells

are equipped with continuous water level recording equipment. These observation wells were not established at the same time, however, as the observation well program has been progressively expanded to give better coverage as development proceeded. Three of these wells were first measured in 1934, one in 1935, thirteen in 1948, three in 1949, twelve in 1953, three in 1954, three in 1956, one in 1957, three in 1958, four in 1959, two in 1962, three in 1963, and four in 1964.

It is very difficult to interpret observation well records in terms of changes in storage as a result of the consumptive use of ground water without being able to identify and separate out changes in ground water levels resulting from climatic variations. Therefore, a theoretical hydrograph of probable fluctuations of ground water levels based on water balances throughout the 1929 to 1965 year period at Clay Center has been prepared (Figure 1Ba) which permits the evaluation of the observation well records in relation to median ground water levels for the 37 year period (1929 to 1965) under undisturbed natural conditions. Clay Center was selected because it has a most complete climatic record for this period and is quite centrally located in the area of well irrigation development. Computations at Seward were also made with very similar results which indicate that the theoretical curve can be applied to all of the area with considerable satisfaction. Obviously the short-term observation well records cannot be used, but those with records beginning in 1953 or earlier can be utilized and theoretical "normal" ground water levels can be assigned to

these observation wells and the 1965 measurements, adjusted to the long-time mean can be referred to these "normal" levels. The 1965 measurements are believed to be about one foot lower than the long-term median. The computations for the observation wells of longer record in the Big Blue River basin are as follows:

County	Well No.	Estimated Normal	Adjusted 1965	Change
Adams	8- 9-14ac	108.78	115.38	- 6.60
"	8-10-26da	96.10	104.09	- 7.99
Butler	A13- 2-30bc	58.89	59.76	- .77
"	A15- 1-27dd	85.86	89.62	- 3.76
Clay	8- 6-12bb	76.80	88.16	-11.64
"	8- 8-17ab	103.57	110.83	- 7.26
Fillmore	6- 3-25ad	77.30	88.73	-11.43
"	7- 1-15ad	83.05	85.60	- 2.55
"	7- 4-17bd	73.56	87.17	-13.61
"	8- 1-10ad	81.53	87.09	- 5.56
"	8- 2-26ad	12.17	16.98	- 4.81
"	8- 4- 5ab	85.82	90.34	- 4.52
Hamilton	9- 8- 9dc	52.88	59.40	- 6.52
"	10- 6-26bc	83.90	91.38	- 7.48
"	10- 7- 3ba	94.55	105.38	-10.83
"	10- 7- 5bb	84.83	92.97	- 8.14
"	11- 6-13cb	89.80	102.37	-12.57
"	11- 8-28bc	27.82	33.66	- 5.84
Polk	13- 1-10db	89.50	99.88	-10.38
"	13- 2- 6dd	67.04	74.78	- 7.74
"	13- 2-30dc	78.03	88.69	-10.66
"	13- 3-30aa	72.85	83.16	-10.31
"	13- 4-27bb	66.77	80.18	-13.41
"	14- 2-12cc	105.65	114.08	- 8.43
"	14- 3-26ad	63.13	74.47	-11.34
Saline	A 7- 3-30ad			No change
Seward	A 9- 2-22cb	10.46	13.46	- 3.00
"	A 9- 3-19aa	61.98	65.89	- 3.91
"	A10- 1- 4ba	82.05	86.60	- 4.55
"	A10- 2-18bd	73.02	77.63	- 4.61
"	A11- 1- 7ab			No change
"	A11- 2-21dd			No change
"	A11- 2-23cc	77.98	81.74	- 3.76
York	9- 1- 8bc	22.36	22.36	No change
"	9- 4- 6dd	80.44	83.52	- 3.08
"	11- 1-35bb	101.51	105.73	- 4.22
"	11- 2-31ba1	82.72	88.96	- 6.24
"	11- 2-31ba2	81.84	86.93	- 5.09

County	Well No.	Estimated Normal	Adjusted 1965	Change
York	11- 3-32dd	60.20	68.43	- 8.23
"	11- 3-36ab	65.82	72.56	- 6.74
"	11- 4-25bc	63.08	73.98	-10.90
"	11- 4-31ba	71.85	82.26	-10.41
"	11- 4-33bb	65.02	78.96	-13.94
"	12- 1-32ab	88.40	90.14	- 1.74
"	12- 4-10cb	73.16	84.77	-11.61

An attempt has been made in Figure 13 to utilize all of the observation well measurements made by our office, as well as by the local well irrigators associations, to indicate general lowering of ground water levels in the basin referred to an approximate "normal" position without close adjustment which is often difficult if not impossible. However, this map does indicate the close relationships between areas of high concentration of irrigation wells (Figure 12) and lowered ground water levels. Computations made at the observation well locations listed in the table are believed to be accurate within about one-half foot and data utilized in Figure 13 is believed to be accurate within about one foot or more.

It has been computed that approximately 2,146,000 acre feet of ground water has been removed from storage utilizing the adjusted observation well changes listed above and assuming that the observed declines are representative. This compares closely with the 2,138,617 acre feet of estimated supplement needs for the 1949-1965 period in Appendix Table 7. Measurable changes in storage are confined to the upper 56 percent of the basin including northern Saline, western Seward, western Butler and all counties farther to the west with the areas of greatest withdrawal confined to southern Polk, northeast

to central Hamilton, northwestern York, northeastern Clay, and west-central Fillmore counties. Most of this withdrawal has probably occurred since 1953 with the greatest rate of withdrawal being concentrated in the 1955-1958 year period. Average annual lowerings of ground water levels in the more intensively developed areas during the 1953-1965 year period have ranged from about 3/4 to one foot with lowerings in much of the remaining area of significant development ranging from less than four-tenths to about three-fourths of a foot.

A careful analysis of the effect of ground water pumping on stream flow and ground water levels in the Big and Little Blue River basins of Nebraska has been made with the use of an electrical analog model of these basins with transmissibilities of water-bearing materials and projected withdrawals built into the electrical circuit and balanced. It was estimated that the consumptive use of ground water for irrigation use would progressively increase from the 1962 estimated level to 150 percent of the 1962 level by 1982, and that there would be a progressive decline in consumptive use from 1982 to 2022 to arrive at the 1962 level by 2022. The lowering in ground water levels, under these assumptions by 2022 is shown in Figure 14 and the anticipated water-table configuration in 2022 is shown in Figure 15.

Up to the present time it is believed that consumptive use has increased at about the same rate as irrigation well installation, but there will be a progressive decline in consumptive use per well as ground water levels lower and productive

capacities of wells are reduced. Moreover, as ground water levels lower and amounts of water in storage are reduced, the areas where effective supplies can be secured will be reduced. Therefore, it is believed that the basic assumptions applied to this analog model study are realistic and may represent the worst conditions that may obtain.

The analog model studies indicated that there would be a 4.8 percent decrease in the base flow of the Big Blue River at Barneston and a 1.2 percent reduction in the average annual total discharge of the Big Blue River at Barneston by 2022. Even though these reductions in stream flow seem to be very small, it is probable that they may be too large because the analog model assumed a perfect connection between surface water and ground water throughout the basin and it is known through investigations that this interconnection is very imperfect. Therefore, it seems fallacious to assume that all of the consumptive use of ground water in the basin will be had at the expense of stream flow. Surface water elevations in the permanent streams in much of the west to central part of the basin are above the ground water levels of the surrounding uplands and probably always have been.

The inter-relationships of surface water and ground water are complex and vary from basin to basin throughout Nebraska. Although it is not the function of this report to evaluate the surface water of the Big Blue River basin, it is necessary that the surface water records be examined in order to attempt an analysis of the inter-relationships of ground water and surface water.

The period from June 1932 to September 1964 was examined and the total measured discharge of the Big Blue River at Barneston was found to be 17,945,640 acre feet compared to total precipitation of 203,780,483 feet during the same period. This indicates an average yield for the Big Blue River of 8.81 percent of precipitation. This compares to a yield of 8.4 percent for the Little Blue River at Fairbury for the same period. Water yields for the Salt Creek valley and other similar streams are about 6 percent while the water yield of the Loup River valley is about 15 percent or more.

The total annual discharge at Barneston varied from 83,240 acre feet in the 1934 water year to 1,600,000 acre feet in the 1951 water year and averaged 551,936 acre feet per year. The average annual recharge to the basin above Barneston is estimated as 168,315 acre feet which is 30.5 percent of the average annual discharge. If the Blue River basin is in hydrologic balance we may assume that 91.19 percent of the total precipitation is lost to evapotranspiration, that 2.69 percent is infiltration which ultimately supports stream flow, and that 6.12 percent is direct runoff under normal conditions. These data, in tabular form, are as follows:

June 1932 to September 1964 at Barneston

Total Precipitation	203,780,483 Acre Ft.	100	Percent
Total Discharge at Barneston	17,945,640 Acre Ft.	8.81	Percent
Estimated Total Ground Water Recharge	5,481,695 Acre Ft.	2.69	Percent
Evapotranspiration Loss in Basin	185,834,843 Acre Ft.	91.19	Percent
Estimated Surface Runoff	12,463,945 Acre Ft.	6.12	Percent
Estimated Ground Water Support to Stream Flow		30.5	Percent

*98.03 Percent of "Normal"

This analysis of stream flow and its relationship to ground water in the Big Blue River basin is oversimplified but it does suggest that the ground water support to stream flow is not as great as may be assumed and that a reduction of ground water support through utilization of ground water and resultant lowering of ground water levels should not result in serious depletions in stream flow at Barneston. If we assume that ground water levels in eastern Hamilton County will be 60 feet lower in 2022 than they are now, or 70 feet lower than they were originally, and that the present valleys of the Big Blue River system are not incised below the water table significantly for a distance of almost 25 miles (132,000 feet) from eastern Hamilton County, then we will have a reduction in hydraulic gradient of only 1/1900 and the reduction of ground water movement from this point to the lower basin will be very small. However, reduction of hydraulic gradients in the central part of the basin will be greater in percent.

There is considerable speculation that lowering ground water levels in the central and western parts of the basin will dry up the permanent streams in this region, but this does not seem probable because the present stream flows in the central part of the basin are derived, in large part, from surface runoff supported by ground water contribution from bank storage within the valleys and this source of support is generally quite independent of the regional ground water because of the low permeabilities in the valley fill materials.

In summation it appears that the overdevelopment of the ground water within the basin will have its greatest effect within the areas of significant utilization and that control of ground water use must be justified largely on the basis of local protection for the overdeveloped areas, and this protection must be demanded by those who will receive a benefit. Many are increasingly aware of the depletions in ground water in storage as a result of varying degrees of overdevelopment, but they are generally unrealistic in determining causes and hopefully expect that miracles can be performed to alleviate situations.

If it is assumed that an area has a long-time average precipitation of 2.00 feet (24 inches), that 50 percent of the precipitation is available to the crop, that 2.00 feet of consumptive use water is needed to secure maximum yields, then it will be necessary to supply 1.00 foot (12 inches) of water from a ground water source. Assuming that five percent of the average annual precipitation of 2.00 feet infiltrates and recharges the ground water supply, then it will be necessary to remove .9 foot from

storage if all of the surface is irrigated. This continued withdrawal is regarded as an overdevelopment of nine times and sustained yield cannot possibly be approached if more than one-ninth of the total surface is irrigated unless some means is developed to increase infiltration and it seems unlikely that infiltration can be increased by a very large percent. One possibility in this connection is to make use of all of the depressional areas in the central and western part of the Basin for infiltration purposes only. This includes 15,800 acres in Hamilton County, 22,500 acres in York County, 6,000 acres in Polk County, about 23,800 acres in Clay County, about 16,500 acres in Fillmore County, and about 14,000 acres in Butler County for a total of about 98,600 acres. If all of the precipitation that is lost to evapotranspiration in these areas could be added to ground water recharge, about 159,000 acre feet of water could be added to the ground water supply annually. This would increase recharge by about 90 percent but this increased amount of recharge, obviously an optimistic amount, would only decrease the overdevelopment of ground water from three times to about two times in the areas of higher concentration.

In order to utilize depressional areas for recharge purposes it would be necessary to acquire this land at an estimated cost of almost one million dollars. It would then be necessary to spray the side slopes of the depression areas to prevent infiltration and to develop V-shaped trenches in the lower parts of the basins to permit easy infiltration of all of the water accumulated in the depression. Subsurface conditions in all of

the depression areas are not favorable to good infiltration and only part of these depressions would be effective.

The transportation of water into the basin from outside sources and the utilization of this "foreign" water for irrigation within the basin would result in accidental recharge to ground water and would reduce the amount of ground water that would have to be pumped in order to supply requirements, but it seems improbable that this could be done even if there was not a state restriction on transwatershed diversions because the stream flow of the Platte River valley is largely committed to present irrigators, especially if the Mid-State Irrigation Project is completed.

Unfortunately, storage of runoff water within the Basin is not likely to benefit the upper and central parts of the Basin because surface water contributions are too small except in the lower half of the Basin and the use of this water in the Lower Basin would not benefit the areas of high ground water withdrawal. However, if water stored in the lower parts of the Basin could be pumped up and utilized in the upper and central parts of the Basin there would be benefits to the ground water supply in that part of the Basin.

Upland areas such as the Big Blue River Basin cannot expect to be able to make effective use of large amounts of ground water without progressively reducing the amount of ground water in storage, but this does not mean that this resource should not be used if it is used effectively. Large-scale problems will not develop until the reservoir approaches

a depletion of about 50 percent and it is not anticipated that this condition will be reached in less than 50 to 75 years in most of the basin. The critical period could be postponed significantly by regulations that would limit irrigated areas from wells to certain percents of total available areas. The closing of this area to any more wells would not result in reducing or limiting the amount of consumptive use because individual wells could be pumped for much longer periods and total withdrawals could be increased greatly.

The possibilities of increasing infiltration and ground water recharge through intensive application of soil conservation measures throughout the Basin should be examined realistically. It appears that the most significant benefit that can result so far as ground water supply is concerned is through increasing the soil moisture to the degree that less water will have to be pumped to return maximum yields, but it should be realized that this may be at the expense of stream flow because there may be a reduction in runoff which supports about 70 percent of the stream discharge. There is a potential of evaporating or transpiring from two to three times the average annual precipitation in the Basin and unless means are found to reduce the evapotranspiration losses the net result of holding all of the water where it falls will be a net loss in total water available. However, the need for more intensive soil conservation practices within the Basin is fully justified on the basis of improving soil moisture conditions, preventing soil erosion and reducing flood hazards. A reduction in total stream flow discharge may be beneficial

in eliminating discharge peaks and may actually increase stream flow during low flow periods when there is a greater need for water.

The storage of water in many small ponds throughout the Basin cannot be expected to increase the total available water supply where the surface area of the ponds is large compared to the total amount of water stored because of the potential of losing much of the stored water to evaporation without beneficial use. Larger reservoirs, where larger amounts of water can be stored in relation to surface areas, have a much greater potential of increasing the beneficial use of the available water supply. The use of runoff collection pits in connection with well-irrigated fields and the reuse of this excess water on the land is a good conservation practice that should be encouraged.

The appendix in this report includes tabular data which have been utilized in the evaluation of the ground water resources of this Basin. Some of the tables include an analysis of the Big and Little Blue River basins as a single unit.

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*Above figures on file in the Planning Division of the Soil and Water Conservation Commission.

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Appendix Table 1

Long-Term Average Annual Precipitation and
Evaporation Potential at Weather Bureau Stations
Within or Adjacent to Big Blue River Basin

(All figures converted to feet)

	Precipitation	Evap. Potential	Evap. Potential / Precipitation
David City	2.20	4.38	1.92
Osceola	1.98	4.47	2.26
Central City	1.98	4.44	2.24
Grand Island	1.82	4.18	2.30
Aurora	1.98	----	
Bradshaw	2.07	----	
York	2.20	4.59	2.09
McCool Junction	2.16	----	
Utica	2.12	----	
Seward	2.25	4.48	1.99
Crete	2.35	4.64	1.97
Friend	2.15	----	
Western	2.23	----	
Fairmont	2.17	4.48	2.06
Geneva	2.25	4.50	2.00
Bruning	2.22	----	
Clay Center	1.95	4.57	2.34
Hastings	2.00	4.60	2.30
Fairbury	2.39	4.92	2.06
Beatrice	2.41	4.67	1.94
Virginia	2.34	----	
Barneston	2.50	4.93	1.97

Appendix Table 2

Estimated Average Annual Recharge

Big Blue River Basin
(Above Barneston)

Adams County	69,469	Acres	x	1.98	x	.04	=	5,502	Ac.	Ft.
Butler County	184,451	Acres	x	2.18	x	.02	=	8,042	"	"
Clay County	174,870	Acres	x	2.03	x	.04	=	14,199	"	"
Fillmore County	258,711	Acres	x	2.17	x	.03	=	16,842	"	"
Gage County	426,394	Acres	x	2.42	x	.01	=	10,319	"	"
Hall County	40,723	Acres	x	1.93	x	.06	=	4,716	"	"
Hamilton County	320,993	Acres	x	1.97	x	.06	=	37,941	"	"
Jefferson County	155,706	Acres	x	2.36	x	.02	=	7,349	"	"
Lancaster County	4,791	Acres	x	2.37	x	.01	=	114	"	"
Pawnee County	23,955	Acres	x	2.42	x	.01	=	580	"	"
Polk County	172,474	Acres	x	2.03	x	.04	=	14,005	"	"
Saline County	356,925	Acres	x	2.25	x	.02	=	16,062	"	"
Seward County	289,853	Acres	x	2.22	x	.02	=	12,868	"	"
York County	364,112	Acres	x	2.12	x	.03	=	23,158	"	"
Total	2,843,427	Acres					=	171,697	"	"

(Below Barneston)

Gage County	55,096	Acres	x	2.53	x	.01	=	1,416	Ac.	Ft.
Jefferson County	2,395	Acres	x	2.45	x	.02	=	117	"	"
Pawnee County	40,723	Acres	x	2.57	x	.01	=	1,047	"	"
Total	98,214	Acres					=	2,580	"	"

(Total Basin)

2,941,641 Acres 174,277 Ac. Ft.

Average Annual Recharge .0592 = .71 inches

(Analog Model analysis indicates recharge of .06 feet or .72 inches)

Appendix Table 3

Big Blue Barneston Discharge in Acre Feet NE-SW 13-1N-7E

Total Discharge June 1932 to Sept. 1964 = 17,945,640 Acre Feet

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water Yr.
1932									138,400	38,700	73,800	27,800	278,700+
33	8,610	8,510	10,100	9,720	8,000	13,300	10,900	27,600	8,630	17,000	38,100	14,800	175,000
34	4,860	5,790	8,320	2,060	6,570	9,000	7,830	5,900	4,120	1,890	1,300	20,600	83,240
35	13,990	9,190	8,110	12,060	10,950	11,010	22,350	124,100	228,400	39,030	5,480	18,090	502,400
36	7,690	12,640	9,010	8,130	61,160	66,030	12,220	26,750	12,330	2,390	1,970	4,110	224,400
37	4,620	4,610	5,510	4,160	17,090	13,360	8,050	11,490	29,280	27,880	20,890	6,960	159,900
38	5,670	6,170	7,090	7,510	6,980	14,320	13,290	90,270	80,860	50,890	20,390	36,000	339,400
39	5,560	9,000	7,820	8,220	7,450	51,490	18,550	9,460	49,790	25,570	16,870	3,010	212,800
1940	4,910	5,670	6,880	5,850	6,680	14,300	9,510	10,520	15,860	4,120	30,800	5,380	120,500
41	3,780	7,080	8,530	9,660	36,470	48,410	23,440	21,650	242,300	11,280	11,760	165,700	590,100
42	69,330	34,310	40,230	51,870	15,490	54,080	15,850	116,800	102,800	26,080	28,980	54,230	610,000
43	10,840	9,910	11,020	14,130	85,230	14,660	12,590	28,760	302,900	64,580	17,920	6,470	579,000
44	7,140	8,260	7,750	8,970	9,040	15,430	82,770	104,400	254,600	77,470	87,990	69,530	733,400
45	23,500	17,090	13,920	15,780	17,170	60,720	81,480	237,600	201,800	103,200	32,410	10,540	815,200
46	20,000	11,600	10,150	15,610	30,620	23,770	11,660	12,590	65,420	59,760	11,300	10,260	282,700
47	22,170	52,710	12,550	11,740	15,420	21,320	110,900	28,860	477,500	45,410	12,090	8,480	819,200
48	8,410	7,190	8,220	15,480	129,400	317,400	26,900	14,410	29,690	63,440	83,150	33,580	737,200
49	9,470	14,580	12,610	71,630	117,500	354,700	42,330	150,300	260,300	105,600	58,620	169,200	1,367,000
1950	37,750	15,610	13,030	12,980	17,270	47,350	15,840	187,900	59,380	197,300	74,640	39,470	718,500
51	132,100	17,350	14,040	12,990	20,990	60,700	71,530	101,200	622,600	255,300	159,700	131,100	1,600,000
52	30,060	21,760	18,780	26,470	22,180	120,200	147,700	60,900	108,300	183,500	68,850	20,640	829,300
53	12,660	15,670	19,470	18,850	25,960	22,050	17,120	25,720	31,530	17,750	13,970	7,490	228,200
54	7,710	12,810	14,760	10,960	14,130	12,900	16,020	62,110	167,400	13,940	321,400	18,490	672,600
55	27,680	12,720	12,030	12,710	53,500	26,160	14,850	11,300	44,500	23,230	3,290	5,840	247,800
56	8,270	6,520	8,080	8,430	9,490	11,640	8,520	14,760	48,640	76,940	14,160	8,170	223,600
57	5,750	5,850	7,610	7,080	8,560	10,740	20,850	29,890	254,900	50,000	26,520	45,720	473,500
58	21,070	10,870	9,550	10,320	44,160	76,750	41,980	18,160	24,900	335,800	39,970	154,100	787,600
59	11,630	10,910	10,820	10,060	26,190	39,740	22,080	257,000	45,860	116,600	24,650	25,440	601,000
1960	59,340	15,260	11,760	14,270	30,210	243,800	262,800	91,190	159,800	83,060	68,580	25,250	1,065,000
61	18,760	12,470	12,950	13,020	14,190	37,790	39,310	66,470	56,810	20,980	14,400	84,030	391,200
62	63,640	35,360	14,490	59,010	86,270	174,800	31,450	55,440	67,280	46,050	23,320	19,270	676,400
63	47,110	12,650	12,840	10,700	41,960	56,800	20,770	42,270	142,400	36,450	47,860	38,280	510,100
64	19,850	10,460	10,050	11,670	11,360	12,070	25,970	34,310	111,400	13,120	13,160	17,260	290,700
													17,945,640
32 years													
Min.	3,780 (1941)	4,610 (1937)	5,510 (1937)	2,060 (1934)	6,570 (1934)	9,000 (1934)	7,830 (1934)	5,900 (1934)	4,120 (1934)	1,890 (1934)	1,300 (1934)	3,010 (1939)	83,240 (1934)
Max.	132,100 (1951)	52,710 (1947)	40,230 (1942)	71,630 (1949)	129,400 (1948)	354,700 (1949)	262,800 (1960)	257,000 (1959)	622,600 (1951)	335,800 (1958)	321,400 (1954)	169,200 (1949)	1,600,000 (1951)
Mid-point	67,940 (6%Ab.)	28,660 (9.4%+)	22,870 (3%+)	36,845 (9.4%+)	67,985 (9.4%+)	181,850 (9.4%+)	135,315 (6¼%Ab)	131,450 (12½%+)	313,360 (6%)	168,845 (12.1%+)	161,350 (3%+)	86,105 (12.1%+)	841,620 (6.1%+)
Aver-	22,935 (28%+)	13,768 31¼%+	11,752 43 3/4%+	16,004 15.6%+	31,489 (28%+)	64,462 (21.9%+)	39,607 (25%)	61,877 (37½%+)	134,869 (39.4%)	67,706 (30.3%+)	44,494 (30.3%+)	36,524 (30.3%+)	551,936 (50%)
50%	12,145	11,255	10,125	11,705	17,220	31,975	21,925	31,585	91,830	45,730	25,585	20,620	566,136

Appendix Table 4

Total Precipitation, June 1932 to September 1964

Weather Bureau Stations In and Near Big Blue Basin

(Total Water in Feet)

David City	71.46	Friend	72.45
Osceola	66.30	Western	73.34
Central City	63.98	Fairmont	69.41
Grand Island	59.66	Geneva	72.08
Aurora	66.04	Bruning	72.45
Bradshaw	67.12	Clay Center	64.57
York	71.21	Hastings	65.78
McCool Junction	70.43	Fairbury	78.01
Utica	69.20	Beatrice	77.62
Seward	72.66	Virginia	81.83
Crete	76.61		

(Total precipitation during this period was 98.03 percent of long-term averages)

Appendix Table 5

Estimated Annual Consumptive Use of Ground Water
Exclusive of Irrigation Use
Big and Little Blue River Basins

(Figures in Acre Feet)

County	Rural	Urban	Total	Big Blue Total
Adams	146	13,708	13,854	6,814
Butler	113	1,796	1,909	1,909
Clay	155	3,095	3,250	1,453
Fillmore	153	2,806	2,959	2,128
Franklin	11	264	275	-----
Gage	306	9,550	9,856	9,856
Hall	16	156	172	172
Hamilton	133	1,835	1,968	1,968
Jefferson	231	3,805	4,036	1,715
Kearney	61	1,498	1,559	-----
Lancaster	5	None	5	5
Nuckolls	102	712	814	-----
Pawnee	40	84	124	124
Polk	107	1,945	2,052	2,052
Saline	230	4,530	4,760	4,617
Seward	187	4,453	4,640	4,640
Thayer	230	2,747	2,977	-----
Webster	39	563	602	-----
York	231	4,646	4,877	4,877
Total	2,496	58,193	60,689	*42,330

* When this is added to 278,580 Acre Feet needed to supply 100 percent of requirements for irrigation at present level of development total groundwater use is 320,910 Acre Feet (exclusive of some industrial use).

Appendix Table 6

Estimated Well Irrigated Acreage

Big and Little Blue River Basins

(As of January 1, 1966)

County	Big Blue	Little Blue	Total
Adams	15,700	47,100	62,800
Butler	16,000	---	16,000
Clay	46,000	41,500	87,500
Fillmore	45,400	25,800	71,200
Franklin	---	2,800	2,800
Gage	12,300	---	12,300
Hall	13,600	---	13,600
Hamilton	127,900	---	127,900
Jefferson	9,200	3,500	12,700
Kearney	---	22,000	22,000
Nuckolls	---	24,000	24,000
Polk	47,500	---	47,500
Saline	30,600	100	30,700
Seward	37,200	---	37,200
Thayer	---	48,800	48,800
Webster	---	3,200	3,200
York	119,300	---	119,300
Total	520,700	218,800	739,500

Appendix Table 7

BIG BLUE RIVER BASIN

Consumptive Use Requirements to Supply Water for Maximum Yields from Ground Water

(Figures in Acre Feet)

County		1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	Consumptive Use Normal Precip. 1965 Level
Adams	(.5867)	302	984	000	1,330	1,753	2,953	5,653	7,382	1,925	4,543	1,553	1,595	3,270	3,872	6,081	5,667	000	6,102
Butler	(.5005)	557	854	000	636	1,095	1,537	5,754	12,935	7,343	6,970	2,301	4,669	8,648	4,839	5,467	3,947	000	8,208
Clay	(.5749)	534	2,644	000	4,250	7,681	8,093	17,069	25,264	1,851	11,625	5,890	12,111	12,331	14,705	16,369	33,267	1,031	22,824
Fillmore	(.4479)	000	1,466	000	1,849	5,049	9,991	21,419	27,018	16,093	13,823	8,914	3,974	17,984	26,391	34,391	34,293	000	30,412
Gage	(.3650)	000	76	000	101	281	000	2,069	4,732	1,625	000	1,703	726	776	1,471	4,505	6,962	3,070	4,708
Hall	(.5921)	304	547	202	935	1,001	1,202	2,524	7,642	1,595	4,811	1,103	2,829	2,859	4,045	8,081	7,328	000	8,526
Hamilton	(.5621)	6,479	6,936	8,870	17,222	25,807	22,104	57,239	100,218	193	63,636	14,529	14,627	51,139	44,129	61,236	69,483	13,756	76,614
Jefferson	(.3692)	000	000	000	000	000	000	310	1,932	149	806	327	842	337	1,430	869	2,633	1,219	1,993
Polk	(.5575)	2,158	3,239	801	2,158	3,239	5,632	16,587	27,247	3,937	20,300	000	14,596	23,701	10,940	21,449	25,828	000	26,425
Saline	(.4207)	000	676	000	431	1,916	1,200	8,245	11,563	5,864	4,810	000	1,182	7,702	10,556	10,243	17,807	000	13,084
Seward	(.4664)	169	689	000	203	958	1,749	9,145	20,805	4,822	11,408	4,924	10,088	10,360	14,287	21,255	22,885	000	18,236
York	(.4908)	3,900	3,260	1,469	5,998	18,349	11,288	40,329	78,897	000	45,153	15,247	34,964	49,046	56,442	75,302	84,599	000	61,448
Total		14,403	21,371	11,342	35,113	67,129	65,749	186,343	325,635	45,397	187,885	56,491	102,203	188,153	193,107	265,248	314,699	19,076	278,580

(.5867) Estimated acre feet requirements per acre from ground water storage with normal precipitation.

County	1949 - 1965 Supplement Needs	% of Storage
Adams	48,865 Acre Feet	(3.59)
Butler	67,552 " "	(1.38)
Clay	174,715 " "	(4.77)
Fillmore	222,616 " "	(2.67)
Gage	28,107 " "	(.78)
Hall	47,008 " "	(4.18)
Hamilton	577,603 " "	(5.61)
Jefferson	10,854 " "	(.44)
Polk	181,112 " "	(3.82)
Saline	82,195 " "	(1.29)
Seward	133,747 " "	(1.94)
York	524,243 " "	(4.02)
Total	2,138,617* " "	

* This assumes 100 percent efficiency in providing water when needed; also assumes that wells have average use on 100 acres ~~and that wells installed during the year were in full use~~; no benefit for recharge outside of irrigated acreage is asssumed and no credit is given to recharge during periods of little or no use.

County	Estimated Ground Water in Storage	Anticipated Date of Reduction of Storage to 50 Percent Under 1965 Level of Use
Adams	1,358,944 Acre Feet	2068
Butler	4,907,259 " "	2256
Clay	3,663,174 " "	2038
Fillmore	8,336,736 " "	2095
Gage	3,582,089 " "	2339
Hall	1,125,750 " "	2025
Hamilton	10,299,765 " "	2025
Jefferson	2,483,578 " "	2582
Polk	4,745,909 " "	2048
Saline	6,365,388 " "	2202
Seward	6,878,833 " "	2146
York	13,045,078 " "	2062
Total	56,592,493/ " "	

/ Exclusive of 461,563 Ac. Ft. in Lancaster and Pawnee counties.

Note: Forecast dates assume no increase in irrigated acreage and apply to average storage in entire county. Reduction to 50 percent levels in local areas of concentrated use may be expected at earlier dates.

Appendix Table 8

SUMMARY

BIG AND LITTLE BLUE BASIN

County	Planimetered Area in Basins		Big Blue	Little Blue	Ground Water in Storage*	Potentially Irrigable Area (G.W. Source) (Acres)	1965 Irrigated Area		Normal Precipitation		Average Annual Recharge	Cons. Use Req.	Normal Cons. Use 1965 Development (Ac. Ft.)	Degree of Over-development
	Acres	(%)	Acres	Acres			Acres	% of potential	Ft.	Acre Ft.				
Adams	351,400	(7.55)	53,100	298,300	12,261,427	266,880	68,600	25.70	2.00	702,800	28,112	.80	54,880	1.95
Butler	181,200	(3.90)	181,200	-------	4,995,765	107,280	16,400	15.29	2.18	395,016	7,900	.69	11,316	1.43
Clay	372,300	(8.00)	166,500	205,800	10,519,329	273,480	88,700	32.43	2.02	752,046	30,083	.79	70,073	2.33
Fillmore	368,100	(7.91)	264,750	103,350	11,250,369	246,480	74,300	30.14	2.21	813,601	24,408	.67	49,781	2.04
Franklin	26,100	(.56)	-------	26,100	348,366	14,280	3,100	21.71	1.93	50,373	1,511	.84	2,604	1.72
Gage	490,200	(10.54)	489,450	750	3,588,781	66,360	12,900	19.44	2.42	1,186,284	11,863	.55	7,095	.60
Hall	39,300	(.84)	39,300	-------	1,097,362	27,720	14,400	51.95	1.94	76,242	4,575	.84	12,096	2.64
Hamilton	320,250	(6.88)	320,250	-------	10,348,071	255,480	136,300	53.35	1.98	634,095	25,446	.81	110,403	4.34
Jefferson	368,850	(7.93)	156,600	212,250	4,658,336	99,840	12,700	12.72	2.38	877,863	17,557	.57	7,239	.41
Kearney	146,700	(3.15)	-------	146,700	5,270,165	96,000	23,500	24.48	1.93	283,131	11,325	.84	19,740	1.74
Lancaster	8,100	(.17)	8,100	-------	158,318	5,640	0	0	2.33	18,873	189	.60	------	----
Nuckolls	244,800	(5.26)	-------	244,800	1,494,430	37,560	24,700	65.76	2.08	509,184	10,184	.75	18,625	1.83
Pawnee	64,350	(1.38)	64,350	-------	291,842	480	0	0	2.58	166,023	1,660	.45	------	----
Polk	171,600	(3.69)	171,600	-------	5,663,948	135,240	47,400	35.05	2.04	350,064	14,003	.78	36,972	2.64
Saline	367,800	(7.91)	356,850	10,950	6,445,729	139,800	31,100	22.25	2.30	845,940	16,919	.62	19,282	1.14
Seward	299,500	(6.44)	299,500	-------	7,170,299	145,440	39,100	26.88	2.23	667,885	13,558	.66	25,806	1.90
Thayer	368,400	(7.92)	-------	368,400	8,426,150	187,800	52,400	27.90	2.25	828,900	24,867	.65	34,160	1.37
Webster	93,300	(2.01)	-------	93,300	655,134	6,360	3,400	53.46	2.00	186,600	3,732	.80	2,720	.73
York	369,300	(7.94)	369,300	-------	12,883,694	281,160	125,200	44.53	2.17	801,381	24,041	.70	87,640	3.65
Total	4,651,550		2,940,850	1,710,700	107,528,515	2,393,280	774,200	32.35		10,146,301	271,933		570,433	
% of Total	100		63.22	36.78										

* Includes only amount in permeable material: probably 30 percent recoverable.

WATER UTILIZATION SECTION PREPARED BY
THE NEBRASKA DEPARTMENT OF WATER RESOURCES

Report of Nebraska
Department of Water Resources
to
The Nebraska Soil and Water
Conservation Commission
for
Coordinated Planning Report
on the
Big Blue River Basin

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Compact Negotiations

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EXISTING CONDITIONS IN THE BASIN

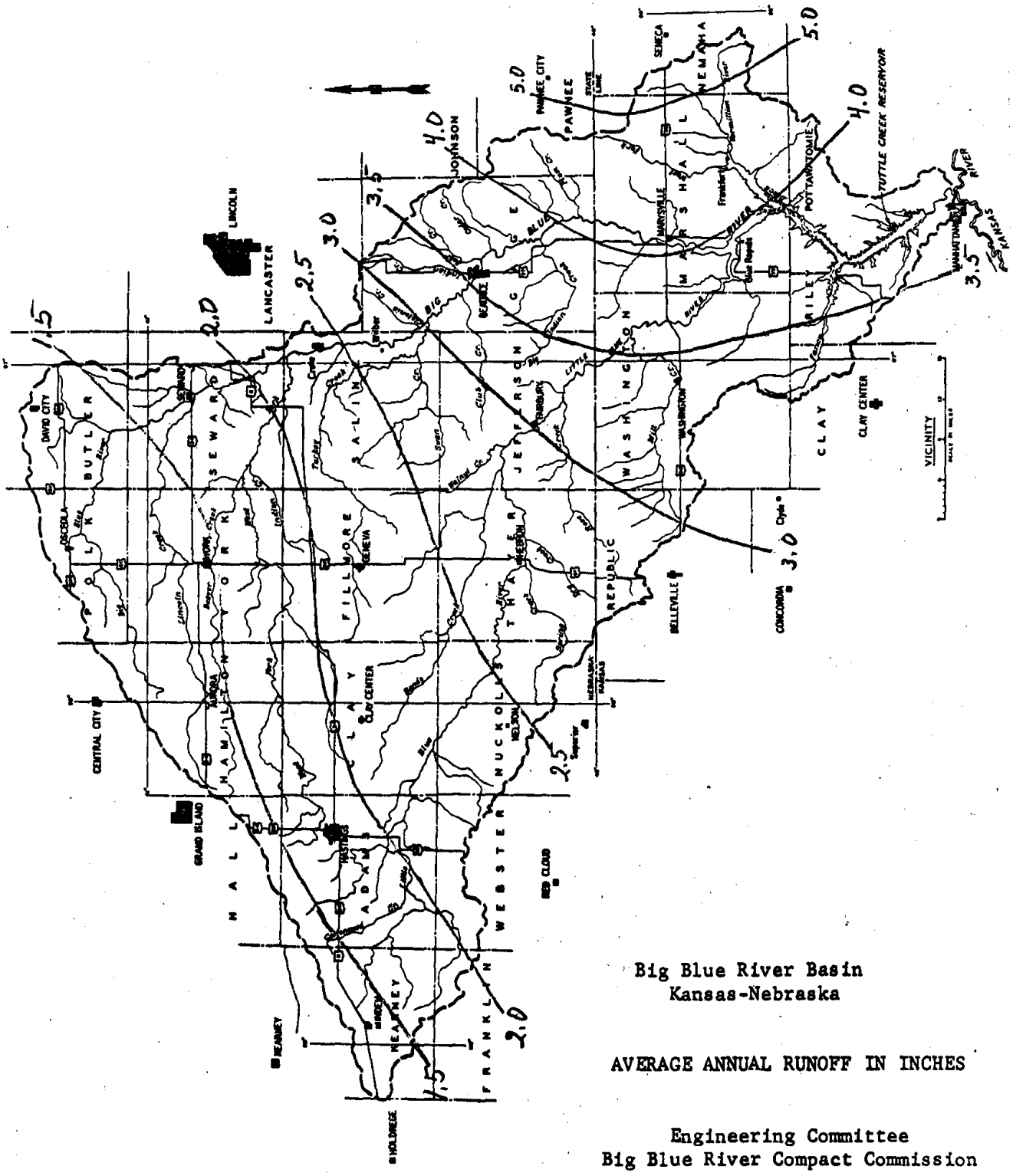
a. Description of the Basin. --The Big Blue River, a major tributary of the Kansas River drains an area of nearly 10,000 square miles in south-central Nebraska and north-central Kansas. The following paragraphs deal with the physical characteristics of the basin.

Size and Location.--The Big Blue River Basin is the third largest basin contributing to the flows of the Kansas River, with 9,696 square miles of drainage area. Seventy-five per cent of the Big Blue River Basin is in Nebraska. The streams draining the basin flow in a general southeasterly direction in Nebraska. The Big and Little Blue Rivers, the two principal tributaries, merge near Blue Rapids, Kansas, and from there the Big Blue River flows generally southward to join the Kansas River near Manhattan, Kansas. A map of the basin with principal streams is shown on plate 1. Table 1 lists the drainage areas at some of the key points in the basin:

TABLE 1

Drainage Areas for Big Blue River Basin

Location	Drainage Area in Square Miles		
	Total	Nebraska	Kansas
Big Blue River			
Mouth	9,696	7,242	2,449
Tuttle Creek Dam	9,642	7,247	2,449
Mouth of Fancy Creek	9,223	7,247	1.976
Mouth of Little Blue	4,901	4,593	308
Little Blue	3,543	2,654	889
State Line	2,654	2,654	0
Fairbury	2,347	2,347	0
Angus Damsite	1,042	1,042	0
State Line	4,526	4,526	0
Barneston	4,449	4,449	0



Big Blue River Basin
Kansas-Nebraska

AVERAGE ANNUAL RUNOFF IN INCHES

Engineering Committee
Big Blue River Compact Commission

Plate No. 3

Water Supplies

Surface Water

(a) Surface waters constitute the most readily available water source in the basin. In order to measure the supply available for use and to provide data for water resource development, a program of water flow measurements at a number of key points in the basin has been maintained.

The stream gaging program is maintained and reported by the United States Geological Survey in cooperation with various Federal and State agencies. The current program includes 6 gaging stations and one reservoir stage station on the Big Blue River; 5 gaging stations on the Little Blue River; and 7 other stations on major tributaries. Periods of record at the gaging stations are shown in Table 2 with drainage areas and average discharges given in Table 3.

The gaging stations in the Big Blue River basin are shown on plate 2. The map also shows the normal annual flow at Manhattan and on the Big Blue River near Crete and Seward. Plate 3 shows the normal annual runoff in inches for the basin.

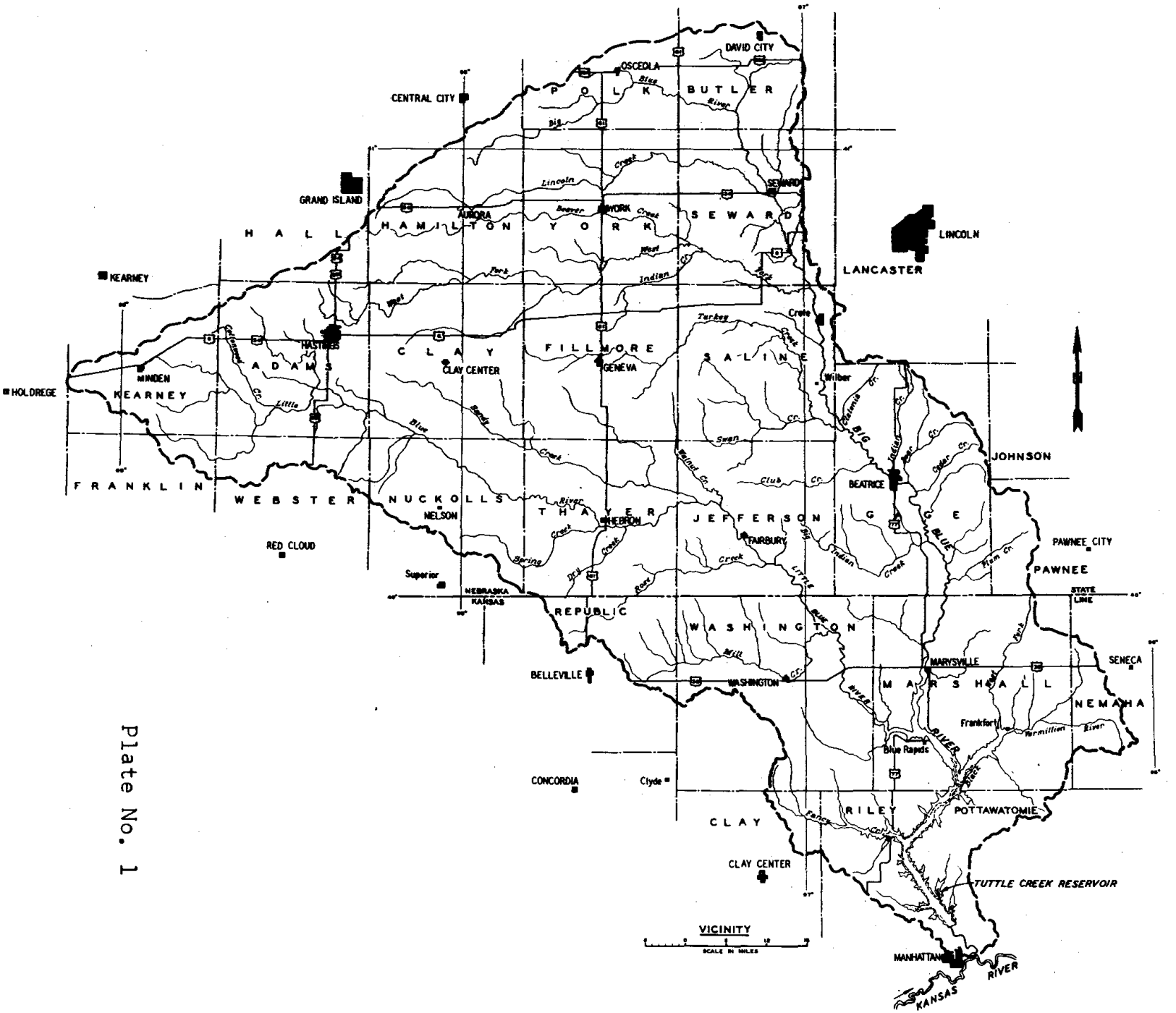

DAVID CITY
OSCEOLA
CENTRAL CITY
POLK
BUTLER
GRAND ISLAND
AURORA
YORK
SEWARD
HALL
HAMILTON
YORK
SEWARD
LINCOLN
LANCASTER
KEARNEY
HASTINGS
CLAY
FILLMORE
SALINE
ADAMS
CLAY CENTER
GENEVA
Crete
Wilber
HOLDREGE
MINDEN
KEARNEY
FRANKLIN
WEBSTER
NUCKOLLS
THAYER
JEFFERSON
GAGE
JOHNSON
BEATRICE
NELSON
HEBRON
FAIRBURY
RED CLOUD
PAWNEE CITY
PAWNEE
Superior
NEBRASKA
KANSAS
STATE LINE
REPUBLIC
WASHINGTON
MARYSHALL
SENECA
BELLEVILLE
WASHINGTON
MARYSHALL
NEMAHA
Frankfort
Blue Rapids
CONCORDIA
Clyde
CLAY
RILEY
POTTAWATOMIE
CLAY CENTER
TUTTLE CREEK RESERVOIR
VICINITY
SCALE IN MILES
MANHATTAN
KANSAS RIVER

Plate No. 1

Table 2

U. S. Geological Survey Stream Gaging Stations--Blue River Basin

Period of Record (Water Years)

Station	29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 61 62 63 64
Big Blue River	
at Seward	
near Crete	
at Barneston	
near Randolph (Apr. 1918)	
near Manhattan	
Little Blue River	
below Pawnee Creek	
near Deweese	
near Gilead	
near Fairbury 1/	
near Barnes 2/	
Tributaries	
North Branch Big Blue, Surprise Lincoln Creek near Seward	
West Fork Big Blue near Dorchester	
Turkey Creek near Wilber	
Black Vermillion River near Frankfort	
Fancy Creek at Winkler	
Mill Creek at Washington	

1/ Formerly near Endicott. Record also includes May 1908 through September 1915. Data from U. S. Geological Reports through 1964 Water Year.

2/ Formerly at Waterville.

Table 3.

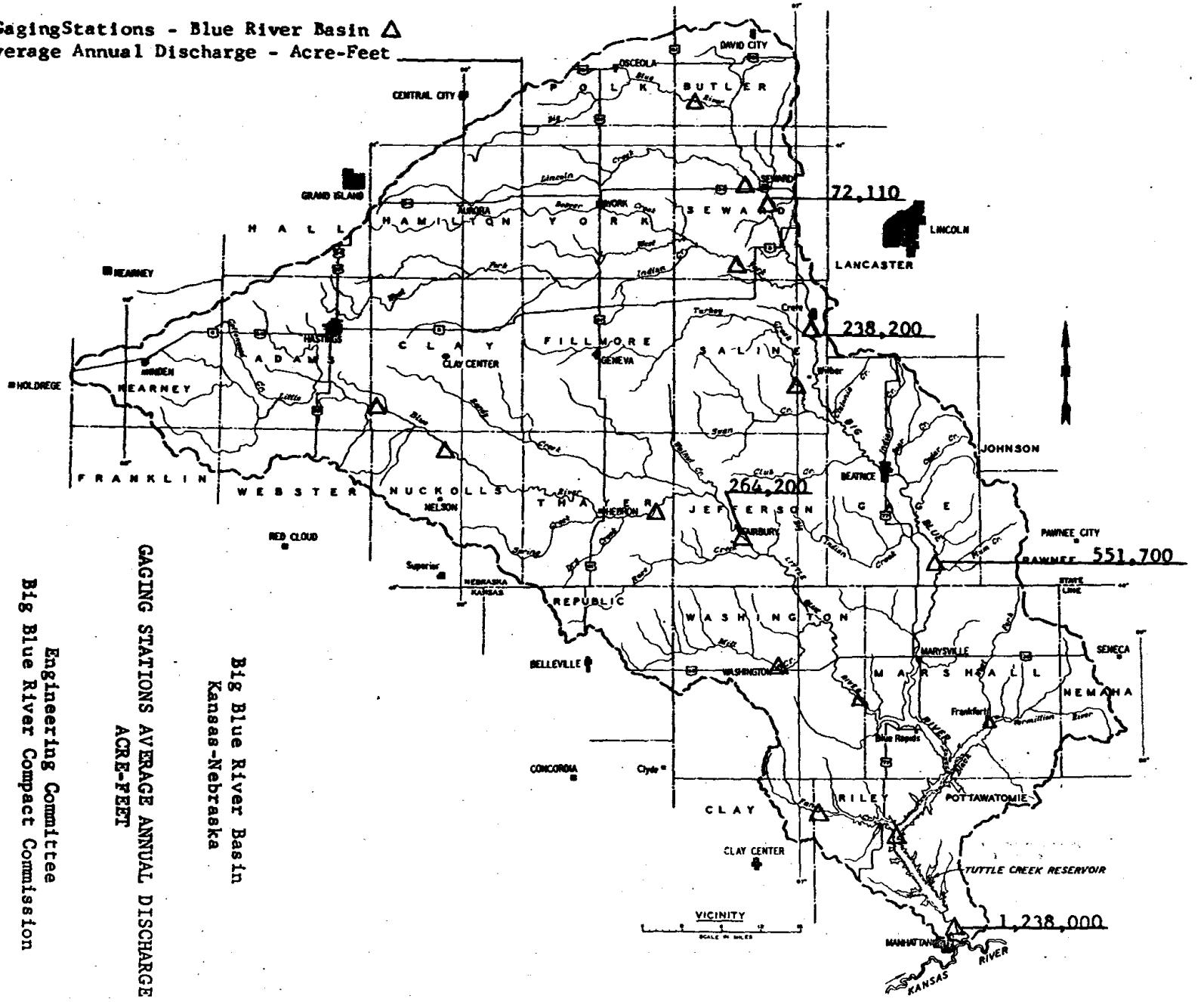
U. S. Geological Survey Stream Gaging Stations - Blue River Basin

Station	Drainage Area (Square Miles)	Average Discharge For Period of Record (cfs)	(AF/Yr)
Big Blue River			
at Seward	1,070	100	72,110
near Crete	2,680	329	238,200
at Barneston	4,420	762	551,700
near Randolph	9,100	1,650	1,194,000
near Manhattan	9,560	1,710	1,238,000
Little Blue River			
below Pawnee Creek	949		
near Deweese	1,140	140	101,400
near Gilead	1,400	244	176,600
near Fairbury 1/	2,320	365	264,200
near Barnes 2/	3,330	649	469,900
Tributaries			
North Branch Big Blue, Surprise	345		
Lincoln Creek near Seward	420	45	32,580
West Fork Big Blue near Dorchester	1,210	182	131,800
Turkey Creek near Wilber	490	71	51,470
Black Vermillion River near Frankfort	412	123	89,050
Fancy Creek at Winkler	176	42	30,550
Mill Creek at Washington	344	94	67,980

1/ Formerly near Endicott. Record also includes May 1908 through September 1915. Data from U. S. Geological Reports through 1964 Water Year.

2/ Formerly at Waterville.

GagingStations - Blue River Basin △
Average Annual Discharge - Acre-Feet



Big Blue River Basin
Kansas-Nebraska

GAGING STATIONS AVERAGE ANNUAL DISCHARGE
ACRE-FEET

Engineering Committee
Big Blue River Compact Commission

2

Flow Duration Analysis

The U. S. Geological Survey has the following information available which was made as a part of a cooperative program with the Department of Water Resources. Flow duration curves are available for the period of record for the following stations: Big Blue River at Barneston, Big Blue River at Seward, Big Blue River near Crete, Lincoln Creek near Seward, Little Blue River at Deweese, Little Blue River near Fairbury. Low flow frequency curves are available for the following stations: Big Blue River at Barneston, Big Blue River at Seward, Big Blue River near Crete, Lincoln Creek near Seward, Little Blue near Deweese, Little Blue near Fairbury. Duration hydrographs are available for the period of nineteen years for the Big Blue River at Barneston and the Little Blue River at Fairbury, and a duration hydrograph is available for a twenty-nine year period for the Little Blue River at Fairbury.

The Nebraska duration curves are prepared for the full period of record at the gaging station, up through 1959 or 1960. The discharge for the particular gaging station is also shown directly in cubic feet per second.

The flow duration curves illustrate the characteristics of the streams. A characteristic shown by the curve is that the curve demonstrates dramatically the fact that the base flow of the streams is quite low and that the flow 50 per cent of the time at the two state line stations on the Little and Big Blue Rivers is only approximately 1/3 of the average annual discharge in cubic feet per second. This comparison means that the major

portion of the runoff of the two streams is flood flow at these two stations. Included in the Nebraska duration curves, as mentioned above, are curves for the Big Blue River at Seward and the Lincoln Creek near Seward. These curves show that at times in the summer the flow drops to almost zero. This is due in part to diversion from the streams above the gaging stations by stream pumps, but it should be emphasized that this also indicates that the base flow of the Big Blue River and Lincoln Creek above Seward is very low. This is due to the fact that these streams above Seward are fed primarily by perched water tables and, as a consequence, are not affected to any extent by the deep well pumping which takes place along these streams.

The stream flow data for the two state line stations, the Big Blue River at Barneston and the Little Blue River at Fairbury or Endicott have also been arranged so that flow duration hydrographs can be plotted showing the flow for any per cent of time on any day. The curves furnished show the discharge for 10-20-30-50-70-80-90 per cent of time and for the highest and lowest mean daily discharge for the period of record. The period of continuous records is longer for the flow at Endicott on the Little Blue River and for the Big Blue River at Barneston. Therefore, the flood duration hydrograph is shown for a 29-year period for the Little Blue River at Fairbury and for a 19-year period for the Big Blue River at Barneston. The duration hydrograph for the Big Blue River at Barneston shows that the low flow actually occurred during the winter months in December and January due to freezing of the stream. The duration hydrograph

also shows that the flow of the Big Blue River at Barneston varies quite drastically for periods of a day or two due to the storage behind the power dam located upstream from the gaging station near the town of Barneston. The hydrograph shows that the lowest daily discharge was only 20 second-feet. However, the average of the discharges through the period commencing with about the 20th of July through September 30, which is the critical period for irrigation would be between 60 and 70 second-feet. The hydrograph for the Little Blue River near Fairbury or Endicott shows that the lowest recorded flow during the same period was much more uniform and would average between 40 and 50 second-feet. Duration hydrographs are an important tool for the study of any stream.

Flood History.--The flood problems of the Big Blue River basin are concentrated in the broad flood plains of the main stem and the major tributary valleys. The Blue has also been a contributor to Kansas River floods. Locally intense rainfall has resulted in severe, but localized, flooding in many areas throughout the basin. Severe floods along the main streams are generally caused by widespread, heavy rainfall. Flooding has been recorded in 34 years of the 64-year period, 1902-1965; and during the 25-year period, 1941-1965, 52 floods occurred. About 70,000 acres of cropland and several communities in the basin have suffered from repeated flooding.

Most of the floods in the basin have occurred in the spring and early summer months, but floods have occurred during almost every month of the year. The greatest flood damage and depths have occurred in the eastern part of the basin, particularly along the main stem and the lower parts of the major tributaries. While the more western part of the basin is also subject to high intensity rainfall, the high infiltration rates due to permeable soils and flat gradients in much of the area reduce the runoff considerably. Most of the severe floods in that part of the basin are local rather than general in nature. Heavy rainfalls in this area may, however, contribute appreciable to flooding in the eastern part of the basin.

Maximum floods of record, with date of occurrence at various stations within the basin, are shown in table 4.

Table 4.--Maximum Floods of Record on Big Blue River

Stations	Flood Stage	Flood of Record Date	Flood of Record Stage	Discharge	Acres Flooded in Basin
Randolph	22.0	June 1941	30.8	98,000	
Randolph	22.0	July 1951	28.9	77,800	
Barneston	22.0	June 1941	34.3	57,700	82,000
Barneston	22.0	June 1951	28.8	26,000	138,380
Crete	16.0	July 1950	28.7	27,600	72,000
Seward	18.0	June 1957	22.3	15,300	65,700
Ulysses	15.0	June 1963	24.9		25,400

While these floods are maximum floods of record, their characteristics are typical of a wide range of discharges. Floods originating on the main stem and tributaries in the middle basin areas, such as those of July 1950, June 1957, and June 1963 usually cause severe damage in the storm areas, but decrease in severity as they progress downstream, often with little overflow below the Nebraska-Kansas line. Those floods which resulted from heavy rainfall in the lower third of the basin have caused severe rural and urban damage downstream and have contributed substantially to Kansas River floods.

Snowmelt is seldom a major contributing factor to floods in the basin. However, during March-April 1960, snowmelt was the primary cause of a flood which created relatively high stages in the Big Blue River basin. This flood caused light rural damages and moderate damage at the cities of Beatrice and Fairbury, Nebraska, and to Marysville and

Frankfort, Kansas.

The recently completed Tuttle Creek Reservoir will essentially eliminate flood damage on the Blue River below the dam and will reduce flood damage along the Kansas River. Local protection projects, completed or under construction, at Frankfort and Marysville, Kansas, and at Seward, Nebraska, will provide a high degree of protection to those cities.

Water Quality

The value of water for most beneficial uses is related to its quality. Quality requirements are generally determined by municipal, agricultural, and industrial uses. In meeting these needs the United States Public Health Service "Drinking Water Standards" are commonly accepted as desirable minimum requirements for municipal use. Irrigation quality requirements are dependent upon soil characteristics, crops, etc., and therefore the USPES standards are not applicable.

Surface Water Quality

The natural chemical quality of surface waters of the Big Blue Basin is considered good for most municipal, industrial, and agricultural uses. There does not appear to be much difference between the average quality of water of the Little Blue River and the Big Blue River. The concentration of total solids would be approximately 200 mg/l at the mean discharge of each stream. Total solids are less than 400 mg/l most of the time.

The maximum and minimum concentrations of selected chemical constituents of surface water of the Big Blue Basin are as follows:

Table 5.--Maximum & Minimum Concentration (mg/l) of Selected Chemical Constituents, Big Blue River Basin

Station	Big Blue River @ Manhattan, Ks.		Big Blue River near Crete, Nebr.*		Little Blue River near Deweese, Nebr.**	
	Max.	Min.	Max.	Min.	Max.	Min.
Dissolved solids	414	82	314	80	286	71
Hardness	238	52	252	21	193	24
Chloride	47	0	11	0	9.5	0
Sulfate	50	4	47	6.8	34	3.8

*From 21 analyses, flow ranging from 106 to 21,500 c.f.s.
**From 95 analyses, flow ranging from 26.7 to 10,960 c.f.s.

The Nebraska Department of Health has furnished information in the report entitled "Water Quality in the Big Blue River" by William F. Rapp, Jr., and F. E. Krabs. The report reveals that in all cases dissolved oxygen in the river water was in excess 5 p.p.m. and that during the winter months the flow was often supersaturated. It is also shown that the pH remains about 7.0, varying only slightly during the year. These data indicate that the coliform organisms have decreased in the Big Blue River during recent years. This reduction can be attributed to the fact that all communities located on the river now have sewage treatment plants.

The U. S. Bureau of Reclamation is studying the waters of both the Big and Little Blue Basins for the development of

multiple purpose irrigation projects. Their primary interest has been to determine whether the waters of the streams are suitable for irrigation use and whether the return flows from irrigation will seriously deteriorate the quality of the streamflows below these projects.

The Bureau of Reclamation has made available to the Big Blue River Basin Compact Engineering Committee a project report for the Little Blue Unit in the Little Blue River basin dated 1962, and the Reconnaissance Report on the Blue Division, Nebraska-Kansas, dated July, 1965. The quality of water information in the Little Blue Report is summarized in that report as follows: "The total concentration of dissolved solids is very low, with the maximum being 372 p.p.m. The sodium absorption ratio and specific conductance indicated by the analysis of the samples that the waters have an extremely low sodium (alkali) hazard rating and a low to medium rating for salinity hazard. None of the samples analyzed for boron content contain more than the recommended maximum allowable concentration. The maximum content of the samples analyzed had 0.13 p.p.m. Only a few of all samples analyzed has ion concentrations suitable for the formation of residual sodium carbonate. The largest concentration was 0.17 milliequivalents per liter. Waters containing less than 1.25 m.e./l is acceptable for irrigation." The Reconnaissance Report on the Blue Division contained in part the following relative to the quality of surface waters:

"The total salt concentration as measured by specific conductance range from 65 to 584 micromicrons per centimeter. The adsorption ratio ranges from 0.2 to 0.9 Boron concentrations were determined to range from o.2 to 0.10 p.p.m." The development discussed in this study will not adversely affect the quality of downstream flows or the maintenance of desirable minimum flows below Tuttle Creek Reservoir."

Quality of Ground Waters

The chemical quality of ground water varies considerably from one point to another in the basin. Aquifers commonly used include the Dakota formation, glacial gravels, and valley alluvium. The depths of the wells range from 65 to over 200 feet.

The chemical quality of raw well waters being used at various municipalities in the Big Blue River basin in Kansas and downstream from Crete, Nebraska, range in total dissolved solids from 300 to more than 2,000 p.p.m., with a median of approximately 580 parts per million. Total hardness ranges from 225 to 1,300 with a median of about 400 p.p.m.

The quality of the well water sometimes differs considerably within relatively short distances.

Water from specific well locations that contain a high total solids content often have an unacceptably high amount of sodium, chlorides, and sulfates. Some municipalities have spent considerable sums in developing ground water sources that would supply municipal needs with water of

acceptable quality.

The U. S. Geological Survey Water Supply Paper No. 1474 is a report of the Geology and Groundwater Resources of the Big Blue River Basin in Nebraska above Crete, Nebraska. Additional reports of ground water resources have been published by counties. The Crete Report, published in 1959, included the chemical analysis of ground water for 19 samples, including 8 taken in 1945 to 1947. These samples show that the water is a calcium bicarbonate type; however, some samples in the western part of the area showed some sulfate. Concentrations of dissolved solids ranged from 245 to 804 p.p.m.; calcium and magnesium calculated as calcium carbonate, from 165 to 529 p.p.m.; sodium from 10 to 45; and sulfate from 19 to 315 p.p.m. The recharge from the Platte River to the ground water reservoir is considered a possible source of the sulfate; however, in the western 1/3 of the area the most probable source is the underlying Niobrara formation.

The U. S. Geological Survey ground water reports show that the ground water is generally classed as hard but the hardness can be treated for municipal purposes; however, many municipalities do not treat the water.

Development and Water Uses

Water Law. Nebraska has legislation which defines the procedure for acquiring and establishing water rights and for the administration of such rights. Water rights are

based on the principle of beneficial use and can be terminated by nonuse. A summary of the statutory provisions follows.

The 1889 law was the first move by the Nebraska legislature to get away from the common-law doctrine of riparian rights which had prevailed in the state up to that time. No administrative procedures were provided, however, by the 1889 law or by any previous legislation. Due to serious conflicts among appropriators it became apparent that some type of regulation would be required; and, in 1895, the legislature enacted the first comprehensive code dealing with the surface waters of the state. This law was based on the Wyoming and Colorado laws. The 1895 act established the State Board of Irrigation with jurisdiction over all matters pertaining to water rights, and it gave to the Board the duty of adjudicating existing claims to water and provided that in the future a water appropriation could be acquired only by filing an application with the Board, the appropriation taking a priority date as of the date of filing. This Board eventually became the Department of Roads and Irrigation, and in 1957 the Department of Water Resources was separated from the Department of Roads.

Some of the more important provisions of the 1895 act which are still effective are as follows:

(1) "Water for the purposes of irrigation in the State of Nebraska is hereby declared to be a natural want."

(2) "The water of every natural stream not heretofore appropriated within the State of Nebraska is hereby declared to be the property of the public and is dedicated to the use of the people of the state, subject to appropriation as herein provided."

(3) "As between appropriators, the one first in time is first in right."

(4) "The right to divert the unappropriated waters of every natural stream for beneficial use shall never be denied. Priority of appropriation shall give the better right as between those using the water for the same purpose, but when the waters of any natural stream are not sufficient for the use of all those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming it for any other purpose, and those using the water for agricultural purposes shall have the preference over those using it for manufacturing purposes; provided, that no inferior right to the use of waters of this state shall be acquired by a superior right without just compensation therefor to the inferior user."

The laws relating to surface waters have occasionally been amended to meet changing conditions; but, basically, the original law has not been changed materially. From time to time there has been litigation among water appropriators and riparian owners. The decisions rendered in such cases have interpreted and strengthened the laws, firmly establishing in Nebraska the appropriative theory as opposed to the riparian theory.

The construction of dams and the storage of water for irrigation or other useful purposes are regulated, and permits may be issued after a submission of the essential data to the Department of Water Resources.

The first legislation relating to the use of ground water by irrigation wells was passed by the 1959 legislature. This legislation does not provide for control by the Department of Water Resources. However, under this legislation ground water conservation districts may be organized which would provide local control under which the people could establish pumping rates or any other desired conservation regulations. Other legislation provides for a limitation as to the spacing of new wells on adjoining property. Under Nebraska Supreme Court decisions, subterranean waters are subject to reasonable use upon overlying lands and cannot be extracted in quantities that result in injury to owners of other overlying lands.

(2) Present Water Uses. The water resources of the Big Blue River Basin have not been fully developed. Average runoff is sufficient in most years to meet the stream flow requirements for irrigation purposes. There are no large group irrigation projects in either the Big or Little Blue Basins; but, beginning with the drought of the 30's stream pumps have been utilized to supplement precipitation. During the irrigation season the flows of the streams sometimes become depleted to a large extent. The flow duration curves, show conclusively that in both river basins streamflow is available for additional development and use if regulation is provided. Many irrigation wells have also been drilled in Nebraska. Small power dams and on-the-farm water

conservation structures have been installed to facilitate use of the water by the people of the basin.

Approximately 64,000 acres now have rights in the Big Blue Basin to pump water from the streams in Nebraska. No records are available of the amount of water diverted by these stream pumps but the amount of water pumped varies greatly from year to year due principally to the variation in rainfall. In 1954, for the first time in history, it was necessary to administer water rights in the Big Blue Basin because of insufficient supply upstream from Seward and on the West Fork of the Big Blue River between Hastings and Harvard. Some administration was also required in 1957 and 1958 on the stream and on the Little Blue River in Nebraska. Table 6 shows the surface water applications in effect as of September 30,1062.

Table 6.--Surface Water Rights in Nebraska

	Big Blue		Little Blue	
	Number	Amount	Number	Amount
For Irrigation	592	438 c.f.s.	215	158 c.f.s.
For Power	7	2,490 c.f.s.	3	19 c.f.s.
For Storage	17	814 a.f.	8	650 a.f.
Acres under appropriation	48,289		Acres under appropriation	16,600

A field inventory of the use of surface water in the Little Blue Basin in Nebraska was made during the summer of 1960. The results of this inventory revealed that the total acreage under appropriation for irrigation purposes was 16,606 acres and that the area being irrigated that year was

RESULTS OF FIELD INVENTORY OF USE OF WATER IN THE LITTLE BLUE RIVER BASIN
INVENTORY MADE BY M. E. BALL THE SUMMER OF 1960

	Approved Appropriations Acres Accum. Totals	Active Acreage 1960 by Years	Active Acreage 1960 Accum. totals	Approved Appropriations Acres to be Submerged in Angus	Active Acreage to be Submerged in Angus	Irrigated Acreage Annual Actual	a	b	c	d	x	*
1929	637.23	131.36	131.36	187.72	131.36	356.3	154.5	0	14.0	0	0	187.8
30	1109.23	0	131.36			356.3	154.5	0	14.0	0	0	187.8
31	1737.03	32.00	163.36			635.3	154.5	157.0	136.0	0	0	187.8
32	1817.61	17.00	180.36			698.9	218.1	157.0	136.0	0	0	187.8
33	1833.01	15.40	195.76			726.6	233.5	152.0	153.0	0	0	187.8
34	2227.62	264.61	460.37			910.9	279.3	243.8	200.0	0	0	187.8
35	2531.42	244.00	704.37	29.00	29.00	1353.7	279.3	382.8	415.0	59.8	0	216.8
36	2531.42	0	704.37			1351.7	279.3	380.8	415.0	59.8	0	216.8
37	2795.19	10.00	714.37	15.50	10.00	1617.5	351.3	512.8	415.0	59.8	0	278.6
38	2837.69	42.50	756.87			1585.0	279.3	555.3	415.0	59.8	0	278.6
39	2883.79	46.10	802.97			1588.0	279.3	555.3	415.0	59.8	0	278.6
40	3047.29	125.00	927.97			1709.2	270.8	555.3	415.0	59.8	186.1	222.2
41	3178.79	40.20	968.17	40.20	40.20	1729.0	270.8	506.7	415.0	59.8	186.1	210.6
42	3478.09	299.30	1267.47			1468.3	155.7	697.0	265.0	0	140.0	210.6
43	3828.79	350.70	1618.17			1819.0	155.7	1047.7	265.0	0	140.0	210.6
44	3848.79	0	1618.17			1819.0	155.7	1047.7	265.0	0	140.0	210.6
45	3905.79	57.00	1675.17			1748.0	155.7	1047.7	143.0	0	191.0	210.6
46	3930.79	0	1675.17			1722.0	155.7	1047.7	143.0	25.0	140.0	210.6
47	4160.59	229.80	1904.97	166.00	166.00	1858.8	192.5	1047.7	143.0	0	140.0	334.6
48	4577.59	185.00	2089.97	153.00	153.00	1981.4	192.5	976.3	143.0	0	140.0	529.6
49	4713.09	0	2089.97	85.50	0	2116.9	192.5	1026.3	143.0	0	140.0	615.1
50	4976.69	108.60	2198.57	82.60	82.60	2407.5	306.5	1093.3	143.0	0	167.0	697.7
51	5066.29	49.60	2248.17			2495.1	356.1	1133.3	143.0	0	165.0	697.7
52	5243.79	65.60	2313.67	65.50	65.50	2509.6	332.6	1133.3	129.0	0	167.0	747.7
53	6125.39	168.50	2482.17			3015.2	549.1	1303.4	249.0	0	166.0	747.7
54	7508.39	632.50	3114.67	198.00	198.00	3850.9	792.6	1327.9	528.7	0	256.0	945.7
55	9240.36	922.77	4037.44	55.79	55.79	4981.0	776.6	1699.9	923.7	158.3	421.0	1001.5
56	12268.45	1666.19	5703.63			6340.0	672.6	2214.4	1211.0	392.3	794.7	1055.0
57	16280.95	2797.70	8501.33			8940.8	713.3	2257.4	1459.0	1791.3	1596.8	1123.0
58	16356.95	76.00	8577.33			8798.4	611.8	2282.3	1459.0	1791.3	1531.0	1123.0
59	16487.95	131.00	8708.33			8403.2	582.8	2190.3	1459.0	1811.3	1306.0	1053.8
60	16605.95	118.00	8826.33			7367.5	381.8	1835.8	1218.7	1589.5	1297.9	1043.8
				1078.81	931.45							

a=above Angus Reservoir
*=Submerged by Angus Reservoir
b=Angus Dam to Gilead Div. Dam
c=Gilead Div. Dam to State Line
d=Diversions from Big & Little Sandy & Tribs.
x=Diversions from Rose Creek

Table No. 6

8,826 acres. The inactivity of many of the water rights in the Little Blue Basin , due primarily to variation in the rainfall, as mentioned above, has also been affected by the frequent flooding of the stream. This stream has a high flood frequency; and since much of the land irrigated during the earlier years was bottom land subject to flooding, many of the land owners became discouraged and abandoned the stream pumps.

The study showed that there was an increase in the number of surface water rights after 1950. About two-thirds of the water appropriations in Nebraska in this basin are junior to 1950. A hasty survey was also made in the Big Blue River basin below Milford, Nebraska, and similar ratio of activity was indicated in that basin. The stream water rights above Milford, Nebraska, have not recently been inventoried.

There are approximately 465,000 acres irrigated from wells in the Big Blue River basin and 125,000 acres irrigated from wells in the Little Blue River Basin. This development in the use of water by irrigation from wells for the most part has taken place since 1950. An analysis of the stream flow records indicates that up to the present date the consumptive use of ground water for irrigation purposes appears to have taken place largely from water stored in the aquifers and consequently this use has had only a minor effect on the stream flow. In some areas in the basin the reverse has been true with respect to streamflow, and some of the ordinarily

dry streams have become living streams due to runoff waters from lands irrigated from wells.

MODEL STUDY by NEBRASKA

An electric Analog model of the Big and Little Blue River Basin in Nebraska was constructed in the summer of 1963 by the U.S. Geological Survey's Analog Model Unit at Phoenix, Arizona. The objective of this study was to determine the effect of ground-water withdrawals in the Blue Basin on the flow of the Big and Little Blue Rivers at or near the Nebraska-Kansas State line.

An electric analog model of a hydrologic system is simply an array of electrical components selected and placed in such a manner that the electrical network functions as a scaled version of the hydrologic system. An electrical analog model enables the hydrologist to simulate directly all pertinent parameters of the system.

Prime factors in this type of study are the areal extent of the aquifer, its boundaries, and its properties of storage and transmissibility. Inasmuch as continuous programs of systematic test drilling, well inventory, and water-level measurement have been conducted during the last 2 decades, many of the data needed to construct and analyze an electric analog model of the Blue River basin were already available.

The area modeled (7,405 square miles) was somewhat larger than the actual topographic basin as the boundaries were based in part on hydraulic rather than topographic criteria. The north boundary was placed at the Platte River rather than at

at the topographic divide between the Platte and Blue drainage basins because the Platte River may be, under certain conditions, a source of recharge to the Blue River basin. The east boundary coincides with the west margin of the "Drift Hills" because they mark the approximate boundary between the more permeable material underlying most of the Blue River basin. The south boundary of the model was formed in part by the state line and in part by a ground-water divide between the drainage basins of the Blue and Republican River.

A preliminary steady-state analysis was made with appropriate boundary and internal conditions imposed to duplicate the regional water-level contours observed prior to the extensive ground-water development. The surface water drainage system was simulated on the model. This was determined from field data by the following trial-and-error approach. When the model's "electrical" base flow agreed with the observed base flow and the electrical head agreed with the observed configuration of ground-water head, it was assumed that the hydraulic connection modeled was analogous to actual conditions.

The accuracy and reliability of the model was further assessed by a study of the records of water levels and estimated historic ground-water withdrawals.

Results

To determine future base-flow changes and water-level declines the imput function was programmed to include, for the period 1962-82, a uniform progressive increase in consumptive-use

pumpage totaling 50 percent over the 1962 level and, for the period 1982-2022, a uniformly progressive decrease back to the 1962 level. The predicted 50 percent recuction between 1982 and 2022 was made because it is expected that the declining water levels will result in smaller well capacities and higher pumping costs. Undoubtedly some stabilization of ground-water levels, controlled in part by economics and in part by hydraulic changes, eventually will occur.

Base-flow depletions were predicted at 6 gaging stations in the basin for the period 1948 through 2022. The depletion of 9.6 cfs at Barnston by 2022 represents 4.8 percent of the average annual base flow, only 1.2 percent of the average annual total discharge. The depletion of 5.0 cfs at Fairbury by 2022 represents 3.8 percent of the average annual base flow and 1.4 percent of the average annual total discharge.

Municipal and Industrial Water Use

The Division of Nebraska Resources was contacted concerning the probability of increased use of water for manufacturing purposes in this basin, and according to the director of the department, the increase in the manufacturing in the Big Blue Basin is not considered to be a significant factor to be considered in the negotiation of a compact with Kansas. All of the towns in the basin obtain their water from wells, therefore any change in the population would be reflected in the use of groundwater. Some of the towns bordering the streams discharge their sewage effluent into the streams and the water in the streams is only of importance as a carrier for this effluent. According to the director of the Division of Nebraska Resources, it is not expected that any of them would have any large expansion in industrial use of water during the next 20 tO 30 years. Seward appears to be the most probable town to receive some industrial expansion, but this is only problematical. No data could be furnished on which to base a prediction for the increase in use of water for manufacturing purposes in the basin. The Phillips Petroleum Company and the Cominco Products, Inc. are constructing fertilizer plants at Beatrice. The Phillips plant is scheduled to go into operation in 1966 and the other in 1967. The Cominco Corporation will use the products of the Phillips Company. The plants will use approximately 50 million gallons of ground water per month,

a portion of which will be consumed. The effluent from the plants will discharge into the Big Blue River. The Nebraska Department of Health is working in close cooperation with the two plants and the department is requiring that the effluent to the stream will not deteriorate the quality of the water of the Big Blue River to the extent that with treatment at Marysville, Kansas, will not meet drinking water requirements.

(6) Power (Steam and Hydro). We should not expect any major expansion of conventional steam electric generating plants since the drainage area is not large and has no good source of fossil fuel. The possible exception was Hastings where it was predicted that an additional 100,000 KW generating unit would by added by 1975, and that two 100,000 KW units would be added by the year 2000. The Hastings plant is presently using groundwater for cooling purposes. Approximately 12 second-feet of groundwater is being returned to a branch of the West Fork of Big Blue River after cooling use is made of the groundwater. This pumping of groundwater has caused a moderate lowering of the groundwater table in the vicinity of Hastings and some pressure is being placed upon the municipality to discontinue this use. This pumping of groundwater was initiated in 1958 and has been additional water to the flow of the West Fork of Big Blue River. It is not probable that the potential expansion of the Hastings power plant will be made using groundwater for a coolant.

Discussions before the Power Review Board of Nebraska by the various power interests indicate that the center of power need in the State is near York or Tamora. This in the head waters of the Big Blue Basin. This does not necessarily mean; however, the plant would be located there or that the additional industrial development would take place near the proposed power plants, for if such a plant were to be built it would be tied in with the Nebraska Public Power System serving all of the eastern half of Nebraska with the exception of the Omaha area.

The Power Commission reported that the nuclear power facilities at Hallam would have no effect on the quality of water in the Big Blue Basin. The site of the Hallam plant is at the upper end of the Salt Creek Basin near the intersection of the divides separating the drainage basins of Salt Creek, the Big Nemaha River and the Big Blue River. The topography of the land surface and the hydraulic gradient of the groundwater indicate that water from precipitation in the area moves overland or underground toward points of discharge into Salt Creek. The use of water for power purposes in the Nebraska portion of the Big Blue Basin is rapidly being phased out. Since the initiation of the compact negotiations, the hydroelectric plant at Hebron and several small hydropower plants on the Big Blue River have been discontinued and their water rights cancelled.

Irrigation

An inventory of the use of water in the Little Blue Basin was made in Nebraska during the summer of 1960. Table 7 was prepared showing the acreage covered and the acreage that was actively being irrigated in each of the pertinent stream sections. Plate 4 was prepared from that larger table and shows by years the approved appropriation acres, the active acreage, in 1960, and the acreage on the Big and Little Sandy tributaries of the Little Blue River. The active acreage is indicated to be approximately 50 per cent of the record acreage. This acreage will be reduced by 1043.8 acres which will be submerged in Angus Reservoir if the Little Blue Project proposed by the Bureau of Reclamation is developed. The plate also shows the rapid expansion in use of water in the Big and Little Sandy tributaries of the Little Blue River commencing in 1955 and reaching a maximum in 1959 of 1,811.3 acres. This use of water in the Big and Little Sandy Creeks has taken place due to the wasting of water from lands using irrigation wells. These streams were ordinarily dry prior to this wasting of water. This acreage will surely decrease in the future as the farmers become more frugal in their use of groundwater.

Table 8 lists the small pump diversions by streams in the Big Blue River Basin:

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18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

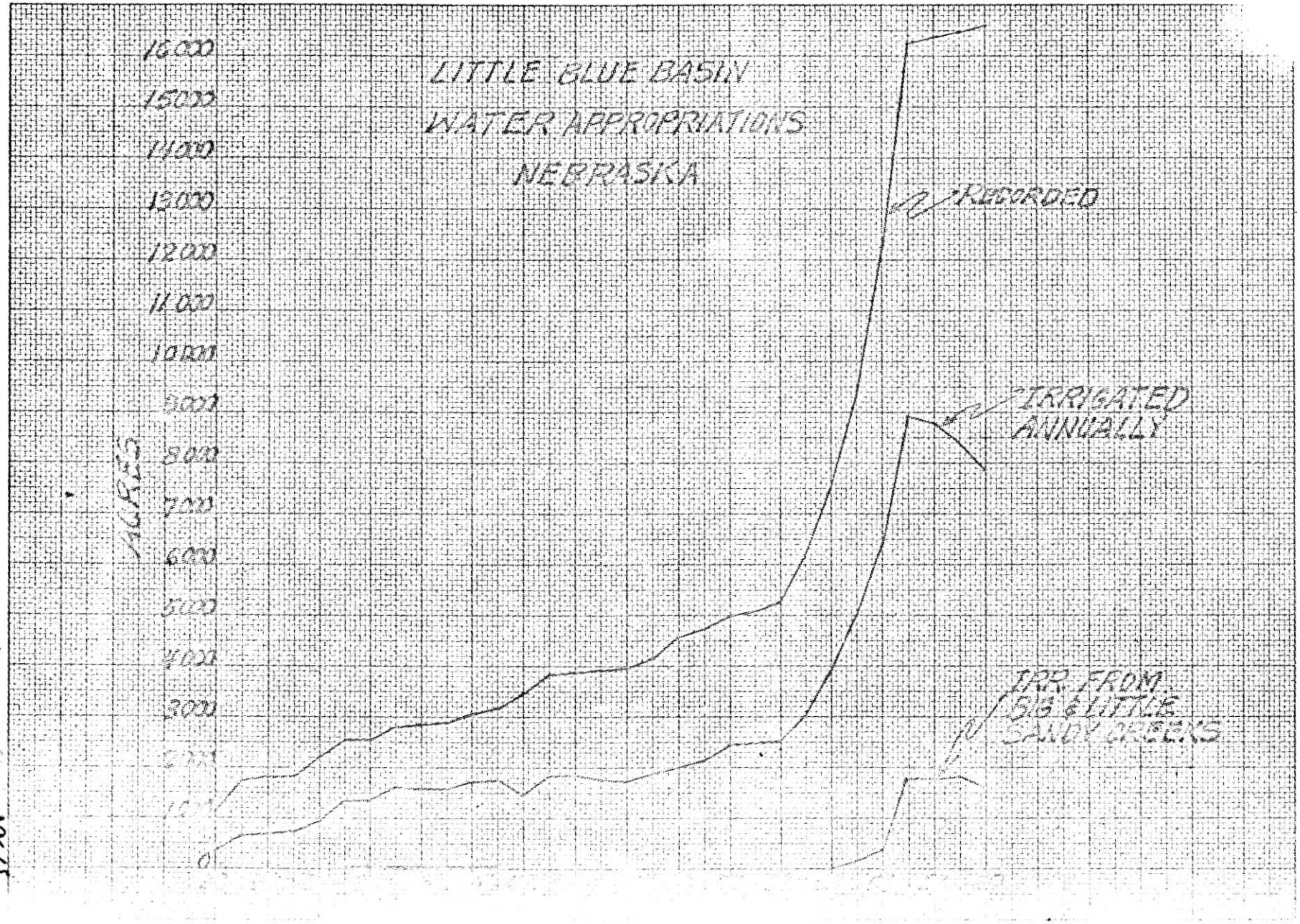


Fig. 17

TABLE 8
Claims and Applications by Streams in Division 1-D
Big Blue River Basin in Nebraska
For Irrigation to September 30, 1962

Number	Source	Grant in Second-Feet	Acres
8	Bear Creek + Pierce	12.10	846
20	Beaver Creek	7.61	895
179	Big Blue	160.60	16,854
193	West Fork Big Blue	122.31	14,4~~0~~92
3	Crooked Creek	2.36	331
8	Cub Creek	4.86	505
15	Indian Creek	11.43	~~1,132~~ 1251
44	Lincoln Creek	27.47	3,475
7	School Creek	2.93	350
16	Swan Creek	15.01	1,642
99	Turkey Creek	71.79	7,648
592		438.46	48,~~289~~

Plate 5 shows the area under irrigation by stream basins as indicated in Table 8.

There are no canals diverting from the streams in either the Big or Little Blue River basins. An inventory of the use of stream pumps from the Big Blue River Basin below Milford, Nebraska, showed a ratio of activity in the Big Blue Basin similar to the Little Blue Basin.

Measurements of the stream pumps in both basins are made only for regulatory purposes, therefore, there is no record available of the amount of water used in the two basins. Assuming that the stream pumps divert water to satisfy the

Area under Irrigation Application
Big Blue River Basin in Nebraska
to September 30, 1962

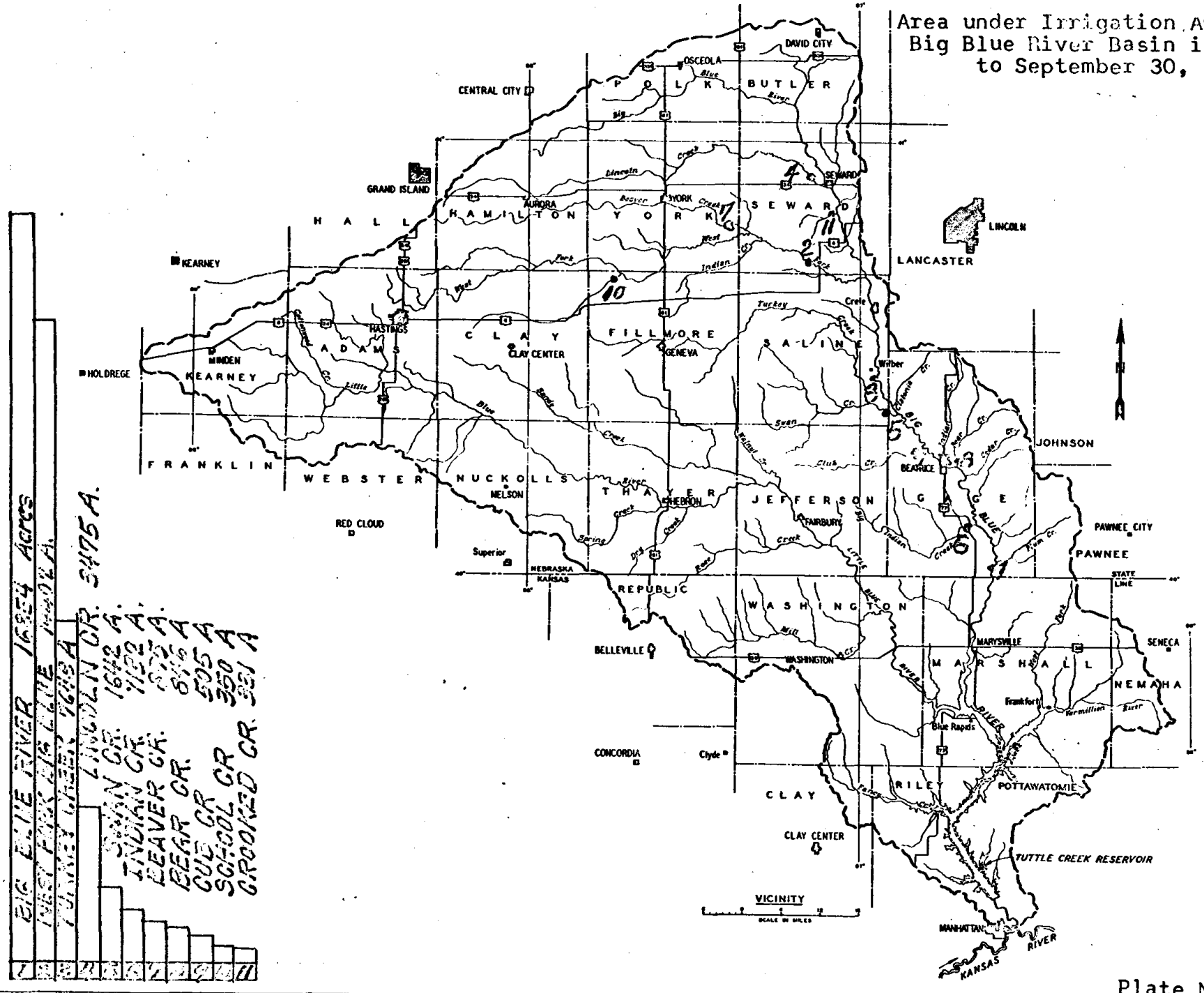


Plate No. 5

consumptive use not met by precipitation, the average annual consumptive use of water by small stream pumps amounts to approximately 0.80 of an acre-foot per acre. Under actual conditions the lands served from stream pumps probably did not receive sufficient water to meet the consumptive use requirements, as in dry years was not always available.

Plate 6 shows that the number of acres irrigated in the Little Blue Basin from small stream pumps increased materially after 1952. This graph shows that acreage actually irrigated remain about the same after 1956. A graph is not presented for the Big Blue River Basin but the growth by years is similar to that shown on the graph of the Little Blue River Basin. Table 9 and plate 7 show the area under irrigation from wells by counties in Nebraska to December 31, 1962.

Studies were made for the groundwater analog model study for the purpose of determining the groundwater consumed by irrigation wells annually. This study showed an average annual consumptive use requirement of 0.5 acre-feet per acre.

Table 9

Irrigation Wells in Big and Little Blue Basins in Nebraska to December 31, 1962

Number	County	Acres
1,209	Hamilton	114,855
1,150	York	103,500
802	Clay	80,200
677	Fillmore	71,085
625	Adams	56,250
443	Thayer	39,870
408	Polk	36,720
330	Seward	31,350
249	Saline	19,920
213	Nuckolls	19,170
145	Kearney	13,050
142	Butler	12,780
111	Jefferson	10,545
147	Hall	8,820
97	Gage	8,245
18	Webster	1,620
13	Franklin	1,040
0	Pawnee	0
	Total	629,020

Area under Irrigation from Wells in the Big and Little Blue River Basin in Nebraska to December 31, 1962.

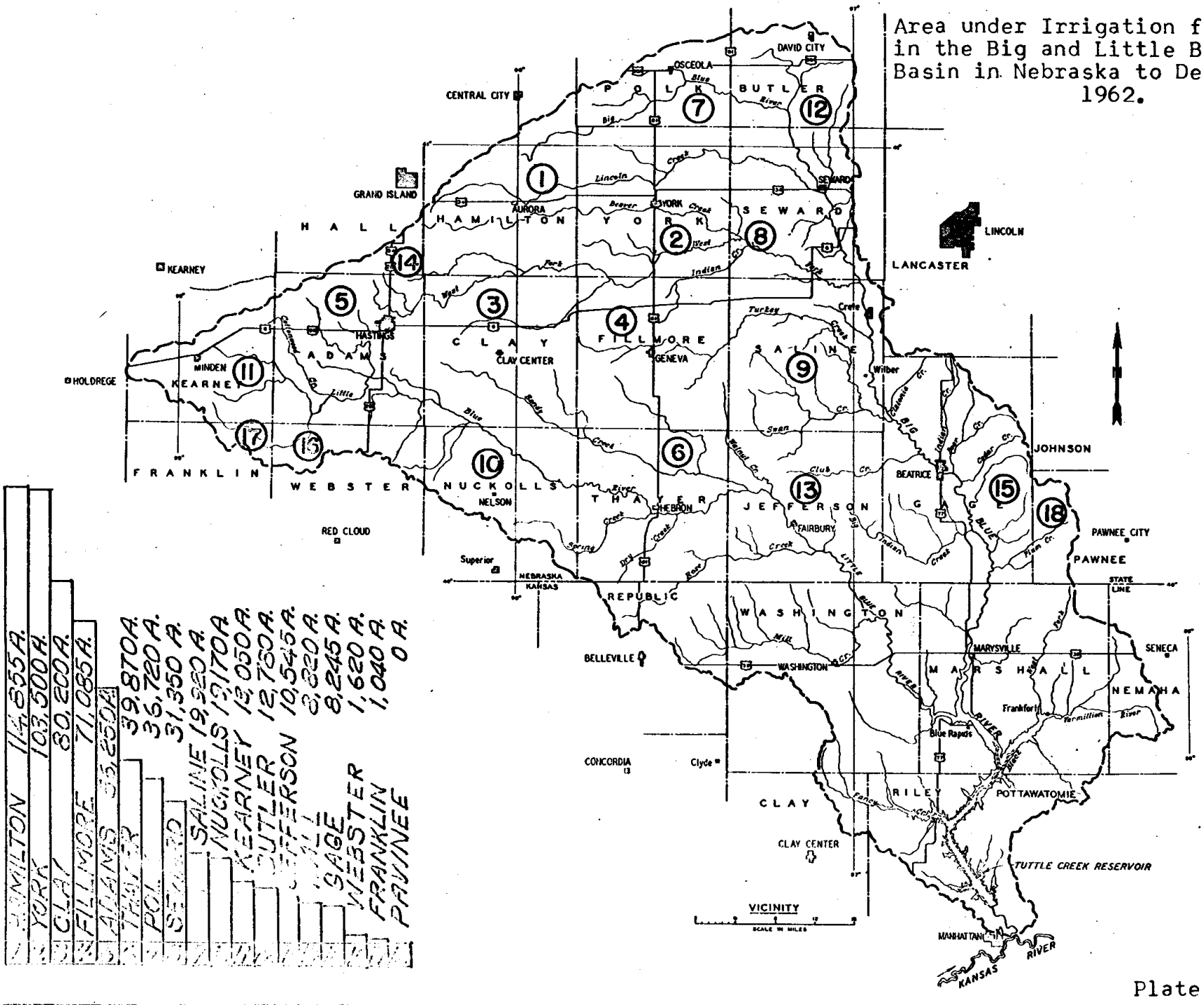


Plate No. 7

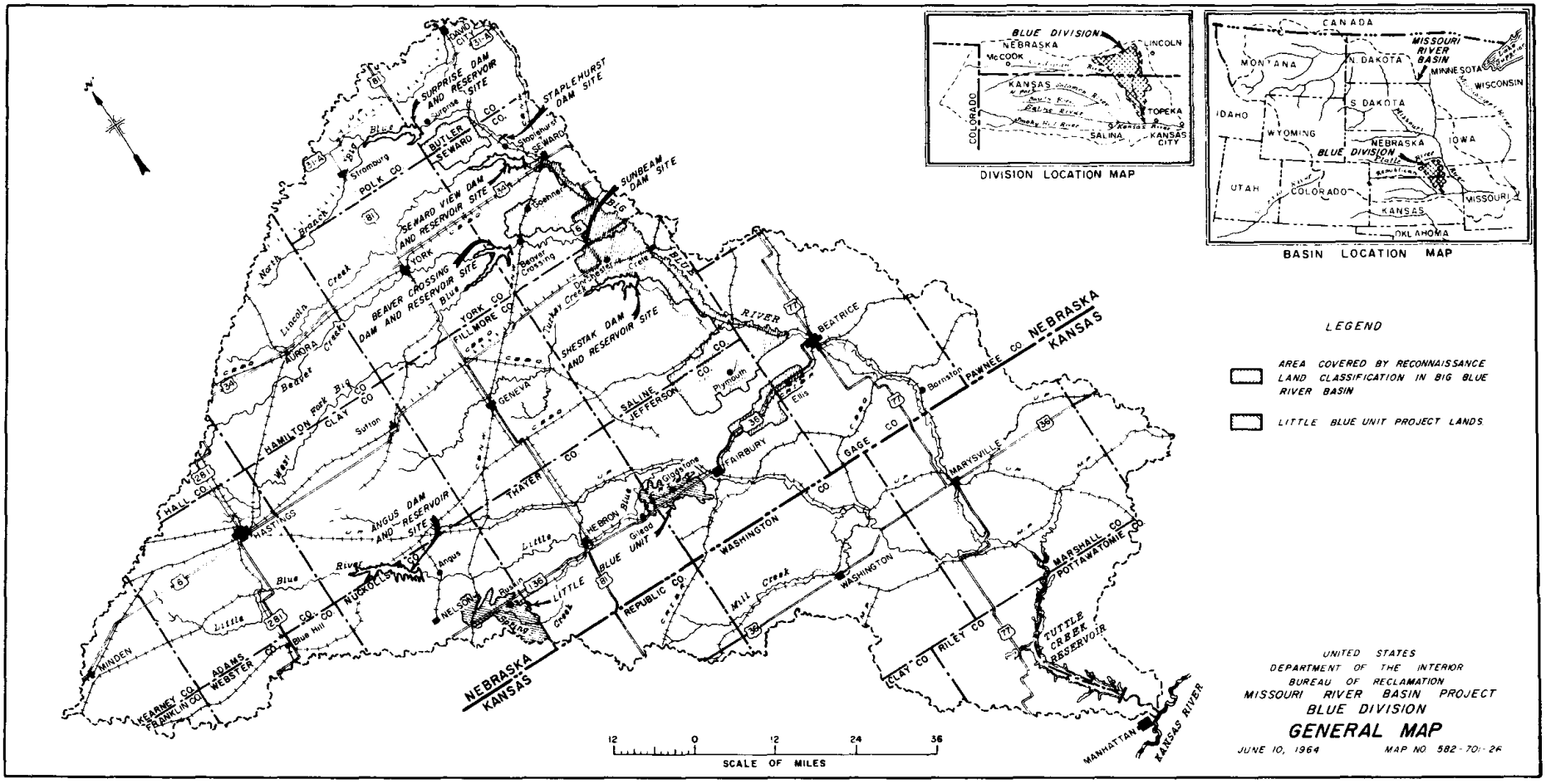
NEBRASKA
POTENTIAL DEVELOPMENT
(Near Future-1975)

3-a The potential development in the Big and Little Blue River Basins in Nebraska will probably be limited to the increase in irrigation of land from ground-water wells and from irrigation of land along the streams by pumping from surface sources. Estimates have been made that the 1962 acreage irrigated from wells will increase 50 per cent by 1982 and would reduce to the 1962 level by 2022.

It is believed that the number of stream pumps, and the irrigation of land therewith has more or less reached a saturation point until storage regulation is provided. Field inventories of the use of land irrigated from stream pumps has shown that only about 50 per cent of the land covered by water rights is actively being irrigated in both the Big and Little Blue River Basins.

The future uses of surface waters are described in detail in paragraph 3-b-1 and the future use of groundwater is described in paragraph 3-b-2. No project development for irrigation purposes is expected to be completed to the point where depletions will take place due to irrigation of land by 1975. The report for the Little Blue Project for the irrigation of 20,000 acres in the Little Blue Basin was completed in 1962 by the Bureau of Reclamation. Since the

completion of the report, the cost of providing irrigation to the project lands has been considered to be excessive and the irrigation portion of this project development has been temporarily deferred. It is possible that construction of the Angus Reservoir could be initiated and completed prior to 1975.


DIVISION LOCATION MAP
BLUE DIVISION
NEBRASKA
McCOOK
LINCOLN
KANSAS
TOPEKA
SALINA
KANSAS CITY
COLORADO
BASIN LOCATION MAP
CANADA
MISSOURI RIVER BASIN
MONTANA
N DAKOTA
MINNESOTA
WISCONSIN
S DAKOTA
IDAHO
WYOMING
IOWA
NEBRASKA
BLUE DIVISION
UTAH
COLORADO
KANSAS
MISSOURI
OKLAHOMA
LEGEND
AREA COVERED BY RECONNAISSANCE LAND CLASSIFICATION IN BIG BLUE RIVER BASIN
LITTLE BLUE UNIT PROJECT LANDS
SURPRISE DAM AND RESERVOIR SITE
STAPLEHURST DAM SITE
SEWARD VIEW DAM AND RESERVOIR SITE
SUNBEAM DAM SITE
BEAVER CROSSING DAM AND RESERVOIR SITE
SHESTAK DAM AND RESERVOIR SITE
ANGUS DAM AND RESERVOIR SITE
TUTTLE CREEK RESERVOIR
BUTLER
SEWARD
POLK CO
YORK
YORK CO
FILLMORE CO
HAMILTON
CLAY CO
HALL CO
HASTINGS
NUCKOLLS CO
ADAMS
WEBSTER CO
KEARNEY CO
FRANKLIN CO
MINDEN
GENEVA
SALINE
JEFFERSON
THAYER CO
NEMAHA
NEBRASKA
KANSAS
REPUBLIC CO
WASHINGTON
CLAY CO
RILEY CO
MARSHALL CO
POTTAWATOMIE CO
PAWNEE CO
GAGE CO
BEATRICE
FAIRBURY
MARYSVILLE
MANHATTAN
KANSAS RIVER
SCALE OF MILES
12 0 12 24 36
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
BLUE DIVISION
GENERAL MAP
JUNE 10, 1964
MAP NO. 582-701-2F

NEBRASKA

3-b POTENTIAL INCREASE OF WATER USE

SURFACE WATER

1-a Municipal and Industrial

No use of surface water for municipal and industrial purposes is expected to be made except as a carrier for treated wastes. The discharge of treated wastes from numicipalities and industrial systems to the streams would consist of ground-water pumped from wells.

POWER

1-b

No surface water is expected to be used consumptively for power purposes.

IRRIGATION

Little Blue Basin Private Development

The only use of surface water in this basin for irrigation purposes up to the present time has been that pumped from the streams by individual land owners.

The reconniassance survey made in 1960 by the Nebraska Department of Water Resources revealed that approximately 8,800 acres or 53 per cent of the acreage covered with water rights was being regularly irrigated. Many of the original pumps had been removed or physically abandoned. The irrigation of land by stream pumps in the basin appears to be decreasing about as rapidly as the irrigation of additional land is taking place. The erratic nature of stream pumping is due in part to the fact that much of the irrigated lands are river-bottom lands subject to frequent flooding. In years of low stream flow, priority administration has been put into effect, thus eliminating diversion by some of the pumps.

The stream flow regulation which will be provided by the proposed Angus Dam and Reservoir, a part of the Little Blue Project, may give impetus to additional stream pump irrigation downstream from the reservoir. The inactive water rights will be cancelled prior to the construction of the Little Blue project and any new irrigation will be subject to priority administration for the benefit of the Little Blue Project.

In addition the ground water is rising in the vicinity of the headwaters of the Little Blue River, caused by irrigation from the Tri-County Project in Kearney County. This rise in the water table may continue and may eventually cause an increase in the flow of the Little Blue River tributaries in Kearney County. The 1960 inventory showed that pumping from the Little Blue River west of Ayr, Nebraska, had been discontinued due to the inadequate supply in the river. This may have been due in part to the availability of groundwater for serving the same lands. The pumping from the stream west of Ayr may be resumed if the stream flow is increased.

The area covered with water rights in the Big and Little Sandy Creek basin in 1960 amounted to 1811.3 acres of which 1589.5 were irrigated. Irrigation will cease in the area to be included in the proposed Angus Reservoir at such time as the reservoir is constructed. In 1960, 1079 acres were covered with water rights in the area to be submerged by the reservoir of which 1043.8 acres were irrigated.

For purposes of projecting the future increase in private development, it is assumed that the Angus Dam will be completed by 1975. Based on this assumption the conclusion is made that due to the river regulation provided by the Angus Reservoir, and with the probable increase in stream flow due to the rise in the water table in Kearney County, that the acreage irrigated from stream pumps from the Little Blue River will increase after 1975 from that irrigated in 1960

to the land covered with water rights in 1960. It is concluded that this development will take place by the year 2000.

With the reduction of irrigated acreage that is expected to take place in the Big and Little Sandy Creek basins and in the area covered by Angus Reservoir, the probable future irrigated acreage by stream pumps appears to be 13.716 (16,606 minus 2,890), by the year 2000.

No continuous record of diversions by stream pumps has been made in the Blue Basin in Nebraska. The computed historical diversion not reflected in the records and the diversion in acre-feet per year by land not now irrigated, but which will be irrigated in the future, has been computed by the Department of Water Resources. The methods used were the same as used in the Little Blue Project report by the Bureau of Reclamation.

The depletion for future private development based on the foregoing conclusions is 5500 acre-feet annually for approximately 6800 acres. The discharge records at Fairbury should also be corrected for the historical diversions not reflected in the records. The acreage irrigated historically excluding about 1800 acres irrigated in the Big and Little Sandy Creek, leaves approximately 5900 acres. The historical depletion for this area not reflected in the records amount to 2700 acre-feet average annual, after allowing credit for the area submerged by the Angus Reservoir.

Big Blue Basin - Private Development

The records of the Nebraska Department of Water Resources show a total of 48,269 acres with water rights in the Big Blue River Basin as of December 31, 1962. A field reconnaissance by the Department indicates that similar to the Little Blue River Basin, only about 50 per cent of the land with water rights is actively being irrigated.

Applying the same conclusion as in the Little Blue Basin, no material increase in stream bank pumping would appear to be justified, without reservoir regulation. Approximately 24,000 acres were actually under irrigation in 1962. It is expected, that if development of large reservoirs will cause some upsurge in the irrigation of land along the streams by private irrigators, that the Department of Water Resources will cancel the unused water rights prior to construction by the Bureau of Reclamation and that private irrigation established afterward would be regulated on a priority basis.

The diversion requirements, not reflected in the records prior to 1962, for the acreage actively irrigated (24,000 acres) amounts to about 11,200 acre-feet annually. The expansion beyond the area presently irrigated cannot be accurately predicted, however, there is no basis for assuming that the acreage will exceed the sum presently covered with water rights. The remaining irrigated lands which can be reached with stream pumps are either small scattered tracts

or have inadequate drainage. The consumptive use requirement for water for an additional 24,000 acres would amount to about 19,300 acre-feet annually.

For projection purposes the conclusion is made that the maximum irrigated from stream pumps will be reached by the year 2000. A much more probable prediction of increase in stream bank pumping would be a 50 per cent increase above the present level or an additional depletion of 9,600 acre-feet annually.

Project Depletion

The Bureau of Reclamation has conducted a reconnaissance type investigation in the Big Blue River Basin and a feasibility of the Little Blue Unit, including Angus Dam and Reservoir. These studies are summarized in the Blue Division Report - Nebraska, dated June, 1965. The following is a brief summary.

Big Blue Basin

Four reservoir sites and three areas of arable lands have sufficient promise to warrant further investigation. The attached general map, dated June 10, 1964, shows the reservoir sites and the arable land for both the Big and Little Blue Basins. All reservoir sites would provide irrigation, flood control, recreation, fish and wildlife, and stream flow regulation benefits.

The multiple purpose dams and reservoirs selected as warranting further investigation are Surprise, Seward View, Beaver Crossing, and Shestak. Pumping would be required for irrigation at each of the four areas.

The Sunbeam unit, comprised of the Beaver Crossing Reservoir and the Goehner and Dorchester irrigation areas, appears to have the highest degree of feasibility of any practical combination of the reservoirs and areas in the Basin, These facilities would serve 24,000 acres of arable uplands; 15,000 acres in the Goehner area, and 9,000 acres in the Dorchester area.

The stream runoff at the four dam sites would provide a water supply for the following areas of arable lands:

Reservoir	Acreage
Surprise	3,000 Acres
Seward View	5,000 Acres
Beaver Crossing	24,000 Acres
Shestak	5,000 Acres
Total	37,000 Acres

The reservoir capacities at these four dam sites are proposed as follows:

Capacity in Acre-Feet

Initial Conditions

Item	Surprise	Seward View	Beaver Crossing	Shestak
Dead & Inactive	2,700	3,300	10,500	3,500
Conservation	56,000	68,000	120,000	77,000
Flood Control	118,000	156,000	404,000	100,000
Total	176,700	227,300	534,500	180,500

No correction to the historical stream flow records for past uses was made, as it was assumed that the historical uses were reflected in the records. Small depletions were made for future increases of surface water. A depletion of 100 acre-feet per month was made at the Surprise Dam during the May to October period. At the Seward View Dam site a depletion of 200 acre-feet per month was made. No depletion was made for the Beaver Crossing and Turkey Creek sites where it was expected that any future depletions were expected to use ground water. Therefore, depletions were limited to the estimated base flows or 15,000 acre-feet at the Beaver Crossing site and 3,600 acre-feet at Shestak.

The depletions in acre-feet annually for each of the units

for project development, as determined in the report, would be as follows:

Surprise	5,000 Acre-Feet
Seward View	9,000 Acre-Feet
Beaver Crossing	14,500 Acre-Feet
Shestak	9,300 Acre-Feet
Total	40,200 Acre-Feet

This amounts to a depletion of 8.5 per cent of the average annual flow at Barneston for the 1930--61 period of the studies.

Little Blue Project

The principal features comprise the Angus Dam and Reservoir, Gilead Diversion Dam and the pumping plants and distribution systems to serve 20,000 acres of high quality irrigable land of which 13,000 acres are near Ruskin and 7,000 acres are near Gladstone. The unit will provide irrigation, flood control, recreation, and fish and wildlife benefits. Angus Reservoir will have an initial capacity of 400,000 acre-feet, allocated as follows: dead storage, 8,200 acre-feet; irrigation, 94,800 acre-feet; and flood control, 337,000 acre-feet and will have a surcharge capacity of 56,000 acre-feet.

The details of the project are described in the report on the Little Blue Unit dated May, 1962. This report was prepared as a basis for eventual Congressional authorization of the Unit.

Depletion studies were made in the report for the private irrigation use not reflected in the records for future private development using surface water, and for future irrigation from wells. The future ground water depletions were estimated to be 21,400 acre-feet annually for the area above Angus Dam site and 11,800 acre-feet between the Angus site and the Gilead diversion dam site.

No attempt is made herein to discuss the virtues of the project plan. An analysis of the probable depletions of the project is made, however, to determine the potential stream flow depletions for compact negotiations. The irrigation

features of the Little Blue Project will deplete the stream flow 26,400 acre-feet average annually, not counting the future private depletions.

The irrigation features of the Little Blue Project have been deferred temporarily for re-study; and as a consequence, it is not considered that the irrigation features will be placed into operation before 1975. The Bureau of Reclamation is, however, making efforts to get the flood control features of the project authorized and assumed for this report that Angus Dam may be completed by 1975. It is further concluded, that the irrigation features of this unit may be completed by the year 2000.

3-b-1-d Watersheds

In response to a request to the U. S. Department of Agriculture from the Engineering Committee made through the Federal Commissioner, Harold Engstrom stated that the per cent of watershed area influenced by conservation practices as of 1985 is considered to be about 42 per cent. His report states, "It was suggested that a depletion of 2 per cent to 4 per cent of the total runoff be used to estimate the effect of future conservation measures in the Big Blue Watershed. Approximately one-third of the watershed in the Big Blue Basin in need of conservation practices has been treated. It is estimated that by 1985 a substantial portion of the land in need of conservation treatment will have been treated."

Floodwater damage on the main stem, lower stream reaches of the principal tributaries and the upstream drainages, surface water disposal from the upland flat and depressional areas, and the lowering of the groundwater tables are the major water and related land resource problems in the Big Blue Basin.

The principle tributary streams now have adequate channel and floodway capacity through their middle section. The problem here is to see that this condition is improved and maintained. The floodway, in particular, has been and is in the process of deterioration due to fallen trees and the position of debris and sediment. A plan to clean up these areas, establish a higher quality of vegetation and provide

for annual maintenance should be considered.

The installation of a higher order of land treatment measures through out the basin, and particularly in the upper reaches, seem to be the most effective means of supporting the groundwater tables. Such measures as increasing the use of contour planting and terraces on lands with little slope, reducing the down-row irrigation grades to the minimum by construction of bench levels of contour planting, increasing the infiltration characteristic of the soils by crop residues management and better selection of crops in the rotation systems and including deep rooted crops in the cropping plan, would tend to reduce the volume of water needed to be supplied by irrigation.

The reconnaissance survey of the watersheds in the Little Blue have been completed. These show the areas of significant damage and the potential for project development.

The principal water and related land resource problems in the basin are floodwater damages to the main stem and the inadequate water disposal from the upland depressional and flat areas. The preliminary watershed project surveys show Rose Creek, Big Sandy Creek, and several small drainages near Fairbury as favorable. These are being investigated further by hydrologic, engineering and economic investigations of preliminary investigation intensity.

The key structure in the Basin is the Angus Dam. With its installation, the detention reservoirs in the Big Sandy, Fairbury tribs, and Rose Creek Watershed should provide ample control for intensive agricultural use.

Improving and maintaining present channel systems by removal of dead and fallen timber, clearing debris and setting up a plan for annual maintenance is a project the local group could undertake to bring about an immediate reduction in damages.

NEBRASKA
GROUND WATER - MUNICIPAL AND INDUSTRIAL

3-b-2-a

The water used for municipal and industrial purposes is at present being supplied entirely from groundwater sources. It is expected that the use for these purposes will continue in the future from groundwater. The population of municipalities in the Big and Little Blue Basins in Nebraska is expected to increase approximately 17,000 by the year 2000. This increase is projected at the same rate of increase as during the period 1920-60. This increase in population is divided; 15,000 for towns in excess of 2,500 and 2,000 for towns less than 2,500 persons. The increase in use of water by municipalities, based on a rate of 150 gallons per capita per day, would result in an increase of 0.165 acre-feet per capita per year or a total of 2,800 acre-feet per year.

The rural population in Nebraska has declined at a uniform rate from 183,000 in 1910 to 107,000 in 1960. The decline in rural population is expected to continue, but at a decreasing rate. Projections of the decline in rural population indicates a future decrease of about 20,000 people. The estimated changes of urban and rural population indicated that the total population in the basin in Nebraska will continue to decline despite the increase of urban population, up to the year 2000, and that then the increase in urban population should about offset the decline in rural population.

The use of water by towns, bordering the streams along the perennial sections of the streams, will have a more direct effect on the flow of the streams than those towns further removed from the river channels. The towns of Seward, Milford, Crete, and Beatrice, in the Big Blue Basin, are expected to have a combined increase in population of 5,700 people. The increase in groundwater pumping would amount to approximately 1,000 acre-feet annually of which about 50 per cent would be discharged into the stream. The towns of Fairbury and Hebron in the Little Blue Basin, are expected to have a combined increase in population of approximately 1,600 which would bring about a pumping increase of 270 acre-feet annually of which 50 per cent would be returned to the stream.

It is not expected that any of the towns would have any large expansion in industrial use of water during the next 20-30 years. It is possible that Seward, Beatrice and Hastings may receive some industrial expansion, but this is only problematical. No data is available on which to base a prediction for an increase in the use of water for manufacturing purposes in the basin.

Information obtained from the Federal Power Commission with respect to power is as follows: Two questions were asked by the Engineering Committee.

1. What effect will the potential nuclear power development in the area have on the quality of the surface and underground supplies?

2. What effect will the potential R.E.A. gain have on water demands?

Answer to the first question was made that the nuclear development in the basin would have no effect on the quality of surface and ground-water supplies that would in anyway have a bearing on the compact studies.

With respect to question 2, posed by the Engineering Committee it was pointed out that the hydro-electric plants in the basin are nonconsumptive and nonaddative. The suggestion was made that we assume that the existing hydro-electric plants be in operation in 1975 and out of service by the year 2000. Five of the 10 small hydro-electric plants which were in operation in the Big and Little Blue River Basins in 1962 were retired by the year 1965. The four small hydro-electric plants along the Big Blue River downstream from Wilber, Nebraska, and the one plant located in Fairbury, Nebraska, on the Little Blue are obsolete and will probably be out of existence before 1975.

The statement was made that "We should not expect any large expansion of conventional steam electric generating plants in the Big Blue Basin for the reason that the drainage area is not large enough and has no good source of fossil fuel." The city of Hastings was the one exception. The present capacity of the stream generating plant at Hastings is 32,000 KW and the use of water was shown to be 36 second feet. It was predicted that an additional 100,000 KW generating units will be added by 1975 and that two additional 100,000 KW units will be added by the year 2000.

This prediction of additional generating units for Hastings was apparently made on the basis that the future power requirements of the Nebraska Public Power system would be met by an expansion of the Hastings plant. The projection of the increase in population at Hastings appears to warrant an additional 6,000 KW unit by 1966 and it is not expected that the generating capacity would more than double by the year 2000.

It is not probable that the potential expansion of the Hastings power plant will be made using groundwater for a coolant.

The Consumers Public Power District has initiated investigations in eastern Nebraska to determine the site of a potential 1000 megawatt steam power plant. One criterion for its location is the availability of sufficient cooling water from streams. Approximately 65 cubic feet per second average flow would be required for such a plant. It is assumed that storage would be provided to regulate the flow. This quantity of water would be available only in the lower reaches of the main streams of the Big and Little Blue Rivers, insofar as the Blue River Basin is concerned.

Ground Water Irrigation Nebraska

3-b-2-b

The irrigation development using ground water has increased in recent years to the extent that it has caused concern in the Big Blue River Basin regarding the relationship between the groundwater and the surface flow of the streams. There were about 465,000 acres being irrigated in the Big Blue Basin and approximately 125,000 acres irrigated from wells in the Little Blue Basin in 1960.

Detailed studies of the stream discharge records failed to disclose any appreciable effect of the groundwater use on the stream discharge. The flow-duration studies do show that under the present conditions of the balance of nature that the flow fifty per cent of the time of the Big Blue River at Barneston is about thirty-three per cent of the average annual flow. In the Little Blue River Basin the flow fifty per cent of the time is approximately forty-one per cent of the average annual flow at Endicott, Nebraska. These two stations are considered to represent approximately the discharge at the state line.

The median discharge of these two streams is fairly representative of the base flow or groundwater contributions of the streams, and is consequently approximately the water which is subject to depletion by groundwater pumping. The Bureau of Reclamation as a part of the water supply studies of the Little Blue Project report estimates of depletion due to groundwater pumping for the purpose of estimating the depletion that could occur to stream flow as a result of the

well developments in the Little Blue Basin. The rate of development was projected to the year 2010. The depletion to the stream during the year 2010 was computed to be 21,446 acre-feet for the area above the Angus Dam site and 11,852 acre-feet for the area between the dam and the Gilead Diversion Dam.

Due to the importance of the problem of the relationship between groundwater and surface water the Department of Water Resources initiated the construction of an electric analog model in an effort to more accurately define the effect of the groundwater diversion in the Big and Little Blue Basins. It is possible to simulate groundwater aquifer conditions in an electric model and to determine the effect of sustained pumping on stream flow and the practical sustained yield of the aquifer. The model study is described in paragraph II-c-2-b.

The results of the analog model study show that up through 1962 the flow of the Big Blue River at Barneston has been depleted about 1.2 cubic feet per second average flow. For the same year the flow of the Little Blue River near Fairbury has apparently been depleted about 0.7 cubic feet per second. The model study shows in addition that the flow of the Big Blue River at Barneston in the year 2010 which would be comparable to the period of time used by the Bureau of Reclamation that the discharge at Barneston would be depleted approximately 8.2 cubic feet per second which would be

approximately 6,000 acre-feet per year. The flow of the Little Blue River near Fairbury in the same year would be depleted approximately 4.4 cubic feet per second which would be equal to approximately 3240 acre-feet per year. This compares with the 33,298 acre-feet per year of estimated depletion as estimated by the U. S. Bureau of Reclamation for the Little Blue River.

No contention is made by Nebraska that the model study represents a precise answer. It is only a tool used to attempt to solve the complicated groundwater problems. The above results show that the model indicates that the depletion in the Little Blue Basin due to the pumping from wells would be only about ten per cent of the estimate made by the mathematical analysis in the Little Blue Project Report.

BIG BLUE RIVER BASIN COMPACT NEGOTIATIONS

The United States Bureau of Reclamation has determined that a feasible project of about 20,000 acres can be developed in the Little Blue Basin in Nebraska, and on April 15, 1957, Mr. Paul Berg, Project Engineer for the Kansas river projects, wrote to the Department of Water Resources suggesting the desirability of a compact for the Little Blue River.

Nebraska's primary interest in the negotiation of a compact relating to the Big and Little Blue Rivers is to avoid possible conflicts and controversies between the two states in the future.

Pursuant to the authorizing legislation of the States of Nebraska and Kansas and the Congress of the United States, the Nebraska Department of Water Resources through its Director, Dan S. Jones, Jr., and Compact Commissioner for Nebraska, is undertaking the negotiation of a compact dividing the waters of the Big Blue and Little Blue River Basins between Nebraska and Kansas.

Authority for consent of Congress to the States of Kansas and Nebraska to negotiate and enter into a compact relating to the apportionment of waters of the Big Blue River is contained in Public Law No. 86-489, 86th Congress.

The membership of the Compact Commissioners is as follows:

<u>Kansas</u>

Arno Windscheffel, July, 1961 to April, 1962

Robert L. Smith, May, 1962 to August, 1962

Dwight Metzler, September, 1962 to September, 1966

Keith S. Krause, appointed October, 1966

Nebraska

Dan S. Jones, Jr.

Federal

Brigadier General W. R. Shuler, July 1961 to June, 1962

Robert F. Seedlock, July, 1962 to February, 1964

Louis G. Feil, March, 1964 to date.

Progress: The Big Blue River Compact Commission, at its first meeting on July 6, 1961, at Beatrice, Nebraska, set up a permanent engineering committee consisting of one representative from each state and the representative of the Federal Government serving as Chairman. The engineering committee was authorized to secure additional direction and administrative support and data as might be needed to accomplish its task.

The membership of the Engineering Committee is as follows:

Kansas	Nebraska
Mr. William E. Steps	Mr. Marion E. Ball

Federal

Mr. Louis G. Feil, appointed February 24, 1961, and served to February 27, 1964.

Mr. Willis G. Fish, appointed February 27, 1964.

The Compact Commissioners have held eight meetings and the Engineering Committee has held 17 meetings through September, 1966. A meeting of both groups is scheduled for November 23, 1966. The work of the Engineering Committee has been to prepare an engineering report, the outline of which is attached. Parts one, two, and three of the engineering report have been completed.

Parts four through seven are summary in nature and it is expected that the engineering report will be completed by the end of 1966. The work of the commissioners has been to review the results of studies prepared by the engineering committee.

The Compact Commissioners have not yet agreed on any specific terms for a formula for the division of waters between the two states. Nebraska has presented to Kansas a tentative formula for the Little Blue Basin which in essence recommended priority administration regardless of the state line. No specific formula has been discussed by the Big Blue Basin. The primary interest of the Kansas representatives in the Little Blue River Basin seems to be to maintain certain minimum flows at the Kansas State line for irrigation along that stream in Kansas. The main interest with respect to the Big Blue appears to be toward maintenance of minimum flow during dry years so that Tuttle Creek Reservoir, with other Kansas Reservoirs, will be able to regulate the flows of the Kansas river for the domestic and industrial uses.

The Compact Commission had originally set a goal of having a compact prepared for review by the legislature of the two states during 1967. It now appears that it will be impossible to meet this goal.

BIG BLUE RIVER BASIN
DEPLETIONS OF HISTORICAL AVERAGE ANNUAL
FLOWS AT THE NEBRASKA-KANSAS STATE LINE
TO DETERMINE PROBABLE FUTURE AVERAGE FLOWS
VALUES IN ACRE-FEET

Basin & Purpose	Historical Depletions Not Reflected in Records	Future Depletions to 1975	Future Depletions to 2000	Total
Big Blue				
Private Irr.	11,200	0	19,300	30,500
Ground Water	400	2,200	6,000	6,000
Project Dev.	0	0	40,200	40,200
Watershed Dev.		(a)5,500	(a)16,500	16,500
Municipal	0	0	500	500
Totals	11,600	7,700	82,500	93,700
% Ave. Annual Flow	21	1.4	14.9	17.0
Little Blue				
Private Irr.	4,200	0	5,500	8,200
Groundwater Dev.	250	1,250	3,240	(b) 3,240
Project Dev.	0	*6,000	(c)26,400	(c)26,400
Watershed Dev.		(a)2,600	(a) 7,800	7,800
Municipal	0	0	150	150
Totals	4,450	9,850	43,090	45,790
% Ave. Annual Flow	1.7	3.7	16.3	17.3

*Evaporation Loss Angus Reservoir
(a) Based on 2% in 1975 and 4% in 2000 with 1% reflected in records
(b) - USBR - 33,200 acre-ft.
(c) - For Irrigation Features of the Little Blue Project