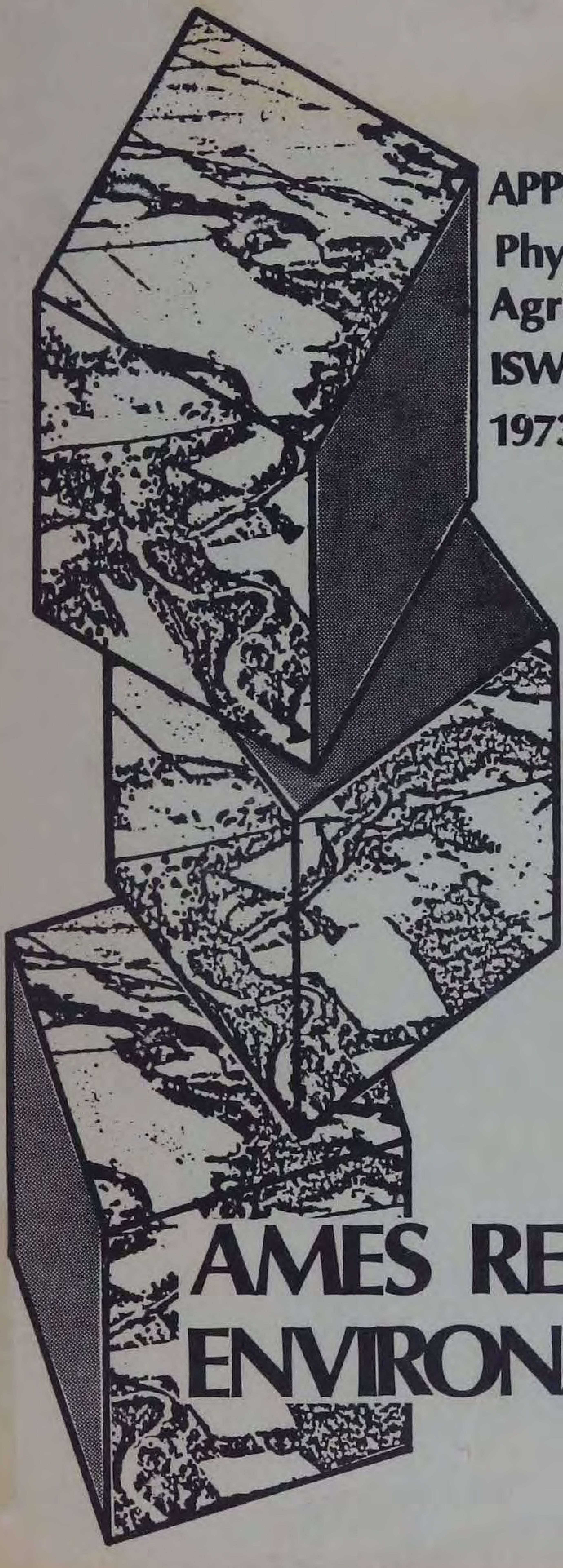

APPENDIX 4

Physical Relationships with the Agricultural Sector

ISWRRI-60-A4

1973

AMES RESERVOIR ENVIRONMENTAL STUDY

Iowa State Water Resources Research Institute
Iowa State University
Ames, Iowa 50010

AMES
RESERVOIR
ENVIRONMENTAL
STUDY

APPENDIX 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

By

Iowa State Water Resources Research Institute
and Engineering Research Institute,
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Ames, Iowa

Prepared for

U.S. Army
Corps of Engineers
Rock Island District
Contract DACW25-72-C-0033

Category Leaders:
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For Ames and upper Skunk River basin:
Land use, water quality implications of nutrients, pesticides and livestock, sedimentation, agricultural flooding and water management programs.

Iowa State University
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Ames Reservoir Environmental Study

Appendix 4

Physical Relationships with the Agricultural Sector

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Appendix 4

Physical Relationships with the Agricultural Sector

FOREWORD

Appendix 4 contains the results of studies of the agricultural influence on the proposed Ames Reservoir. The studies were conducted by faculty and graduate students in the Agricultural Engineering, Agronomy, and Civil Engineering Departments of Iowa State University.

The Rock Island District, U.S. Army Corps of Engineers, supported the environmental review study through a research contract, DACW 25-72-0033. The purpose of the project review is to provide a comprehensive and authoritative basis for preparation of an adequate environmental impact statement by the Corps of Engineers in compliance with the National Environmental Policy Act of 1969, PL 91-190. The specific objective of the Appendix 4 is to report studies describing the interaction of agriculture with the proposed reservoir.

The Ames Reservoir Project is proposed for what is largely an agricultural setting. As such and regardless of the details of its final form there will be numerous interactions between project components and the surrounding agricultural community.

Agricultural practices, by both kind and degree, influence both costs and benefits. A portion of the reservoir volume must be allocated to sediment storage but the magnitude depends on the agricultural practices. Other runoff parameters are strongly dependent on how the agricultural land is used. Examples are the content of nitrogen, phosphorous, pesticides, and organic matter. Land use, including capital investments such as drainage, erosion control, and irrigation, alters the time rate of runoff and the distribution of this runoff among surface, tile flow, and base flow components.

Costs of and benefits from agricultural operations are altered by the project. Land used by the project reduces the size of some farms making them uneconomical to farm. Thus, some farm operators will find it necessary to either cease operations at their present location or to compete with other land users for the purchase of additional acres. Indirectly, the project will take additional acres out of agricultural production by conversion at an increasing rate to rural residences and recreation uses. Production costs are raised when additional measures must be taken to reduce erosion from the land and runoff from livestock production lots. Some changes may be necessary if drainage systems are to continue to function in a satisfactory manner.

In this appendix some of the more significant interactions between the project and agriculture have been documented. In many cases basic data is complete. In a few cases new evaluative techniques have been developed. In some cases estimates based on experience are presented.

In retrospect the events of the last year, particularly the energy problem and the radical changes in value of farm products and land prices, point out the difficulty of evaluating project effects, benefits and costs as little as 25 years into the future. Planners have little choice but to make the best judgments possible with current evidence, while realizing that factors external to the project under consideration may change the picture considerably.

The studies made as a part of this appendix report have received administrative support from several groups at Iowa State University and

the University of Iowa. These include at Iowa State University: the Iowa State Water Resources Research Institute, the Engineering Research Institute, the Agricultural Experiment Station, Colleges of Agriculture and Engineering, the Office of the Vice-President for Research, and other arms of the University support services. University of Iowa coordination was achieved with the assistance of the Institute of Urban and Regional Research, Iowa Institute of Hydraulic Research, and the Department of Economics. Several communities, including Nevada and Story City, also cooperated in the study by supplying information.

The assistance and cooperation of the two assigned coordinators of the Rock Island District, Corps of Engineers, Mr. George Johnson, Chief, Water Control Section, and Mr. Charles Farnham, Hydraulic Engineer, in providing supplemental data, conducting additional reservoir operation studies, and in participating in discussions of sedimentation and flood problems are duly recognized. Other individuals in federal, state, county and local agency offices also provided information, discussed problems and results, and otherwise contributed to the study. The assistance of all of these groups is gratefully acknowledged by the authors of each chapter. The efforts of the key individuals involved with coordinating the various studies being conducted were essential to the successful completion of this report. Certainly Dr. Merwin Dougal and Dr. Norris Powell of the Iowa State Water Resources Research Institute are to be commended for their patient and consistent support in all phases of the study.

AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

Chapter 1

AGRICULTURAL LAND USE PATTERNS

by

E. R. Duncan, W. D. Shrader, and D. B. Palmer

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Chapter 1

AGRICULTURAL LAND USE PATTERNS

E. R. Duncan, W. D. Shrader, and D. B. Palmer

The future will bring changes in the crops grown, yield per unit area, and the location of cropped land. Certain of these changes would be accelerated by the Ames Reservoir Project. This chapter includes quantitative predictions as to the nature of such changes as influenced by the reservoir. Fertilizer and agricultural chemical use in the watershed is also set forth.

Historic and Projected Crop Yields for Project Lands

Crop yields are closely associated with soil conditions, weather and management. Soil conditions vary with weather and with management, but they are more nearly finite and dependable than weather.

Soils in the proposed Conservation Pool area (to 950 feet) are variable, ranging from silty clays with slow internal drainage to loams with gravel and sand at varying depths from the surface. The soils underlain by coarse materials may be droughty. Field sizes tend to be small and as a result the management skills of the farm operator tend to be lower. This situation is reflected in lower yields. Sand, gravel and limestone is being exploited in the Pool area and this activity can be expected to increase. The result will be fewer acres of cultivated land available, but the remaining acres will tend to be more productive. Another factor which

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Duncan (formerly professor of agronomy at Iowa State University) is a consultant, Shrader is professor of agronomy, and Palmer was associate professor of agricultural engineering at Iowa State University, now with Harza Engineering Company, Chicago, Illinois.

might reduce the cultivated land is the anticipated use of the noncultivated steep land for homesites and probable purchase of some of the cultivated areas for pasture.

Soils in the Flood Pool area up to the Take Line (to about 983 feet) are generally gently sloping to level with poor natural internal drainage. These soils would include Webster silty clay loams, Canisteo silty clay loam, a limited amount of Nicollet loam and associated Clarion and Storden loams. Without development of the reservoir, drainage would be expected to progress and yields in the proposed Flood Pool area would be expected to be similar to those of the entire watershed, and management skills of the farmer would be similar to those in the watershed.

With the establishment of the reservoir, drainage conditions in the pool area would deteriorate with resulting lower yields.

Table 4-1-1 shows estimated present and future yields for the Conservation Pool area, the Flood Pool area and the Watershed without establishment of the reservoir. Present average yields have been adapted from the township and county yields reported in the Annual State Farm Census and the supplementary township information. Yields used for 1980 represent an estimate of the proportionate soils and their yields from Special Report No. 66 (Fenton, 1971). These yields are a reasonable estimate of what can be expected to be attained as a five year average within the next few years. The yield estimates shown for the years 2000 and 2025 are no more than a rough guess. They are the yields that we believe are reasonable with no major technical advancements. Trend lines were not used in arriving at these figures. Weather conditions will be the principal yield deterrents.

Yields shown for the watershed area are higher than for either the permanent Conservation Pool or the Flood Pool. This is due to relatively

Table 4-1-1. Estimated crop yields for selected soils and areas in central Iowa (without project)

		Years			
		Av. for 1966-70(a)	1980(b)	2000	2025
Conservation Pool area(c) 910-950 ft.	Corn	85	95	98	105
	Soybeans	32	34	38	40
	Oats	57	80	85	85
	Hay	2.0	2.5	3.0	3.5
Flood Pool to Take Line 950-983 ft.	Corn	97	105	120	130
	Soybeans	32	40	47	50
	Oats	60	80	87	95
	Hay	2.8	4.0	4.5	5.0
Watershed above 983 ft.	Corn	100	110	125	150
	Soybeans	33	42	48	57
	Oats	64	85	95	100
	Hay	2.8			
Clarion-Stordan 3-8%	Corn	95	108	115	130
	Soybeans	33	40	44	50
	Oats	58	85	87	95
	Hay	2.5	4.5	5.0	5.0
Webster-Canisteo	Corn	105	109	120	150
	Soybeans	63	85	90	100
	Oats	35	42	47	57
	Hay	3.0	4.3	4.8	5.5
Nicollet-Webster	Corn	108	114	130	165
	Soybeans	36	44	50	64
	Oats	65	41	96	100
	Hay	3.5	4.7	5.5	5.5

Table 4-1-1. Continued

		Years			
		Av. for 1966-70[a]	1980[b]	2000	2025
Colo-Zook[d]					
Some sands	Corn	103	105	115	140
Soybeans	Soybeans	34	40	44	54
	Oats	63	85	87	95
	Hay	3.0	4.0	4.5	5.0

---

[a] Adapted from State Farm Census, County and Township Reports (For example, see Iowa, 1968).

[b] Based on yields in Fenton, 1971.

[c] Soils range from slowly permeable silty clays to loams over sand and gravel.

[d] These soils and yields represent for Skunk River bottom and from Ames to Colfax.

large acreage of higher producing Nicollet soils in the watershed, and the higher level management used by farmers outside the two pool areas.

The Colo, Zook soils classification shown in Table 4-1-1 can be considered satisfactory yield estimates for the Skunk River bottom lands between Ames and Colfax without the Ames reservoir impoundment.

Agricultural Land Use in the Project Watershed

The information presented in Table 4-1-2 is based on data from the Statistical Reporting Service and reported in the published Annual Reports and from unpublished township statistics from the same agency (for example, see Iowa, 1968). The percent of townships included in the watershed were estimated after the watershed boundary line was drawn.

The "Acres Cropped" actually represent most of the homestead acreage, with pasture and noncrop land including roads, homesites and idle acres removed from the total acres in farms.

The "Actual Noncrop" figure is a total of the reported "pasture and noncrop acres" taken as a percentage of all land in farms. The crop acres and actual noncrop acres should equal the total acres in farms.

Crop Yield Reduction Due to Inundation

Table 4-1-3 shows the estimated yield reduction for corn, soybeans, oats and hay caused by 10 days of surface inundation and 15 days of total or partial root inundation. The planting is time-phased to show yield reductions resulting from later than normal planting and replanting of the crop. The figures are based on evidence when it was available, observations and best reasoning in the absence of either.

Table 4-1-2. Area in crops, percent land in crops and yields for acres associated with the Ames Reservoir

County & Townships	% Twp. in WS.	Cropped Area		Corn			Soybeans			Oats			Hay	
		Acres(a)	%(b)	Acres	%(c)	Yield(d)	Acres	%	Yield	Acres	%	Yield	Acres	%
Story Co. Av. 1966-70		243674	71.7	130329	53.5	9800	107281	44.0	3300	9837	4.0	6000	14287	5.9
Hamilton Co. Av. 1966-70		272381	75.5	142570	52.3	10000	107102	39.3	3300	10757	3.9	6400	11217	3.8
Story Co.														
Franklin Twp.	8	11167	68.5	6108	54.7	9700	3762	33.7	3100	468	4.2	6100	738	6.6
Milford	14	16416	74.0	9115	55.5	10000	6165	37.6	3500	392	2.4	6000	641	3.6
Howard	86	14709	71.8	7974	54.2	10000	5328	36.2	3600	483	3.3	6100	867	5.9
Lafayette	78	16168	73.7	8467	52.4	10100	5795	35.8	3300	843	5.2	6100	1120	6.9
Hamilton Co.														
Blairsburg	17	19100	81.6	9794	51.3	10000	7754	40.6	3200	937	4.9	5900	564	2.9
Ellsworth	100	15425	75.9	8090	52.4	9600	5583	36.2	3600	695	4.5	5900	965	6.3
Rose Grove	27	17814	79.5	9738	54.7	10200	6419	36.0	3300	522	2.9	6900	672	3.8
Liberty	100	18048	77.2	8990	49.8	10000	7541	41.8	3200	711	3.9	5900	657	3.6
Lincoln	85	20886	81.5	12730	60.9	10900	6088	29.1	3500	759	3.6	7000	1003	4.8
Lyon	100	15372	75.9	8834	57.5	9800	5294	34.4	3300	686	4.5	6000	774	4.6
Scott	88	17027	76.2	9655	56.7	10200	5872	34.5	3400	630	3.7	6300	809	4.4
Williams	27	15695	78.2	8697	55.4	10600	7767	49.5	3300	479	3.0	6700	579	3.7
Independence	22	17860	76.2	7981	44.7	9800	7385	41.3	3100	569	3.2	6300	521	2.9
Clear Lake	44	19054	76.4	9499	49.8	9600	7822	41.0	3300	868	4.6	6900	890	4.7
Hamilton	56	16838	79.6	8226	49.0	9900	7037	41.8	3300	913	5.4	6700	578	3.4

(a) Includes "other" and pasture lands (actual cropped)

(b) Divide cropped area by area in farms.

(c) Corn acres as a percent of cropped acres

(d) All yields are in pounds per acre.

Table 4-1-2. Continued.

County & Townships	% Twp. in WS.	Area in farms	Area in pasture		Noncrop area		Pasture plus non-crop acres	Actual noncrop %[(f)]
		Acres	Acres	%[(e)]	Acres	%		
Story Co. Av. 1966-70		339820	30408	11.1	65738	19.3	96146	28.3
Hamilton Co. Av. 1966-70		360727	25720	9.4	62625	17.0	88345	24.5
Story Co.								
Franklin Twp.	8	16294	2033	15.3	3093	19.0	5157	31.5
Milford	14	22194	1488	8.3	4290	19.3	5778	26.0
Howard	86	20482	1598	9.8	4175	20.4	5773	28.2
Lafayette	78	21948	1937	10.7	3843	17.5	5780	26.3
Hamilton Co.								
Blairsburg	17	23421	595	3.0	3726	15.9	4321	18.4
Ellsworth	100	20315	1394	8.3	3496	17.2	4890	24.1
Rose Grove	27	22399	1143	6.2	3913	17.5	5056	22.6
Liberty	100	23387	1224	6.4	4115	17.6	5339	22.8
Lincoln	85	25612	708	3.3	4018	15.7	4726	18.5
Lyon	100	20244	1581	9.3	3291	16.2	4872	24.1
Scott	88	22352	1389	7.5	3936	21.4	5325	23.8
Williams	27	20055	963	4.6	3597	17.9	4360	21.7
Independence	22	23421	1747	8.9	3814	16.3	5561	23.7
Clear Lake	44	24926	1278	6.3	4594	18.4	5872	23.6
Hamilton	56	21162	1123	6.2	3208	15.1	4331	20.5

[(e)] % Pasture = [Acres in pasture ÷ (Acres in farms - "Other" acres)]100

[(f)] % Actual noncrop = (Acres in pasture plus noncrop ÷ Acres in farms)100

Table 4-1-3. Percent crop yield reduction from 10-day surface inundation and 15-days root inundation.

Dates of Inundation	Percent yield reduction			
	Field corn	Soybeans	Oats	Brome-alfalfa Hay
April 1-15	0	0	100	100
April 15-31	0	0	20 D	30
May 1-15	5 D(a)	0	50 R	40
May 16-31	15 D or R	5	0(b)	70
June 1-15	30 R	20 D or R		100
June 16-31	60 R	60 R		100
July 1-15	100	70 R		50 PH(c)
July 16-31	100	100		20 PH(d)
Aug. 1-15	100	100		20 PH
Aug. 16-31	100	100		20 PH
Sept. 1-15	100	100		0 H
Sept. 16-30	60	90		0 H
Oct. 1-15	50	70 PH		0 H
Oct. 16-31	30 PH	0 H		0 H
Nov. 1-15	20 PH	0 H		0 H
Nov. 16-30	10 PH	0 H		0 H

(a) D - Delayed Planting
R - Replanted
H - Harvest Completed
PH - Partial Harvest

(b) For inundation of oats after May 16, land would be replanted to soybeans.

(c) One crop would be harvested before July 1.

(d) Two crops would be harvested before July 16.

The yield reductions shown, due to late planting, may be lower than will actually occur because it is assumed that replanting can be done immediately following the 15 day inundation period. This will not always be possible. Yield reductions will be greater at higher average yield levels than at lower levels, and may, in fact, result in a greater percentage yield decrease as well as a greater actual yield decrease.

The yields on which these decreases were based were: corn - 85 bushels per acre, soybeans - 32 bushels per acre, oats - 60 bushels per acre and hay - 2.5 tons per acre.

Historical Base for Calculating Time and Depth of Flooding

A summary of operational hydrographs for the installed reservoir have been calculated for the period 1935 to 1965. This data is summarized in Table 4-1-4.

Table 4-1-4. Water depth and days of inundation - 960' base(a)

Year	Elevation Range (feet)	Duration (days)	Ave. Depth (feet)	Flooding date	960' Recession date
1935	960 - 961	4	0.6	July 4	July 8
1944	960 - 965	88	12	May 13	Aug. 9
	965 - 970	39	7		
	970 - 974.5	15	2.3	June 16	July 1
1945	960 - 962.7	28	1.4	June 15	July 1
1947	960 - 965	39	11.3	June 9	July 26
	965 - 970	21	6.3		
	970 - 973.8	8	1.9	June 23	
1951	960 - 965	62	3.5	April 11	July 20
	965 - 966	3	0.5	May 3	

Table 4-1-4. Continued

	Elevation Range (feet)	Duration (days)	Ave. Depth (feet)	Flooding date	960' Recession date
1954	960 - 965	14	4.0	June 12	July 6
	965 - 966.5	3	0.8	June 22	
1960	960 - 963.1	66	1.6	April 2	June 11
1962	960 - 961.1	20	0.6	April 3	May 5
1965	960 - 965	22	7.3	April 4	May 5
	965 - 969.8	10	2.4	April 8	

[a] From Operational hydrographs, Plates 1-30 to 1-34, Design Memo No. 1 Calculated from 30 years of observations (U. S. Army, 1968).

These readings are all calculated to a base of 960 feet which is 10 feet above the maximum height of the proposed Conservation Pool (950'). The maximum calculated water depth is slightly above (1944) the maximum proposal for the flood pool level, but well within the proposed "take line".

Table 4-1-4 shows that for the period of record (1935 through 1965) there would have been nine years with inundation above the 960 ft. elevation.

By use of the water stages shown in Table 4-1-4 it is possible to estimate the frequency of crop loss at three elevation ranges: 960-965, 965-970, and 970-975 feet. It is assumed that more serious crop loss occurred at the 950-955 and 955-960 foot elevations in the years shown in Table 4-1-4 and some damage occurred in years not shown in the table at these elevations. See also Table 4-1-3.

Based on judgment of what would have happened to crops with the water levels and durations shown in Table 4-1-4 the following conclusions are drawn. Thirty percent of the years 1935-65 inundations would have occurred at the 960-965 foot level. At the 965-970 foot elevation inundation would have occurred in 17% of the years. At the 970-975 foot elevation inundation would have occurred in 7% of the years. For an approximation the percent figures 30-15-5 can be used for the three elevations.

Table 4-1-5 shows that crop damage due to inundation to the 965' elevation tends to be significantly more serious than at higher elevations. Replanting which was necessary at the lower elevation where damage was lower represents an added cost to production for corn and soybeans.

Table 4-1-5. Percent damage to crops at selected elevations

Elevation and Crop	Percent yield reduction and approximate probability of occurrence[(a)]				
	Percent yield reduction				
	0	25	50	75	100
960-965'					
Corn	3-15		1-5		5-25
Soybeans	3-15	1-5		2-10	3-15
Oats		1-5			8-40
Hay	1-5				7-35
965-970'					
Corn	3-15				2-10
Soybeans	3-15				2-10
Oats	2-10	1-5	1-5		1-5
Hay	2-10				3-15
970-975'					
Corn		1-5			1-5
Soybeans		1-5		1-5	
Oats					2-10
Hay			2-10		

(a) Using 30 years of observation as a base each occurrence would represent 3.3%; in this table each occurrence is considered as 5%.

In the interest of maximizing quality of water in the proposed Conservation Pool it would be reasonable to consider seeding the entire Flood Pool to an elevation of 975 feet to Reed canarygrass and convert the area into grazing land. Such a move would reduce the "mud flats", reduce blowing soil, reduce siltation and other pollutions attributable to cultivated farming and still leave a profitable and beautiful "green belt". Research in Wisconsin and Minnesota has shown that Reed canarygrass can tolerate inundation up to 50 days with little loss of stand. Winter flooding, even with an ice cover, can occur for longer periods, with little crop damage. Research at Iowa State University has shown live beef production on Reed canarygrass pasture ranging between 400 and 600 pounds per acre. Nitrogen fertilizer is needed for such production levels. For those who have concern about possible nitrate movement after such applications should remember that there is a "built in" safety factor against nitrate movement in the denitrification process which can and does take place under anaerobic conditions.

Projected Crop Values for Project Lands

Cropped area, as a fraction of the total area, increases from the valley floor (elevation 910) to the Take Line (elevation 983). At lower elevations more of the land is used for purposes other than crops. This conclusion is based on an analysis of the available aerial photographs for the reservoir area and is represented graphically by Figure 4-1-1. It can be seen that within the conservation pool (below elevation 950) 30 percent of the area is cropped while in the vicinity of the Take Line 62 percent of the area is cropped.

Utilizing the information of Figure 4-1-1 it is possible to specify a percent cropland for any desired elevation increment. Such percentages are

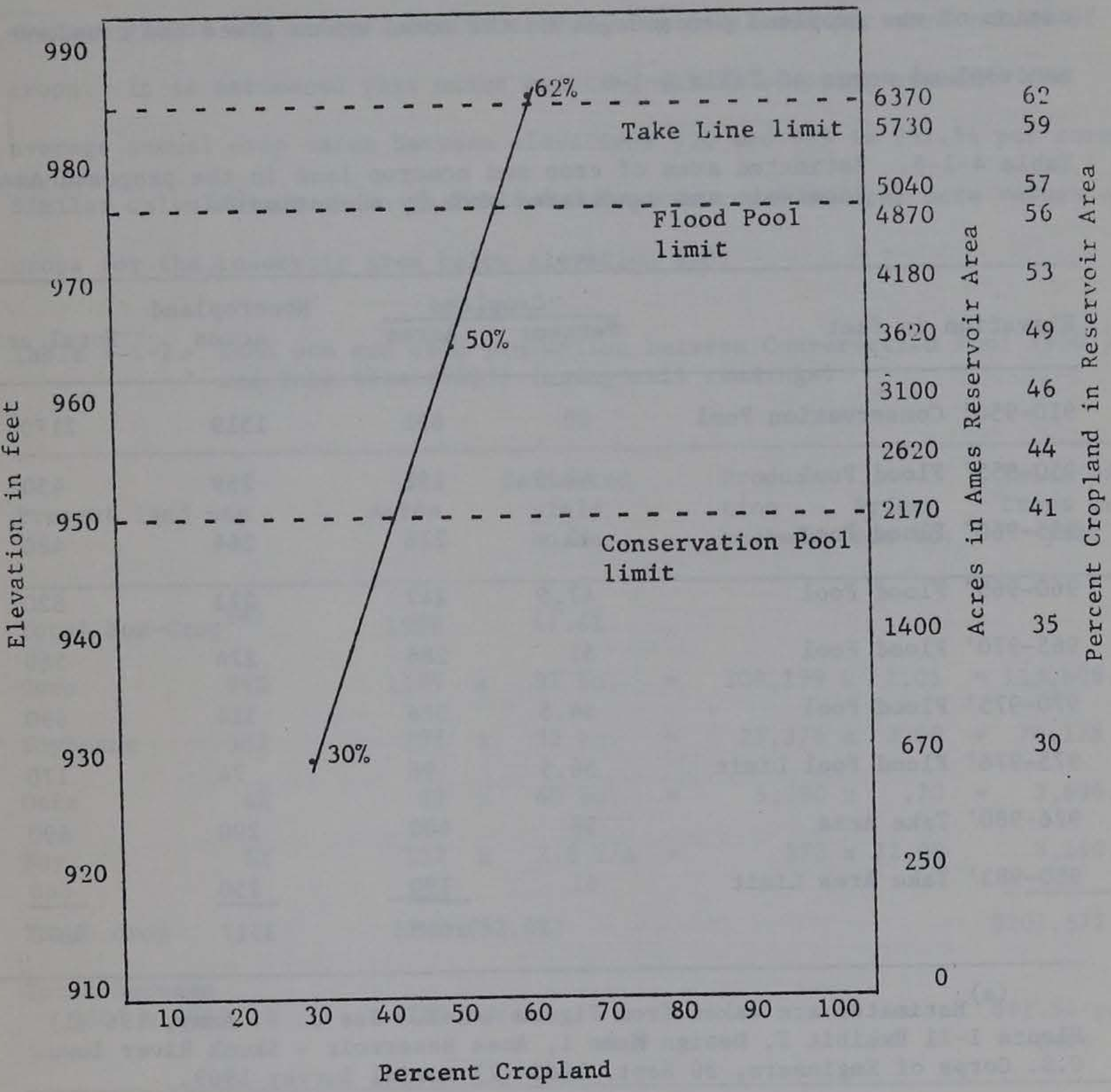

Fig. 4-1-1. Distribution of land and cropland by elevation.

shown in the second column of Table 4-1-6. For example, between elevation 950 and 955, 42.5 percent of the land is cropped. The total acres in each elevation increment is available from Plate 1-21 of U.S. Army, 1968. Application of the cropland percentages to the total acres gives the cropland and noncropland acres of Table 4-1-6.

Table 4-1-6. Estimated area of crop and noncrop land in the proposed Ames Reservoir and associated area by elevation[(a)]

Elevation in feet	Cropland Percent	Cropland Acres	Noncropland acres	Total acres
910-950' Conservation Pool	30	651	1519	2170
950-955' Flood Pool	42.5	191	259	450
955-960' Flood Pool	45	216	264	480
960-965' Flood Pool	47.5	247	273	520
965-970' Flood Pool	51	286	274	560
970-975' Flood Pool	54.5	376	314	690
975-976' Flood Pool Limit	56.5	96	74	170
976-980' Take Area	58	400	290	690
980-983' Take Area Limit	61	390	250	640
		2853	3517	6370

(a) Estimates are taken from Figure 4-1-1. See U. S. Army, 196 (1) Plants 1-21 Exhibit 1, Design Memo 1, Ames Reservoir - Skunk River Iowa. U.S. Corps of Engineers, 30 Sept. 1968 (2) Aerial Survey 1969.

Such an analysis makes possible the prediction of crop values for project lands. From Table 4-1-6 it can be seen that between elevations 950 and 983 the total cropland acres are 2202 (=2853 - 651). A study of the aerial photographs also revealed an average crop distribution below elevation 983 of corn - 54 percent, soybeans - 36 percent, oats - 4 percent, and hay - 6 percent. Applying these percentages to the cropland acres (2202) gives the acres in each of the four crops shown in Table 4-1-7. The subsequent use of average yields and prices permits calculating total and per acre values of crops. It is estimated that under existing (1972) cropping patterns the average annual crop value between elevations 950 and 983 is $91.54 per acre. Similar calculations shown in Table 4-1-8 gives total and per acre values of crops for the reservoir area below elevation 950.

Table 4-1-7. Land use and crop production between Conservation Pool (950') and Take Line (983') (using cell readings)

Present land use		Acres		Estimated yield bu/ac		Production bushels		Price per bu.		Value of crops per year
Total Non-Crop[(a)]		1998		47.6%						
Corn	54%	1189	x	91 bu.	=	108,199	x	1.05	=	113,608.95
Soybeans	36%	793	x	32 bu.	=	25,376	x	3.00	=	76,128.00
Oats	4%	88	x	60 bu.	=	5,280	x	.70	=	3,696.00
Hay	6%	132	x	2.8 T/A	=	370	x	22.00		8,140.00
Total crop		2202		(52.4%)						$201,572.95
Total between 950' & 983'		4200 acres								$91.54 per acre

(a) Includes all noncrop land - roads, etc.

Table 4-1-8. Land use and crop production in proposed Conservation Pool (910-950') (using cell readings)

Present land use	Acres		Estimated yield bu/ac		Production bushels		Price per bu.		Value of crops per year
Pasture & wooded(a)	1462								
Quarries & sand pits	120								
Total noncrop acres (70%)	1582								
Corn (54%)	366	x	85 bu.	=	31,110	x	1.05	=	32,665.00
Soybeans (36%)	244	x	32 bu.	=	7,808	x	3.00	=	23,424.00
Oats (4%)	27	x	57 bu.	=	1,539	x	.70	=	1,077.30
Hay (6%)	41	x	2 T.	=	82	x	22.00	=	1,804.00
Total Crop Acres (30%)	678								$58,970.30
					$86.98 per acre				
Total	2260(b) acres								

(a) Includes noncrop land such as roads.

(b) The official estimated acres in the proposed conservation pool is 2170 acres.

By use of a visual reading of the cells on the aerial photographs shown in the Category 1 report of the Reservoir Site and Stream Study by the Water Resources Institute, ISU, 4/5/72, the above estimates are made on acreage in different uses in the area.

Potential Crop Losses in Reservoir

Because high water levels in a flood control reservoir seldom occur, it may be feasible to crop lands within the storage area. Whether it is economically feasible depends upon the time, duration and frequency of flooding as has already been pointed out. In this section an estimate of the average annual dollar loss is made based on historic flooding for a given gate operation (U.S. Army Corps of Engineers, 1968). The percent of land in cropland was assumed to be that indicated in Figure 4-1-1; the percent of each crop was assumed to be that in Table 4-1-7.

Table 4-1-9 presents the estimated losses from flooding by five foot elevation increments.

Table 4-1-9. Crop losses in reservoir storage area from flooding

Elevation and crop[a]	Ave. annual crop value, $[b]	Ave. annual yield reduction, %[c]	Ave. annual flooding loss, $	Ave. annual loss/acre, $/acre
950-955				
Corn	16,737	53	8871	
Soybeans	9,246	51	4715	
Oats	486	44	214	
Hay	1,276	44	561	$75.00/acre
955-960				
Corn	18,850	29	5466	
Soybeans	10,452	28	2927	
Oats	547	26	119	
Hay	1,509	28	423	$41.37/acre

Table 4-1-9. Continued.

Elevation[(a)] and crop	Ave. annual[(b)] crop value, $	Ave. annual[(c)] yield reduction, %	Ave. annual flooding loss, $	Ave. annual loss/acre, $/acre
960-965				
Corn	21,612	18	3890	
Soybeans	11,926	16	1908	
Oats	608	27	164	
Hay	580	23	133	
				$24.68/acre
965-970				
Corn	25,187	7	1763	
Soybeans	13,802	7	966	
Oats	669	6	40	
Hay	1,973	10	197	
				$10.37/acre

(a) Only harvested cropland included.

(b) This equals Acres x bushels per Acre x $ per bushel.

Yields are based on the estimate for 2025.

Price per bushel for corn used was $1.25, a value used by consulting economist, Dr. Bromley. Other prices are: soybeans, $2.68; oats, $0.64; hay, $23.21 per ton.

(c) Average annual yield reduction was based on the probability of flood damage to a crop and resulting yield reduction.

The technique used to determine flood damages was very similar to that defined in Table 4-1-5. Some additional factors which may reduce yield potential are trash deposition, and weeds. The annual loss per acre below elevation 960 is high enough to discourage cropping. Above elevation 970 the flooding frequency is so small that cropping appears to be feasible.

Fertilizer and Agricultural Chemical Use in the Watershed

The soils of this watershed are naturally low in phosphorus and potassium. The organic matter content of the soils is high, but nitrogen release from the organic matter is slow and supplemental nitrogen must be added to provide adequate nitrogen for profitable crop production. The "normal" mineral soils have a pH range from 5.8 to 6.8 which is adequate for corn and soybean production. Supplemental limestone is frequently needed for best production of legumes for hay and pasture. Small areas of peat and muck soils require appreciably higher amounts of commercial phosphorus and potassium for suitable quality corn and soybeans. There are significant areas of "high lime" soils with pH ranging above 7.4 which require somewhat higher levels of phosphorus and potassium than normal associated soils.

Results of contacts with farmers and agricultural input suppliers concerning the amounts of fertilizer and chemicals commonly used are summarized in Table 4-1-9. The average rate of application of fertilizer (125-80-80) is 10 to 20 percent above the state average (107-67-62), but with no reports of use above 170 pounds of nitrogen, 120 pounds of P_2O_5 and 150 pounds of K_2O. Normal practice is to broadcast the fertilizer and incorporate it immediately or in the case of nitrogen to knife in the anhydrous ammonia and liquid nitrogen sources. Some fertilizer is applied in the row at planting time, with at least two inches of incorporation.

Herbicides are widely used on both corn and soybeans. Rates of application are at or below recommended levels. Methods of application are according to recommendations.

Insecticides are not as widely used as herbicides but 50 percent of the farmers report their use. The chlorinated hydrocarbons represented by

Table 4-1-10. Fertilizer and agricultural chemical use.

Chemicals used	Percent of farmers using	Application rate, pounds per acre				
		1st yr corn	2nd yr corn	Soy-beans	Oats	Hay
Nitrogen (N)	85	120	130	0	0	0
Phosphorus (P_2O_5)	95	80	30	0	0	40
Potassium (K_2O)	95	80	80	0	0	40
Herbicides (Corn)	80					
Atrazine	10	--	--	0	0	0
Atrazine combinations	50	--	--	0	0	0
Other Herbicides	20	--	--	0	0	0
Herbicides (Soybeans)	70					
Treflan	60	0	0	-	0	0
Amiben	10					
Other Herbicides	10	0	0	-	0	0
Insecticides	50					
Chloronated Hydrocarbons	30	--	0	0	0	0
Phosphates	20	0	--	0	0	0
Other	10	--	--	0	0	0

Aldrin is still commonly used as a row treatment to control insects that attack first-year corn. Apparently no dairy farmers use this chemical and its use is decreasing. The phosphates and carbamates are commonly used as a western root worm control measure. All use appears to be according to recommendations.

Table 4-1-10 shows the estimated percent of farmers using different chemicals and in the case of fertilizers the indicated average use rate. This was for the 1972 planting season.

Summary

The watershed of the Ames Reservoir contains some of the best soils in the United States. The highest quality land lays above the Skunk River's natural drainage system. The sloping lands along the river and the flood plain lands have less production potential.

The percent of cropped area varies from 70 to 80 percent. Land is largely in corn and soybeans. Within the reservoir the percent of non-crop land is larger varying from 70 percent in the region near the reservoir to about 40 percent near the "take line" elevation.

It may be feasible to crop land above elevation 970 within the reservoir because of the low frequency of flooding. Reed Canary grass may be a feasible crop above the conservation pool, if fertilized and grazed, because of its ability to tolerate inundation for extended periods.

No change in watershed cropping pattern is anticipated. A large percent of the land will continue to be planted to row crop. Fertilizer and pesticides will be used within the usual economic and environmental restraints.

References

1. Iowa Department of Agriculture. 1950 to 1970. "Iowa Annual Farm Census," Bulletin 92-AF, Division of Agricultural Statistics, State of Iowa.

2. Fenton, T. E., E. R. Duncan, W. D. Shrader and L. C. Dumenil. 1971. "Productivity Levels of some Iowa Soils," Special Report No. 66, Iowa Agricultural and Home Economics Experiment Station, Iowa State Univerity, Ames, Iowa.

3. U.S. Army Corps of Engineers. 1968. "Ames Reservoir - Design Memorandum No. 1," U.S. Army Engineer District, Rock Island, Illinois.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

Chapter 2

WATER QUALITY IMPLICATIONS OF CROPLAND NUTRIENTS

by

Howard P. Johnson and James L. Baker

1973

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FIGURES

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Chapter 2

WATER QUALITY IMPLICATIONS OF CROPLAND NUTRIENTS

Howard P. Johnson and James L. Baker

Introduction

Precipitation and natural drainage to streams and lakes contribute nutrients which support the growth of phytoplankton and littoral vegetation. In agricultural areas the quality of drainage waters is influenced by agricultural practices. In the case of the Skunk River Basin above Ames, the land is relatively level and erosion is a minimal problem even though the land is intensively farmed in row crops. Nearly all the level land is tile drained to some degree. During wet periods in the growing season water collects in depressions known as "potholes" and causes crop damage before being drained away.

Nutrients in water which have received the most attention are nitrogen and phosphorus because of their relation to eutrophication. The primary purpose of this chapter is to define within the limits of information available the nutrient delivery to the proposed Ames Reservoir with emphasis on forms of nitrogen and phosphorus.

Nature of the Watershed

Soils. The soils within the Skunk River Basin belong to the Clarion-Nicollet-Webster Soil Association. The parent materials are glacial drift of relatively recent origin. About 75 percent of the area has level to gently

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Johnson is a professor and Baker an assistant professor of agricultural engineering at Iowa State University.

sloping topography. Cash grain farming is more important in this area than in other sections of Iowa.

Table 1 presents some of the pertinent characteristics of the soils.

Table 4-2-1. Characteristics of major types in Clarion-Nicollet-Webster Soil Association Area[a,b]

Soil type	Typical Slope Percent	Natural Internal Drainage	Percent Organic Matter			Particle size, mm	
						Clay <0.002	Silt 0.002-0.05
			At 4"	12"	24"		
Clarion Loam	2-5	Good	2-3	---	---	20-25*	35-50
Nicollet Loam	1-3	Somewhat poor	3-4	---	---	20-25	35-50
Webster silty clay loam	0-2	Poor	5	3.7	0.5	28-35	30-40
Glencoe silty clay loam (Okoboji)	0	Very poor	5	2.3	1.0	30-40	30-45

[*] Percent in each category.

[a] Fenton, T. E., Duncan, E. R., Shrader, W. D., and Dumenil, L. C. Productivity levels of some Iowa Soils. Special Report No. 66, Agriculture and Home Economics Experiment Station and Cooperative Extension Service, Iowa State Univ., Ames, Iowa. 1971.

[b] Oschwald, W. R., Riecken, F. F., Dideriksen, R. I., Scholtes, W. H., and Schaller, F. W. Principal Soils of Iowa. Special Report No. 42, Department of Agronomy, Cooperative Extension Service, Iowa State Univ., Ames, Iowa. 1965.

A high percentage of the soils have poor natural drainage (Runge et. al., 1970). Thirty eight percent of the soils in Story County have poor natural drainage; 51 percent and 31 percent of Hamilton County soils and Hardin County soils, respectively, have poor natural drainage. Three to 5 percent of the acreage is in soils associated with potholes which contain ponded water after heavy rains. With the exception of the Clarion loam soils, the soils are high in total nitrogen. For example the total nitrogen percent varies from 0.40 at 0-to-8 inches depth to 0.11 at 21-to-26 inches depth for Webster clay loam (Slusher et. al., 1961).

Farming practices. The land in the watershed of the proposed reservoir is heavily cropped. Seventy to 75 percent of the land is tilled; 90 to 95 percent of the tilled land is in corn or soybeans. The average rate of application of fertilizer (125-80-80) is 10 to 20 percent above the state average. More details on farming practices may be obtained from the subsection on fertilizer and chemical use in Chapter 1 of Appendix 4.

While about 71 thousand acres of 340 thousand acres of cropland in Story County needs better drainage (Iowa Soil and Water Conservation Needs Inventory Committee, 1970), most of the Webster and Glencoe soils have some tile drainage. The number of feet of subsurface drains per acre varies from about 430 to zero. Several miles of drainage ditches have been constructed in the upper portion of the watershed to provide outlets for tile and surface runoff.

Rainfall and runoff. The mean annual rainfall at Ames is 30.73 inches based on 92 years of record. Twenty two and six tenths inches falls from April through September (U.S. Army Engineer District, Rock Island, 1968). The minimum rainfall at Des Moines, Iowa was 17.07 inches in 1956; the maximum, 43.04 in 1947 (Upper Mississippi River Comprehensive Basin Study Coordinating Committee, 1970). The mean annual class A pan evaporation for the Ames region is about 50 inches.

The average daily flow at the gaging station, Skunk River near Ames, is 133 cubic feet per second or 5.82 inches per year (U.S. Geological Survey, 1971). The minimum water yield recorded is 0.24 inches; the maximum is 13.4 inches.

Content of the Chapter

Nutrients in the Skunk River may be derived from several sources as rainfall, nitrogen fixation, mineralization, animal wastes, fertilizer erosion and sewage effluent. In recent years considerable research has been reported which defines somewhat the sediment and runoff water nutrient load to streams. During the spring and summer of 1972 systematic sampling and analyses of water from the Skunk River were completed. The sampling was done at a bridge located between section 12 and 13 of Franklin Township, Story County. Details of the sampling procedure are found in the Chapter entitled Reservoir Sedimentation. Chemical analyses were performed by Agricultural Engineering or Engineering Experiment Station personnel. The summary of literature and the results of the 1972 observations are presented in the remainder of this chapter.

Selected Literature Related to Nutrient Loads

Nutrients in Runoff Water

Most of the nutrients in the Skunk River are delivered to the river in water. This water is derived from surface runoff after rains, snowmelt, tile effluent and seepage into the streams. Each source of water carries nutrients in certain forms. Surface runoff (rain) and snowmelt carry sediments and dissolved solids. Tile effluent and seepage contain primarily dissolved materials.

To separate the sources of water in the river quantitatively is difficult. A few records of tile discharge have been made (Schlick, 1939; Beer et. al., 1965). Measurements made from 1920 to 1932 during the growing season in Boone, Clay and Cerro Gordo County indicate that an average of 0.8, 0.7, and 1.4 inches of water discharged from the tile systems. The tile diameters at the outlet were 32, 18 and 40 inches, respectively, Maximum discharge in a given season was 4.6 inches in Cerro Gordo District No. 40, lateral No. 5. The average calendar year discharge from the Des Moines River at Kalo and Boone from 1920 and 1926 was 3.02 and 2.67 inches, respectively. Average growing season discharges from the Boone, Clay and Cerro Gordo County drainage district mains were 0.7, 0.8 and 1.3 inches, respectively, for the same period. Detailed records maintained during the growing season at the Davis County Experimental Farm from 1951 to 1962 indicated an average yearly tile discharge during the growing season of 1.9 inches per year from a small level area. The maximum recorded was 6.3 inches in 1959. Measurements of discharge from tile draining a small watershed near Charles City, Iowa indicate that a large percent of the water yield from a completely tile drained area may be derived from subsurface drains.* In 1970 about 5 of 10.5 inches of runoff was derived from subsurface flow; in 1971 about 2.3 of 3 inches.

Data for 1925 through 1928 for partially tile-drained land in St. Louis County and Stearns County, Minnesota indicated average annual tile discharges of 1.16 and 1.08 inches, respectively (Neal, 1934). Most of the water was discharged in one year (3.59 inches and 3.16 inches, respectively) in each case. The rainfall was 7.05 and 3.58 inches above average. Average

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*Unpublished research data from the files of John Laflen, USDA, ARS.

annual rainfall in St. Louis County is about 19.0 inches; in Stearns County, about 21.9 inches. About 15 percent of the rainfall causing runoff was discharged through tile.

Nitrogen and phosphorus in subsurface drainage. A summary of the literature on nitrogen in tile drainage water is presented in Table 4-2-2. Nitrogen is largely in the form of nitrates. Organic N, nitrite N and ammonium N is usually less than 5 percent of total N where there are no open inlets. Of particular interest are reference items 6, 8, 9 and 10, since these data best represent the Iowa region. Note that the nitrate-N level is above 10 PPM in many cases for tile effluent in central Iowa.

Similar information is presented for phosphorus in Table 4-2-3. Since drain discharge water carries little or no sediment, the concentrations of phosphorus are low. The phosphorus is primarily in the form of inorganic orthophosphates. The common range of P for tile discharge from areas similar to the Skunk River watershed is 0.1 to 0.3 PPM.

Willrich (1969) included a few COD measurements as well as other chemical data in his report. The COD values varied from 0 to 14.3 mg./1; the 9 samples were taken on June 3, 1969.

Nitrogen and phosphorus in sediment and surface runoff. The amount of sediment and the characteristics of the sediment in surface runoff are of concern when determining the nutrient loads in streams. Soil particles eroded from a field are derived largely from the soil surface; selectively eroded particles are usually higher in organic matter and nutrients than particles left. The nitrogen in soils in the humid region is carried almost wholly by the organic matter. The precent nitrogen in a soil is usually about 5 percent of the organic matter, but may vary (Lyon and Buckman, 1947).

Table 4-2-2. Nitrogen in subsurface drainage water

Ref.	Location and Description	Average Concn. ppm-NO_3-N	Load lb/ac-Yr
1	San Joaquin, Calif., Central Area Irrigated and fertilized	33	83
1	San Joaquin, Northern Area Irrigated and fertilized	9	35
1	San Joaquin, Southern Area Irrigated and fertilized	9	2
2	Yakima, Washington		19
3	San Joaquin Valley Irrigated land (Range 1.8-62.4 ppm)* *Total N	25.1*	
10	Boone County, Iowa 80#N applied alternate years (Range 13-30 ppm)		
4	Ontario, Canada, Brookston Clay Loam		
	Continuous Corn, 116 lbs N applied	8.9	12.6
	Continuous Corn, None applied	4.4	5.9
	Continuous Bluegrass, 15 lbs N applied	1.1	0.6
	Continuous Bluegrass, None applied	3.5	0.3
5	Michigan Farm Drainage		
	Ferden Farm Range 0.9-8.1 ppm*		10.8*
	Davis Farm Range 1.82-7.2		7.4
	Muck Farm Range 0.2-2.8		16.7
	Dear Creek Range 0.4-4.4		--
	Sloan Creek Range 0.3-3.7		--
	*Total N		
6	New Prague, Minnesota (Range 2.0-24.4 ppm)		
7	Bondville, Illinois tile drains		
	T0 Range 9-22 ppm		
	T1 Range 7-13 ppm		
	T2 Range 6-15 ppm		
	T3 Range 5-13 ppm		
	Livingston County Range 9-16 ppm		
	Tazewell County Range 4-16 ppm		
	Warren County Range 8-16 ppm		
	Woodford County Range 13-21 ppm		
	Douglas County Range 1-13 ppm		
	(Some not fertilized)		

Table 4-2-2. Continued.

Ref.	Location and Description	Average Concn. ppm-NO_3-N	Load lb/ac-Yr
8	Iowa tile outlets		
	Story County Range 8-50		
	Ralston, Carroll County Range 9-12		
11	New York (Cornell Univ.) (Range 3-51.1 ppm)		
9	Story County, Iowa Tile Outlets		
	Outlet No. 1 - Range 5-66	25*	
	Outlet No. 2 - Range 4-37	15	
	Outlet No. 3 - Range 6-23	15	
	Outlet No. 4 - Range 4-41	18	
	Outlet No. 5 - Range 1-28	12	
	Outlet No. 6 - Range 6-38	17	
	Outlet No. 7 - Range 5-44	22	
	Outlet No. 9 - Range 6-47	27	
	Outlet No. 10 - Range 4-32	18	
	*Median Values, Total Nitrogen		

1. Viets and Hageman (1971)
2. Sylvester (1961)
3. Johnston and others (1965)
4. Bolton and others (1970)
5. Erickson and Ellis (1971)
6. Johnson and Straub (1971)
7. Harmeson, Sollo and Larson (1971)
8. Bower and Black (1970)
9. Willrich (1969)
10. Johnson, Campbell and Hanway (1972)
11. Zwerman and others (1972)

Table 4-2-3. Phosphorus in subsurface drainage water.

Ref.	Location and Description	Average Concn. ppm-P	Load lb/ac-Yr
1	San Joaquin, Calif., Southern Area Fertilized and irrigated (PO_4-P)	0.23	
1	San Joaquin, Calif., Other Areas Fertilized and irrigated (PO_4-P ave. concn. in valley)	0.03	
2	San Joaquin, Calif. Fertilized and irrigated (Range 0.05-0.23 ppm) (Total P)	0.08	
3	Ontario, Canada, Brookston Clay Loam		
	Continuous Corn, fertilized (26 lbs P)	0.19	0.27
	Continuous Corn, No fertilizer	0.17	0.23
	Bluegrass Sod, Fertilized (26 lbs P)	0.19	0.11
	Bluegrass Sod, No fertilizer (Filtered total P)	0.17	0.01
4	Yakima, Washington (Total P)	0.25	
5	Illinois lysimeter studies (PO_4-P)	0.08	
6	Michigan Farm Drainage		
	Ferden Farm Range 0.003-0.06		0.03
	Davis Farm Range 0.003-0.03		0.03
	Muck Farm Range 0.003-0.10		0.42
	Dear Creek Range 0.003-0.06		----
	Sloan Creek Range 0.003-0.06 (PO_4-P)		----
7	New Prague, Minnesota (Range 0.13-1.73 ppm) (Tile draining about 49 acres) (Total P)	0.52	0.85
8	Story County, Iowa (Range 0.06-0.13 ppm) Carroll County, Iowa (Range 0.07-0.12) (PO_4-P)		

Table 4-2-3. Continued

Ref.	Location and Description	Average Concn. ppm-p	lb/ac-Yr
9	Story County Tile Outlets		
	Outlet No. 1 - Range 0.0-4.0 ppm	0.2*	
	Outlet No. 2 - Range 0.0-3.0	0.1	
	Outlet No. 3 - Range 0.0-0.7	0.1	
	Outlet No. 4 - Range 0.0-4.0	0.3	
	Outlet No. 5 - Range 0.0-4.0	0.2	
	Outlet No. 6 - Range 0.0-5.2	0.3	
	Outlet No. 7 - Range 0.0-4.2	0.3	
	Outlet No. 9 - Range 0.0-4.0	0.2	
	Outlet No. 10 - Range 0.0-5.0	0.2	
	*Median Value (Total P)		
10	Boone County, Iowa (Range 0.010-0.080 ppm) (Total P)		

1. California Department of Water Resources (1971)
2. Johnston and Others (1965)
3. Bolton and Others (1970)
4. Sylvester (1961)
5. Task Group Report (1967)
6. Erickson and Ellis (1971)
7. Johnson and Straub (1971)
8. Bower and Black (1970)
9. Willrich (1969)
10. Johnson, Campbell and Hanway (1972)

Phosphorus is chemically retained against downward movement in the soil profile in most soils. Surface applied phosphorus appears to move to a depth of less than two inches during the season. Sediments are capable of removing phosphates from solution, and thus may act as a scavenging agent in a stream. While sediments carry considerable nitrogen and phosphorus into surface waters, only a small portion of these nutrients are readily available to the biosystem (Holt, Dowdy and Timmons, 1970).

Much research has been reported in the literature on the nutrient losses from soils by water erosion (Barrows and Kilmer, 1963). Work reported by Timmons, et. al., (1968) indicated average annual total N loss (lbs/ton of soil lost) to be 8.57, 7.03 and 14.26 for fallow, continuous corn and corn-oats-hay rotation, respectively. The average annual nitrogen loss (lb/ac) was 183.1, 66.4 and 31.5, respectively. Phosphorus losses were 1.07 lb/ac (0.05 lbs/ton soil loss) for fallow, 0.85 lb/ac (0.09 lb/ton) for continuous corn, and 0.86 lb/ac (0.39 lb/ton) for the corn-oats-hay rotation. Data were based on a 6 year average of soil loss. The data were recorded for small plots on Barnes loam soil near Morris, Minnesota.

Taylor et. al., (1971) reported data from a 305 acre watershed of gently sloping mixed farmland in Ohio. A fourth of the area was left in hardwood forest. The remainder was in a corn-winter wheat-grass-grass rotation. The average annual NO_3-N in surface runoff was 3.91 lb/ac, the total N, 5.43 lbs/ac. The average P lost was only 0.067 lbs/ac. The average concentrations of NO_3-N, total N and P were 1.28 ppm, 1.79 ppm and 0.022 ppm, respectively. Rainfall contribution averaged 18.3 lb/ac of N annually for the years 1966-1969.

Witzel (1969) reported results from watersheds in Tama and Dubuque silt loams located in Wisconsin. Cover was about one third each of cultivated, hay and pasture land. Data presented were largely for snowmelt and early spring rains. They state "in a year of average runoff, assuming nutrient losses proportional to runoff, the losses would be 2 lb nitrogen, 0.6 lb phosphorus and 4 lb of potassium per acre".

Minshall (1970) described experiments on Rosetta silt loam, Lancaster, Wisconsin, for 10 to 12 percent slopes. Manure was applied in winter and spring on three sets of plots which were planted to contoured corn. Applications of N in manure varied from 64 lbs/ac-Yr to 129 lbs/ac-Yr; P applied in this form varied from 26 to 43 lb/ac-Yr. The average annual loss of total N and total P was 3.89 and 1.17 lbs/ac-Yr, respectively, where no manure was applied. On the manured plots total N loss varied from 3.2 to 11.3 lbs/ac-Yr; total P loss varied from 0.72 to 2.62 lb/ac-Yr.

The research reviewed by Barrows and Kilmer (1963) revealed a range of N loss from runoff and erosion from 2 to 99 lbs/ac-Yr. Research reviewed by Johnson and Straub (1971) showed losses of P ranging from 0.4 lbs/ac-Yr to 48 lbs/ac-Yr for surface runoff. The highest losses were reported for fallow lands. No losses of P over 11 lbs/ac-Yr was reported for conventionally cropped land.

Data From Streams

A summary of measurements (109 stations) of NO_3-N load in rivers (Task Group Report, 1967) indicated a range of mean values from 0.48 to 0.79 ppm. The mean load (lb/ac-Yr) was correlated with mean discharge. For a mean discharge of 0.035 of cfs/sq.mi. for 25 rivers the mean NO_3-N load was 0.085 lb/ac-Yr; for a mean discharge of 1.42 cfs/sq. mi. the mean load was 2.1 lb/ac-Yr. The lower concentrations were associated with the larger mean discharge.

The concentrations of nitrogen found in the streams of central and eastern Iowa are usually lower than those found in surface runoff and tile outlets from small areas. An interesting record for the Iowa River at Iowa City (Dole, 1911) indicated average NO_3-N concentrations of 0.63 ppm during 1906-07. Annual averages for the period 1944-51 at the same station ranged from 1.7 to 3.2 ppm (Task Group Report, 1967). Measurements taken at Marengo, Iowa by the Civil Engineering Department, University of Iowa from 1966 to 1969 (McDonald, 1969) revealed a range of NO_3-N of 0.01

to 5.40 ppm. The average yearly values ranged from 0.17 to 0.76 ppm NO_3-N (see Table A, Appendix).

Civil Engineering Department personnel at Iowa State University have collected detailed water quality data weekly since 1967 on the Des Moines River above Boone (Bauman, 1971). The Des Moines River is similar to the Skunk River in that it drains a region of Iowa and Minnesota which was recently glaciated. The soils, climate, topography and agriculture are very similar. Selected data are presented in Table B, Appendix. The dates were chosen to represent low and high discharges as well as different times of year. NO_3-N values are sometimes very high for a basin of that size (5490 acres). NO_3-N values ranged from a trace to 14 ppm; values ranging from 5 to 10 ppm were common at times of high runoff. The highest organic N concentrations were associated with high discharges in May through September; the concentrations ranging, from zero to 4.88 ppm, were likely associated with high sediment loads (see turbidity, Table B). Ammonia N concentrations were highest in late winter and early spring; the highest NH_3-N concentration recorded was 2.19 on May 29, 1970. Ortho P concentrations ranged from a trace at low flows in summer to a maximum of 1.3 ppm in winter. Some organic carbon and COD values are included in Table B.

The Agricultural Engineering Department (Beer, 1972) of Iowa State University has collected data for three small streams near Traer, Iowa. While the results are preliminary, the concentration of NO_3-N appear high relative to most rivers. Concentrations commonly run from 4 to 10 ppm; values as high as 15 were recorded. Ammonia N values are high at snowmelt time reaching 5 ppm on occasion. Phosphate-P was also high at snowmelt time; peak values of about 6 ppm were measured during early spring. Most values of PO_4-P were less than 0.3 ppm. The estimated N lost in runoff from the watershed was about 19 lb/ac. for the period from April 1970 through March 1971.

Skunk River Watershed Nutrient Observations

Nutrients in River Water

Since the water quality of the proposed reservoir would be influenced by the contribution from agricultural runoff a limited sampling program was initiated to partially define the nitrogen and phosphorus concentrations and loads in the River. Measurements and analyses made by other members of the research team, primarily the "Urban Sector" staff and the "Livestock Production" staff, assisted in this effort. The mean daily flow data and the nutrient concentration data were combined to enable calculation of the total nutrient load from March through August. A few additional measurements and analyses were made.

Sampling. Water samples were taken every other day from March through August with a depth integrating sediment sampler at a bridge located between section 12 and 13 of Franklin Township, Story County. During high river stages several extra samples were taken by Agricultural Engineering personnel. An attempt was made to sample during rising and falling stages. A few samples of snow melt surface runoff, summer storm surface runoff and tile effluent were taken with a portable sediment sampler. Samples were placed in a cold storage room within a half hour after they were taken in most cases.

Analysis. Chemical analysis of the water samples was done under the direction of Dr. James Baker, chemist in Agricultural Engineering, or by the

Engineering Research Institute. Most of the analyses for nitrogen and phosphorus were completed in the Agricultural Engineering Laboratory. A few analyses to check accuracy were made in other laboratories (Table 4-2-4). Analyses for COD, organic nitrogen and total phosphorus were completed by the Engineering Research Institute.

Samples analyzed in Agricultural Engineering for orthophosphate ($PO_4^{\equiv}$) were first filtered through a 0.45 micron membrane filter. The analyses were then performed using Hach Chemical Company's PhosVer III method which is described on page 79 of their manual[a]. This procedure is a modification of the method of Murphy and Riley[b] which is a phosphomolybdate-ascorbic acid reduction colorimetric method. All absorbance measurements for $PO_4^{\equiv}$ and for the colorimetric methods of analysis for NO_3^- and NH_4^+ were made on a Beckman DB-G (double beam-grating) spectrophotometer.

Samples taken through July 8, 1972 were analyzed for NO_3^- using the Hach NitraVer IV method which is described on page 55 of their manual[a]. This is based on the cadmium reduction method outlined on page 395 of the 12th edition of Standard Methods[c]. Samples taken after July 8 were analyzed by the method given on page 458 of the 13th edition of Standard Methods[c] with one modification: the cadmium was amalgamated with copper rather than mercury. These two methods are essentially the same, the main difference being in the mixing of chemicals. In the first case the sample was mixed

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[a] Colorimetric Procedures and Chemicals for Water and Wastewater Analysis, 3rd ed., Hach Chemical Company, September, 1969.

[b] Anal Chim Acta 27: 31, 1962.

[c] Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, New York, 1971.

Table 4-2-4. Comparison of analyses for NH_4^+-N, $NO_3^-(+NO_2^-)$-N and $PO_4^{\equiv}$ (soluble) by various groups at ISU.$^{(a)}$

	Hach Oksnee 4-1065	Hach Parker 4-6111	ERI Schuler 4-8786	Agronomy Hanway 4-2036 (Distill. for N)	Distill. Parker 4-6111	NH_3 Electrode Tabatabai 4-2036	Calculated Baker 4-41131
NH_4^+ N std	2.4	2.4	2.5	2.0	2.8	3.1	2.3
	2.38 2.40 2.34	2.35 2.46	2.55 2.51 2.48	2.105 1.911	2.8	3.1	
NO_3^--N std	3.14	2.20	3.85	2.95	3.50		3.68
	3.266 2.870 3.284	2.20	3.89 3.88 3.78	3.019 2.881	3.50		
$PO_4^{\equiv}$ std	0.64'	0.58	0.48	0.51			0.53
	0.594 0.701 0.629	0.58	0.48 0.48 0.48	0.497 0.518 0.518			
NH_4^+-N sample	0.2	0.03	0.12	0'	0	0.06'	
	0.18 0.19	0.03	0.12	0	0	0.06	
NO_3^--N sample	11.0	10.7	14.1	13.0'	10.5		
	12.250 11.657 9.649 10.336	10.7	14.01 14.10 14.17	13.012 13.074	10.5		
$PO_4^{\equiv}$ sample	1.04	0.61	1.36'	0.64'			
	1.171 1.009 0.955	0.61	1.34 1.36 1.36	0.628 0.638 0.642 3.31*			

'Sample filtered through 0.45μ membrane filter (Agronomy used 0.20μ)

*Agronomy also ran total P on unfiltered sample (expressed in terms of ppm $PO_4^{\equiv}$

(a) Sample taken from Skunk River 5/29/72; std prepared by Baker. Enclosed values (units: ppm NH_4^+-N; NO_3^--N; $PO_4^{\equiv}$) are averages of actual values listed below for each analysis.

with powdered chemicals and in the second with chemicals already in solution. It was felt that the latter method provided a better control of the amount and mixing of chemicals.

Samples taken through July 4, 1972 were analyzed for NH_4^+ using the common Nessler Reagent obtained from Hach Chemical Company and used as directed on page 53 of their manual[a]. This method is based on that given in the 12th edition of Standard Methods[c] page 193. Samples taken after July 4 were analyzed with the Orion Ammonia Electrode in conjunction with a Leeds and Northrup model 7401 pH meter. The ammonia electrode has been shown to be a reliable method for the analysis of NH_4^+[d]. In addition the electrode method is not hampered by interferences present in river water as the Nessler method is.

Calibration curves used in the analyses of $PO_4^{\equiv}$, NO_3^-, and NH_4^+ were obtained by running prepared standards made up from KH_2PO_4, KNO_3, and NH_4Cl respectively. For all colorimetric methods, linear correlations were made between absorbance and concentration. For the potentiometric method for NH_4^+ a straight line was used to relate the logarithm of concentration to the potential.

In order to check the accuracy of our methods and to make a comparison of different methods, portions of a sample of river water and of a prepared standard were distributed in June to various groups on the ISU campus to analyze. The results are presented in Table 4-2-4. The data from the Agricultural Engineering laboratory are in column 1 designated Hach, Osknee; the results, using the same methods but performed by another technician in

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[d] Soil Science and Plant Analysis, 3(2): 159-165, 1972.

another lab, are in column 2 designated Hach, Parker. The data for NO_3^- in column 3 are the results of the method utilized by the Agricultural Engineering laboratory after July 8. Columns 4 and 5 show nitrogen forms analyzed by the distillation method, and column 6 shows NH_4^- analyzed by the electrode method which was utilized by the Agricultural Engineering laboratory after July 4.

Rainfall and stream flow. Weather Bureau rain gages are maintained at four locations useful to hydrologic analysis of the Skunk River Watershed, namely, Ames, Jewell, Webster City and Williams. Daily rainfall for these stations is listed for each month through August 1972 in Table 4-2-5.

Rainfall was unusually heavy in the upper portion of the watershed in 1972. The Williams observer reported 35.01 inches of rainfall from April through September, which is well above the annual average of 30.7 at Ames. Rainfalls of more than three inches were observed, however, little flooding was reported south of Story City. The Skunk River was never out of channel at the gaging station north-east of Ames except at snowmelt time.

The U.S. Geological Survey office at Fort Dodge made available the preliminary mean daily and the bi-hourly discharges (stages and rating curves) from March through September 30. Table 4-2-6 presents the mean daily discharges.

Nutrient concentrations and loads. The total load of NO_3-N, NH_4-N and PO_4-P was calculated from the average daily discharge and the sample concentrations for the period from March 1, 1972 through August 31, 1972. The data for this period is presented in Table 4-2-6. Other data on the quality of the Skunk River water is found in Appendix 5, Physical Relationships with the Urban Sector, and in a thesis (Jones, 1972).

Table 4-2-5. Rainfall, Skunk River Watershed, 1972

	January			February		
Date	Ames	Jewell	Webster City	Ames	Jewell	Webster City
1	T			.20	.05	
2					.08	.03
3				T		.05
4						
5						
6						
7				T		
8				.10	.11	.11
9				T	.30	
10				.45		.24
11	T		T			
12			.05			
13						
14	T		T			
15						
16				.06		.32
17				.06		T
18		.04		T	.21	
19						
20	T					
21						
22	T		T			
23	.32	.21	.11			
24	.01		.12			T
25			.08	.25	.35	.25
26						
27	.11					
28		.17	.13			
29			T			
30	T					
31						
Total	.44	.40	.49	1.12	1.10	1.00

Table 4-2-5. Continued.

	March			April			
Date	Ames	Jewell	Webster City	Ames	Jewell	Webster City	Williams
1	.17		T	.02	T	T	
2		.20					
3	T		.01	.01		.02	
4	T	.26	.23		.11		
5							
6							
7				T		.03	
8							
9							
10							
11						.03	.06
12	T		.05	T			
13	.01	.04			.03		
14			T	.04		T	
15			.01	.01	.03	T	.07
16			T	1.08	1.11	.81	.85
17							
18							
19				.15		.01	
20	T			T	.09		.05
21	.09		.08	.29	.26	.46	.28
22		.06					.15
23							
24							
25							
26			T				
27	.48	.19	.32	.05		.05	
28		.22	.32	.58	.68	.79	.54
29				.65	.25		.38
30	.02		T	.03	.10	.15	.08
31	.01		T				
Total	.79	.97	1.02	2.91	2.66	2.35	2.46

Table 4-2-5. Continued.

	May				June			
Date	Ames	Jewell	Webster City	Williams	Ames	Jewell	Webster City	Williams
1	.14	.28	1.03	.53				
2	.26	.20	.25	.22				
3			T					
4	.04	.09		.19	.03	.35	.07	
5	.14				1.05	1.49	1.76	3.25
6	1.02	.76	2.10	3.65		.09	.09	.20
7	.37	.63	.10	.40	.17			
8				.01	.01		.51	.91
9								
10								
11	T							
12								
13	.57	.11	.15	.14	1.54	.34	.32	.93
14	.12	.51	.12	.35	1.46	1.31	.80	.97
15						.07	.11	.07
16					T		T	
17					.22	.05		T
18								
19					.21		.02	
20						.38	.06	.36
21								
22								
23	.19							
24	.19	.40	.52	.51				
25								
26	.52							
27	.03		.65	.13				T
28	.39	.48	.10	.06	.39	.42	.62	.69
29	.07	.29	.20		.05	.42	.15	.13
30	.05	.07	.04	.50				
31								
Total	4.10	3.82	5.26	6.69	5.13	5.23	4.51	7.51

Table 4-2-5. Continued.

	July				August			
Date	Ames	Jewell	Webster City	Williams	Ames	Jewell	Webster City	William
1			.03		2.16	.52	.57	.50
2	T	.19	.22	1.00	1.12	2.34	1.55	2.02
3		.05	.04	.10			.03	T
4								
5					T			
6			T		.85	1.95	3.30	2.41
7	.08			T		.11	.17	.27
8	.02				.42		1.18	.50
9		.68	1.05	.60				
10								
11	.12		T		.13		T	.07
12	.19	.72	.87	.54			T	
13	.02	.12	.11	.07			T	
14	.02							
15	1.22	.90	.35	.57				
16								
17	.98	.60	1.74	.40				
18	.02	.16	.13	.52				
19	.16		T					
20				.08				
21			.06		.04	.09	.17	.33
22							.20	
23							T	
24	.16	.07	.06	.08			T	
25					.47	.40	.48	.47
26	1.18	.66	.68	.61			.51	.09
27	T	.07			T		T	
28								
29			T					
30			T					
31	T				.01	.03		
Total	4.17	4.22	5.34	4.58	5.20	5.44	8.16	6.66

Table 4-2-6. Total load of NO$_3$-N, NH$_4$-N, and PO$_4$-P -- Skunk River, 1972.

Date	Time[a]	Mean[c] Daily Q (cfs)	Concn. NO$_3$-N (ppm)	Concn. PO$_4$-P (ppm)	Concn. NH$_4$-N (ppm)	Lbs. of NO$_3$-N	Lbs. of PO$_4$-P	Lbs. of NH$_4$-N
Feb. 29	17:50		0.40	0.77	4.04			
March 1	8:20	1570	1.41	0.75	2.82	11,954	6,329	23,907
2		525	1.56	0.79	3.17	4,422	2,227	8,987
3	7:50	398	1.72	0.83	3.53	3,696	1,779	7,586
4		161	1.70	0.70	3.03	1,478	612	2,634
5		64	1.70	0.70	3.03	587	243	1,047
6	17:00	295	1.70	0.58	2.53	2,708	924	4,030
7	8:10	3980	1.58	0.63	2.35	33,957	13,592	50,506
8	8:25[b] 17:35	3690	1.80	0.70	2.33	35,866	14,031	46,428
9	8:45	2810	2.69	0.73	2.21	40,818	11,130	33,535
10		1340	2.56	0.71	1.89	18,524	5,166	13,676
11	6:30	953	2.44	0.70	1.58	12,556	3,590	8,131
12		450	2.55	0.69	1.35	6,196	1,680	3,280
13	10:15	331	2.66	0.68	1.13	4,754	1,223	2,019
14		291	2.63	0.61	0.98	4,132	953	1,540
15	8:35	344	2.60	0.53	0.83	4,830	981	1,542
16		280	3.56	0.49	0.67	5,382	739	1,013
17	9:30	219	4.52	0.45	0.52	5,345	536	615
18		180	4.25	0.42	0.33	4,131	412	321
19	6:50	150	3.98	0.40	0.14	3,224	322	113
20		130	3.84	0.40	0.08	2,696	281	56
21	9:00	108	3.70	0.40	0.03	2,158	236	17
22		92	3.40	0.37	0.04	1,689	185	20
23	9:40	72	3.10	0.34	0.06	1,289	132	23
24		62	3.20	0.43	0.12	1,071	144	40
25	9:45	57	3.31	0.52	0.17	1,019	160	52
26		51	3.50	0.51	0.15	964	139	41
27	9:50	57	3.70	0.49	0.14	1,139	150	43
28		64	4.08	0.48	0.35	1,410	164	121
29	9:50	67	4.46	0.46	0.57	1,614	167	206
30		62	4.34	0.47	0.45	1,453	158	150
31	10:40	58	4.22	0.48	0.34	1,322	150	106
						222,384	68,535	211,785

EXAMPLE: 1:41 ppm x 1570 cfs days x 5.4x10^6 lbs/cfs day = 11,954

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[a] Time water sampled for nutrients.

[b] Average was used for calculations if two or more samples were taken on a day.

[c] Based on Q from preliminary gage height data - Skunk River near Ames.

Table 4-2-6. Continued.

Date	Time	Mean Daily Q (cfs)	Concn. NO_3-N (ppm)	Concn. PO_4-P (ppm)	Concn. NH_4-N (ppm)	Lbs. of NO_3-N	Lbs. of PO_4-P	Lbs. of NH_4-N
April 1		51	4.30	0.42	0.29	1,184	117	80
2	10:50	47	4.39	0.37	0.23	1,141	93	58
3		44	3.91	0.35	0.18	927	83	43
4	10:55	40	3.43	0.34	0.12	740	73	26
5		40	3.11	0.30	0.06	671	64	13
6	9:55	44	2.79	0.26	0.01	633	61	2
7		43	3.15	0.24	0.00	731	56	0
8	11:00	36	3.51	0.22	0.00	682	44	0
9		34	3.24	0.20	0.00	595	36	0
10	8:55	34	2.97	0.17	0.00	545	31	0
11		32	2.55	0.19	0.00	440	33	0
12	9:20	32	2.13	0.21	0.00	368	37	0
13		32	1.80	0.20	0.00	311	34	0
14	8:20	31	1.48	0.18	0.00	248	30	0
15		30	1.45	0.20	0.00	235	33	0
16	7:55	62	1.42	0.22	0.00	475	74	0
17		108	2.86	0.24	0.00	1,668	142	0
18		100	2.86	0.24	0.00	1,544	132	0
19		82	2.86	0.24	0.00	1,266	108	0
20	7:10	68	4.29	0.27	0.00	1,575	98	0
21		72	4.09	0.26	0.09	1,590	101	35
22	8:45	71	3.89	0.26	0.17	1,491	99	65
23		71	4.92	0.22	0.10	1,886	82	38
24	7:50	60	5.95	0.17	0.04	1,928	56	13
25		52	4.27	0.17	0.05	1,199	49	14
26	9:55	47	2.60	0.17	0.06	660	44	15
27		44	2.75	0.15	0.04	653	37	10
28	11:35	57	2.89	0.13	0.02	889	41	6
29		82	3.28	0.15	0.01	1,452	67	4
30	8:15	105	3.67	0.17	0.00	2,080	96	0
						29,837	2,051	422

Table 4-2-6. Continued.

Date	Time	Mean Daily Q (cfs)	Concn. NO_3-N (ppm)	Concn. PO_4-P (ppm)	Concn. NH_4-N (ppm)	Lbs. of NO_3-N	Lbs. of PO_4-P	Lbs. of NH_4-N
May 1		118	4.47	0.22	0.00	2,848	143	0
2	9:00	150	5.28	0.28	0.00	4,276	227	0
3		155	6.50	0.25	0.00	5,440	207	0
4	14:20	135	7.71	0.22	0.00	5,620	159	0
5	18:20	118	7.40	0.23	0.00	4,715	147	0
6		190	9.90	0.28	0.39	10,157	284	400
7	11:00 19:15	760	12.40	0.33	0.78	50,890	1,338	3201
8	7:45	550	12.21	0.37	0.25	36,264	1,084	742
9	9:00	390	15.30	0.20	0.00	32,222	419	0
10	7:45	300	12.64	0.48	0.00	20,477	782	0
11	8:50	240	12.05	0.20	0.00	15,617	254	0
12		200	10.58	0.20	0.00	11,426	211	0
13	14:45	185	9.10	0.20	0.00	9,090	199	0
14		175	10.80	0.20	0.00	10,206	191	0
15	15:50	160	12.51	0.21	0.00	10,808	177	0
16		145	10.87	0.20	0.00	8,511	156	0
17	7:55	130	9.23	0.18	0.00	6,479	128	0
18		118	11.60	0.32	0.00	7,392	203	0
19	18:55	105	13.97	0.46	0.00	7,920	260	0
20		98	11.43	0.31	0.00	6,048	164	0
21	11:15	94	8.89	0.16	0.00	4,512	83	0
22		86	8.79	0.14	0.00	4,082	67	0
23	7:55	84	8.69	0.12	0.00	3,941	55	0
24		92	9.27	0.13	0.00	4,605	66	0
25	12:20	84	9.85	0.14	0.00	4,468	65	0
26		82	9.22	0.17	0.00	4,082	75	0
27	16:30	110	8.60	0.20	0.00	5,108	116	0
28		132	9.05	0.24	0.06	6,450	174	42
29	7:10	210	9.50	0.29	0.12	10,773	329	136
30		255	11.70	0.27	0.06	16,110	373	83
31	15:10	180	13.90	0.25	0.00	13,510	244	0
						344,047	8,380	4,604

Table 4-2-6. Continued.

Date	Time	Mean Daily Q (cfs)	Concn. NO_3-N (ppm)	Concn. PO_4-P (ppm)	Concn. NH_4-N (ppm)	Lbs. of NO_3-N	Lbs. of PO_4-P	Lbs. of NH_4-N
June 1		140	17.61	0.24	0.24	13,313	182	181
2[a]	16:45	120	21.32	0.23	0.48	13,815	150	311
3		103	15.98	0.36	0.24	8,888	200	133
4	8:10	92	10.65	0.49	0.00	5,290	241	0
5	8:50 14:25 20:25	53	7.96	0.38	1.04	2,278	110	297
6	7:20 16:40	1530	11.34	0.26	0.32	93,691	2,155	2,644
7	14:15	870	11.93	0.22	1.33	56,047	1,011	6,248
8	17:45	520	13.81	0.28	0.65	38,778	778	1,825
9	13:55	470	13.45	0.19	0.58	34,136	480	1,472
10[b]	6:00	330	18.17	0.20	0.16	32,378	360	285
11	5:15	255	14.48	0.22	0.86	19,939	301	1,184
12		210	14.17	0.26	0.45	16,069	296	510
13	7:00	400	13.86	0.31	0.04	29,937	662	86
14	7:45 16:15	870	12.23	0.30	0.44	57,456	1,424	2,067
15	8:50 15:50	1250	14.06	0.29	0.62	94,905	1,980	4,185
16	13:55	640	13.55	0.25	0.00	46,828	867	0
17	11:00	440	14.31	0.21	0.56	34,000	496	1,331
18	12:00	350	16:01	0.24	1.63	30,258	456	3,080
19		305	20.65	0.15	1.85	34,010	252	3,047
20[a]	10:15	280	25.28	0.07	2.07	38,223	98	3,130
21		245	20.19	0.12	1.15	26,711	160	1,521
22	10:10	225	15:10	0.18	0.22	18,346	214	267
23		197	15.20	0.22	0.19	16,170	234	202
24	9:10	178	15.30	0.21	0.15	14,706	202	144
25		159	15.32	0.19	0.14	13,154	163	120
26	14:20	153	15.34	0.17	0.12	12,674	141	99
27		137	14.67	0.19	0.13	10,853	141	96
28	9:50	130	14.01	0.21	0.15	9,835	147	105
29		147	14.58	0.21	0.15	11,574	166	119
30	9:30	130	15.16	0.21	0.15	10,642	147	105
						844,904	14,214	34,794

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[a] Engineering Research Institute (ERI) values:

Date	Concn. NO_3-N (ppm)	Concn. NH_3-N (ppm)	Concn. PO_4-P (ppm)
June 2	15.35	--	--
6	13.91	0.24	0.10
20	19.45	0.27	0.13

[b] Concentration of NO_3-N for June 10 is average of three values 21.79, 15.30, 17.41 --- 18.17

Table 4-2-6. Continued.

Date	Time	Mean Daily Q (cfs)	Concn. NO_3-N (ppm)	Concn. PO_4-P (ppm)	Concn. NH_4-N (ppm)	Lbs. of NO_3-N	Lbs. of PO_4-P	Lbs. of NH_4-N
July 1		113	15.57	0.22	0.10	9,501	134	61
2	12:30	113	15.99	0.24	0.05	9,757	146	31
3		99	13.05	0.21	0.04	6,977	112	21
4	13:00	90	10.12	0.19	0.04[a]	4,918	92	19
5		81	10.13	0.19	0.08	4,431	83	35
6	9:40	75	10.15	0.19	0.12	4,112	77	49
7		76	9.97	0.18	0.11	4,092	74	45
8	11:00	71	9.79	0.17	0.11	3,753	65	42
9		90	10.99	0.18	0.17	5,341	87	83
10	9:10	145	12.20[b]	0.20	0.24	9,553	157	188
11		104	12.12	0.24	0.18	6,807	135	101
12	9:22	95	12.05	0.29	0.13	6,182	149	67
13		106	12.77	0.38	0.20	7,310	218	114
14	7:15	97	13.50	0.47	0.28	7,071	246	147
15		164	13.15	0.38	0.20	11,646	337	177
16	15:40	140	12.80	0.29	0.12	9,677	219	91
17	15:15	122	12.25	0.32	0.16	8,070	211	105
18	20:42	331	10.60	0.39	0.28	18,946	697	500
19	7:00	277	11.35	0.32	0.09	16,977	479	135
20	9:10	196	14.20	0.26	0.11	15,029	275	116
21	13:35	149	15.95	0.27	0.09	12,833	217	72
22		117	15.42	0.29	0.08	9,742	183	51
23	11:10	95	14.90	0.32	0.08	7,644	164	41
24		80	14.22	0.31	0.05	6,143	134	22
25	9:15	69	13.55	0.31	0.02	5,049	116	7
26	15:15	81	14.00	0.31	0.08	6,124	136	35
27	7:00	79	9.60	0.30	0.08	4,095	128	34
28		68	10.12	0.31	0.05	3,716	114	18
29	10:05	61	10.65	0.32	0.03	3,508	105	10
30		53	10.72	0.30	0.04	3,068	86	11
31	18:48	46	10.80	0.28	0.05	2,683	70	12
						234,755	5,446	2,440

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[a] After July 2 NH_4^+ was measured with ammonium electrode.

[b] After July 8 NO_3^- was determined by Cd reduction column.

Table 4-2-6. Continued.

Date		Time	Mean Daily Q (cfs)	Concn. NO_3-N (ppm)	Concn. PO_4-P (ppm)	Concn. NH_4-N (ppm)	Lbs. of NO_3-N	Lbs. of PO_4-P	Lbs. of NH_4-N
Aug.	1	15:10	105	8.20	0.39	0.22	4,649	221	125
	2	8:45 17:30	1350	8.30	0.43	0.36	60,507	3,135	2,624
	3	8:35	1300	13.30	0.36	0.14	93,366	2,527	983
	4	8:50	613	15.00	0.28	0.10	49,653	927	331
	5	14:00	418	15.70	0.25	0.08	35,438	564	181
	6	10:55 19:25	1720	9.00	0.40	0.24	83,592	3,715	2,229
	7	8:35	2830	7.55	0.33	0.21	115,379	5,403	3,209
	8	7:00	2500	9.60	0.29	0.17	129,600	3,915	2,295
	9	9:00	2110	10.30	0.38	0.08	117,358	4,330	912
	10	10:30	1250	11.70	0.24	0.09	78,975	1,620	608
	11	13:45	831	13.15	0.28	0.08	59,009	1,256	359
	12	9:55	591	13.50	0.24	0.08	43,084	766	255
	13		448	13.15	0.24	0.09	31,812	581	218
	14	8:45	347	12.80	0.25	0.11	23,985	468	206
	15		267	13.15	0.24	0.11	18,960	346	159
	16	9:35	210	13.50	0.24	0.11	15,309	272	125
	17		185	12.75	0.26	0.08	12,737	260	80
	18	7:30	165	12.00	0.28	0.05	10,692	249	45
	19		135	11.50	0.20	0.04	8,384	146	29
	20	18:38	117	11.00	0.23	0.04	6,950	145	25
	21		109	10.10	0.25	0.03	5,945	147	18
	22	9:20	97	9.20	0.28	0.03	4,819	147	16
	23		93	9.17	0.27	0.03	4,605	136	15
	24	8:45	85	9.15	0.26	0.03	4,200	119	14
	25		113	9.05	0.28	0.04	5,522	171	24
	26	18:50	153	8.95	0.31	0.06	7,394	256	50
	27		122	9.45	0.28	0.04	6,226	184	26
	28	9:05	104	9.95	0.25	0.02	5,588	140	11
	29		90	10.12	0.24	0.02	4,918	117	10
	30	9:25	77	10.30	0.24	0.02	4,283	100	8
	31		70	10.30	0.24	0.02	3,893	91	8
							1,056,832	32,454	15,198

Jones reported data for 1970, a year of about average rainfall over the basin, (Ames, 35.6 inches; Jewell, 29.16 inches, Webster City, 25.73 inches) and less than normal runoff (4.27 inches). The mean annual runoff is 5.82 inches. Water samples for nutrient analysis were taken weekly during the spring and fall, and twice weekly during the summer. Measurements of nitrate nitrogen were begun on March 6 and continued until December 21, 1970. The nitrate nitrogen concentration varied from zero ppm on June 30 (all stations) to a maximum of 9.9 ppm on May 16 at a point between the outlet of Bear Creek and Keigley Creek. The mean concentration for the period of analysis was about 3 ppm. It is interesting to note that the mean NO_3-N concentration of the Story City and Ames sewerage effluent was 2.1 ppm and 2.8 ppm, respectively, while the peak concentrations were 6.3 ppm and 7.8 ppm, respectively. No significant differences existed between mean NO_3-N concentrations for nine sampling stations located along the river from above Story City to below Ames. Effluent from the Ames plant ranged from 4.5 to 5.2 cfs. Jones (1972) stated that there was a significant correlation between river flow and nitrate nitrogen concentrations.

Ammonia nitrogen concentration ranged between 0.21 and 3.60 ppm NH_3-N with a mean of 0.75 ppm in 1970 (Jones, 1972). The mean orthophosphate phosphorus concentrations varied from 0.05 ppm at low flows to 0.16 ppm at high flows. In 1970 the mean COD value from Story City to Ames was 21.9 ppm, ranging from 3.8 to 87.6 ppm. The mean values of turbidity (JTU) for the same reach varied from 33 to 38 for four stations. The mean values for high flows varied from 44 to 64.

Some additional data for the region of the river near Ames is available from the Iowa Water Pollution Control Commission (1967). Samples taken as a part of a water quality surveillance program between 1963 and 1967 showed the following concentration ranges: NO_3-N, 1.9 to 8.5 ppm; NH_3-N, 0.0 to 1.3 ppm; PO_4-P, 0.2 to 0.4 ppm. COD values ranged from 10 to 50 ppm.

Data taken during 1972 indicated unusually large loads of nutrients, partly because of the higher than average flows (see Table 4-2-6). The discharge from the watershed was about 7.0 inches from March 1 to August 31, 1972. The mean concentration of NO_3-N, NH_4-N and PO_4-P was 9.09, 0.36, and 0.31 ppm during that time. The ranges of concentrations in samples taken at the station were as follows: NO_3-N, 0.4 to 25.3 ppm; NH_4-N, 0 to 4.04 ppm; PO_4-P, 0.12 to 0.83 ppm. Based on the measured concentrations and the mean daily discharge at the gaging station "near Ames", the total load of the above soluble nutrients delivered to the flow gaging station from March 1 to August 31 was 1366 tons (13.5 lbs/acre) of NO_3-N, 135 tons (1.33 lbs/acre) of NH_4-N and 65.5 tons (0.65 lbs/acre) of PO_4-P.

Fewer samples were taken during the fall months, however, an estimate of the NO_3-N nutrient load was made from the available data. About 396 tons of nitrate nitrogen (3.9 lbs/acre) moved past the "near Ames" station from September 1 through October 18. Concentrations of NO_3-N remained between 10 and 13 ppm during the fall months. Thus with the continued high flows, somewhere between 20 and 25 lbs/acre of NO_3-N left the watershed in 1972. When the flow and nutrient data are available a better estimate of the NO_3-N load can be made. The phosphate P load from March through October 18 was about 0.8 lbs/acre; the NH_4-N about 1.35 lbs/acre. The phosphate P concentration remained high during March (0.5 to 0.75 ppm), but dropped to less than 0.3 ppm most of the time thereafter. Ammonium N was highest during the snow melt period (2 to 4 ppm) but remained less than one most of the gaging period. Several organic -N, total p and COD analyses of river water were made from March 6 to August 30 (Table 4-2-7). As expected the highest organic N and COD values were recorded for high flow periods. The median value of organic N for the few samples taken was 0.64 ppm, which compares closely with the values reported by Category 5, Urban Sector. If 8.6 inches of water flowed from the watershed from March 1 to October 18, and the concentration of organic-N is assumed to be 0.6 ppm, about 1.75 lbs/acre of organic N left the watershed. By another route if the 270 tons/acre of sediment which was transported from the watershed were 5 percent organic matter and the organic matter were 5 percent organic N, the contribution would be about 2.2 lbs/acre. Phosphate P ranged from about 1/4 to about 3/4 of total P. Thus P in the River as particulate matter was about equal to that in the water (as indicated by the method of analysis); thus about another 0.8 lb/acre was added to the flow.

Several samples of surface runoff were collected during the season within the watershed (see Tables 4-2-8 and 4-2-9). Runoff on February 29 (snow melt) was lower than expected (2.1 ppm or less) in NH_4-N. Also the PO_4-P was less than that in the River. Sample analysis of surface runoff taken from two cornfields in the watershed in June revealed NO_3-N concentrations of less than half the River concentrations.

Samples of tile effluent were taken at four tile outlets discharging into a drainage ditch west of Story City on August 7, during relatively high discharge. The concentration of NH_4-N ranged from 0.05 to 0.38 ppm. The NO_3-N concentrations at two locations were 24.9 and 27.8 ppm; one was only 2.63 ppm(1). Samples taken throughout the summer at three other

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[1] One sample was lost.

Table 4-2-7. Water quality data, Skunk River, 1972[a]

Date	Org-N ppm	Total P ppm	COD ppm
March 6-9[b]		0.9	
13-17		0.8	
19-25		0.5	
27-31		0.6	
April 2-8		0.2	
10-14		0.2	
16-22		0.2	
4	0.80		18.8
22	0.44		34.3
28	0.56		15.2
24-30		0.2	
May 4-11		0.9	
4	0.67		16.8
11	0.77		21.8
17	0.75		20.0
13-19		0.3	
21-27		0.2	
25	0.61		16.4
29-6/2		0.6	
June 5	2.26		102
4-11		1.3	
6	Missing		78.8
15	0.71		44.9
13-18		1.1	
22	0.18		21.2
28	0.39		16.7
July 6	0.64		11.0
12	0.54		Missing
19	1.09		49.4
27	1.01		23.8
Aug. 2	0.74		83.0
6	Missing		62.3
16	Missing		35.0
30	Missing		18.5

(a) Analyses by Engin. Res. Inst.; P samples were not filtered.

(b) Samples composited over a week; 3 to 11 samples included.

Table 4-2-8. Quality snow melt runoff, 1972[(a)]

Location	NH_4-N ppm	NO_3-N ppm	Org-N ppm	Soluble P (PO_4)[(b)] ppm	Total P[(c)] ppm
Brome Meadow	2.10	0.73	0.62	0.24	0.29
Corn Field	0.95	1.73	0.11	0.27	0.32
Plowed Bean Ground	0.95	1.95	0.54	0.37	0.38
Plowed Bean Ground	1.18	2.92	0.58	0.12	0.23
Skunk River (near Ames)	6.98	1.30	0.51	0.95	1.00
Skunk River (Ellsworth)	3.28	2.00	0.38	0.75	0.75

(a) February 29, 1972

(b) Hach method; unfiltered sample

(c) Hach method; unfiltered sample

Table 4-2-9. Quality surface runoff water, 1972

Location	NH_4-N ppm	NO_3-N ppm	Org.-N ppm	Total P ppm
Cornfield-Ames[(a)]	0.02	3.9	0.83	0.10
Cornfield-"pothole"[(b)] (Highway 20)	0.02	6.2	----	0.10

(a) Taken June 14, 1972

(b) Taken June 6, 1972

locations near Ames showed concentrations of 20 to 40 ppm. A fourth showed concentrations of about 6 ppm.

Figures 4-2-1 and 4-2-2 present the Skunk River discharge at the near Ames station and the accompanying concentrations of NO_3-N. Before May 1 concentrations were less than 5 ppm; later the concentrations were over 8 ppm and fluctuated considerably. After June 1 the concentration of NO_3-N tends to drop when the River flow increased (which may indicate dilution by surface runoff) and increase after the peak discharge passes. After the peak discharge most of the River water would have been contributed from tile drains and seepage from ditch and creek banks. While not well substantiated, it appears that the relatively high NO_3-N concentrations in the River in 1972 were associated with tile and bank drainage water derived from the frequent high water tables.

Several additional quality parameters are presented in the Urban Sector Appendix (Category 5). Of particular interest may be the weekly readings of dissolved oxygen and biochemical oxygen demand (5 day). The BOD concentration measured above Story City, which would be a measure of that contributed from farm land, varied from 2.2 to 7.1 ppm for samples taken between April 14 and October 24, 1972. The highest concentrations were associated with high discharges and at times approached the dissolved oxygen content. On August 15 the D.O. concentration was 7.52 ppm at the station, the BOD was 7.1 ppm. Mass amount of BOD and D.O. are compiled in the Urban Sector Appendix.

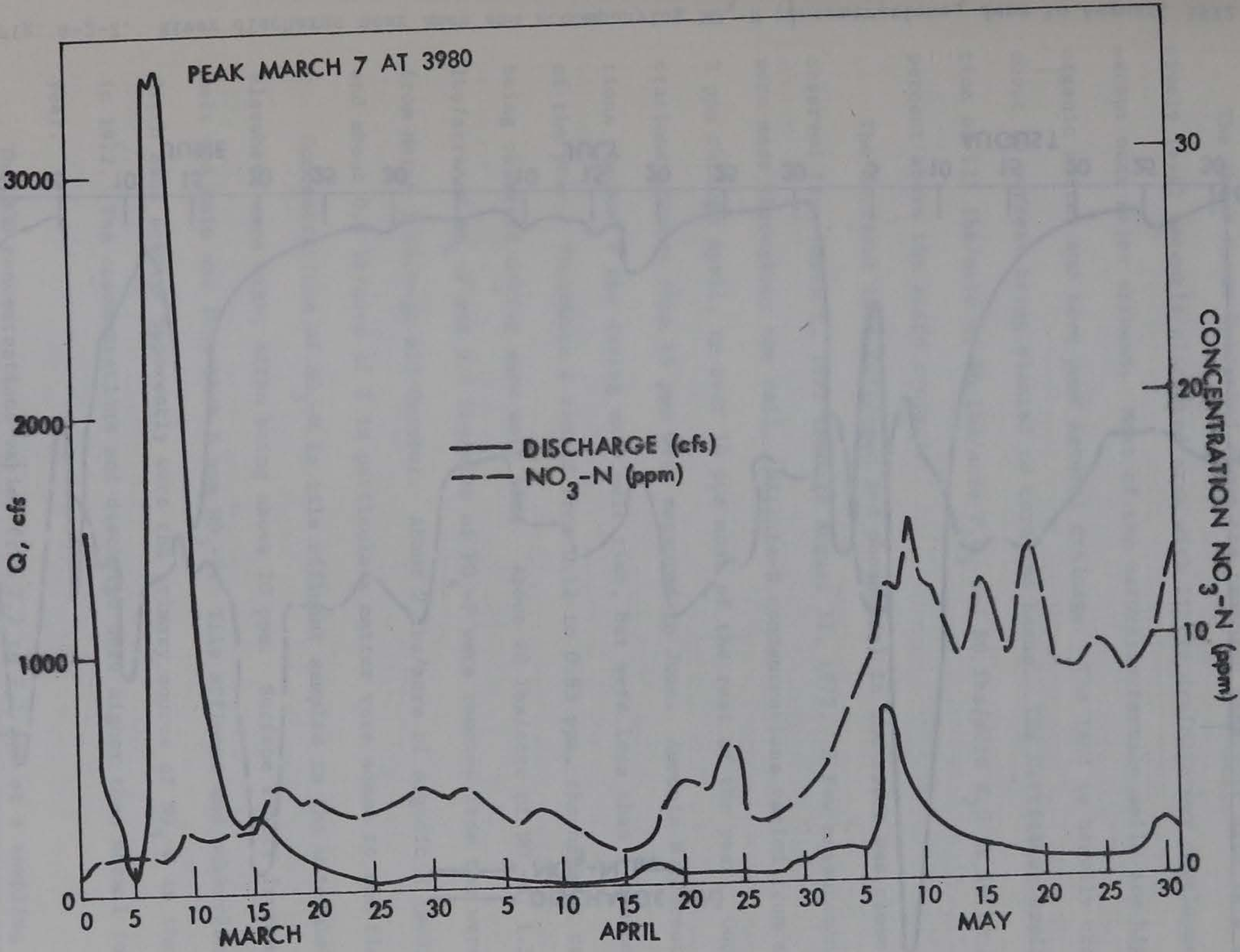

Fig. 4-2-1. River discharge near Ames and accompanying NO_3-N concentrations, March to May, 1972

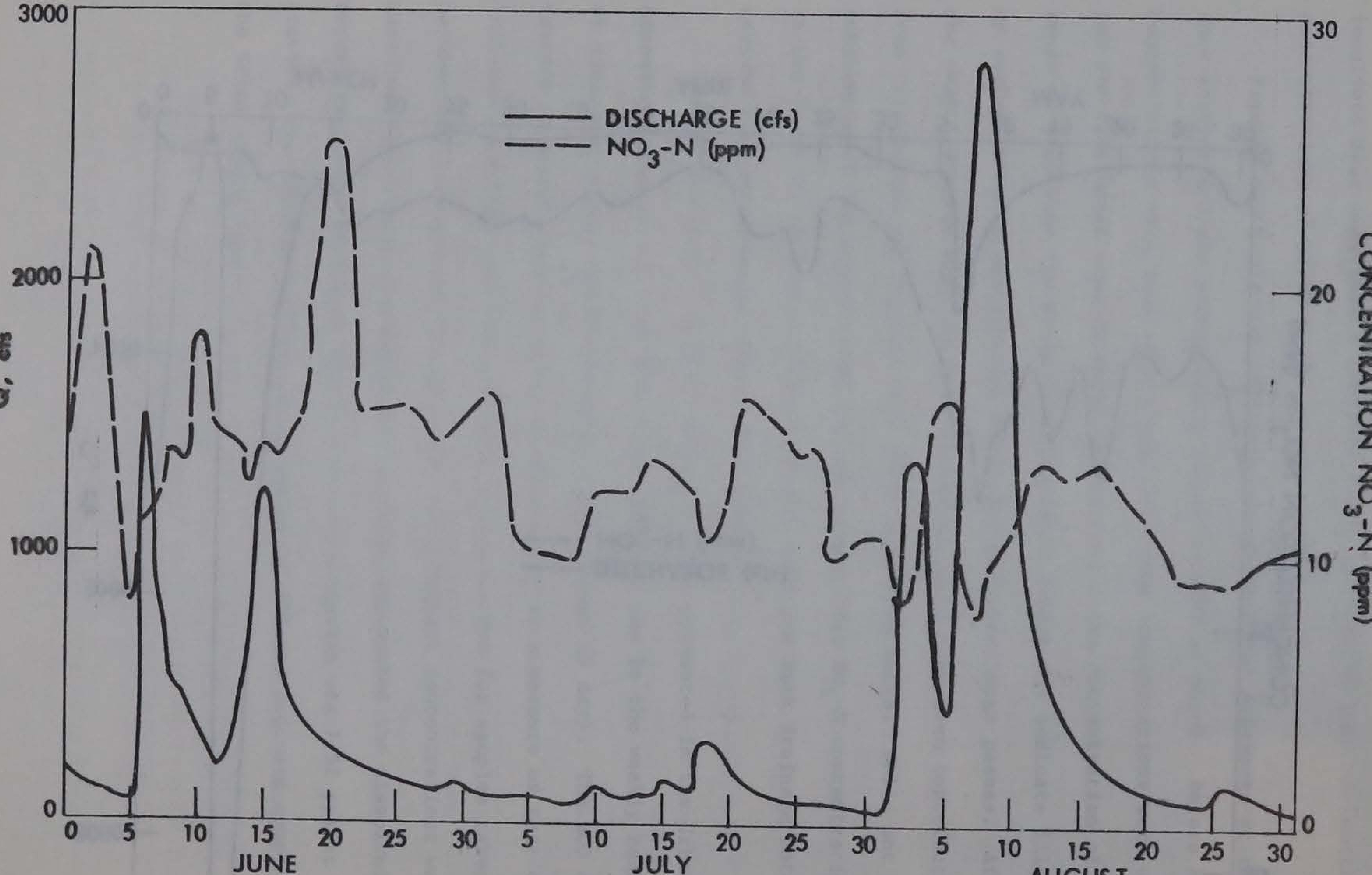

Fig. 4-2-2. River discharge near Ames and accompanying NO$_3$-N concentrations, June to August, 1972

Summary

The Skunk River Watershed above the proposed reservoir site is a relatively level recently glaciated area with little drainage way development except near major streams. Most of the naturally fertile soils are high in organic matter and have poor natural drainage. The land is heavily cropped, about 70 percent being planted to corn and beans. The fertilizer application of 125 lbs/acre N, 80 lbs/acre P_2O_5 and 80 lbs/acre K_2O is 10 to 20 percent above the state average.

The nutrient load (nitrogen and phosphate) in the river was closely observed from March 1, 1972 through August 31, 1972. A few measurements were made throughout the fall. Nitrate-N concentrations varied from about 3 ppm through April, to over 10 ppm most of the rest of the year. Concentrations greater than 15 ppm were measured in June. Ammonia N concentrations reached 4 ppm during snow melt time, but were less than 1 ppm most of the year. Phosphate P ranged from 0.12 to 0.83 ppm, the highest readings being observed during snow melt time. About 20 lbs/acre of NO_3-N, 1.35 lbs/acre of NH_4-N and 0.8 lbs/acre of PO_4-P were removed from the watershed from March 1 through mid-October. About 2 lbs/acre of organic N (sediment) and about 0.8 lb/acre of P in particulate matter were added to the flow.

Concentrations of NO_3-N in tile effluent sampled in the watershed and elsewhere were high, often being above 20 ppm. Surface runoff from snow melt and rain was less than 6 ppm NO_3-N. Tile effluent and subsurface ditch bank seepage apparently were the primary source of NO_3-N in the river in 1972. The concentrations and discharge were higher than normal for the year.

The BOD concentrations varied from 2.2 to 7.1 ppm at a sampling station above Story City and approached the dissolved oxygen concentrations at times of high discharge.

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APPENDIX

TABLE A

Iowa River Water Quality Data

	Q* cfs	Turbidity	Nutrient Concentration NO_3-N	NH_3-N	Ortho - PO_4
			1968-1969		
ct. 22	2900	63	0.10	0.33	1.34
ec. 3	2800	8	0.27	0.08	1.07
an. 15	1580	14	0.42	0.79	0.26
an. 25	2300	10	0.64	0.52	0.38
		(Jan. 21)	(Jan. 21)	(Jan. 21)	(Jan. 21)
eb. 18	380	25	----	----	1.34
arch 27	9200	115	0.74	1.17	0.53
pril 22	1200	62	0.06	0.22	0.50
ay 10	9600	31	0.48	1.12	0.42
		(May 8)	(May 8)	(May 8)	(May 8)
une 5	1400	50	5.40*	0.67	0.95
une 24	9300	72	0.18	0.03	0.66
uly 9	18,000	37	----	0.23	1.66
uly 22	23,800	52	----	0.33	0.71
ept. 10	10,200	25	0.09	0.70	0.09
ept. 26	2800	37	0.01	Trace	0.09
			1967-1968		
ct. 15	200	26	0.04	0.15	0.12
ov. 1	410	140	1.04	0.57	0.92
ec. 28	160	9	0.52	0.21	0.21
Jan. 15	90	3.5	0.27	1.86	0.14
				(Jan. 16)	(Jan. 16)
eb. 6	380	75	0.86	1.25	0.81
March 5	140	20	0.44	0.58	0.26
March 12	860	310	1.88	72.00	0.76
April 2	300	42	0.12	0.74	0.21
April 4	1780	500	1.44	0.92	0.23
		(April 9)	(April 9)	(April 9)	
April 17	580	600	0.45	0.08	2.08
April 27	1980	1100	1.21	0.63	0.25
		(April 25)	(April 25)	(April 25)	
June 24	280	525	0.14	----	1.54
July 2	1920	1400	0.48	0.15	1.41
July 17	460	45	0.18	0.28	1.13
July 23	2720	280	0.06	0.10	0.91
July 31	970	260	0.07	0.22	10.4
Aug. 6	3070	700+	0.33	0.25	1.27
Sept. 4	260	35	0.90	0.33	0.90

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*Approximate values.

[+] Sampling at Highway "0" (Johnson County Road) - Q at Marengo.

Table A, continued.

	Q cfs	Turbidity*	Nutrient Concentration NO_3-N	 NH_3-N	 Ortho - PO_4
			1966-1967		
Oct. 4	188	40	0.07	0.12	0.02
Nov. 1	156	15	0.10	0	0.14
Jan. 4	85	19	0.08	1.00	1.60
Jan. 25	1500	45	0.39	1.31	1.80
		(Jan. 24)		(Jan. 24)	(Jan. 24)
Jan. 31	470	90	0.42	0.88	4.00
Feb. 15	1400	42	0.16	1.50	2.56
		(Feb. 14)	(Feb. 14)	(Feb. 14)	(Feb. 14)
March 7	162	14	0.07	1.00	0.74
March 22	2250	550	0.30	2.52	2.00
May 29	241	23	0.10	0.55	0.36
June 19	7100	140	0.10	0.45	0.95
		(June 21)	(June 21)	(June 21)	(June 21)
July 25	517	43	0.12	0.30	0.55
			1969-1970		
Oct. 7	480	34		0.08	0.21
Jan. 27	240	17		----	0.32
March 2	360	550		1.10	0.42
March 9	2100	64		1.18	0.59
March 4	(8500)				
March 23	1600	300		0.35	0.38
May 11	1000	220		0.50	0.21
May 18	6100	850		0.10	1.81
May 15	(10,200)				
July 13	400	58		0.25	0.53
Aug. 6	4500	29		0.38	0.47
Aug. 5	(5000)				
Sept. 14	4800	67		0.20	0.36

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*Over 100 on Jackson apparatus others read on Hach apparatus.

Appendix

TABLE B

Selected Des Moines River Water Quality Data

ek	Date	Q cfs	Turbidity	COD*	Organic N	NH_4 N	NO_3^- N	Ortho P	Organic Carbon
				1970-1971					
	9 Sept.	167	33	81	2.13	0.12	0.07	0.4	36
3	12 Oct.	790	33	40	0.82	0.28	1.45	0.5	--
8	18 Nov.	1470	20	25	0.20	0.36	6.77	0.9	17
8	25 Jan.	498	3	20	0.70	1.10	3.90	1.3	0
35	16 March	13,800	64	84	0.73	1.14	3.78	0.6	0
7	9 June	8120	300	182	3.74	0.38	7.66	0.2	79
51	6 July	8670	65	88	1.63	0.35	8.91	0.4	29
				1969-1970					
1	18 July	10,600	69	39	1.09	0.47	4.38	0.5	18
3	30 July	13,900	67	27	0.70	0.24	6.20	0.5	23
13	9 Oct.	402	25	54	0.64	0.13	0.10	0.1	25
18	13 Nov.	674	16	40	0.43	0.17	11.82	0.1	28
30	5 Feb.	198	0	3	0.12	1.09	3.08	1.0	--
34	5 March	2180	71	32	1.42	0.78	5.83	0.5	--
39	10 April	3260	60	40	0.0	0.43	6.07	0.3	--
44	15 May	11,700	490	161	4.88	0.82	6.08	0.2	--
52	11 July	2910	34	55	1.18	0.24		0.1	25
				1968-1969					
2	12 July	748	23	63	0	0.27	5.94	Trace	24
3	19 July	3610	230	79	0.55	0.63		0.35	29
11	12 Sept.	265	27	32	1.67	Trace	0.04	Trace	20
14	2 Oct.	1070	66	34	1.10	0.20	5.05	0.56	25
17	23 Oct.	7890	83	23	0.76	0.15	14.00	0.54	21
27	2 Jan.	650	2	13	0.25	0.33	6.20	0.62	6
38	20 March	5300	91	81	Trace	1.44	2.16	0.85	49
39	26 March	19,100	76	51	Trace	0.59	5.29	0.89	32
42	16 April	23,800	91	45	0.14	0.27	3.65	0.26	15
49	4 June	2820	37	34	0.55	0.30	8.70	0.11	11
52	27 June	11,300	31	58	3.77	0.27	9.00	0.40	49
54	9 July	19,300	--		--	0.44	5.68	0.50	26
				1967-1968					
1	6 July	2520	35	208(?)	5.62	0.85	6.55	0.62	--
5	3 Aug.	562	30	47	2.03	0.11	0.0	0.07	19
10	10 Sept.	265	30	49	2.63	0.43	0.17	0.18	21
16	21 Oct.	138	26	49	0.68	0.25	0.02	0.11	33
18	4 Nov.	187	20	26	0.37	0.20	0.0	0.15	43
27	5 Jan.	51	12	56	1.42	0.38	Trace	0.81	--
37	15 March	279	--	21	0.45	0.49	0.71	0.82	18
43	27 April	958	38	50	----	0.54	2.00	0.13	41
50	14 June	748	83	80	3.50	0.29	0.0	0.35	--
52	28 June	2980	74	66	1.65	0.46	10.75	0.58	25

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*Concentrations are expressed as ppm.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

Chapter 3

WATER QUALITY IMPLICATIONS OF PESTICIDES

by

James L. Baker

1973

CONTENTS

FIGURES

TABLES

Chapter 3

WATER QUALITY IMPLICATIONS OF PESTICIDES

James L. Baker

Introduction

In assessing the quality of drainage water from agricultural lands, the fate of chemicals which are introduced into the environment as a result of the farmers' activities must be considered. Although these chemicals represent a possible source of pollution they are an economic benefit not only to the farmer but also to the consumer of his food and fiber products. Pesticides, poisons used to control a wide range of plants and animals, are among these chemicals and are used in large quantities. The estimation that insecticides return five dollars for every dollar spent (President's Science Advisory Committee, 1965) explains their extensive use. In 1969, 348 million pounds of herbicide and 502 million pounds of insecticide were sold (U.S. Tariff Commission, 1970), and it is predicted that in 1980, 1 billion pounds of pesticideswill be used (Faust and Gomaa, 1972).

From a survey of some farmers and farm chemical dealers in the drainage basin for the proposed Skunk River reservoir, taken in June, 1972, it was estimated that 80% of the farmers in the watershed used herbicides on corn and soybeans and 60% used insecticides. These percentages are higher than those estimated for the United States by the U.S. Department of Agriculture which, in 1966, were 27% for herbicides and 12% for insecticides

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on all cropland. The higher percentages result from increased pesticide sales from 1966 to 1972, and intensive farming in the area. Pesticides will continue to be used since nonchemical methods of weed and insect control are not expected to supplant the use of chemicals in the foreseeable future (Division of Biological Agriculture, National Academy of Sciences, 1969).

When a pesticide is released into the environment, the primary reservoirs are soil, surface water and air. There are a number of transport mechanisms by which a pesticide can be conducted from one reservoir to another; Fig. 4-3-1 illustrates the major non-biological pathways. Eventually, although it may take years, all the pesticide released will be degraded as illustrated by the arrows dead-ending into the center box labeled "DEGRADED".

The potential for pollution and possible poisoning is dependent on the availability of the pesticide to susceptible non-target organisms, which in turn is dependent on how effective the transport mechanisms are in dispersing the pesticide to areas where it is not desired. C. A. Edwards (1970) in a review of pesticides in the environment advanced the opinion that the potential hazards of pesticides in soils are probably not great. In addition, since most agricultural pesticides used in Iowa are registered for use in the field to be applied to the soil or plant surface, pollution should result only if the pesticide is lost from the field to the atmosphere or water. The extent of this loss, if any, is determined in each instance by physical and chemical properties of the particular pesticide and of the soil involved, by methods of application and ensuing tillage, by meteorological conditions and by all the interrelationships of these factors.

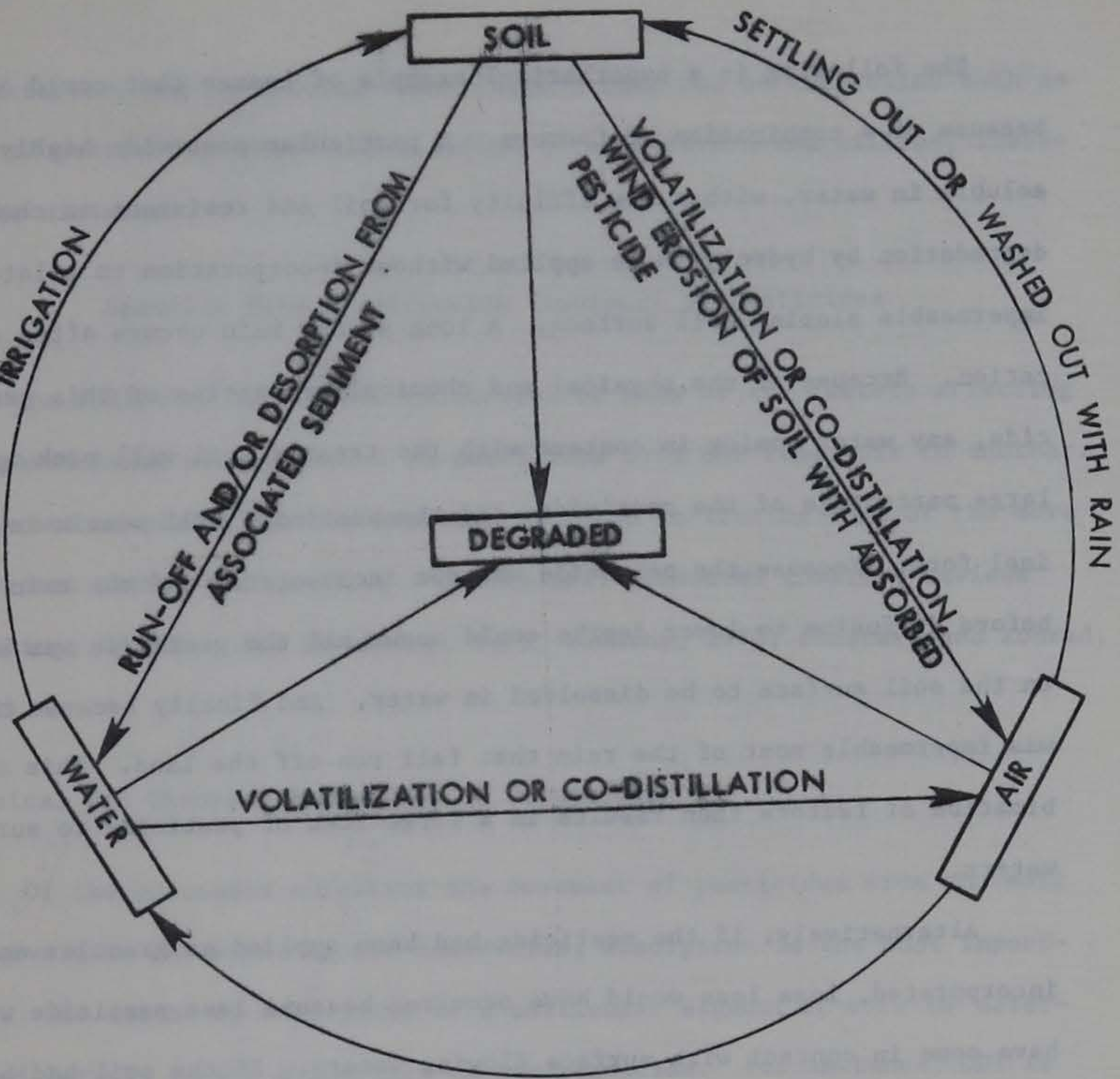

Fig. 4-3-1. Pesticide transport mechanisms.

The following is a hypothetical example of losses that could occur because of a combination of factors. A particular pesticide highly soluble in water, with a low affinity for soil and resistant to chemical degradation by hydrolysis is applied without incorporation to relatively impermeable sloping soil surface. A long steady rain occurs after application. Because of the physical and chemical properties of this pesticide, any water coming in contact with the treated soil will pick up a large percentage of the pesticide, and the pesticide will remain in its original form. Because the pesticide was not incorporated and the rain occurred before diffusion to lower depths could occur all the pesticide was available on the soil surface to be dissolved in water. And finally because the soil was impermeable most of the rain that fell ran off the land. This combination of factors then results in a large loss of pesticide to surface waters.

Alternatively, if the pesticide had been applied as granules and/or incorporated, less loss would have occurred because less pesticide would have come in contact with surface flowing waters. If the soil had been highly permeable and dry, no runoff and therefore no overland transport of pesticide would have resulted from a long, steady rain although losses to depths below the root zone due to leaching may have occurred. If the pesticide had not been soluble and was adsorbed strongly to soil, losses would not have occurred with runoff water. However, if erosion took place, pesticide losses would have accompanied soil losses.

It is evident that the numerous factors and possible combinations thereof make it impossible to totally prevent pesticide losses. However, utilizing the limited available knowledge of the interrelationships of these factors and optimizing those factors that can be controlled such as kind of pesticide, formulation, method of application and tillage, losses can be minimized.

Specific Factors Affecting Transport of Pesticides

The following is a brief discussion of some of the factors affecting the persistence and transport of pesticides from one reservoir to another. It is not complete; instead emphasis is given to listing some of the more important points and examples. Others have presented complete reviews (Helling, Kearney, and Alexander, 1971; Edwards, 1970; Chesters and Konrad, 1971).

Physical and Chemical Properties of Pesticides

Of the processes affecting the movement of pesticides from the soil reservoir to the water or air reservoirs, adsorption is the most important. The extent of adsorption to a particular segment of soil is determined largely by the properties of the pesticide. For instance, DDT is soluble in water to about 1.2 ppb (parts per billion) but is a million times more soluble in resins, waxes, fats and oils (Spencer, 1971) and therefore is found associated very strongly with the organic matter segment of soils. Diquat and paraquat, on the other hand, are associated strongly with the clay faction of soils; these cationic herbicides are attached to the fixed negatively charged sites on the clay. Anionic or organic acid pesticides are not held by montmorillonite illite or vermiculite clays due to a lack of positively charged sites (Burnside and Lavy, 1966). In order to increase adsorption and decrease the mobility of acidic herbicides, they are often applied to soils as esters; however, conversion to the free acid may readily occur in the soil and thus negate the effect of esterification.

The vapor pressure of a pesticide determines in part the amount that can be lost due to volatilization; the higher the vapor pressure the greater the expected loss. There is a wide range of values. EPTC has a vapor pressure of 2.0 mm Hg at 24°C (Weed Society of America, 1967), (fumigants often have values so high they are completely gaseous at room temperature) whereas some chlorinated hydrocarbon insecticides have vapor pressures as low as 10^{-7} mm Hg (Edwards, 1966). As stated earlier adsorption plays a key role in determining movement with increased strength of adsorption resulting in decreased volatilization.

Solubility like vapor pressure exhibits a wide range of values; DDT being soluble to 1.2 ppb with some cationic herbicides exhibiting solubility in excess of 70% (Weber, 1971) or roughly four hundred million times more soluble than DDT. Although solubility is important, adsorption also plays a key role with respect to losses with water. Losses from the surface with runoff or into the soil below the root zone by leaching are reduced by adsorption. However, strong adsorption may immobilize a pesticide on the soil surface where it is then liable to losses through erosion, both by wind and water.

Degradation whether by chemical reaction, microbiological activity or photodecomposition is determined to a large degree by the chemical structure of the pesticide. One class of pesticides, the chlorinated hydrocarbon insecticides, are generally quite resistant to decay by all three means and are therefore persistent. The approximate half-life of dieldrin, BHC and DDT in soil is listed in Table 4-3-1. Values for other classes of insecticides and herbicides are also listed. It should be emphasized that these values are approximate since most pesticides do not decay exactly in an exponential manner, the rate of decay being somewhat dependent on the concentration. Edwards (1966) found that proportionately more pesticide disappears from small doses than from larger ones. In addition, climatic and soil conditions influence the rate of decay, and values other than those found in Table 4-3-1 can be found in the literature; for instance in Rodenheser's (1960) study, the amount of DDT left after six years' decay would correspond to a half-life of about 10 years.

Table 4-3-1. Persistence of pesticides in soils (a)

Pesticide	Approximate Half-life (years)
Lead, Arsenic, Copper, Mercury	10-30
Dieldrin, BHC, DDT insecticides	2-4
Triazine herbicides	1-2
Benzoic acid herbicides	0.2-1
Urea herbicides	0.3-0.8
2,4-D; 2,4,5-T herbicides	0.1-0.4
Organophosphorous insecticides	0.02-0.2
Carbamate-insecticides	0.02-0.1

(a) Metcalf and Pitts, 1969.

Physical and Chemical Properties of Soils

As stated earlier, adsorption is the most important process affecting the movement of pesticides. The properties of soils determines to what extent a certain pesticide is adsorbed. For instance, organic matter content, which is generally the most important of soil properties governing pesticide adsorption, accounted for 90% of the variability in adsorption of simazine by different soils (Williams, 1968). The surface charge characteristics and thus the type of clay in the mineral segment of soil was important in determining adsorption for the organic cationic herbicides such as diquat and paraquat (Weed and Weber, 1968). The pH of a soil determines whether acidic herbicides as chloramben and 2,4-D exist as anions or nonionized acids; the nonionized acid form being adsorbed more strongly and therefore being less mobile than the anion form. It has been shown that dieldrin losses by volatilization are dependent on soil moisture conditions with up to 18% of that applied lost in five months from a moist soil (Willis, et al., 1972); this may be due to water molecules competing with dieldrin for adsorption sites (Weber, 1971). Thus soil properties, by affecting adsorption, affect the movement and possible loss of pesticides to water and air by runoff and volatilization.

Although leaching to water table depths is possible for some pesticides under certain soil and climatic conditions, pesticides are generally not found in ground or tile water (Willrich, 1969; Lichtenstein, 1958; Harris, 1969). When they are, it is usually the result of polluted irrigation water (Johnson, et al., 1967), direct contamination (Walker, 1961), or unusual circumstances (Iowa Academy of Science, 1970) rather than leaching through the soil.

The persistence of pesticides is determined in part by soil properties, for example, heavy clays retain insecticides longer than lighter sandy soils. There is evidence that organophosphorous insecticides persist longer in acid soils than alkaline (Edwards, 1970). Soil moisture affects adsorption when highly polar water molecules compete with polar pesticides for adsorption sites on soil particles. Therefore, high moisture contents may cause pesticides to be released and to subsequently be more readily degraded or physically removed.

Methods of Application, Ensuing Tillage, and Climatic Conditions

The method of application and formulation used can partially determine persistence and losses to the surroundings. Application by spraying may result in losses to the atmosphere in the tens of percent even on still days because some of the droplets are so small they never settle but eventually either evaporate or are adsorbed onto dust.

Sprays are used to distribute the pesticide over the soil surface as evenly as possible; however, all of the pesticide is then available to the surface elements to be decayed or lost to the surroundings. In order to increase the persistence of some highly degradable pesticides, granules are used which act as "time-release" capsules that allow the pesticide to diffuse slowly from the protective granule.

By tilling the soil after application the pesticide can be incorporated into the soil where it is not as susceptible to volatilization, soil erosion or to photodecomposition resulting from the sun's rays. Lichtenstein, et al. (1962), found that insecticide residues falling upon the soil surface but not cultivated into the soil disappear as much as 10 times faster as those which are thoroughly cultivated into the soil. The type of tillage, of course, determines the type of soil surface; for example, minimum tillage leaves a mulch of last year's crop material on the surface which has been shown to reduce runoff and erosion and therefore reduces the associated loss of pesticides (Ritter, 1971; Edwards, 1972). However, some of the sprayed pesticides fall on the mulch which decreases that reaching the soil surface. Excessive tillage, on the other hand, can result in inccreaded erosion and loss of pesticide (Edwards, 1972).

Climatic conditions have obvious effects on the transport of pesticides from the soil; wind and rain having the most effect. Since many pesticides are susceptible to photodecomposition, the amount of sunlight is a factor in the persistence of these pesticides. Temperature is important because it affects solubilities, vapor pressure, rates of reactions and microbiological activity which determines rates of losses by transport or decomposition. Also the timing of storms is very important since storms occurring shortly after application result in much greater losses through runoff than those occurring later in the season (Ritter, 1971; Edwards, 1972; Trichell, et al., 1968).

Pesticides Contamination of Water

Chlorinated Hydrocarbon Insecticides

From a chemical viewpoint, the chlorinated hydrocarbon insecticides are a family and in general are unreactive, are practically insoluble in water, and are soluble in fat. The fact that they are generally unreactive and therefore are not very susceptable to chemical degradation, to biological breakdown or to photodecomposition, results in their persistence. Their low solubility in water and high solubility in resins, waxes, fats, and oils results in their low concentrations in water and their high concentrations in the organic matter associated with soils. Therefore, in the transport of insecticides from treated fields, most is found in the sediment. Heptachlor and gamma chlordane, soluble in water to 10 ppb, were found distributed between sediment and water in the ratio of about 20 to 1 (Federal Water Pollution Control Commission, 1961). Lindane, an exception, being soluble in water to 3000 ppb, has been found to be transported primarily with water (Nicholson, 1969).

In 1967 the Iowa State Hygenic Laboratory located at the University of Iowa monitored runoff from two farms in Johnson County on which the insecticide aldrin was applied (Iowa Academy of Science, 1969). About one month after application at the rate of 2 pounds active ingredient per acre, a four inch rain caused the first surface runoff of the growing season. Samples of water collected from surface drains in the fields contained from 0.26 ppb to an undetectable level of aldrin plus its degradation product dieldrin. The sediment contained from 290 ppb to the undetectable level. In both the case of water and its associated sediment more dieldrin than aldrin was found, implying that the month during which aldrin was on the soil was sufficient time for a majority of it to be converted to dieldrin.

The State Hygenic Laboratory in 1968 also sampled major streams in Iowa for pesticide concentration. They sampled the Mississippi River at Dubuque and Davenport, the Cedar River at Cedar Rapids, the Iowa River at Iowa City, the Raccoon River at Des Moines and the Missouri River at Council Bluffs monthly April through October. At that time no common chlorinated hydrocarbon insecticide was found in excess of 0.012 ppb.

Morris and Johnson continued their monitoring program in 1969 and 1970 adding sampling sites on the Little Sioux at Cherokee, Nishnabotna River at Hamburg, Skunk River at Oskaloosa, and the Upper Iowa River at Decorah. Three distinct trends were seen in their data (Johnson and

Morris, 1971). The overall pesticide concentration varied from year to year, from season to season, and the levels and particular pesticides found varied from river to river. The year to year variation was found to be related to flow with increasing surface runoff resulting in increased dieldrin levels. The season to season variation was such that in June and July following the May application of aldrin, which is rapidly converted to dieldrin, the dieldrin concentration increased, and then decreased in later months. Finally the river to river variation was found to be related to the agricultural activity in the drainage basin; the rivers which did not drain highly cultivated areas consistently had low pesticide concentrations. In 1969 and 1970 the highest level of dieldrin found was 0.065 ppb; for DDT plus DDE it was 0.023 ppb. These levels are well below the permissible limit of 42 ppb for human consumption shown in Table 4-3-2; however, the criterion for freshwater organisms is such that any addition of persistent chlorinated hydrocarbon insecticides can result in damage to aquatic populations.

In 1971, samples of water and bottom sediment were collected monthly from April through October from the Des Moines River below Fraser, Iowa. Analyses of these samples for dieldrin showed concentrations of less than 0.1 ppb in the river water and less than 5 ppb in bottom sediment.[1] Again the level in the water is far below the permissible level, but biomagnification may result in dieldrin concentrations in fish greater than the Food and Drug Administration's action guideline for edible portions of fish taken from the river.

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[1] Bulkley, R., Ames, Iowa, Private communication, 1972.

Table 4-3-2. Surface water criteria for pesticides in public water supplies[(a)]

Pesticide	Permissible Criteria (parts per billion)
Aldrin	17
Chlordane	3
DDT	42
Dieldrin	17
Endrin	1
Hyptachlor	18
Heptachlor epoxide	18
Lindane	56
Methoxychlor	35
Organic phosphates plus carbamates	100
Toxaphene	5
2,4-D plus 2,4,5-T, plus 2,4,5-TP	100

(a) Nicholson, 1969.

The FDA limit for dieldrin in fish is 300 ppb. Morris and Johnson (1971) determining dieldrin in catfish composites from interior Iowa streams, found levels up to five times the limit. They also found levels in excess of 300 ppb in other bottom feeding fish as Carp and Big Mouth Buffalo; however, pan and predator fish contained levels uniformly below the dieldrin limit. They also noted a correlation between high dieldrin levels in catfish with high levels in the river from which they were caught. Pesticide levels in turn correlated with turbidity of rivers since soil erosion is a transport mechanism, so a logical method of improving the situation is more and better soil conservation practices.

Hindin and Bennett (1970) monitored runoff from a plot that was treated with DDT. In the five year period of analyses, the highest concentration found in water was 3.38 ppb. In the associated sediment the highest concentration was 1873 ppb. These values were obtained for irrigation return flows from water applied one day after application of the pesticide. For later applications of water, concentrations were decreased from these values considerably. They found that there was considerable carryover of DDT and calculated a half-life from their limited data of 1.8 years.

A sampling survey for DDT and its metabolites TDE and DDE has been conducted on the Red Cedar River. This river is located in south-central Michigan and is considered a representative midwestern agricultural and urban stream. From the sampling of sediment, their work showed that a rapid partitioning occurred between soil and water indicating that the stream possesses the potential to decontaminate itself if further pesticide introduction was limited. Their work also showed the largest amount of pesticide contamination entering the Red Cedar River came from waste treatment plants and therefore it was felt that more emphasis should be placed on the amount of contamination from urban and surburban areas (Zabik, et al., 1971).

Field surveys for DDT were conducted in North Shore streams in the Minnesota drainage basin of Lake Superior (Minnesota Pollution Control Agency, 1971). In two streams values in excess of 20 ppb were obtained following a heavy runoff; however, ordinary mean levels of DDT for all streams were less than or equal to 0.03 ppb. The samples were not filtered before analysis which would explain how the values could be above the solubility of DDT in water.

Brown and Nishioka (1967) reported the monthly analysis of eleven western United States streams in 1966 for nine chlorinated hydrocarbon insecticides and three chlorinated hydrocarbon herbicides (no herbicide was found at any time in any stream, probably due in part to their susceptability to degradation). The insecticides when detected were generally at levels less than 0.005 ppb with the maximum value being 0.11 ppb of DDT. Manigold and Schulze (1969) reported the results of the continuation of this survey in 1967 and 1968. DDT was the insecticide most often found with a maximum level of 0.12 ppb. (2,4-D was found at a maximum level of 0.35 ppb).

Lichtenberg et al. (1970) reported the results of a five year survey of surface water in the United States for chlorinated hydrocarbon pesticides. Dieldrin, DDT and its congeners DDE and DDD were detected most often and their levels were well below the limits shown in Table 4-3-2. These levels reached a peak in 1966 and then declined in 1967 and 1968 commensurate with decreased usage of the chlorinated hydrocarbon insecticides.

The banning of DDT and more recently of aldrin and dieldrin (American Chemical Society, 1972) should accelerate the decline in introduction of these pesticides to the surface waters of the United States. After a period of time for these chlorinated hydrocarbons already present in the soil from previous applications to decay, they will not be a source of pollution. However it is possible these bans will be revised upon appeal and subsequent court action resulting in a reintroduction of these pesticides to the environment.

Organophosphorous and Carbamate Insecticides

Organophosphorous and carbamate insecticides, which are less persistent in soil and natural water environments are replacing the chlorinated hydrocarbons. A survey of farmers (Knutson, et al., 1971) in a newly developed irrigation district in central Kansas illustrates this very nicely. In 1963, the first year for the 6600 acre irrigation district, 100% of the insecticides used were chlorinated hydrocarbons. In 1966, 9% were chlorinated hydrocarbons, 2% were carbamates, and 89% were organophosphorous compounds. In 1969 these percentages were 0.1%, 16%, and 84% respectively. This survey also illustrated the increased use of insecticides that occurs when an area is more intensively farmed. In 1962, before irrigation, only 81 pounds of insecticides were used on the 6600 acre district; in 1969, 3011 pounds were used.

One of the hazards of some of the organophosphorous and carbamate insecticides is that they are highly toxic to mammals although in general they have lower acute toxicity to fish than the chlorinated hydrocarbon insecticides (Cope, 1966). It has been shown that organophosphorous and carbamate insecticides would be quite persistent in water if chemical hydrolysis were the only means of degradation (Faustand Gomaa, 1972). However, in a study made with raw river water, where there is microbiological activity, only azodrin of nine organophosphorous compounds studied was stable throughout the eight week study period. All seven of the carbamate compounds were significantly changed within one week and all but baygon was completely lost after eight weeks (Eichelberger and Lichtenberg, 1971).

At the same time that the Iowa State Hygenic Laboratory monitored runoff for aldrin they also monitored runoff from a field on which diazinon was applied (Iowa Academy of Sciences, 1969). A four inch rain one month after application of two pounds active ingredient per acre caused the first runoff of the growing season. No diazinon was found in surface runoff which led the investigators to conclude that the majority of diazinon had degraded in the month since application. This is reasonable since it has been found that organophosphorous insecticides in general have half-lives less than two months (see Table 4-3-1). It has been shown that diazinon in particular has a half-life of about four weeks in soil at 77°F and 20% moisture content (Getzin, 1968). At 110°F and 23% moisture diazinon has a half-life of less than a week (Ritter, 1971).

In 1968 and 1969 measurements were made on runoff samples taken from watersheds on the Western Iowa Experimental Farm (Ritter, 1971). These watersheds had been treated with one pound per acre of diazinon applied in a band and incorporated to a depth of one to two inches. Storms occurring within 10 days of application resulted in runoff water and sediment samples with concentrations ranging from 80 ppb to undetectable and from 200 ppb to undetectable, respectively. For later storms lower concentrations were found.

Sievers <u>et al</u>. (1970), using simulated rainfall on three different soils treated with insecticides, created runoff on which they performed analyses for diazinon and phorate. Depending on the soil, 192 to 0.53 ppb of diazinon was found in runoff water. The highest concentration may have resulted from the movement in the runoff water of diazinon granules. Phorate was found in the sediment in excess of 2000 ppb; in runoff water from a trace to 2.5 ppb.

Hindin and Bennett (1970), in addition to DDT, also monitored runoff for ethion. Maximum concentrations in water and sediment were for runoff occurring immediately after application and were 17 and 536 ppb, respectively. Runoff occurring 30 days after application resulted in much lower concentrations of 2 ppb for water and less than 0.01 ppb in the sediment.

In a survey of New York State groundwaters and natural watersheds no samples collected from 1964 through 1966 contained organophosphorous pesticide contamination (Zweigand Devine, 1969). One of the samples collected in 1967 from a farm pond had 0.13 ppb of ethion; this value is well below the 100 ppb limit listed in Table 4-3-2 for human consumption.

Work done on the mobility of insecticides with water indicates that there is little probability that diazinon, disulfoton or phorate will be moved below the plow layer be leaching (Lichtenstein, 1958). Therefore, these insecticides would not be found in groundwater of water from tile drains.

Herbicides

In general herbicides have very low mammalian toxicities, as most act interfering with biochemical systems that are peculiar to plants. Since herbicides act against photosynthesis and plant growth hormones they must be used at low dosages in order to prevent harmful effects on the crops being grown. Therefore, low toxicities and low dosages plus the fact that herbicides have short half-lives in the soil (see Table 4-3-1) make the herbicides much safer to use and much less a threat to the environment than insecticides.

An experiment monitoring the losses of atrazine and propachlor from a watershed under conventional tillage has been performed on the Western Iowa Experimental Farm (Ritter, 1971). From four years of record (twenty storms) the highest concentration of atrazine in runoff water was 2,870 ppb with the associated sediment containing 4,470 ppb. The storm causing this runoff occurred in 1970 just seven days after application and resulted in the loss of 15% of the 3 lb/A atrazine applied. This was by far the most severe loss. One other storm caused a 3% loss. None of the other 18 storms of record resulted in losses in excess of 0.17% of that applied. For these 18 storms atrazine in runoff water averaged 140 ppb and in the sediment 230 ppb. The use of a minimum tillage system on an adjacent watershed for three years resulted in a decrease of runoff water to 53% and sediment to 10% of that from the conventionally tilled watershed for the same three years. For this same period atrazine losses from the field under minimum tillage were only 24% of those from the conventionally tilled field. This again illustrates the potential for reduction of pesticide pollution by the use of conservation oriented practices.

The storm in 1970 that resulted in the severest loss of atrazine also caused a 2.6% loss of the 6 lb/A propachlor applied. The concentration in the runoff water was 1280 ppb with 3010 ppb in the sediment. Storms occurring later in the season caused losses of less thab 0.3% of that applied. For the other three years of record no detectable losses from runoff occurred presumeably because propachlor was appreciably degraded before storms occurred.

In 1972 four samples from the Skunk River were analyzed for atrazine and alachlor (a herbicide quite similar to propachlor). One sample was taken on May 29 and one on June 5 during periods of runoff (flow was about 200 cfs and 1500 cfs respectively). Approximately 800 ml of sample were extracted with 20 ml of benzene. Ten microliters of the extract were then injected into a Microtek 220 gas chromatograph equipped with a Ni-63 electron capture detector. From the areas of the peaks obtained and the retention times on three different columns, atrazine and alachlor were detected qualitatively and quantitatively. Atrazine and alachlor were detected in both samples but at levels less than 10 ppb and 5 ppb, respectively.

The other two samples were composites of a number of grab samples taken during periods of normal flow. One was a composite of samples taken on May 2, 4, 6, 8, 10, 12, 14, and 16; the other June 2, 10 and 15. Neither composite sample contained detectable residues (greater than 1 ppb) of atrazine or alachlor. This is as expected since during periods of normal flow a large proportion of the water is from tile drains and is free of pesticides, having percolated through the soil. Runoff water on the other hand, in its overland route, has the opportunity to pick up pesticides from the surface of the soil.

Summary

From the literature review it appears that should the Skunk River dam be built as proposed, pesticide levels resulting from runoff from treated agricultural land would never exceed maximum permissible values allowed for human consumption (Table 4-3-2); and therefore, from the pesticide standpoint the reservoir would be a safe water supply for Ames. However the sediment in the reservoir would be contaminated with dieldrin because of the large amount of its parent compound, aldrin, that has been used on the soil in the past years. It is then possible that bottom feeding fish types caught from the proposed reservoir will have dieldrin concentrations exceeding permissible limits for human consumption. The impounding of the Skunk River would not be the direct cause of the contamination as bottom feeders caught from free flowing Iowa streams have contained excessive amounts of dieldrin, but it is felt (Morris and Johnson, 1971) that impondment allows silt to settle out over broader areas making the pesticide it contains more readily available to fish and thus increasing their chances of contamination.

Recently the Environmental Protection Agency banned all major uses of aldrin and dieldrin; however, this ban is subject to appeal and court action is pending. Should the ban be upheld, the problem of fish contamination by dieldrin would be alleviated with time as it has been shown that decreased usage of chlorinated hydrocarbon insecticides resulted in decreased levels in streams (Lichtenberg, et al., 1970). However, because of the persistence of dieldrin in soils, the ban will not immediately result in zero dieldrin levels in streams; but instead it may be years before the dieldrin in the soil is degraded and that associated with sediment is degraded or flushed away to the extent that no fish contamination will occur.

An important question that is yet to be answered is what the farmer in central Iowa will substitute for aldrin and dieldrin in insect control. The survey from Kansas (Knutson, et al., 1971) indicates that it will not be another chlorinated hydrocarbon which may result in a similar problem as with aldrin and dieldrin, but will be organophosphorous and carbamate insecticides. These compounds, while generally quite toxic to mammals, are less toxic than chlorinated hydrocarbons to fish (Cope, 1966) and are quickly degraded in the natural environments of soil and water (Eichelberger and Lichtenberg, 1971; Metcalf and Pitts, 1969).

Also in the future is possible increased utilization of soil and water conservation practices which reduces runoff and erosion such as building tile inlet terraces or using new minimum tillage systems. By holding the soil in the field a major transport mechanism of pesticides is controlled and thus the quality of surface waters are enhanced. For this reason the chairman of the Iowa Water Pollution Control Commission in 1970 stressed the need for legislation for an adequate level of soil erosion control and land use.

With the present concern for the environment, the resulting social pressures, economic incentives and laws have resulted in better ecological practices with respect to pesticides to be used. Therefore, if the dam is built, after an initial recovery period for dieldrin levels to decline, there should not be a pesticide problem. However, monitoring of surface waters, and research regarding the fate of pesticides and in particular their metabolites should be continued to expose any presently unforeseen problems.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

Chapter 4

WATER QUALITY IMPLICATIONS OF LIVESTOCK PRODUCTION

by

T. E. Hazen, D. H. Vanderholm, and J. R. Miner

1973

CONTENTS

TABLES

Chapter 4

WATER QUALITY IMPLICATIONS OF LIVESTOCK PRODUCTION

T. E. Hazen, D. H. Vanderholm, and J. R. Miner

Literature Review - Background

Introduction

The quality and quantity of water stored in any major surface water impoundment is a function not only of the climate and topography of the drainage basin, but of the activities within the basin as well. The Skunk River drainage basin above the proposed dam is used extensively for livestock and crop production. Animal manures are the principal concern related to livestock production and their potential contribution to impairing water quality within the reservoir.

The major water pollutants from animal manures are oxygen-demanding matter (principally organic matter), plant nutrients, and infectious agents. Color and odor are potential polluting constituents of secondary importance. Organic matter from livestock wastes, like that from other sources, serves as a substrate for aerobic bacteria when it enters a receiving stream. Associated with bacterial metabolism is the utilization of dissolved oxygen. When the rate of oxygen utilization exceeds the reaeration rate of the stream, oxygen depletion occurs. Further additions of organic matter will reduce the oxygen concentration below the level

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necessary for fish survival and the maintenance of a desirable aquatic environment. Under severe circumstances, dissolved oxygen is entirely depleted and anaerobic conditions result.

Organic matter in waste water has been historically measured as biochemical oxygen demand (BOD). This measurement evaluates the concentration of oxidizable organic matter that can be utilized by aerobic bacteria in terms of how much oxygen they will require to metabolize this material during a specified time, generally five days, and at a specific temperature, generally 20°C. Chemical oxygen demand (COD) is another measure of organic and other oxygen demanding material based on a chemical rather than on a biological oxidation. The COD exceeds the BOD of the wastes because the aerobic bacteria do not completely utilize the more resistant constituents under the conditions of the BOD test. Both COD and BOD values are commonly utilized in assessing the importance of a water pollution source and estimating its impact on the receiving water quality.

In addition to oxygen depletion and resulting changes in aquatic life, decomposing organic matter contributes to color, taste, and odor problems in public water systems utilizing surface sources. Excessive quantities of organic matter also create water quality conditions that are not conducive to recreational uses of the water.

Nitrogen and phosphous are the plant nutrients of primary concern with respect to livestock wastes. These elements contribute to the accelerated growth of aquatic plants in an impounded water body. In addition, toxicity caused by increased nitrate concentration is important in the ground water supplies of rural areas.

Livestock wastes are also sources of infectious agents that may infect other animals and in some instances, man. Among the potential water-born diseases transmissable from animals are anthrax, brucellosis, coccidiosis, encephalitis, erysipelas, foot rot, histoplasmosis, hog cholera, infectious bronchitis, mastitis, New Castle disease, ornithosis, gastroenteritis, and salmonellosis (Wadleigh, 1968). Although contractions of water-born diseases are relatively rare in our country, increasing emphasis on water based recreation creates new opportunities for this mode of infection. Leptospirosis has been spread from cattle to swimmers by the water-born route (Diesch and McCulloch, 1966).

Although animal waste may contribute to water quality deterioration in the various methods mentioned above, the escape of these pollutants can be controlled. Pollution is more a result of the livestock production technique and the animal waste management practice being utilized than of the numbers of livestock being produced. Any attempt to estimate the impact of animal production on water quality, therefore, must consider the management techniques in use as well as the location and number of animals involved.

For animals grazing a vegetative land area (range or pasture), little effect has been shown with respect to water pollution. Manure is randomly distributed in a light application, liquids are absorbed by the soil, and the vegetative cover utilizes the added nutrients and inhibits erosion. Low intensity rainfalls are usually absorbed by the soil and high intensity rainfalls in excess of soil infiltration rates provide sufficient dilution to minimize the concentration of potential pollutants in the runoff. In range and pasture systems, extensive waste treatment takes place as runoff carried pollutants pass over the soil surface and are alternately delayed and freed by the action of the vegetative cover. The vegetative cover provides effective screening as well as settling for the particulate matter. Mixing and aeration stimulate biological breakdown of soluble organic matter.

Unlike the pasture systems, animals produced in feedlots, pens, and other uncovered enclosures in densities that prevent vegetative cover present pollution hazards. During and immediately after rain and spring thaws, water may flow over the manure covered feeding areas, carrying both particulate and soluble manure components with it. This pollution source has received considerable public interest and must be considered in assessing the impact of livestock production on a surface water impoundment.

Roofed livestock confinement units offer advantages to the intensive producer because of the ease with which the distribution of feed and water, and the collection of manure can be mechanized. Roofed confinement also offers the possibility of environmental control and elimination of the open-lot runoff problem; but they offer alternate potentials for water pollution if the wastes do not receive proper management and control. With proper waste collection, transport, and application to crop land, the manure from confinement livestock feeding operations need not cause water pollution.

Animal waste characteristics. Considerable data exist concerning manure produced by the various species of livestock. These data represent manure characteristics as produced by the animal, not contribution to stream pollution. Tables 4-4-1 through 4-4-4 summarize these data. Similar data reported on a per animal basis are given in Table 4-4-5. These data

Table 4-4-1. Quantities of manure produced daily by 1000 lb. live-weight of various livestock species (Miner 1971).

Specie	Weight lb./day	Volume gal.	Moisture content percent
Cattle	88	12	90
Swine	50	7	85
Sheep	37	5	75
Poultry	59	8	70

Table 4-4-2. Quantities of organic matter and solids (lb./day) produced by 1000 lb. live-weight of various livestock species (Miner 1971).

Specie	COD	BOD	Total solids	Volatile solids
Cattle	10.5	1.7	9	7.2
Swine	6.2	2.1	7.2	5.9
Sheep		0.7	8.4	6.9
Poultry	16	4.4	17.4	12.9

Table 4-4-3. Quantities of plant nutrients produced daily (lb./day) by 1000 lb. live-weight of various livestock species (Miner 1971).

Specie	N	P_2O_5	K
Cattle	.36	0.10	0.15
Swine	.40	0.18	0.10
Poultry	2.0	0.8	0.36

Table 4-4-4. Numbers of fecal coliform bacteria produced daily by various livestock species (Gieldrich 1966).

Specie	Number of fecal coliforms per day
Hog	8.9×10^9
Cow	5.4×10^9
Chicken	0.24×10^9

Table 4-4-5. Production quantities and characteristics of livestock manures, pounds per day per animal (Environmental Protection Agency 1971).

Animal	Total Manure	BOD	SS[1]	Nitrogen	P_2O_5	Sodium
Dairy cow	90	1.45	1.95	0.33	0.13	0.03
Beef Steer	50	1.65	2.05	0.16	0.10	0.01
Feeder pig	10	0.38	0.34	0.06	0.04	0.006
Sow	14	0.41	0.18	0.062	0.042	0.008
Sheep (lamb)	8	0.22	0.11	0.03	0.02	0.001
Sheep (ewe)	12	0.32	0.21	0.05	0.03	0.002
Horses	55	1.40	1.90	0.26	0.09	0.01
Chicken (broilers)	0.09	0.009	0.08	0.0033	0.0002	0.0001
Chicken (layers)[2]	0.31	0.025	0.013	0.004	0.0028	0.00025
Turkeys (broilers)	0.16	0.013	0.011	0.0015	0.0008	0.00018

[1] Suspended Solids.

[2] Similar values useful for heavy turkeys.

are sufficient to demonstrate the importance of animal waste management that prevents water pollution but are inadequate for predicting the actual impact of livestock production operations on a specific watercourse.

To judge the importance of livestock production to environmental pollution, specific types of operations that can contribute pollutants must be examined. Among those of interest in Iowa are pasture rearing, feedlots, and roofed confinement areas.

Application to cropland. The numbers of total coliforms and fecal coliform bacteria present in runoff from pastured and non-pastured watersheds in northern New England was reported in a study by Kunkle (1970). Total coliform counts were 50 or more times the usual non-storm values below both pastured watersheds and hay fields. The percent of total coliforms that were fecal types, however, was much higher in the runoff from the pastured area (usually over 15%) than in the hay field runoff (usually under 5%). In the runoff below the pastured watershed, fecal coliform concentrations ranged from 230 to 14,000 per 100 milliliter following storms. For the same storms total coliform concentrations ranged from 2,600 to 80,000.

A series of grass plots to which manure was applied at various rates was used by McCasky et al. (1971) to study the characteristics of runoff. Manure was applied by the use of sprinkler irrigation equipment, tank wagons, and conventional manure spreader type devices. Their results indicated that the application of manure sufficiently stimulated the grass growth that the quantity of runoff from those plots was significantly reduced. When adjusted to the same runoff volume, no significant additional BOD, nitrogen, or phosphorus escaped from these plots when compared to the control plot receiving no manure.

The quantity and quality of runoff from six feedlots in eastern South Dakota was studied for a two-year period by Madden and Dornbush (1971). They concluded that one half of the total annual runoff may be attributed to rainfall events which do not produce runoff from the general area surrounding the feedlots, thus, diversion of foreign water and minimum detention facilities would greatly reduce the pollutants escaping from these operations. The further concluded that typically 95 percent of the total waste produced by the animals was either being removed by the cleaning operations or waste decomposing on the feedlot surface. Potentially, five percent of the total waste generated might leave the feedlot in surface runoff. Standard pollution control measures such as minimum detention facilities, diverting of foreign drainage and reduction of runoff velocities would further reduce the pollution potential to less than two percent of the total animal waste produced.

A study of barn lots in Ohio by Edwards, et al. (1971) again demonstrated the runoff from animal feeding areas to be concentrated sources of BOD, nitrogen, and phosphorus. However, their research indicated that when these wastes were allowed to flow a distance of 500 feet through a grassed waterway considerable reduction in pollution was achieved; i.e., a 8.3 fold reduction in nitrogen concentrations and a 27.9 times reduction in the phosphorus content. Further, the average total solids content at the waterway outlet was only 0.02 percent while the heaviest concentration of solids in the barnlot runoff was 2.7 percent. BOD averaged 121 mg/l at the barnlot while at the waterway outlet the average 4.0. Deposition of the highly enriched, organic and mineral solids in the waterway and dilution of the barnlot runoff by water of lower nutrient concentration from the surrounding areas were considered to be the major mechanisms by which the runoff quality was improved in passing through the waterway.

Research conducted at a major Kansas cattle feedlot in which manure was being applied in large quantities to crop land showed that irrigation tailwater was not of severely bad quality (Manges, et al., 1971). COD concentrations ranged from 10 to 50 mg/l while nitrogen levels were about 15 mg/l. These values compare to concentrations of 700 mg/l of COD applied and nitrogen contents up 150 mg/l. Thus again, even under unusually severe application conditions they demonstrated that high degrees of pollutant recovery was taking place.

Samples were collected below a number of sites in North Carolina in which manures were being applied to crop land (Robbins et al., 1971). The results indicate that land spreading can effectively control stream pollution. The average BOD entering streams below the sites was less than 2% of the BOD applied to the crop land. Where wastes were applied at high rates on bare soil and in defined drainage paths some excessive escape of pollutants was noted but in this latter case less than 10% of the potential pollution of the animal waste escaped to the stream. In the sites where manure was applied at conventional rates and by avoiding the obvious pollution causing operations the BOD ranged from five to less than ten mg/l in the runoff water.

Where animals are produced in pasture type operations in which they are confined at such a low density that a vegetative cover is maintained on the soil surface the ultimate in waste recycling is practiced. The nutrients in animal manure are used by the cover crop and the organic matter is biologically decomposed at the soil surface. As indicated previously by McCoy (1969) the survival time of coliform and related enteric microorganisms is very short under these conditions. The one practice related to pasture operations which can cause significant quantities of animal waste to enter the streams is allowing the animals access to the stream. Under these conditions the manure deposited by the animals in the stream area is transported from the site. Thus, one of the practices to maintain water quality is to fence animals from flowing streams.

Where animals are maintained in feedlots at such densities as to remove all vegetative cover, definite pollution potential exists due to rainfall and snowmelt runoff. Such hazards have been widely recognized and pollution control measures widely adopted throughout the Midwest. The most common method of pollution control is to minimize the amount of feedlot runoff, then collect the runoff in a retention basin and apply it to crop land as is done with manure from confinement operations. By so doing, the escape of manure to a watercourse can be almost entirely eliminated or restricted to less than one percent of that produced by the animals.

Confinement systems. The confinement production of livestock has many advantages to the producer as well as to those persons interested in preventing stream pollution, although it may create other problems, e.g., odor. Confinement allows the maximum degree of control over animal waste and protects the stream from runoff due to unanticipated storm flow. Considerable research has been done on various treatment schemes for waste from confinement livestock production facilities. Treatment schemes investigated include lagoons, oxidation ditches, aerated lagoons, and trickling filters. In every case it has been evident that these treatment facilities are not adequate to produce a water which is acceptable for discharge into receiving streams of the size found in the Skunk River Basin. Thus, the most usable scheme is one which does not rely upon discharge into a receiving stream but accomodates land application for the final disposal technique. All of the above mentioned waste treatment schemes are then usable with the system containing sufficient storage capacity to allow application of treated manures to crop land during such times as it can be accommodated without causing runoff hazards. Research has demonstrated that animal manures should not be applied to frozen and snow covered crop land, thus animal waste management schemes must contain sufficient storage capacity to allow retention of wastes during that period of the year.

Impact of the reservoir on livestock production. Just as the presence of livestock production within the drainage basin may be expected to have an effect on the quality of water impounded, so too will the presence of the reservoir affect livestock production in the area. Because of the impoundment, livestock producers in the drainage basin will be required to practice a higher degree of pollution control to prevent long term degradation of water quality.

The other consequences of reservoir development related to livestock production is the increased number of people who will be drawn into the area. Many of these persons may be unfamiliar with the activities associated with livestock production and judge odors, noises, and the general aesthetics offensive to their motive of recreation and escape from their normal activities. Previous experience indicates that when large numbers of people are drawn into a previously agricultural area, conflicts are likely which place limitations on the previously accepted practices. Thus zoning, particularly if residential developments are attracted, will become a consideration of prime importance to equitably protect the livestock producers and prospective inhabitants of any land development.

Related pollutants. Although water pollution is of major concern relative to livestock production in the drainage basin of a surface impoundment, other aspects must be considered. In those areas which will be utilized for commercial and recreational pursuits, odor control will be of importance. Odor control is best achieved by maintaining separation between sites of concentrated business and recreational activity, and intensive livestock operations such as feedlots and other confinement facilities. Proper selection of manure management systems can also be helpful in minimizing odor generation. Dust, noise and flies are other potential byproducts of livestock enterprises which should be given appropriate consideration particularly in the immediate vicinity of the reservoir.

Summary. Animal manures as excreted by cattle, swine, and poultry contain high concentrations of organic matter, plant nutrients, and potentially infectious microorganisms. Thus, in order to avoid degradation of water quality, manure management systems which prevent a direct entry of this material into lakes, reservoirs, and streams are essential.

Application to crop land is the one proven method of manure disposal which can reduce to less than one percent the portion of excreted pollutants escaping to the environment. Satisfactory systems for applying manure to crop land can incorporate solid manure spreaders, manure tank wagons, irrigation equipment, or a variety of other devices when used in accordance with good practice.

Various techniques for the treatment of animal wastes have evolved. They are often helpful to the livestock producers by increasing his flexibility as to when manure must be spread. Additionally, they may be helpful in minimizing odors reducing the solids content of manure or in allowing the use of a more highly mechanized disposal system. Among the treatment devices in common use are oxidation ditches, anaerobic lagoons, and aerated lagoons. The effluent from none of these devices, however, is sufficiently free of pollutants to be acceptable for discharge to a surface watercourse.

Livestock Production in the Ames Reservoir Basin

Introduction

Livestock production in those portions of Story and Hamilton Counties included in the Ames Reservoir Drainage Basin may be generally described as nonintensive. With a few exceptions, livestock and poultry are maintained in conjunction with other farming operations.

The major portion of livestock and poultry production within the watershed is in the fertile upland areas. For this reason, many facilities are located where slope is very mild and, in some instances, almost nonexistent. In addition, distances from production facilities to streams are often quite large. These two factors tend to minimize the pollution potential of many livestock operations in the watershed.

In general, livestock density throughout the watershed is relatively low, with the exception of a few large operations. Turkey production is high in some areas of the watershed, but the turkeys are not normally placed on range until after snowmelt runoff and the majority of spring rains have occurred.

The large cattle operations within the watershed are primarily open feedlots. Only two of these were observed to be located on sloping ground near streams. These two apparently fall under Iowa feedlot registration laws and have runoff control facilities installed. Due to their location, the remaining large operations pose little or no pollution hazard.

In general, the physical characteristics of the watershed and current livestock production practices cause pollution potential due to livestock to be minimal. The use of adequate waste management methods, however, must be continued to prevent significant water pollution of animal waste origin.

Table 4-4-6 summarizes the livestock population of the basin. Combining the data of Tables 4-4-5 and 4-4-6, the daily manure and constituent productions can be estimated (Table 7).

The totals calculated in Table 4-4-7 again demonstrate the large quantities of manure produced in a rural area which must be effectively managed to prevent water quality degradation. The large number of producers and the relative small herd sizes make this type of management possible.

Table 4-4-6. Inventory of livestock and poultry in those portions of Story and Hamilton counties included in the Ames Reservoir Drainage Basin.

Item	Story County	Hamilton County	Total
Dairy cows	225[1]	440	665
Beef cows	480	1,930	2,410
Fed beef cattle	4,420[2]	18,952	23,372
Hogs	19,470	80,868	100,338
Sheep	506	791	1,297
Laying hens	29,040	21,608	50,648
Turkeys	34,830	564,215	599,045

Notes:

[1] Large portion of these is maintained in one enterprise, near Story City.

[2] Includes four feedlots of over 100 head capacity.

Table 4-4-7. Estimated daily manure, BOD, nitrogen and P_2O_5 production by livestock in the Ames Reservoir Drainage Basin.

	Production (lb./day)			
Item	Manure	BOD	Nitrogen	P_2O_5
Dairy cows	49,500	800	180	72
Beef cows	120,000	4,000	385	241
Fed beef cattle	1,160,000	38,600	3,740	2,337
Hogs	1,000,000	38,000	6,000	4,000
Sheep	10,400	290	65	39
Laying hens	15,700	1,270	202	142
Turkeys	96,000	7,800	895	480
Total	2,451,600	90,760	10,967	7,311

Sampling Program to Confirm Potential Animal Waste

Contribution to water quality degradation. A limited sampling program was initiated during the spring of 1972 to confirm the predicted impact of livestock production on water quality in the Ames Reservoir Drainage Basin. This program was designed to gather data during the critical spring thaw and runoff period though, of necessity, limited in both duration and scope. Previous experience has indicated spring to be the time of greatest likelihood of detecting animal manure escape.

Sampling sites were selected to reflect the influence of specific livestock practices which might be important in altering water quality.

Sampling Sites 1 and 2 were selected to show the effect of a small feedlot. Located on Keigley Creek in Section 32 of Ellsworth Twp., Site 1 was just upstream of a feedlot with about 75 cattle and some hogs, so that its lower corner was 20 feet from the creek. Site 2 was far enough downstream of the feedlot to permit adequate mixing of the lot runoff with stream flow.

Site 3 is a roadside ditch along the north side of Sec. 17. Drainage into this ditch is from agricultural land with no livestock production.

Sites 4 and 5 are in Sec. 16 of Lafayette Twp., Story Co. along Keigley Creek above and below pasture land which is stocked with beef cow herds. These sites were selected to indicate the influence of stocked pasture land.

Site 6 is approximately 1.5 miles downstream on Keigley Creek from Site 5. In the drainage area between sites 5 and 6 is a sizeable livestock operation including hogs, fed cattle, and turkeys. Sampling was done only during snowmelt as no runoff was occurring at other sampling times.

Sites 7 and 8 were on the north and south limits respectively of Sec. 15, Lafayette Twp., Story County along the East Branch of Keigley Creek. A feedlot of 200 head of 1000 lb. steers (as of March 1972) is in this reach. The steers were removed from the lot between March 10 and 15. Lot drainage enters the road ditch that discharges into a drainage ditch. Site 7 is about 1 mile upstream and Site 8 just below the junction of the road and drainage ditches.

Sites 9 and 10 were above and below, respectively, a pasture used for turkey range during 1971. This enterprise is along the north side of Sec. 36, Ellsworth Twp., Hamilton County. Only one runoff event was sampled after turkeys were placed on pasture in late spring, 1972.

General procedures. Sampling sites were established early in the spring and sampling began as snowmelt runoff occurred. These first snowmelt runoff samples are probably the only ones taken when actual runoff from feedlot surfaces was occurring. Later samples in April and May were taken during relatively low flow periods to characterize dry weather periods. The last three samplings were made immediately after rainfall events in an attempt to obtain rainfall runoff effects. While it was hoped sampling could be done during actual runoff, storm and runoff duration were so short that, in each case, runoff had essentially stopped prior to sampling.

Summary of sampling and analysis data. BOD values were too low to reliably measure for all but the second and third samplings. Kjeldahl N values also were so low in the latter samplings to make accurate determinations difficult and cast some doubt on the reliability of the recorded values. In general, no concentrations of nutrients or oxygen-demanding materials were found to be particularly high.

During snowmelt runoff, COD values at the downstream station of pairs were consistently higher than the upstream station values. This is probably the single most important observation to be made and supports a conclusion that livestock operations do contribute to water pollution under these conditions. Nutrient concentrations also support this, but are not as consistent.

Concentrations during dry weather, low flow periods serve as good indications of base flow quality with negligible livestock effects. Stream quality is obviously at its best under these conditions.

Stream quality again deteriorates under high flow conditions caused by rainfall runoff. Differences between paired stations, however, are not obvious under these circumstances. Since runoff from the selected point sources was not occurring during sampling, the true source of the increased pollutants cannot be specified. It is safe to say that many sources are partially responsible, including livestock operations when runoff actually does occur.

Table 4-4-8. Analyses of water samples (mg/l) collected from Sites 1 and 2, above and below a 75 head cattle feedlot near Keigley Creek.

Constituent	DATE							
	3/1/72[1]	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
	Site 1, above feedlot							
COD	95	78	33	20	10	4.3	29	112.6
BOD	- - -	16	1.0	- - -	- - -	- - -	- - -	- - -
Total P	3.5	4.4	- - -	- - -	- - -	- - -	- - -	- - -
Ortho P	- - -	- - -	.77	0.43	0.40	0.31	0.34	0.64
Kjeldahl N	7.0	3.5	1.4	4.7	- - -	- - -	1.4	2.1
Ammonia N	7.2	6.9	3.5	0.77	0.75	0.48	- - -	3.5
Nitrate N	1.7	3.0	4.0	3.9	3.2	10	6.0	2.3
Volatile Solids	- - -	- - -	60	192	- - -	- - -	- - -	- - -
	Site 2, below feedlot							
COD	132	68	53	28	20	13.0	29.0	109.4
BOD	- - -	16	3.0	- - -	- - -	- - -	- - -	- - -
Total P	2.7	2.1	- - -	- - -	- - -	- - -	- - -	- - -
Ortho P	- - -	- - -	.75	0.43	0.25	0.20	0.18	0.53
Kjeldahl N	9.8	- - -	1.9	- - -	- - -	- - -	1.4	5.6
Ammonia N	7.3	7.2	4.3	0.77	0.56	0.48	- - -	3.0
Nitrate N	1.7	3.5	4.2	4.2	3.4	7	7.5	2.6
Volatile Solids	- - -	- - -	72	220	- - -	- - -	- - -	- - -

Note: [1] See Table 4-4-13 for climatic and stream conditions at the time of sampling.

Table 4-4-9. Analyses of water samples (mg/l) collected from Site 3, a roadside ditch draining agricultural land with no livestock production.

	DATES[1]							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
Constituent	Site 3, a roadside ditch							
COD	62	102	Not Flowing	Not Flowing	Not Flowing	Not Flowing	Not Flowing	Not Flowing
BOD	- - -	49						
Total P	6.3	3.8						
Ortho P	- - -	- - -						
Kjeldahl N	4.2	4.9						
Ammonia N	5.2	7.2						
Nitrate N	1.2	1.1						
Volatile Solids	- - -	- - -						

Note: [1] See Table 4-4-13 for climatic and stream conditions at the time of sampling.

Table 4-4-10. Analyses along Keigley Creek of water samples (mg/l) collected from Sites 4, 5 and 6. Site 4 upstream, Site 5 below a beef cow pasture and Site 6 below a second livestock operation.

	DATES[1]							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
Constituent	Site 4, Upstream							
COD	80	63	- - -	87	9	15.2	19.0	87.6
BOD	- - -	12	3.0	- - -	- - -	- - -	- - -	- - -
Total P	4.0	2.3	- - -	- - -	- - -	- - -	- - -	- - -
Ortho P	- - -	- - -	.88	.58	.27	0.29	0.18	0.73
Kjeldahl N	7.0	3.5	- - -	- - -	- - -	- - -	1.4	7.3
Ammonia N	7.3	6.1	4.3	1.75	.64	0.45	- - -	4.3
Nitrate N	1.9	2.0	5.0	3.4	2.8	10	6.0	2.6
Volatile Solids	- - -	- - -	104	240	- - -	- - -	- - -	- - -
	Site 5, below pasture operation							
COD	95	73	66	33	13	8.7	29.0	125.0
BOD	- - -	16	3.0	- - -	- - -	- - -	- - -	- - -
Total P	13	1.9	- - -	- - -	- - -	- - -	- - -	- - -
Ortho P	- - -	- - -	.64	.66	.29	0.20	0.17	0.73
Kjeldahl N	8.4	3.5	- - -	4.7	- - -	- - -	1.4	6.2
Ammonia N	8.5	6.9	5.3	.98	.61	0.50	- - -	2.1
Nitrate N	1.8	1.9	3.7	3.6	2.1	10	6.5	3.6
Volatile Solids	- - -	- - -	160	- - -	- - -	- - -	- - -	- - -

(continued)

Table 4-4-10 (continued).

	DATES[1]							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
				Site 6, below second livestock operation				
COD	102	68	56	36				
BOD	- - -	4	1.5	- - -				
Total P	3.6	1.5	- - -	- - -				
Ortho P	- - -	- - -	.73	.50				
Kjeldahl N	7.0	3.5	- - -	4.7				
Ammonia N	7.8	6.4	4.3	.98				
Nitrate N	1.2	1.6	3.9	3.7				
Volatile Solids	- - -	- - -	192	204				

Note: [1] See Table 4-4-13 for climatic and stream conditions at the time of sampling.

Table 4-4-11. Analyses of water samples (mg/l) collected from Sites 7 and 8, above and below a 200 head cattle feedlot located on the East Branch of Keigley Creek.

	DATES[1]							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
Constituent	Site 7, upstream							
COD	70	63	30	26		6.5	10.0	28.1
BOD	---	13	3.0	---		---	---	---
Total P	3.0	2.4	---	---		---	---	---
Ortho P	---	---	1.2	0.77		0.06	0.15	0.75
Kjeldahl N	7.0	3.5	---	---		---	0.0	0.0
Ammonia N	8.9	6.1	2.5	0.86		0.35	---	2.5
Nitrate N	3.0	2.3	4.5	6.1		12	6.5	2.7
Volatile Solids	---	---	152	253		---	---	---
	Site 8, below feedlot							
COD	80	83	30	26		17.4	10.0	50.0
BOD	---	18	4.5	---		---	---	---
Total P	5.6	1.9	---	---		---	---	---
Ortho P	---	---	1.1	0.65		0.14	0.12	1.00
Kjeldahl N	25.9	4.2	1.9	4.7		---	1.4	0.0
Ammonia N	20.7	6.9	2.4	0.84		---	---	3.7
Nitrate N	2.1	3.8	4.3	7.1		11	6.5	3.0
Volatile Solids	---	---	172	244		---	---	---

Note: [1] See Table 4-4-13 for climatic and stream conditions at the time of sampling.

4-4-12. Analyses of samples (mg/l) collected from Sites 9 and 10 along the Skunk River above and below pasture land used for turkey range during the summer of 1971.

	DATES[1]							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
Constituent	Site 9, above turkey range							
COD	---	83	36	33	11	---	---	53.1
BOD	---	19	3.5	---	---	---	---	---
Total P	---	2.5	---	---	---	---	---	---
Ortho P	---	---	1.34	0.84	0.69	---	---	0.69
Kjeldahl N	---	4.2	2.8	---	---	---	---	0.0
Ammonia N	---	6.6	2.3	1.01	0.5	---	---	2.5
Nitrate N	---	2.5	5.4	4.9	4.0	---	---	2.5
Volatile Solids	---	---	188	284	---	---	---	---
	Site 10, below turkey range							
COD	---	170	43	29	13	---	---	65.6
BOD	---	33	4.0	---	---	---	---	---
Total P	---	3.8	---	---	---	---	---	---
Ortho P	---	---	1.62	0.84	0.64	---	---	0.69
Kjeldahl N	---	4.2	3.3	4.7	---	---	---	2.1
Ammonia N	---	6.6.	2.5	0.95	0.4	---	---	2.5
Nitrate N	---	2.5	4.8	7.1	5.5	---	---	3.2
Volatile Solids	---	---	188	272	---	---	---	---

Note: [1] See Table 4-4-13 for climatic and stream conditions at the time of sampling.

Table 4-4-13. Climatic and stream flow conditions at the time of sample collection.

	DATE							
	3/1/72	3/8/72	3/15/72	3/22/72	4/5/72	4/20/72	5/29/72	6/6/72
Air temp. (°C)	15	5	11	5	15	10	15	16
Water temp. (°C)	1	1	5	1-2	11			
Estimated flow, Keigley Creek, cfs	100-250	200-300	25-50	5-10	<5	10-15	20-25	50-75
Note	snowmelt	very windy snowmelt lowland flooding		very windy			fairly turbid	very turbid

Table 4-4-14. Mean discharge, cfs, of Skunk River 2-1/2 miles north of Ames, Iowa.

Water Year	MONTH											
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1970 - 1971	173	206	101	36.4	410	576	144	122	84.7	133	7.77	2.85
1969 - 1970	36.6	72.1	29.7	12.8	50.9	147	118	158	94.9	26.2	65.5	32.4
1968 - 1969	83.9	60.7	43.1	29.0	28.1	767	363	315	711	1430	224	59.3
1967 - 1968	4.55	5.62	5.18	2.60	4.13	20.6	48.5	30.6	349	143	27.6	15.3
1966 - 1967	1.64	3.11	2.19	3.14	3.79	20.1	11.2	6.64	850	74.2	25.6	3.38
1965 - 1966	246	120	221	130	131	171	158	322	402	53.0	14.6	2.92

Interpretation of samplings. The samples collected in this program tended to verify previous experience with animal wastes and the conclusions reached in the literature. Under most conditions of drainage and stream flow, the influence of animal production was not detected in samples collected. Immediately below the cattle feedlot, increased organic matter concentrations were measured under runoff conditions as existed on March 1. Under the still higher flows as existed on March 8, little or no influence was detected. When samples were collected under moderate to low flow conditions after March 15, the livestock production sites were not showing a measurable impact on stream quality.

Conclusions and Recommendations

Livestock production is currently of major importance in the Ames Reservoir Drainage Basin. There are a large number of relatively small enterprises, a small number of large turkey producers and one large dairy. No cattle feedlots or swine operations with more than 1000 head currently exist. Over two million pounds of manure are produced daily. Based on BOD, if all of this manure were discharged directly into streams in the area, it would be equivalent to the discharge of untreated sewage from a human population of approximately 500,000 people. Most of the manure is applied to crop land for its fertilizer value, however, using conventional hauling equipment for housed animals and by natural distribution for the pastured livestock.

Field observations and the sampling program indicate that under current conditions, adequate pollution control is being exercised to protect water quality. The construction of a reservoir as currently proposed would place additional waste management demands on present and potential future livestock producers. The exact cost of the required pollution control facilities are difficult to predict but represent a cost associated with the development. Typically, costs for providing runoff control from cattle feedlots has ranged from $1.00 to $10.00 per head of lot capacity. Lower costs are generally associated with larger lots and with those located with some previous thought to the addition of runoff control facilities. For lots located immediately adjacent to streams or which pose other critical difficulties, relocation may be the most feasible solution. Manure management associated with confinement livestock facilities also represent a cost of production. The increased cost associated with a higher water quality demand is not readily measured but may be expected to be in the range of 0.5 to 1.0 cent per pound of livestock or poultry produced or 0.1 to 0.2 cents per pound of milk sold. Pollution control associated with pasture operations is most often related to being unable to graze areas adjacent to streams and reservoirs, thus, again adding cost and inhibiting further development.

An additional impact of reservoir development in areas of livestock production may be anticipated under the category of aesthetic concerns. On the basis of appearance, some recreational interests will object to the presence of livestock even if this is insufficient justification to restrict livestock production. A more common complaint will be about dust and odors. Increased numbers of people and especially recreational development increase the frequency of odor complaints. The most effective technique for minimizing odor complaints is separation. This again limits both present livestock producers and the economic potential of the area in terms of animal production. Zoning should be a prime consideration in reservoir development plans.

Guidelines of good practice. Livestock wastes can be managed so that stream pollution is minimized and the standard indicators of water quality abuse are avoided. The following guidelines are being currently proposed to producers as aids in managing manures to avoid water and air quality degradation.

1. Provisions should be included in every livestock production scheme to prevent the direct discharge of manure to streams and reservoirs.

2. For confinement livestock production units, application to crop land is the only practical means of disposal in current use which can prevent the escape of pollutants. Waste treatment systems are useful to mechanize manure handling but none of the systems currently in use produce an effluent suitable for stream discharge.

3. Where animals are confined at a density sufficient to preclude a vegetative ground cover, i.e., feedlots, some means of runoff collection and land application is necessary.

4. Feedlot boundaries should be located away from streams a distance of at least two feet per head of cattle, one foot per head of swine, and 0.1 foot per head of poultry.

5. Animals raised in pasture are not generally considered to present a significant pollution hazard. Animals should not be allowed to graze the area within 100 feet of the reservoir flood water line.

6. In those areas where animals are pastured in fields through which streams flow, the animals should be fenced out of the water if their number is sufficient to disturb the stream banks or to prevent growth in the area.

7. When applying manure to crop land, the following guidelines should be considered to avoid water pollution:

   a. Manure should not be applied to frozen, snow covered or water saturated soils.

   b. Manure should not be applied to land within 100 feet of a stream.

   c. Manure should be spread uniformly and at a rate not to exceed the nutrient utilization of the crop.

   d. Immediate incorporation into the plant root zone of the soil is advisable whenever manure is applied to barren land or when odor control is important.

8. Distance is the best protection against odor complaints. Known odor sources are best located remotely from housing, commercial and recreational areas.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIPS WITH THE AGRICULTURAL SECTOR

Chapter 5

RESERVOIR SEDIMENTATION

by

Barry Nudd and C. E. Beer

1973

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FIGURES

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Chapter 5

RESERVOIR SEDIMENTATION

Barry Nudd and C. E. Beer

Sediment Yield Estimate Using Regional Data

An estimate of the long-term average sediment yield of the Ames reservoir watershed and identification of areas of high sediment contribution were needed to meet the objectives set forth in the category of physical relationships in the agricultural sector.

The sediment yield was estimated by using sediment yield data from comparable watersheds located in central and north-central Iowa. To compare sediment yields, watersheds need to be located in areas of similar physical characteristics that affect erosion rates. In the Upper Mississippi River Comprehensive Basin Study, Appendix G Fluvial Sediment, the entire basin is divided into land resource areas. These areas have been defined on the basis of similarities in geology as well as agricultural production with emphasis on combinations or intensities of problems in soil and water conservation. The resource areas are characterized by particular combinations or patterns of soils, slopes, erosion potentials, climate, land use and kinds of farming.

The Ames reservoir watershed is located in land resource area 103, which includes the central Iowa and Minnesota till prairies. Most of the area is level to gently rolling. A high percentage of the land is in farms with about 3/4 of the farm land in cropland.

Nudd is a research assistant and Beer a professor of agricultural engineering at Iowa State University.

The Upper Skunk River Watershed is very flat with poor natural drainage. Therefore most of the cropland is tile drained, a major portion of the water being removed from the land by tile. Sheet erosion on the relatively flat land occurs but with poor surface drainage little of the eroded material is transported into the stream system.

Four watersheds in central Iowa, for which sediment yield data were available, were used to estimate sediment yields. The four watersheds were the Des Moines River gaged at Boone, the Iowa River gaged at Marshalltown, the Skunk River gaged below Ames and Four Mile Creek gaged near Traer. Figure 4-5-1 shows the relative locations and sizes of the watersheds. The Skunk, Des Moines, and most of the Iowa River watersheds are in land resources area 103. A small portion of the lower Iowa River and the entire Four Mile Creek watershed are in land resource area 108. Area 108 is a dissected loess-mantled glacial plain with rolling to hilly relief with less flat uplands as compared to area 103. Sediment yields are generally higher in area 108 than in area 103. The watershed of the Skunk River gaged below Ames includes all the Ames reservoir watershed plus the Squaw Creek watershed of 242 sq. mi.

Records from the Skunk River consisted of daily concentrations (parts per million) of sediment that were combined with mean daily flow data to compute a sediment load in tons. The period of record for each watershed is summarized as follows:

Watershed	Water Years	Years Record
Des Moines	1940-67	28 yr.
Iowa	1945-67	23 yr.
Skunk	1968-71	4 yr.
Traer	1970-71	2 yr.

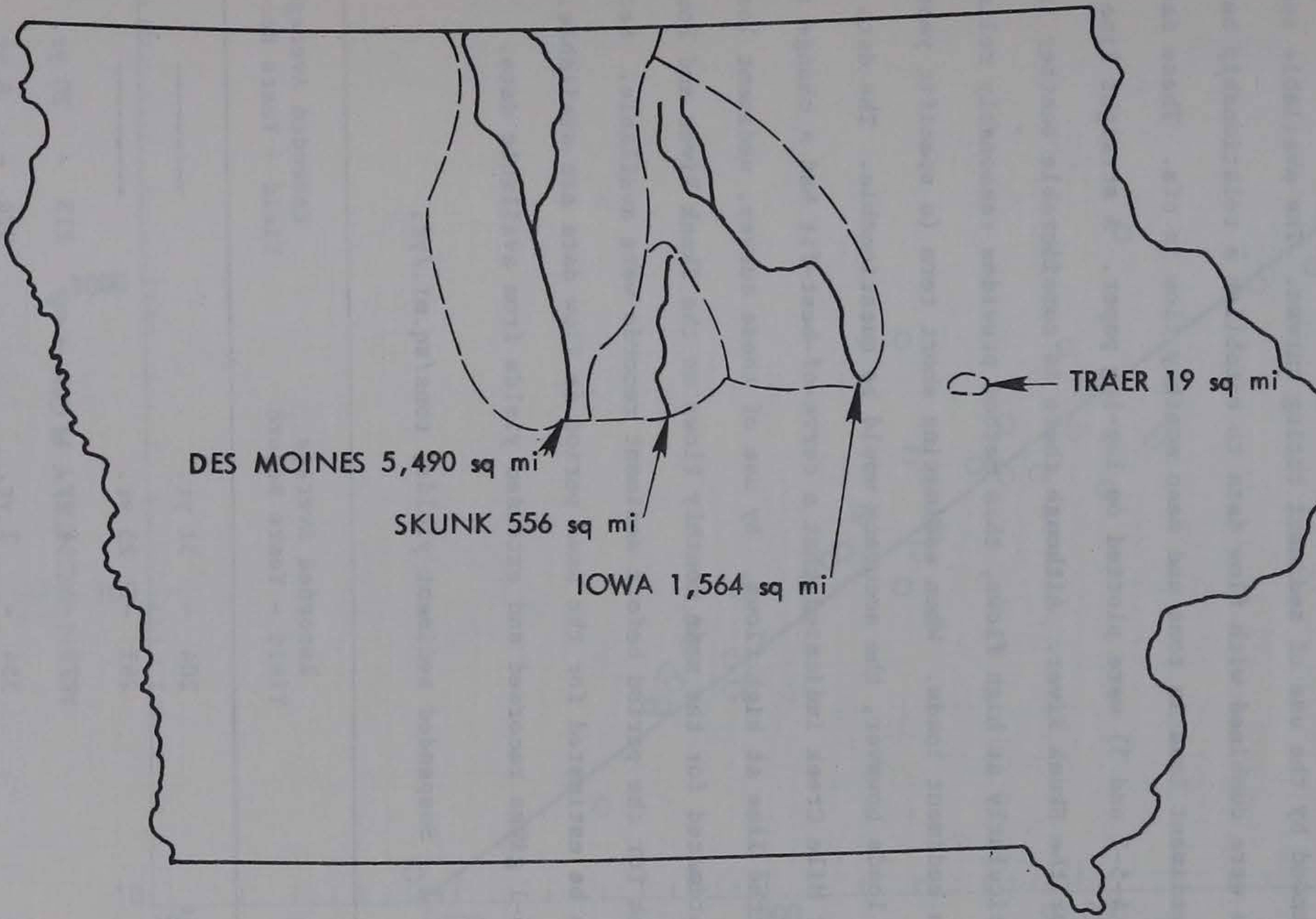

Fig. 4-5-1. Locations and sizes of watersheds.

Sediment yields of streams vary greatly from year to year due to the large variation in the number, intensity and types of storms that occur in a watershed each year. To obtain the best long-term average sediment yields, the short-term records for the Skunk River and Four Mile Creek were extended by the use of sediment rating curves. The available sediment data were combined with flow data to establish a relationship between monthly sediment load in tons and mean monthly flow in cfs. These data (Figures 4-5-2 and 3) were plotted on log-log paper. A straight line was fitted for the Skunk River. Although there is considerable scatter in the data particularly at high flows, this method provides reasonably reliable long-term sediment loads. When estimating short term (a specific year) sediment loads however, the accuracy would be questionable. The data from Four Mile Creek indicated that a curve-of-best-fit had a change in slope of the line at high flows. By use of these curves, sediment loads can be estimated for the mean monthly flows on the Skunk River and Four Mile Creek for the period before sediment records were available. Sediment loads can be estimated for the same period as flow data are available. Table 4-5-1 gives recorded and extended yields from available data.

Table 4-5-1. Suspended sediment yields, tons/sq.mi./yr.

Watershed	Recorded Average Yield - Years Record	Extended Average Yield - Years Record
Des Moines	204 - 31 yr.	---------
Iowa	291 - 23 yr.	---------
Skunk	273 - 4 yr.	213 - 20 yr.
Four Mile	354 - 2 yr.	324 - 8 yr.

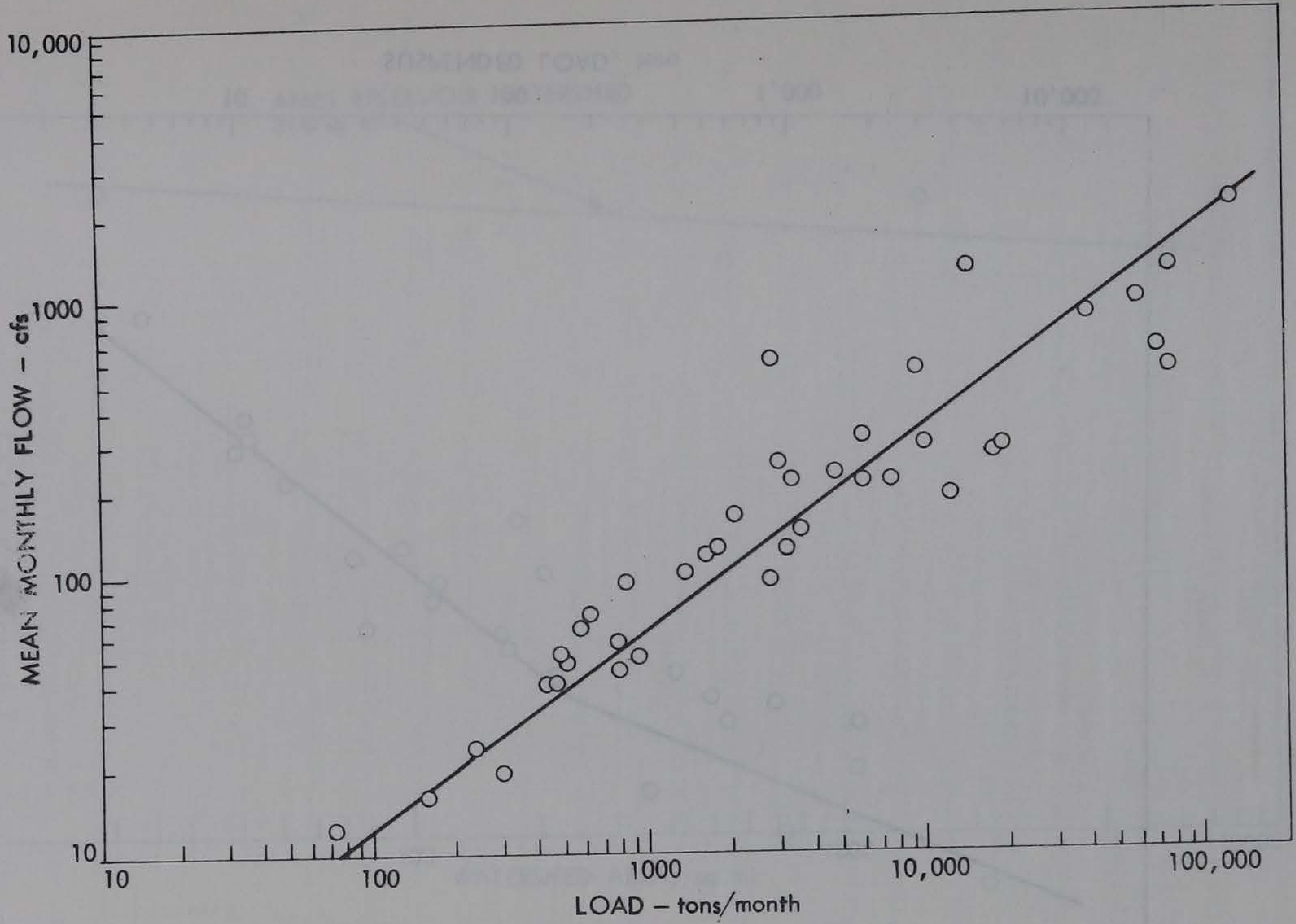

Fig. 4-5-2. Sediment rating curve, Skunk River below Ames.

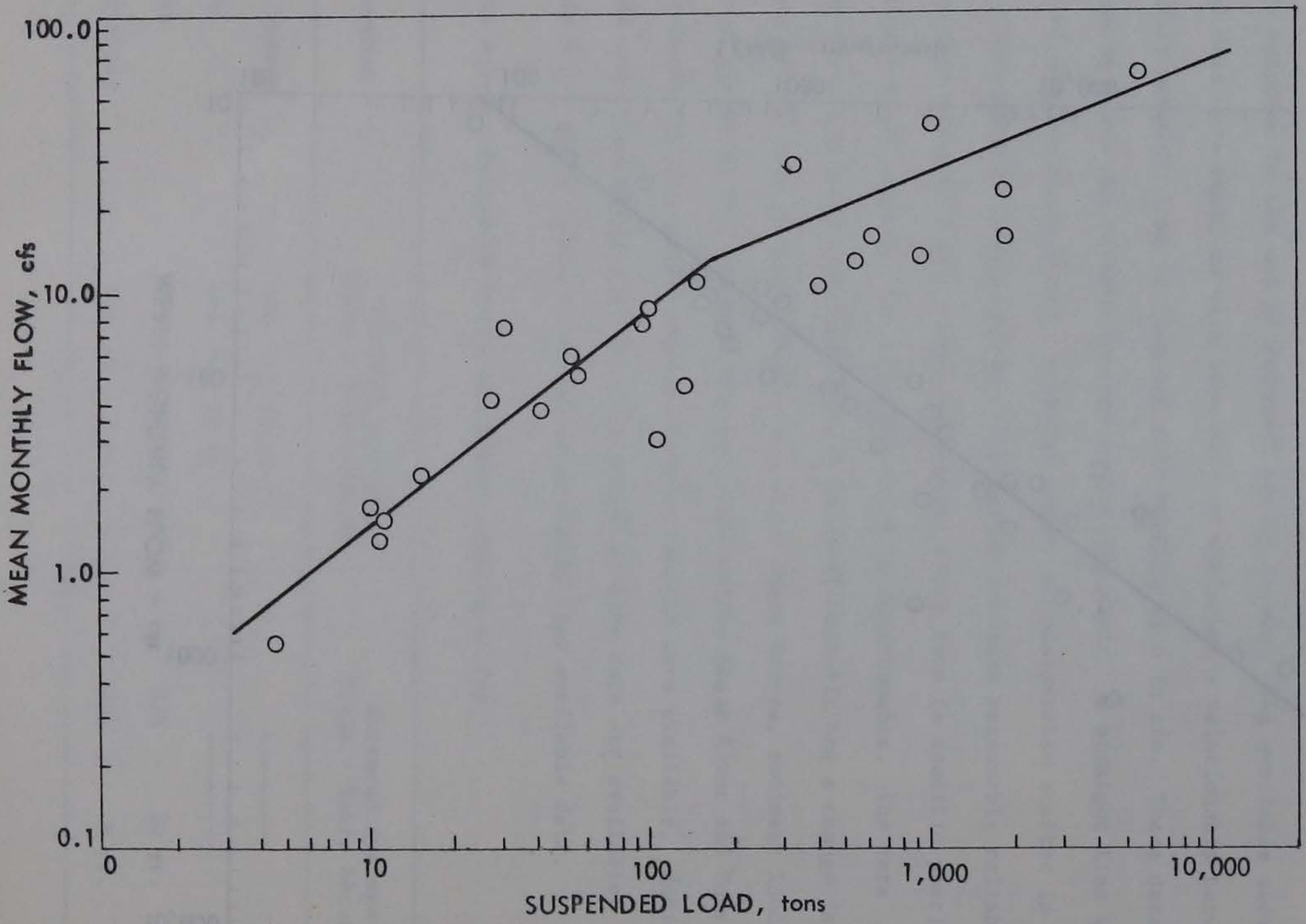

Fig. 4-5-3. Sediment rating curve, Fourmile Creek near Traer.

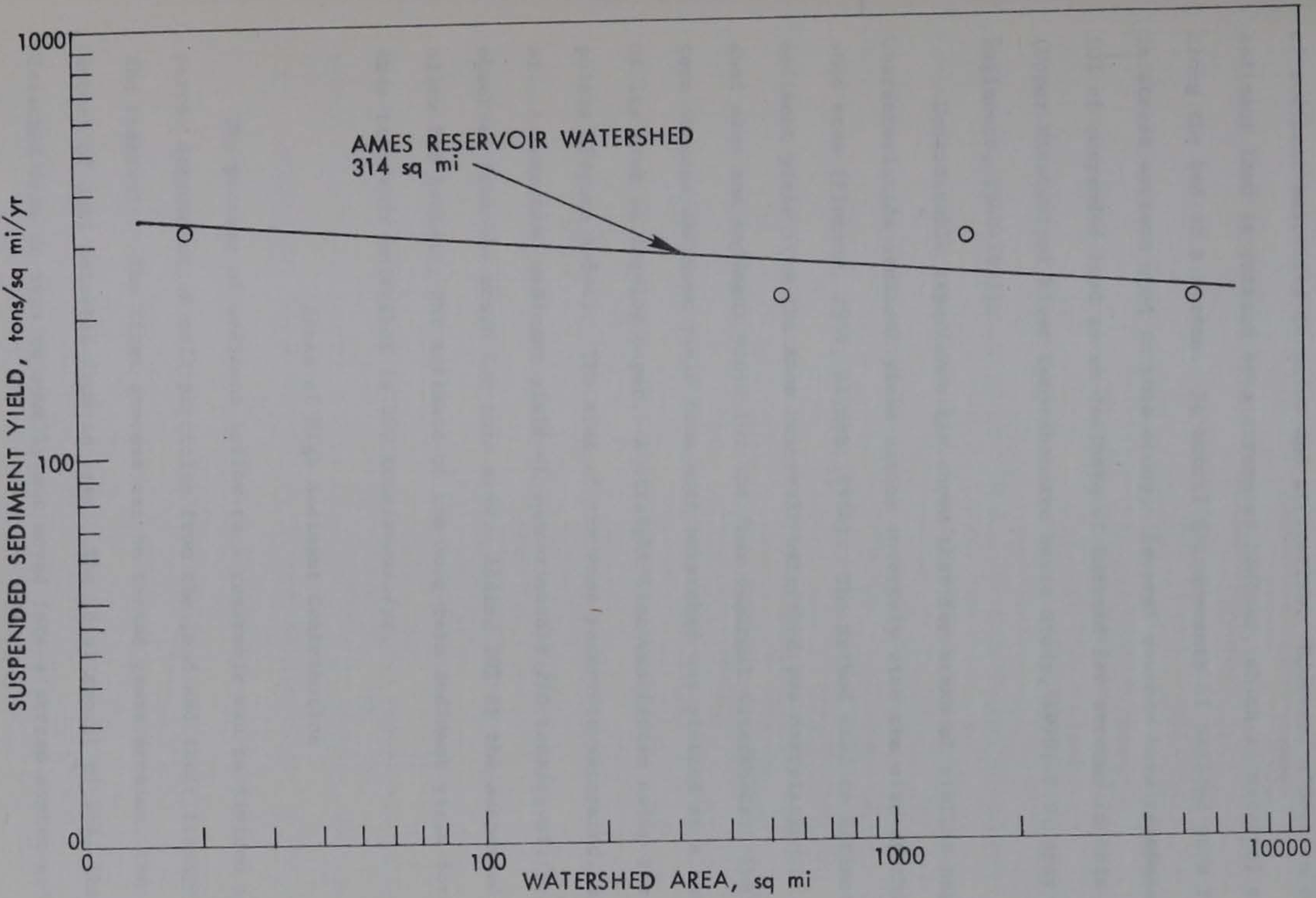

Fig. 4-5-4. Area correlation curve.

Sediment yield data are derived from measurements of the concentration of sediment suspended in water and streamflow. However, a portion of the sediment load is carried by a stream as bedload, which is material moved along the bed of a stream. No actual measurements of bedload were recorded in stream systems used in this study. Several sources have recommended using 10% of suspended load as an estimate of bedload for streams in this area (Upper Mississippi River Comprehensive Basin Study, 1970; U.S. Army Corps of Engineers, 1940-1971).

Considerable experience has shown that for areas of similar physical characteristics sediment yield varies inversely with the size of the watershed area (Fleming, 1969; Glymph, 1954). The method used to estimate the sediment yield from the Ames reservoir watershed was correlation of watershed area and sediment yield for the four regional watersheds. The long-term average sediment yield from each watershed was plotted as a function of its area on log-log paper. A straight line was fitted using the 4 known points (Figure 4-5-4). The area of the Ames reservoir watershed is 314 sq. mi. A suspended sediment yield of approximately 270 tons/sq.mi./yr. is observed from the graph for this area. Adding 10% of the suspended load to allow for bedload, the estimate of the long-term sediment yield for the Ames reservoir watershed is 300 tons/sq.mi./yr.

Areas of High Sediment Contribution

The process of sediment inflow to a reservoir can be divided into two parts: detachment of soil particles from the land and their transport into the reservoir. The first process can be termed gross erosion, the total amount of soil detached from an area. The total amount of soil that is detached from an area is usually not moved into a stream system and out of the watershed. The ability to move all the detached soil out of the watershed is a measure of the efficiency of the transport system. The efficiency of a sediment transport system in a given area is termed the delivery ratio of the area: the ratio of the amount of soil moved out of the watershed to the total amount of soil detached within the watershed.

Most of the Ames lake watershed is flat or gently rolling. Research has shown that the delivery ratio for terraced land with surface tile inlets is about 0.05 (Laflen, et al., 1972). Most of the soil loss from the terraced land is removed through the surface outlets (a direct connection between depressions in which water collects above terraces and the tile lines). Observations indicate that not all depressions in the watershed are drained by surface inlets. It is reasonable to expect the delivery ratio of the flat portion of the Ames watershed to be less than 0.05.

Sheet erosion does not account for the total sediment yield of the watershed. Some sediment is supplied by channel or bank erosion. The portion of the total load derived from channel erosion is impossible to estimate without some measurements of channel sections made at regular intervals. The intensity of the meanders in the Skunk River and some of its tributaries make it likely that channel erosion is a relatively significant contributor to the total sediment load. In areas where livestock is grazed near the streams, cattle and hogs tend to loosen the soil on stream banks making it easily eroded when stream flow is high. The additional sediment contributed by the actions of livestock is impossible to predict.

By dividing the watershed into areas of similar gross erosion rates and delivery ratios it is possible to estimate the percentage that each area contributes to the total sediment load. This approach makes no attempt to relate a specific sediment yield to a specific area of the watershed, but serves to demonstrate how sediment yields vary between areas. The assumptions made in dividing the watershed into different areas involve an attempt to average the extremely large variation in factors that affect sediment production in a watershed of this size. These assumed conditions are used in the universal soil loss equation (Wischmeier and Smith, 1965) to arrive at a ratio of sediment production rates between the areas.

The 314 sq. mi. Ames lake watershed may be divided into two major areas: the flat lands and the sloping stream valley areas. The valley area may be further subdivided into the steep sloping valley sides and the much flatter land characteristic of a flood plain. Measurements from a 25 foot contour interval topographic map indicate the total length of well defined valley in the watershed is 114 mi. Assuming that the valleys average 1/2 mi. in width the valley area encompasses 57 sq. mi. The valleys can further be divided into 10 sq. mi. of steep sloping area (averaging about 20% slope) leaving 47 sq. mi. of flatter (around 5% slope) valley floor area. Two independent estimates, one based on a delivery ratio and the erosion equation, and the other based on sediment yields from flatland watersheds indicate that more than 75% of the sediment contributed to the Skunk River above Ames is derived from the valley area.

Assumptions Used In Calculations

I. Valley areas 57 sq. mi.

  A. 10 sq. mi. steep sloped area

    average slope 20%

    no row cropping, some pasture in poor condition

    C = .10 (cropping management factor)

    LS = 6 (slope length factor)

    D.R. = .50 (delivery ratio)

B. 47 sq. mi. flat valley area

average slope 5%

50% land in row crop C = .40

50% land non row crop C = .04

LS = 1

D.R. = .50

II. Remainder of watershed 257 sq. mi.

average slope 2%

70% row crop C = .40

30% non row crop C = .04

LS = 0.5

D.R. = .03

III. RKP in soil loss equation is constant throughout the watershed, RKP = G (a constant). The assumptions are used to calculate the soil loss rates for each area in terms of G, the constant.

A_v = Soil loss rate in the valley area

$A_v = RKPCLS$

$G = RKP$

$A_v = G\,(CLS)$

The soil loss rate is equal to G times each set of CLS values representing the different conditions in the 57 sq. mi. valley area. The CLS values are weighted according to the percentage of land they occupy in the valley area.

$$A_v = G[\Sigma LS(C)\ \%\ \text{of area}]$$

$$A_v = G[6(.10)\,\frac{10}{57} + 1(.40)\,\frac{23.5}{57} + 1(.04)\,\frac{23.5}{57}] = 0.288G$$

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*Rainfall, erodibility and erosion control practice factors.

Soil loss rate in the remainder of the watershed, A_w:

$$A_w = G[.5(.40).70 + .5(.04).30] = 0.146G$$

Equating the G's,

$$A_v = 1.97\ A_w$$

The average gross erosion rate in the valley area is nearly twice as great as the rate over the remainder of the watershed. Quanities of sediment can be calculated by multiplying the rates by the areas and delivery ratios of each area.

Load from the valleys, $L_v = A_v(.50)\ 57 = 28.5\ A_v$

Load from rest of watershed, $L_w = A_w(.03)\ 257 = 7.71\ A_w$

Substituting $A_v = 1.97\ A_w$

$$L_v = 7.3\ L_w$$

The valley area accounts for 88% of the total load ($L_v + L_w$). The universal soil loss equation estimates soil loss from sheet erosion only. Bank or channel erosion by definition occurs in the valley area.

Another watershed in resource area 103 for which sediment data is available is the East Fork of Hardin Creek near Churdan, Iowa. The Upper Mississippi River Comprehensive Basin Study lists an adjusted sediment yield of 65 tons/sq.mi./yr. for this watershed using data gathered by the U.S.G.S. The 24 sq. mi. watershed is relatively flat and is characterized by numerous shallow depressional storage areas. The watershed is extensively drained by subsurface tile which outlet into an open drainage ditch. This area is very similar to the flat uplands in the Skunk

River watershed. Assuming that the 65 tons/sq.mi./yr. yield is produced by the upland area of the Ames watershed, another estimate of the yield of the valley area can be made.

Ames Reservoir Watershed

Upland area 257 sq. mi. assuming average yield of upland area is 65 tons/sq.mi./yr.

Yearly load from upland area

257 sq. mi. x 65 tons/sq.mi. = 16,800 tons

Total average load from watershed

314 sq. mi. x 300 tons/sq.mi. = 94,200 tons

Yearly load from valley area

94,200 tons - 16,800 tons = 77,400 tons

% of yearly load from the valley area

$$\frac{77,400}{94,200} = 82\%$$

The two approaches used to identify the area of high sediment production are in reasonable agreement. Realizing the limitations imposed by the simplified assumptions, it can be concluded that about 3/4 of the total sediment load from the watershed comes from the immediate stream valley area.

Any effort to reduce sediment production in the watershed would best be applied in the immediate valley areas. Some of the valley area will be inundated and cease to be a source of sediment. Any soil conservation practices applied to the valley area would help reduce the sediment load to the reservoir.

Measured Sediment Load

A sediment gaging station was established on a county bridge (mile 231.5) approximately 1.5 miles upstream from the dam site to verify the estimated sediment production. The station consisted of a U.S. D-43 depth integrating sediment sampler and a wire gage for determining river stages. Sediment samples were obtained every other day for a period of six months beginning March 1 and ending September 1, 1972. During storm flows, 3 samples were taken on a rising river stage, 2 or 3 samples on the recession and then daily sampling for several days on the recession of the storm flows. The U.S.G.S. at Iowa City determined the sediment concentration. The mean daily flow rate of the river was measured at the U.S.G.S. gage north of Ames (designated - South Skunk River near Ames, Iowa). The minor difference in the flow at the flow gaging station and the sediment station was neglected because the contributing watershed area between the two stations was small (U.S. Geological Survey, 1962-1971).

During periods of rapidly changing flow, the sediment concentration also changes rapidly. During such periods samples were obtained at least daily. When more than one sample was taken in any one day the average concentration was used. For base flow periods sediment concentration changes slowly and samples were taken every other day. The concentration on the day not sampled was taken as the average of the previous and following days.

Measured Sediment Loads

Month 1972	Load Tons	Tons/Sq.Mi. (314 sq. mi.)
March	6,136	19.5
April	85	0.3
May	5,672	18.0
June	19,421	61.8
July	2,580	8.2
August	24,550	78.2
	Total	186.0

Sediment yields are quite variable from year to year. Short term records probably are not indicative of the long term production of sediment in a watershed. In order to use short term sediment yield data from the sampling station, the sediment discharges were correlated with river flow for which there are long term records. This approach relates sediment yield to only one of many contributing factors and thus a close relation between the two may not be expected. The relation between sediment load and flow is illustrated in the plot of data points on the rating curve, Figure 4-5-5. U.S.G.S. records of bi-hourly gage height readings at the Skunk River near the Ames station were used to estimate the instantaneous flow rate at the time of sampling. If the flow rate and the sediment concentration are known, a rate of sediment flow can be calculated. By using the appropriate conversion factors, the sediment flow rate or sediment production rate was obtained with units of tons per day. The stream flow rates and their corresponding sediment load production rates were plotted on the sediment rating curve. Data points are identified as to the period of their measurement to illustrate possible seasonal changes in the relation. The high flows occurring in March are a result of snow melting and not rainfall. Sediment loads for snowmelt are significantly lower than average loads for high flows from rainfall events. When drawing the sediment rating curve, the higher loads at high flows were given more weight so the curve would predict, on the average, conservative values. A conservative sediment yield estimate (over estimation of long term yield) seemed preferable to an underestimate.

The long term flow history of the Skunk River is summarized in a flow-duration curve (Figure 4-5-6), a plot of flow vs. the percentage of time the flow is equalled or exceeded. It is assumed that the flow pattern in the past will continue in the future. Computation of the long term sediment

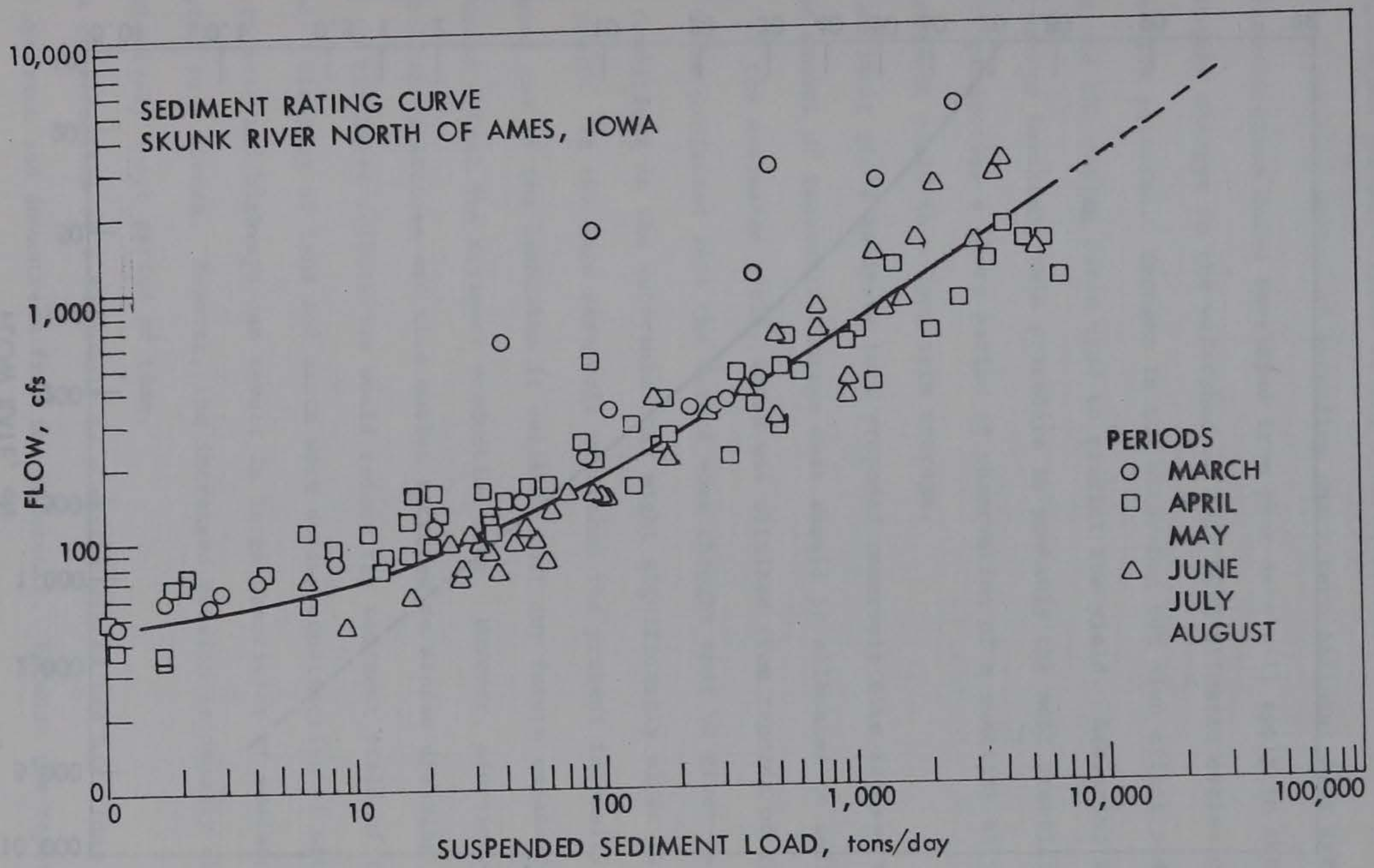

Fig. 4-5-5. Sediment rating curve, Skunk River north of Ames.

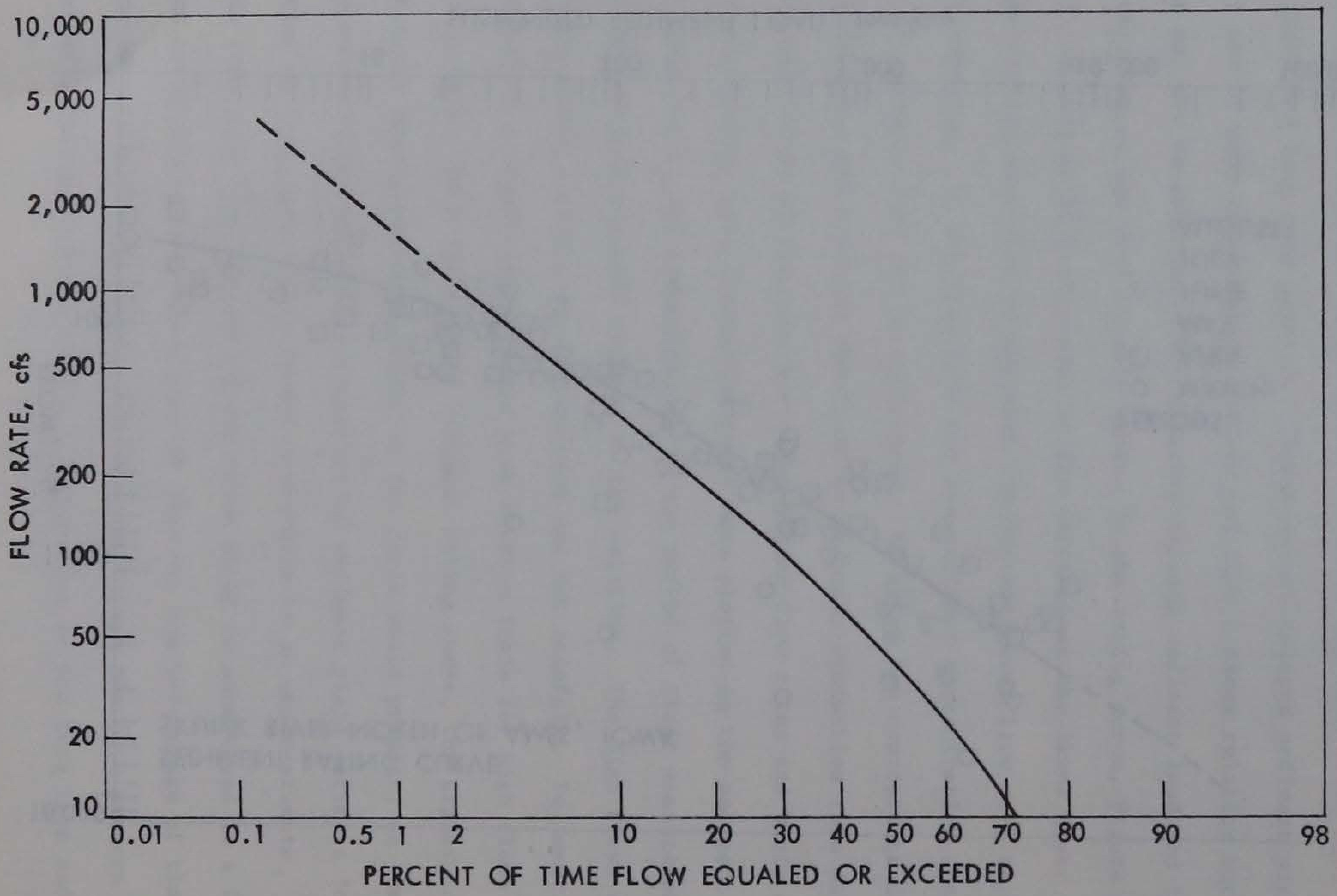

Fig. 4-5-6. Flow duration curve, Skunk River near Ames.

yield using sediment rating and flow-duration curves is illustrated in the table of calculations, Table 4-5-2. The best estimate of the sediment yield using the measured sediment loads is 270 tons/sq.mi./yr.

The flow-duration method of extending short term sediment data assumes that the flow-duration curve developed from past data will apply in the future. Future changes in the watershed or long term climatic cycles can change the flow patterns. Changes in the watershed can also effect sediment production and the rating curve used to predict the yield. Realizing the potential errors involved, this procedure is probably the most practical approach to projecting a short period of observation of a quantity as variable as sediment yield to a long term average.

The sediment yield estimate to a proposed reservoir site is used to calculate the amount of reservoir storage that should be allocated to sediment storage. If the estimated yield, which was obtained from records of the past, is to be projected into the future some thought must be given to changing conditions in the watershed that might significantly alter future sediment yield. In the Ames reservoir watershed the present intensity of agricultural use of the landmakes it unlikely that any future expansion of tillage would affect the sediment production rate. However, adoption of minimum tillage practices and tile outlet terraces on slopes draining directly to the River tributaries would reduce the sediment yield of the watershed. Clearing of land and earth work during construction of urbanization projects and highways can result in large quantities of sediment being contributed to a stream. However, the increased erosion is usually observed for a relatively short period of time.

The construction of a reservoir in a stream system can have long term effects upstream and downstream from the reservoir. Because the reservoir

Table 4-5-2. Computation of long term average sediment discharge -Skunk River, from Jordan, et al. (1964).

Percentage of Time	Water Discharge Equaled or Exceeded[1] CFS	Suspended Sediment Discharge[2] TONS/DAY	Interval Between Suceeding Percentage of Time	Ave. Suspended Sediment Discharge for Time Interval TONS/DAY	Sediment Discharge Multiplied by Time Interval
0	8630[3]	42,000			
			0.1	31,000	3100
0.1	4800	20,000			
			0.1	16,250	1625
0.2	3500	12,500			
			0.1	11,250	1125
0.3	2900	10,000			
			0.2	8,100	1620
0.5	2200	6,200			
			0.5	4,850	2425
1.0	1500	3,500			
			1.0	2,700	2700
2	1000	1,900			
			1.0	1,550	1550
3	760	1,200			
			2.0	975	1,950
5	540	750			
			2	625	1,250
7	430	500			
			3	395	1,185
10	316	290			
			5	220	1,100
15	220	150			
			5	117.5	588
20	165	85			
			10	60	600

Table 4-5-2. Continued.

Percentage of Time	Water Discharge Equaled or Exceeded[1] CFS	Suspended Sediment Discharge[2] TONS/DAY	Interval Between Suceeding Percentage of Time	Ave. Suspended Sediment Discharge for Time Interval TONS/DAY	Sediment Discharge Multiplied by Time Interval
30	105	34	10	22	220
40	68	10	10		0
50	43	--	50		
100	---	---			
		Total	100%		21,038

Average Suspended Sediment Discharge

TONS/DAY - 210.4
TONS/SQ.MI./YR. - 245

Total Load (Suspended load + 10% Bedload)[4] -- 270 Tons/Sq.Mi./Yr.

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[1] From Flow-Duration Curve

[2] From Sediment Rating Curve

[3] Maximum Daily Discharge for Period of Record

[4] Corps of Engineers' estimate of bedload

traps most of the sediment delivered to it, the water downstream from the reservoir carries a reduced sediment load. The river bed downstream may scour, change its slope and pick up sediment to approach the water-sediment equilibrium that was disturbed by construction of the reservoir. While it is difficult to predict the amount, some degradation downstream from a reservoir is common. A reservoir changes somewhat the slope of a river upstream from the reservoir because of backwater effects. This change in slope causes aggradation or deposition of sediment in the river channel upstream from the reservoir. Quantitative evaluation of scour and deposition is difficult.

Trap Efficiency

It is also estimated that the proposed reservoir will trap most if not all of the sediment delivered to it. The trap efficiency of a reservoir is largely dependent on the capacity-inflow ratio (Upper Mississippi River Comprehensive Basin Study, 1970). This is the ratio of the volume of the reservoir (in acre-feet) to the average annual water yield (acre-feet per year). At ratios of 0.3 and above, studies have shown that over 90 percent of the sediment will be retained in the reservoir, for normal ponded reservoirs such as that envisioned with the proposed conservation pool of the Ames Reservoir. As a reservoir fills with sediment, its capacity-inflow ratio decreases as does its trap efficiency. As its capacity is reduced to zero, its trap efficiency also reduces to a negligible amount. Data available for the United States are listed in Table 4-5-3.

Because of the proposed long duration of temporary storage in the flood pool of the Ames Reservoir, and associated low release rates, it

Table 4-5-3. Trap efficiency of ponded reservoirs in the United States, for suspended sediment loads[1].

Capacity-inflow ratio Acre-feet of volume per acre-feet annual inflow	Trap efficiency, percent	
	Range	Average value
0.001	0	0
0.01	30-58	45
0.10	78-94	86
0.30	90-98	95
1.0	94-99	97
10.0	96-100	98

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[1] Upper Mississippi River Comprehensive Basin Study (1970).

also would act much as a ponded reservoir. With an annual inflow of about 80,000 acre-feet per year from the Skunk River, a total conservation and sediment pool volume of 35,000 acre-feet and a flood pool with an additional volume of 93,000 acre-feet (no subimpoundments), the capacity-inflow ratio varies from about 0.5 to more than 1.6. Therefore, from 90 to 95 percent trap efficiency is estimated, based on reservoir sedimentation studies reported in the literature. For the purposes of the Ames Reservoir environmental review study, and in consideration of the short-term nature of the sediment yield data for the Skunk River it is assumed that all of the sediment will be trapped. For the density of sediment estimated for the project by the Corps of Engineers, the annual volume of storage lost to sediment is considerably less than 100 acre-feet per year. As a result, even after a 100-yr period, the minimum capacity-inflow ratio would remain above 0.3, and high trap efficiencies would still be experienced. Therefore, the initial estimate of reservoir sedimentation using complete trap efficiency is reasonable and also is conservative.

Summary

An estimate of the sediment yield of the Ames reservoir watershed was made using regional sediment data. Four watersheds in northern Iowa with similar physical characteristics and available sediment data were used. Sediment yield was related to each watershed's drainage area, all other factors affecting sediment yield were assumed to be constant among the watersheds. Area correlation yields an estimate of the long term sediment production rate of 300 tons/sq.mi./yr.

Suspended sediment samples from the Skunk River near the dam site were taken for a period of six months (March 1, to September 1, 1972). Daily sediment loads were correlated with the flow rate of the river. The long term flow characteristics of the stream were combined with the load-flow correlation to calculate a long term sediment load. Bed load of the river was assumed to be 10% of the suspended load. The actual sediment measurement near the dam site yields an estimate of sediment production rate of 270 tons/sq.mi./yr. The estimate of 300 tons/sq.mi./yr. is probably the most realistic design value for the long term yield of the Ames reservoir watershed.

Sediment production potential of different areas within the watershed were estimated. The watershed was divided into the flat to gently rolling uplands and sloping valley areas. The universal soil loss equation and data from a small watershed compariable to the upland area of the Ames watershed were used to determine that at least 3/4 of the total sediment load is produced by the valley area, a small percentage of the total watershed area.

The estimate of sediment yield of the Corps of Engineers and these independent estimates agree closely. Sedimentation of the proposed Ames Reservoir is a minimal problem. The bedload and coarse suspended sediment will deposit in the headwaters of the reservoir, forming a delta region. The suspended sediment will be distributed above and below the elevation of the conservation pool (950 feet), most of it probably coming to rest in the conservation pool and into the "gross sediment storage pool", that volume below elevation 833 feet.

On the basis of the computations made and review of trap efficiencies and volumetric displacement by sediment, the sedimentation estimates and life of the reservoir will be much as proposed and estimated in the formulation of the project. The estimated loss of storage of 8,400 acre-feet of storage in 100 years is 24 percent of the 35,000 acre-feet in the combined sediment and conservation pool, and 6.6 percent of the 128,000 acre-feet of total storage available at elevation 976. Other extrapolations can be made, but all indicate that many centuries would pass before the reservoir capacity would be seriously depleted.

Conservation practices applied to the sloping areas of the valley which are currently in row crops would also decrease the sediment inflow and increase the reservoir life. It was roughly estimated for the purposes of the study that diligent application of such practices in the reservoir area, and immediately upstream of the reservoir, would have the potential of reducing by one-half the estimated sediment load to the reservoir, and therefore doubling the time for deposition in any volumetric part of the reservoir.

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APPENDIX

Table 1

Sediment Data - Skunk River North of Ames, Iowa.

March 1972

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
1	136	1620	594
2	[130]	611	214
3	[120]	215	70
4	[100]	173	67
5	[80]	95	20
6	[180]	436	212
7	223	4080	2452
8	62-184*	2870	944
9	22	1960	116
10	[24]	1410	91
11	25	1010	68
12	[71]	460	88
13	117	339	107
14	[290]	299	234
15	338	362	300
16	[280]	299	226
17	157	236	100
18	[150]	196	79
19	127	167	57
20	[100]	125	34
21	72	110	21
22	[62]	92	15
23	38	75	8
24	[36]	64	6
25	17	59	3
26	[17]	53	2
27	17	57	3
28	[19]	66	3
29	22	69	4
30	[16]	65	3
31	11	61	2
		Total Load - March	6,136 Tons

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*Multiple Readings

[ ] - Concentrations in brackets are estimates for days when no sample was taken.

Mean daily flows are preliminary data from the U.S.G.S. at Fort Dodge, Iowa.

Table 1. Continued.

April 1972

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
1	[10]	54	1.4
2	8	49	1.0
3	[9]	47	1.1
4	9	44	1.1
5	[6]	44	0.7
6	4	46	0.5
7	[8]	46	1.0
8	11	38	1.1
9	[14]	36	1.4
10	18	36	1.7
11	11	34	1.0
12	19	33	1.7
13	[18]	33	1.6
14	17	33	1.5
15	[19]	31	1.6
16	44	64	7.6
17	[42]	109	12.3
18	41	99	10.9
19	[31]	82	6.8
20	22	70	4.2
21	[16]	72	3.1
22	11	73	2.2
23	[11]	71	2.1
24	11	62	1.8
25	[8]	55	1.2
26	6	50	0.8
27	[9]	47	1.1
28	12	61	1.9
29	[17]	83	3.8
30	23	107	6.6
		Total Load - April	85 Tons

May 1972

1	[37]	118	11.8
2	51	157	21.6
3	[60]	156	25.2
4	42	136	15.4
5	67	120	21.7
6	[100]	205	55.2
7	1235-875	774	2190.2
8	594	558	893.3
9	370	395	393.9

Table 1. Continued.

May 1972, continued.

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
10	327	301	265.3
11	268	244	176.2
12	[222]	208	124.4
13	177	190	90.6
14	[160]	178	76.7
15	144	165	64.0
16	[125]	145	48.8
17	105	130	36.8
18	[116]	118	36.9
19	128	107	36.9
20	[105]	98	27.7
21	81	93	20.3
22	[76]	88	18.0
23	71	85	16.3
24	[65]	92	16.1
25	59	83	13.2
26	[88]	82	19.4
27	117	114	35.9
28	[345]	135	125.5
29	573	217	335.1
30	[442]	259	308.5
31	311	180	150.9
		Total Load - May	5672 Tons

June 1972

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
1	210	143	80.9
2	110	121	35.8
3	112	105	31.7
4	115	94	29.1
5	2310-717	433	1765.7
6	1580-885	1530	5071.7
7	592	880	1404.0
8	413	517	575.4
9	427	463	532.8
10	447	321	386.7
11	272	250	183.3
12	700	210	397.0
13	1130	410	1248.6
14	1180-1090	930	2844.7
15	1310-500	1220	2975.5
16	330	640	574.4
17	290	443	346.2
18	194	353	184.5

Table 1. Continued

June 1972, continued.

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
19	[186]	300	150.4
20	178	272	130.5
21	[150]	250	99.0
22	[121]	197	64.2
24	117	178	56.1
25	[100]	159	42.9
26	82	153	33.8
27	[75]	137	27.7
28	67	130	23.5
29	[66]	147	26.1
30	66	130	23.1
		Total Load - June	19,421 Tons

July 1972

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
1	[60]	113	18.3
2	53	113	16.1
3	[43]	99	11.5
4	33	90	8.0
5	[50]	81	10.9
6	65	75	13.1
7	[50]	76	10.2
8	35	71	6.7
9	[130]	90	31.5
10	229	145	89.5
11	[165]	104	46.2
12	99	95	25.3
13	[140]	106	40.0
14	174	97	45.5
15	[180]	164	79.6
16	187	140	70.5
17	[550]	122	180.8
18	976-848	311	813.5
19	618	277	461.3
20	337	196	178.0
21	260	149	104.4
22	[233]	117	73.5
23	207	95	53.0
24	[178]	80	38.4
25	148	69	27.5
26	147	81	32.1
27	140	79	29.8

Table 1. Continued.

July 1972, continued.

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
28	[125]	68	22.9
29	111	61	18.2
30	[95]	53	13.6
31	77	46	9.5
		Total Load - July	2579 Tons

August 1972

Day of the Month	Suspended Sediment Concentration PPM	Mean Daily Flow CFS	Load Tons
1	145	105	41.0
2	1500-776	1350	4140.3
3	469-662	1300	1981.2
4	417	613	688.9
5	370	418	416.8
6	733-693	1720	3305.0
7	517	2830	3943.1
8	548	2500	3692.2
9	345	2110	1961.8
10	355	1250	1195.9
11	339	831	759.2
12	300	591	477.8
13	[306]	448	368.2
14	312	347	291.8
15	[300]	267	215.9
16	285	210	161.3
17	[235]	185	117.2
18	186	165	82.7
19	[180]	135	65.5
20	174	117	54.9
21	[143]	109	42.0
22	112	97	29.3
23	[190]	93	47.6
24	268	85	61.4
25	[268]	113	81.6
26	268	153	110.5
27	[197]	122	64.8
28	126	104	35.3
29	[162]	90	39.3
30	198	77	41.1
31	[198]	70	37.3
		Total Load - August	24,551 Tons

Table 2.

DES MOINES RIVER AT BOONE, IOWA
SUSPENDED SEDIMENT LOADS IN TONS

DRAINAGE AREA = 5,490 SQ.M.

WATER YEAR	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
OCTOBER	256	1,405	79,093	25,797	6,063	5,604	3,609	11,390	556	392	469	6,590	14,010	690	886	92,298
NOVEMBER	275	18,590	183,579	6,182	9,390	3,855	2,430	12,299	1,854	907	513	1,372	12,803	624	735	5,048
DECEMBER	284	7,305	40,116	2,060	5,550	1,684	655	7,081	1,602	624	288	496	11,811	573	679	5,846
JANUARY	47	12,687	38,389	1,161	2,940	853	5,039	3,751	496	2,525	146	338	6,225	594	278	2,266
FEBRUARY	108	11,149	3,034	74,481	9,516	13,558	45,554	11,143	10,936	1,081	127	9,871	88,299	1,198	1,395	1,419
MARCH	2,525	48,373	210,885	595,746	42,337	304,138	374,592	64,682	390,124	489,655	56,253	219,839	207,355	72,836	12,226	30,075
APRIL	8,573	95,096	50,374	51,539	157,988	473,144	91,500	332,392	135,120	154,153	13,353	299,723	170,766	27,751	26,546	135,136
MAY	4,239	23,931	321,632	123,050	749,191	390,303	564,999	401,149	183,797	11,708	199,079	221,357	24,559	69,437	101,541	36,556
JUNE	4,988	324,098	295,282	304,939	656,645	765,227	395,184	2,190,504	24,508	20,296	296,711	355,803	67,177	225,624	4,085,914	35,879
JULY	2,396	39,486	199,620	134,249	123,096	389,608	85,562	395,904	9,944	10,259	55,717	341,980	157,483	36,584	84,642	75,660
AUGUST	71,586	3,249	128,053	97,437	18,832	691,309	8,560	3,191	1,920	2,284	7,055	101,574	7,036	52,684	67,523	673
SEPTEMBER	6,886	40,382	198,921	31,602	15,814	7,680	5,558	760	544	893	9,376	49,996	2,952	1,343	5,071	270
TOTAL	102,113	620,240	1,726,923	1,400,243	1,797,362	3,046,963	1,583,194	3,433,730	761,397	694,683	534,087	1,608,939	770,516	489,928	4,387,436	421,126

WATER YEAR	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	TOTAL	AVE.	%
OCTOBER	794	328	451	197	1,641	1,844 4,304	40,070	20,308	1,843	15,401	123,130	1,138	456,209	16,293	1.5
NOVEMBER	502	267	3,612	303	1,740	674	11,278	2,368	981	3,710	17,430	652	303,853	10,852	1.0
DECEMBER	145	201	2,459	140	5,599	685	5,039	3,059	600	4494	19,962	559	129,596	4,628	0.4
JANUARY	142	123	1,419	92	9,077	348	2,176	1,139	469	1668	8,513	420	103,321	3,690	0.3
FEBRUARY	151	258	1,117	96	2,706	2,841	3,592	1,081	612	4817	21,239	463	349,836	12,494	1.1
MARCH	2,841	2,459	1,965	26,679	49,981	514,738	174,395	54,458	940	57,138	39,202	10,590	4,007,017	143,108	12.7
APRIL	2,409	1,163	11,375	5,877	488,586	298,197	244,200	62,190	95,656	803,324	38,785	12,480	4,387,345	156,691	14.0
MAY	3,720	16,531	3,427	368,276	137,213	122,100	96,644	117,520	98,198	220,813	66,990	5,753	4,578,213	163,507	14.6
JUNE	3,405	150,080	135,359	164,491	120,984	71,008	51,211	134,886	18,823	188,111	93,388	54,748	11,648,175	416,006	37.0
JULY	1,341	77,420	134,800	38,420	32,410	17,491	479,032	119,907	6,309	14,613	11,074	26,567	3,096,099	110,575	9.8
AUGUST	1,085	2,086	1,550	3,293	2,995	34,952	26,496	29,181	90,729	2,230	2,591	10,315	1,420,464	50,731	4.5
SEPTEMBER	1,087	1,911	437	1,551	3,180	4,776	177,323	2,908	135,714	249,878	793	1,872	959,423	34,265	3.1
TOTAL	17,622	296,827	297,971	609,415	856,111	1,069,604	1,261,456	548,945	400,869	1,566,197	543,097	592,557	31,439,551	1,122,840	100.0 %

WATER YEAR	TONS/YR SUSPENDED SEDIMENT
1940	102,113
1941	620,240
1942	1,726,923
1943	1,400,243
1944	1,797,362
1945	3,046,963
1946	1,583,194
1947	3,433,730
1948	761,397
1949	694,683
1950	534,087
1951	1,608,939
1952	770,516
1953	489,928
1954	4,387,436
1955	421,126
1956	17,622
1957	296,827
1958	297,971
1959	609,415
1960	856,111
1961	1,069,604
1962	1,261,456
1963	548,945
1964	400,869
1965	1,566,197
1966	543,097
1967	592,557
TOTAL	31,439,551

AVERAGE ANNUAL LOAD = 1,122,841
ADJUSTED FOR BED LOAD = 1,247,601
TONS/SQ MI/YR = 227

CORP OF ENGINEERS DATA
ROCK ISLAND DISTRICT

NCD FORM 16

Table 3.

Iowa River at Marshalltown, Iowa
Observed Monthly Suspended Sediment Loads Expressed in Tons Drainage Area = 1,564 Mi²

Water Year	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
October	1,130	1,362	14,800	612	92	108	1,489	20,190	72	103
November	1,048	1,094	23,500	2,700	354	84	350	2,375	108	113
December	500	900	3,820	2,250	108	57	102	6,450	193	121
January	282	79,000	2,280	410	16,300	34	75	23 500	279	47
February	7,850	66,000	13,400	26,300	4,080	920	61,000	62,500	81,000	212
March	231,755	209,946	71,500	192,000	188,000	169,000	182,000	189,794	62,300	620
April	112,699	6,836	133,538	55,000	15,425	8,930	169,625	64,339	7,349	4,886
May	102,289	42,252	42,894	24,159	2,204	347,210	58,140	29,050	24,793	23,964
June	196,272	80,000	1,028,991	37,655	9,411	368,297	354,756	91,140	128,226	467,581
July	26,717	21,300	115,219	26,004	3,155	1,471	119,819	51,880	11,162	14,531
August	64,396	3,870	3,150	772	334	605	47,173	1113	12,635	90,692
September	4,058	19,000	648	215	243	23,803	11,654	293	133	4,558
Total Tons	752,991	522,560	1,453,740	368,077	239,706	920,519	997,183	542,624	328,250	606,828

Water Year	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
October	47,755	1,579	36	158	722	1,820	1,346	28,101	15,200	94
November	2,212	73	66	570	1,968	8,650	2,000	11250	246	60
December	2,200	31	52	2,220	280	7,700	750	12,000	1,160	136
January	1,480	23	170	1,580	118	16,200	300	4,120	490	152
February	10,800	19	730	7,900	85	4,000	76,000	3,520	640	465
March	19,100	2,800	734	6,030	191,000	72,500	226,000	188,000	88,000	700
April	5,045	615	345	16,076	11,928	255,000	55,634	96,912	25,769	14,373
May	3,293	9,120	68,525	1,052	6,378	135,764	3,558	54,687	47,576	52,306
June	884	415	119,966	189,948	12,373	9,842	20,820	65,500	11,453	21,119
July	15,486	750	88,811	98,827	10,451	3,161	14,448	99,597	42,039	13,534
August	172	900	1,257	30,927	993	4,092	17,436	5,101	1,221	2,529
September	54	3,262	284	2,363	2,380	12,333	4,150	64,500	550	22,200
Total Tons	108,481	19,588	280,976	357,651	238,676	531,062	422,442	633,288	234,844	132,658

NCD FORM 16

Summary

Water Year	Total Susp Sed Load Tons/Yr.	
1945	655,102	Adjusted for R.I. Sampler (x 0.87)
1946	454,627	Adjusted for R.I. Sampler (X0.87
1947	1,264,759	Adjusted for R.I. Sampler (X0. 87)
1948	335,347	Adjusted for R.I Sampler prior to 4/15/48
1949	239,706	
1950	920,519	
1951	997,183	
1952	542,624	
1953	328,250	
1954	606,828	
1955	108,481	
1956	19,588	
1957	280,976	
1958	357,651	
1959	238,676	
1960	531,062	
1961	422,442	
1962	633,288	
1963	2,34,844	
1964	132,658	
Total	9,301,606	

Monthly Avg.

%		
1.4	Oct	6,838
0.6	Nov	2,941
0.4	Dec	2,052
1.5	Jan	7,342
4.4	Feb	21,371
23.6	Mar	114,139
11.0	Apr	53,266
11.1	May	53,960
33.2	June	160,707
7.9	July	38,968
3.0	Aug	14,688
1.8	Sept	8,834
		485,292

Avg. month
38,757

Adjusted for bed load 9,301,606/0.90
Total Load = 10,338,451
Annual Load = 516,922 Tons

Tons/sq. mile/year = 330

CORP OF ENGINEERS DATA
ROCK ISLAND DISTRICT

Table 3. Continued.

IOWA RIVER AT MARSHALLTOWN, IOWA
Suspended Load in Tons
(CONTINUED)

WATER YEAR	1965	1966	1967	AVG	%
OCTOBER	165	30,871	164	7,303	1.5
NOVEMBER	84	5,270	50	2,792	0.6
DECEMBER	256	41,032	84	3583	0.8
JANUARY	184	22,909	356	7,404	1.6
FEBRUARY	23,783	15,814	519	20,327	4.3
MARCH	97,215	26,937	1,152	104,699	22.1
APRIL	177,291	10,326	993	54,519	11.5
MAY	49,692	74,385	914	52,336	11.1
JUNE	37,467	198,862	204,205	158,899	336
JULY	75,468	4,758	639	36,966	7.8
AUGUST	917	2,016	739	12,932	2.7
SEPTEMBER	74,986	234	188	10,960	2.3
TOTAL TONS	537,508	433,414	210,003	472,740	

SUMMARY

TOTAL 1965-1967 = 1,180,925
TOTAL 1945-1964 = 9,304,606
TOTAL 1945-1967 = 10,485,531

AVE. YEARLY LOAD = 455,893
ADJ. FOR BEDLOAD = 506,548
TONS/SQ. MI./YEAR = 324

Table 4

Sediment Load in Tons Skunk River Below Ames. Drainage Area - 556 Sq.Mi.

Water Year	1968	1969	1970	1971	Ave.	%
October	16	3222	588	19,019	5711	3.8
November	2	832	1812	6013	2165	1.4
December	2	633	444	2126	815	0.5
January	26	444	300	798	392	0.2
February	8	789	1376	39,974	10,537	6.9
March	161	78,392	18,064	59,958	39,144	25.8
April	4246	2848	3310	2973	3344	2.2
May	518	8646	77,099	4841	22,776	15.0
June	70,246	14,211	7872	3604	23,983	15.8
July	6072	130,187	922	12,698	37,470	24.7
August	473	10,190	6870	72	4401	2.9
September	239	1620	2764	17	1160	0.8
	81,199	252,014	124,476	152,093		

Ave. 1968-71 151,896 Tons

$$\frac{151,896}{556} = 273 \text{ Tons/Sq.Mi./Yr.}$$

Adjusted For Bedload - 304 Tons/Sq.Mi./Yr.

Table 5

Sediment Load in Tons Four Mile Creek Near Traer. Drainage Area - 19.5 Sq.Mi.

Water Year	1970	1971	Ave.	%
October	41.1	624.8	332.9	4.8
November	27.3	147.5	87.4	1.3
December	15.0	95.9	55.4	.8
January	11.0	56.8	33.9	.5
February	326.5	997.6	662.0	9.8
March	1816.1	5478.8	3647.4	50.0
April	30.0	99.1	64.5	9.4
May	1857.8	542.1	1199.9	17.4
June	53.1	401.7	227.4	3.3
July	10.0	925.4	467.7	6.8
August	109.1	10.9	60.0	0.8
September	135.2	4.7	69.9	1.0
Totals	4445.2	9345.3		

Ave. 1970-71 6895.2 Tons

$$\frac{6895.2}{19.5} = 354 \text{ Tons/Sq.Mi./Yr.}$$

Adjusted For Bedload - 394 Tons/Sq.Mi./Yr.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIP WITH THE AGRICULTURAL SECTOR

Chapter 6

THE USE OF STATISTICAL DISTRIBUTIONS FOR DETERMINING THE MAGNITUDE AND FREQUENCY OF FLOODS

by

Craig E. Beer and Ronald L. Rossmiller

1973

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FIGURES

TABLES

Chapter 6

THE USE OF STATISTICAL DISTRIBUTIONS FOR DETERMINING THE FREQUENCY AND MAGNITUDE OF FLOODS

Craig E. Beer and Ronald L. Rossmiller

Purpose

The purpose of this chapter is to discuss the following items: the use of various statistical distributions and the effect of the choice of distribution on the estimate of the magnitude of a flood for a specific recurrence interval, the problems of "outliers" and variability of the skew coefficient, the efforts of the Water Resources Council to reduce the variability of these estimates, the work being done in Iowa to conform to the uniform technique recommended by the Council, and the relationship of the above factors to the Ames Reservoir Environmental Study.

The discussion is both general and specific in nature and is oriented towards both the technical person and, hopefully, the layperson as well. Examples are used to illustrate the various points. Conclusions will be drawn only implicitly, the purpose here being to present the problems that the hydrologist faces when he attempts to quantify the magnitudes of floods for various recurrence intervals at a single point on a specific river, in this case, the Skunk River, about five river miles north of Ames, Iowa.

Introduction

People who live or work on the flood plain of a river take a very personal viewpoint towards floods. They know from experience that the elevation

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of their homes, places of business, or cropland in relation to the streambed elevation determines whether or not, or how often their property will be flooded. They tend to measure floods in terms of how high the water rises. They also understand the concept of recurrence interval in that the water will rise to a certain elevation every year, will rise to a somewhat higher elevation once every five years, only rarely has risen to a higher elevation, and has never risen to a still higher elevation.

While being well aware of the destructive power of flood waters, the hydrologist takes a more impersonal and different view towards floods. Rather than measuring the magnitude of a flood in terms of how high the water rises, he measures a flood in terms of the rate of flow in cubic feet per second, cfs. This rate of flow is then correlated with a particular recurrence interval. The hydrologist also goes one step further. He estimates the magnitude and recurrence interval of future floods greater than those which have been experienced.

In all rivers and streams, there is a definite relationship between the depth, or stage, of the water and the rate of flow or discharge. The hydrologist calls this a stage-discharge curve or stage-discharge relationship. The curve has the characteristic shape shown in Figure 4-6-1.

Assume that the bed of the river is at elevation 900 and the top of bank is at elevation 915. As the water rises between these two elevations, the water is still confined within the banks of the river giving a large increase in depth with a relatively smaller increase in discharge. As the water rises above elevation 915, the water spreads out over the floodplain where small increases in depth will give a relatively large increase in discharge. The exact shape of the curve is dependent upon the size and shape of the channel and the floodplain, the slope of the river, and the roughness of the ground cover in the channel and on the floodplain.

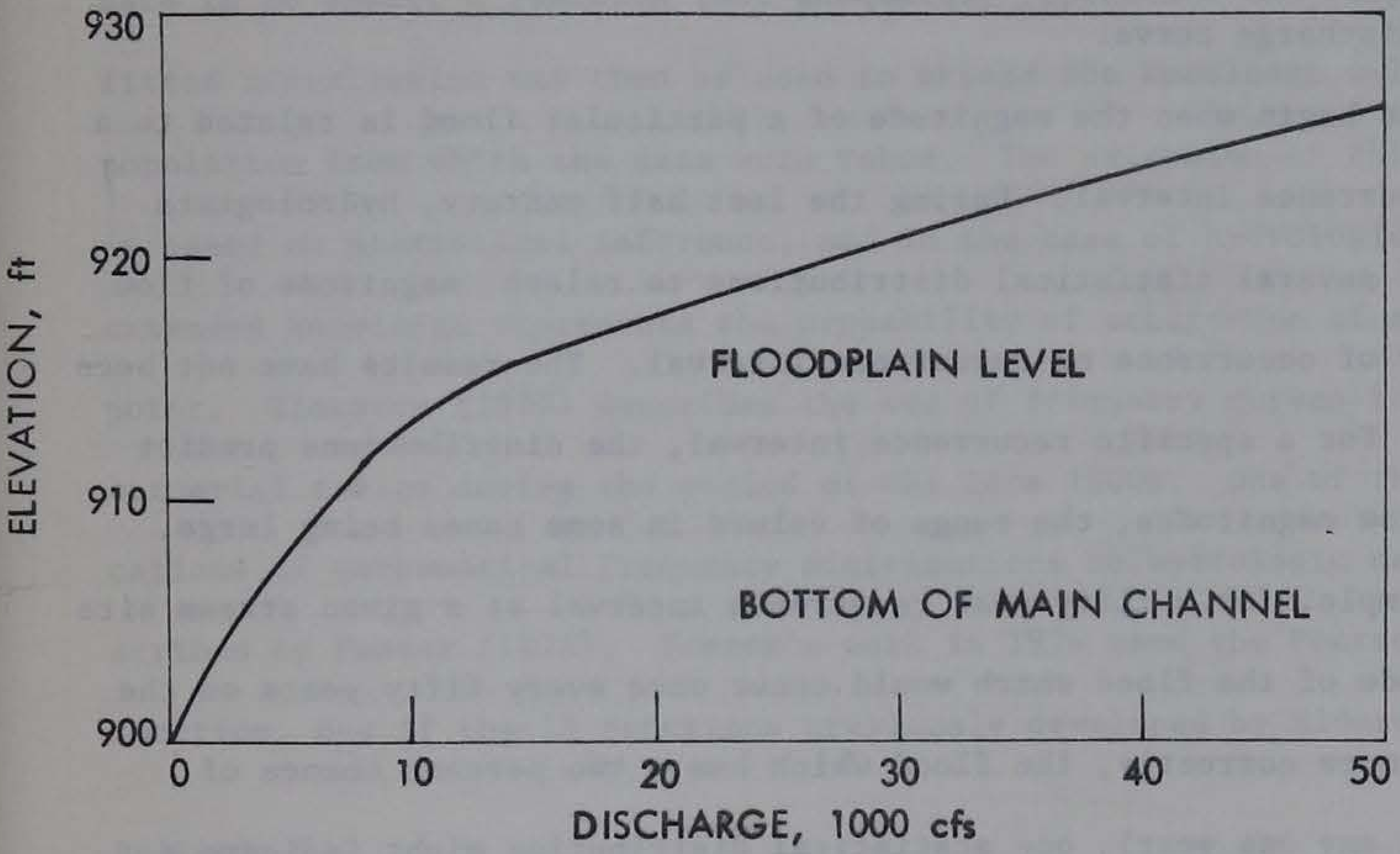

Fig. 4-6-1. Typical stage-discharge relationship.

Up to this point, there would not seem to be any problem. Floods occur and can be measured in terms of how high the water rises or in terms of the rate of flow. The height of rise can be related to the rate of flow by means of a stage-discharge curve.

Problems begin when the magnitude of a particular flood is related to a specific recurrence interval. During the last half century, hydrologists have applied several statistical distributions to relate magnitude of flow to frequency of occurrence or recurrence interval. The results have not been consistent. For a specific recurrence interval, the distributions predict different flow magnitudes, the range of values in some cases being large.

For example, for a fifty year recurrence interval at a given stream site (the magnitude of the flood which would occur once every fifty years on the average, or more correctly, the flood which has a two percent chance of occurring in any one year), one statistical distribution might indicate a rate of flow of 40,000 cfs while another might indicate 30,000 cfs. Referring to Figure 4-6-1, these two rates of flow would correspond to elevations of 924 and 921, respectively. This variation of three feet could mean the difference between having one's home, business, or crops ruined by the flood or being above the flood waters. Throughout the length of the valley, the three feet difference in elevation prediction could mean the difference between tens of thousands of dollars of damage or a relatively minor amount of damage when computed on a frequency or probability basis.

The remainder of this chapter is devoted to looking at these problems: the variations in predicted discharges which occur as a result of the choice of distribution, what has been done on the national and state levels to reduce these variations, how outliers and the skew coefficient affect this variation, and what effects these have on the Ames Reservoir Project.

Efforts on the National Level

The objective of using mathematical frequency distributions to analyze data is to select a function that adequately represents the sample data. The fitted distribution may then be used to extend the knowledge relative to the population from which the data were taken. The extension of this knowledge is based on statistical inference, and in the case of hydrologic data, the extended knowledge represents the probability of occurrence of a given data point. Elderton (1938) describes the use of frequency curves to determine actuarial tables during the period of the late 1800s. One of the first applications of mathematical frequency distributions to hydrologic data is described by Foster (1924). Foster's work in 1924 used the Pearson Type III function, one of the 12 functions previously developed by Elderton.

Bulletin 13

In recent years hydrologists and engineers have used many different frequency functions to analyze hydrologic data. These have included log normal, gamma, extreme value functions of Type I largest and Type III smallest, log Pearson Type III and Weibull. Each distribution differs in the number of parameters (scale factor, shape factor, etc.) available to describe the population. Also each distribution differs in its inherent ability to fit data and may generate anything from skewed bell-shaped curves to J-shaped curves. A discussion of current methodology of analyzing peak annual flows is given in a bulletin prepared by the Committee on Water Resources (1966). Bulletin No. 13 includes discussion on the Hazen (log-normal), Pearson Type III, Gumbel (Extreme Value), gamma, and distribution-free methods.

The Hazen method is a graphical procedure whereby peak annual flows are plotted on log normal probability paper. The plotted points are obtained by the use of the plotting position formula $P = \frac{2m-1}{2n}$ where

n = No. of events

m = rank of the event to be plotted

If a curve fitted to the plotted points (cumulative frequency curve) is not a straight line, Hazen presents a procedure for adjusting the line by considering the coefficient of skew. Although not covered in Bulletin No. 13, two additional methods of analytically generating a log normal cumulative frequency curve are given by Beard (1962) and Chow (1954). Beard's treatment of a log normal distribution states that the logarithms of peak annual flows are normally distributed and that the equation of the cumulative frequency curve is

$\text{Log } X = \overline{\text{Log } X} + kS_{\text{Log } X}$ where X is the variate, $\overline{\text{Log } X}$ is the mean of the logarithms of the sample data, k is a frequency factor whose value is a function of the probability level desired for X, and $S_{\text{Log } X}$ is the standard deviation of the logarithms of the sample data. Since k is a standardized normal variate, no skew can be considered by this method.

Chow (1954) has shown that if the sample data support the relationship, $C_s = C_v^3 + 3C_v$, where C_s is the coefficient of skew and C_v is the coefficient of variation, the data will plot as a straight line cumulative frequency curve on log normal paper. The equation of the frequency curve is $X = \overline{X} + KS$ where X is the variate, $\overline{X}$ is the mean of the sample data, S is the standard deviation of the sample data and K is a frequency factor which is a function of C_s and C_v. Thus Chow's and Hazen's methods are comparable but one is graphical and the other analytical.

Early use of the Pearson Type III distribution involved a frequency factor in an equation that produced a cumulative frequency curve. The sample data were transformed by $X/\overline{X}$, giving a mean, $\overline{X}$, of unity. The coefficients of skew and variation were also computed. A point at a given probability on the cumulative frequency curve was then computed by

$X/\overline{X} = 1 + C_v K'$ where C_v is the coefficient of variation of the transformed sample data and K' is a frequency factor developed by Foster that is a function of probability level and coefficient of skew. Current usage of the Pearson Type III requires the computation of the mean and standard deviations of the logarithms of the sample data. The equation for the cumulative frequency curve becomes

$\text{Log } X = \overline{\text{Log } X} + S_{\text{Log } X} K'$ where K' is exactly the same factor as used in the unlogged Pearson Type III method. Inspection of the two equations show that different values of the variate will be generated (given probability level) when using the two equations even though K' is common to both.

Different techniques have been presented for use of the Extreme Value Type I Largest function for constructing a cumulative frequency curve. The most direct is to use an equation of $X = \overline{X} + S K''$ where the mean and standard deviation of the sample data are used with a frequency factor K" to generate a value of X at a specified probability level. The value of K" at a given probability level is different from k, K or K' discussed previously.

The Gamma distribution is a special case of the Pearson Type III with the origin transferred from the mean to the start of the curve. Maximum likelihood can be used to evaluate the parameters of the distribution such that the density curve may be fitted to sample data. Since the methods of obtaining a cumulative frequency curve are rather involved, the application to peak annual flows is not widely used.

Study by Work Group on Flow-Frequency Methods

In order to evaluate the performance of different frequency distributions when analyzing peak annual flows, Benson (1968) presents the results of applying six methods to flow data from 10 stations. In addition, different agencies were asked to analyze the same data using the same distributions to determine any variability in the use of the same distribution. The following excerpt is taken from Benson (1968).

> The flood data for these stations were submitted to those agencies that had digital computer programs or standardized procedures for computing flood-frequency relations and that volunteered to apply the methods to the data (these were not necessarily methods used by the agencies in their operations.)
>
> The following six methods were applied to the flood series: (1) 2-parameter gamma distribution; (2) Gumbel distribution; (3) log-Gumbel distribution; (4) log-normal distribution; (5) log-Pearson Type III distribution; (6) Hazen method. These methods are not entirely different. For example, the log-normal distribution is a special case of the log-Pearson Type III distribution, for conditions where the skew coefficients of the logarithms of the flood magnitudes are zero. The 2-parameter gamma distribution is a special case of the Pearson Type III distribution (also known as the 3-parameter gamma), in which one of the three parameters has a value of zero. The Hazen method is an early version of log-normal curve-fitting in combination with empirically derived coefficients for fitting skewed distributions. The original Hazen procedures permitted arbitrary adjustments to arrive at close fit to the data.
>
> In applying the six different methods of flood-frequency analysis, five of the six were fitted by programs of more than one agency. In all, 14 sets of computations were made, one for the Hazen method, two for the 2-parameter gamma, Gumbel, and log-Gumbel distributions, three sets (by two agencies) for the log-Pearson Type III distribution, and four for the log-normal distribution. Results of the fitting for the 14 separate computations are shown in Table 2.
>
> Each of the agencies that computed one or more flood-frequency relations used exactly the same set of flood data at each station. None of the items of data was changed or deleted, nor were any gaps in data filled in. At each station, the differences in computed results are therefore due wholly to the basic methods used and to alternate procedures within the basic methods.

The results from one station are taken from Table 2 of Benson (1968) and shown in Table 4-6-1 below. It is apparent that a wide range in values of the variate for a given probability level may be generated by using the different methods. It is also interesting to note that four agencies using the Log Normal computed three widely varying values. Several reasons for the inter-agency variation are possible. An adjustment in the "expected probability" which is a function of the length of record may or may not have been made. The use of a computed skew, regional skew or assumption of no skew would affect the results for any one method.

Table 4-6-1. Results of one station, excerpted from Table 2 of Benson (1968).

Method	Comp. No.	Recurrence Interval (years)					
		2	5	10	25	50	100
		Station No. 8-1500					
2-Parameter Gamma	1	17,637	60,060	97,237	149,658	190,844	232,920
	2	28,000	62,400	95,300	148,000	189,000	231,000
Gumbel	1	27,624	82,755	119,257	165,376	199,590	233,551
	2	27,206	77,177	110,264	152,069	183,090	213,870
Log Gumbel	1	8,590	47,992	149,921	632,261	1,839,032	5,307,051
	2	8,481	40,319	113,190	417,130	1,097,800	2,868,500
Log Normal	1	11,330	50,047	108,769	248,799	424,625	686,137
	2	11,332	50,010	108,680	248,610	424,280	686,260
	3	11,300	48,500	110,000	265,000	480,000	830,000
	4	16,140	49,960	92,270	172,930	261,820	378,630
Hazen	1	16,250	55,140	97,540	174,440	252,140	349,420
Log Pearson Type III	1	12,200	50,700	103,000	226,000	327,000	485,000
	2	12,200	52,000	101,000	207,000	325,000	485,000
	3	12,200	54,000	108,000	225,000	370,000	570,000

Benson quotes:

> These within-method differences are statistical considerations in the treatment of the data. The statistical consultants assisting the Work Group were of the opinion that the state of the art of frequency analysis

> is such that a specific set of procedures cannot be selected as correct or superior within each method at the present time.
>
> As for the large differences in results by different methods, the consultants did not find these surprising in view of the wide confidence limits existing at the upper ends of the frequency relations. In effect, the widely varying results at the higher recurrence intervals are all within the range of uncertainty existing there. The consultants urged that confidence limits should always be computed for flood-frequency computations, instead of only the single-value estimates; however, methods for doing this are not yet fully developed.

Bulletin 15

The work reported by Benson (1968) served as resource material for the development of Bulletin 15 (1967) by the Water Resources Council. Comments leading to the selection of the uniform method reported in Bulletin 15 are excerpted from Benson (1968) as follows.

> The statistical consultants had indicated that no unique procedures could be specified as correct for any one method of flood-frequency analysis. No single method of testing the computed results against the original data was acceptable to all those on the Work Group, and the statistical consultants could not offer a mathematically rigorous method. It appeared, consequently, that if a choice could not be made solely on statistical grounds, a choice on administrative grounds, for which compelling reasons existed, was justified. This administrative choice was largely governed by the relative values of the results and the tests of conformance that were made.
>
> The Work Group realized that its task would not be adequately fulfilled simply by choosing one among several alternative methods of frequency analysis. Its investigations brought out very forcibly that the range of uncertainty in flood analysis, regardless of the method used, is still quite large, that there is still a need for continued research and development to solve the many unresolved questions, and that it would be unwise either to rigidly specify any one method or to restrict in any way the future development of flood-frequency analysis. Taking into consideration the demonstrated need for the utmost possible uniformity, and the state of the art, the Work Group made the following recommendations, all of which it considered highly desirable:
>
> 1. That the log-Pearson Type III distribution (with the log-normal as a special case) be adopted as a base method for analyzing flood-flow frequencies.
> 2. That in such cases where investigation showed that other distributions or techniques would be better suited, these techniques should be used, but justification for the departure from the base method should be documented.

3. That the choice of a base method should not be considered as final and should not freeze hydrologic practice into any set pattern, either now or in the future. That in view of the increasing importance of frequency analysis in water-resources development, studies should be continued for the purpose of resolving uncertainties, improving methods of analysis, and reviewing all work in this field. That when considered desirable, new techniques or methods should be recommended.

The bulletin then outlined the several steps to be followed in applying the log-Pearson Type III distribution and concluded by discussing several additional considerations which are important in flow-frequency analysis. These included the following: short period of record, development of generalized regional relationships to permit determination of flood flow frequencies at ungaged sites, outliers, zero items of data, and the availability of the skew coefficient.

Efforts on the State Level

The Iowa Natural Resources Council (INRC) had been active for a number of years in requesting that federal agencies adopt a uniform approach in calculating flow-frequency relationships. Subsequent to the publishing of Bulletin 15, the INRC entered into a cooperative agreement with the U.S. Geological Survey (USGS) in Iowa City to make a study of the rivers and streams in Iowa using the log-Pearson Type III method of determining flow-frequency relationships.

An ad hoc advisory committee of interested federal and state agencies was formed to assist the INRC and the USGS and to agree on the various methods and techniques to be used in the study. This committee met in September, 1970 and was composed of representatives from the following agencies.

Federal

- Federal Highway Administration
- Federal Housing Administration
- U.S. Corps of Engineers
- U.S. Geological Survey
- U.S. Soil Conservation Service

State of Iowa

- Civil Defense Division
- Department of Soil Conservation
- Iowa Geological Survey
- Iowa Highway Commission
- Iowa Natural Resources Council
- Iowa State University
- State Conservation Commission
- State Health Department
- University of Iowa

Records at 170 stations in Iowa were available for the study. From the list, 129 stations with a minimum period of record of 14 years were selected for use. The drainage areas for these stations ranged in size from 0.33 to 14,030 sq. mi. As a first step, the log-Pearson Type III distribution was used to fit frequency curves to the observed data at each station. These frequency curves were then used to determine flood magnitudes at recurrence intervals of 2, 5, 10, 25, 50, and 100 years at each station. These estimates, based on the station data, appear in Table 4-6-2 in the column headed "Log-Pearson", for the Skunk River stations at Ames.

Flood-frequency relations were then developed that were applicable to an entire region so estimates of flood magnitudes at ungaged sites could be made. Several methods were investigated, but the equations developed using the multiple-correlation method reproduced the base data with the least standard error. This multiple-regression method is a statistical technique which defines a mathematical equation of the relationship between floods of a given frequency of recurrence to hydrologic parameters and basin characteristics. The estimates based upon these multiple-regression equations appear in Table 4-6-2 in the column headed "Regional".

This study by the USGS (1972) has now been completed and is undergoing final review before being published. It has been the object of much discussion and review by the ad hoc advisory committee and, in its final form, hopefully provides a method of estimating flood frequencies acceptable to all federal and state agencies in Iowa.

Variability of the Skew Coefficient

Data presented in a previous section substantiates the position that widely varying values of the variable may be generated by different frequency distributions. To determine the relative variation between methods for the Skunk River data, peak annual flows for two stations (Skunk River near Ames, 315 sq. mi. and Skunk River below Ames, 556 sq. mi.) were analyzed. The log normal, log-Pearson Type III, and regional equation developed by the USGS (1972) were the methods used. The results are shown in Table 4-6-2.

Table 4-6-2. Flood frequencies for Skunk River

Return Period, yrs.	Near Ames			Below Ames		
	Log Normal	Log-Pearson	Regional	Log Normal	Log-Pearson	Regional
2	2799	3089	2143	4844	5861	3615
5	4692	4723	3719	8366	8080	5867
10	6146	5607	4838	11131	8809	7330
25	8198	6505	6188	15094	9276	8846
50	9874	7041	7450	18376	9448	10621
100	11673	7484	8900	21933	9543	12534

For return periods greater than 50 years the regional equation gave results that were greater than those by Log-Pearson Type III, but less than those generated by the log normal. The period of record for the station near Ames (315 mi^2) is 49 years with the maximum recorded flow of record equal to

8630 cfs. The period of record for the lower station is 20 years with the maximum recorded peak of 9260 cfs. The results in Table 4-6-2 were not adjusted for the period of record. If this were done, the predicted values of 8900 cfs and 12,534 cfs from the regional equation would in effect represent the 79-year and 50-year return periods, respectively. These predicted values look reasonable in view of the maximum recorded peaks.

The coefficient of skew of the logarithms for the 47 year period for the Skunk River near Ames is -0.9781 and for the unlogged data, the coefficient of skew is 0.99 and the coefficient of variation is 0.535. If the data were log normally distributed, the coefficient of skew of the logarithms would be zero. Also the C_s and C_v for the unlogged data would need to satisfy the relation $C_s = C_v^3 + 3\ c_v$. The value of the coefficient of variation would have to be 0.324 instead of 0.535 to be log-normally distributed.

Since a majority of the analyses of the logarithms of peak annual flow records give a negative coefficient of skew, the question arises whether one should use a computed skew or use the log normal without skew. Some statistical hydrologists have indicated that one should have 100 years of record to establish a case for skew. The historical record of 170 Iowa streams has been recently analyzed for the computed skew of the logarithms of peak annual flows. If the log normal is applicable, the coefficient of skew should approach zero as the period of record increases. Table 4-6-3 gives the analysis for Iowa streams.

Table 4-6-3. Selected data from analysis of annual peak flows.[1]

Length of Record	Av. Skew	No. of samples	Range in Skew
< 15 yr.	-0.1536	30	-1.8325 to +2.0716
15 - 25 yrs.	-0.2491	81	-2.4004 to +1.1506
26 - 36 yrs.	-0.4936	28	-1.1813 to +0.5297
36 - 45 yrs.	-0.4674	13	-1.2767 to +0.3735
46 - 55 yrs.	-0.6140	9	-1.1180 to -0.2287
56 - 65 yrs.	-0.5057	5	-1.2246 to +0.1438
66 - 75 yrs.	-0.5932	4	-0.8808 to -0.3953

[1] Data furnished by Oscar Lara, U.S.G.S., Iowa City, Iowa.

The data show that as the length of record increases (greater than 45 yrs) the skew coefficient of the logarithms stabilizes to a value of from -0.5 to -0.6 with much less variation than in the samples taken from the shorter period of record. From this analysis of 170 Iowa streams, it seems very questionable whether one can assume the coefficient of skew is equal to zero which is the requirement for use of the log normal distribution.

Effect of Outliers

The computed coefficient of skew is extremely sensitive to conditions where an annual peak flow is very low in comparison to the next lowest peak flow. For example the lowest recorded peak flow for the Skunk River near Ames, below Ames and near Oskaloosa are 376 cfs, 638 cfs, and 782 cfs, respectively, while the next lowest flows are 600 cfs, 1620 cfs and 3700 cfs, respectively. Likewise, the lowest event for the East Nishnabotna River at Red Oak is 355 cfs while next lowest event is 3250 cfs. There would seem to be some justification for excluding the low outliers as not being part of the current population. Also if one were using the partial duration method, they would likely be dropped. Table 4-6-4 shows the effect on the predicted 100 year event when one lowest flow value is removed from the analysis.

It is apparent that the presence of an outlier affects the predicted value of an annual peak flow in the six Iowa stations given in Table 4-6-4. The removal of an outlier produces opposite effects on the predicted values for a 100 year event when comparing the log normal distribution and Log-Pearson Type III distribution. The 100 year predicted peak increases with the Log-Pearson, but decreases with the log normal. When the outlier is removed, $\overline{\text{Log X}}$ increases and $S_{\text{Log X}}$ decreases. For the log normal, where the frequency factor is constant, the effect of reducing $S_{\text{Log X}}$ is more pronounced than the increase in the mean. This is shown graphically on Figure 4-6-2 for the Nishnabotna Station. The slope of the cumulative probability curve is proportional to $S_{\text{Log X}}$ and results in a lower value for the 100 year event in spite of the increase in ordinate of the curve at the mean.

For the Log-Pearson Type distribution, $\overline{\text{Log X}}$, $S_{\text{Log X}}$, and the frequency factor all change with the removal of the outlier. The coefficient of skew increases algebraically which also increases the value of the frequency factor. Therefore the increase in K more than offsets the reduction of $S_{\text{Log X}}$ such that Log X in the equation

$\text{Log X} = \overline{\text{Log X}} + S_{\text{Log X}} K$ increases giving a higher predicted value. This is also shown graphically for the Nishnabotna Station in Figure 4-6-3.

It may be concluded that when low outliers are removed, the difference in predicted values for a 100 year event is much reduced when comparing the log normal and Log-Pearson Type III distributions.

Table 4-6-4. Effect of outliers on prediction of 100 year peak flow

Station	Coef. of Skew of Logarithms		Log Normal 100 yr.		Log-Pearson 100 yr.	
	With Outlier	Without Outlier	With Outlier	Without Outlier	With Outlier	Without Outlier
Skunk Rv. N. Osk.	-2.0518	+0.224	28056	19280	12716	20540
Skunk Rv. N. Ames	-0.978	-0.483	11673	10200	7484	8425
Skunk Rv. Below Ames	-1.893	-1.377	21933	16000	9543	10070
Crane Crk. N. Saratoga	-1.5482	-0.5733	6280	3755	1961	2775
Bear Crk. N. Ladora	-1.3819	-0.461	15111	12100	8841	10450
E. Nishnabotna Rv. at Red Oak	-2.19	-0.21	63500	39000	20200	34700

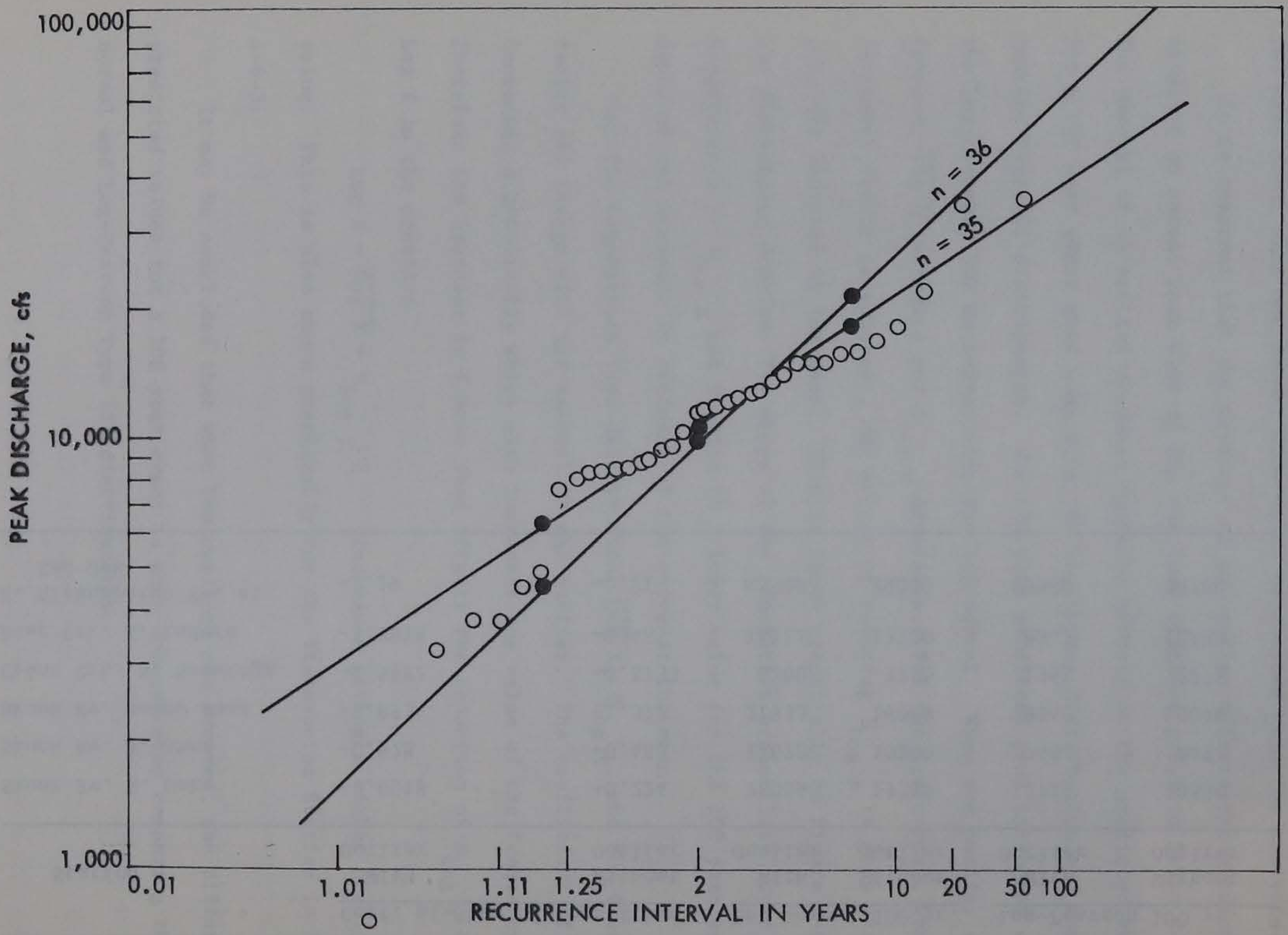

Fig. 4-6-2. Change in log normal cumulative probability curve when lowest event is removed — East Nishnabotna River.

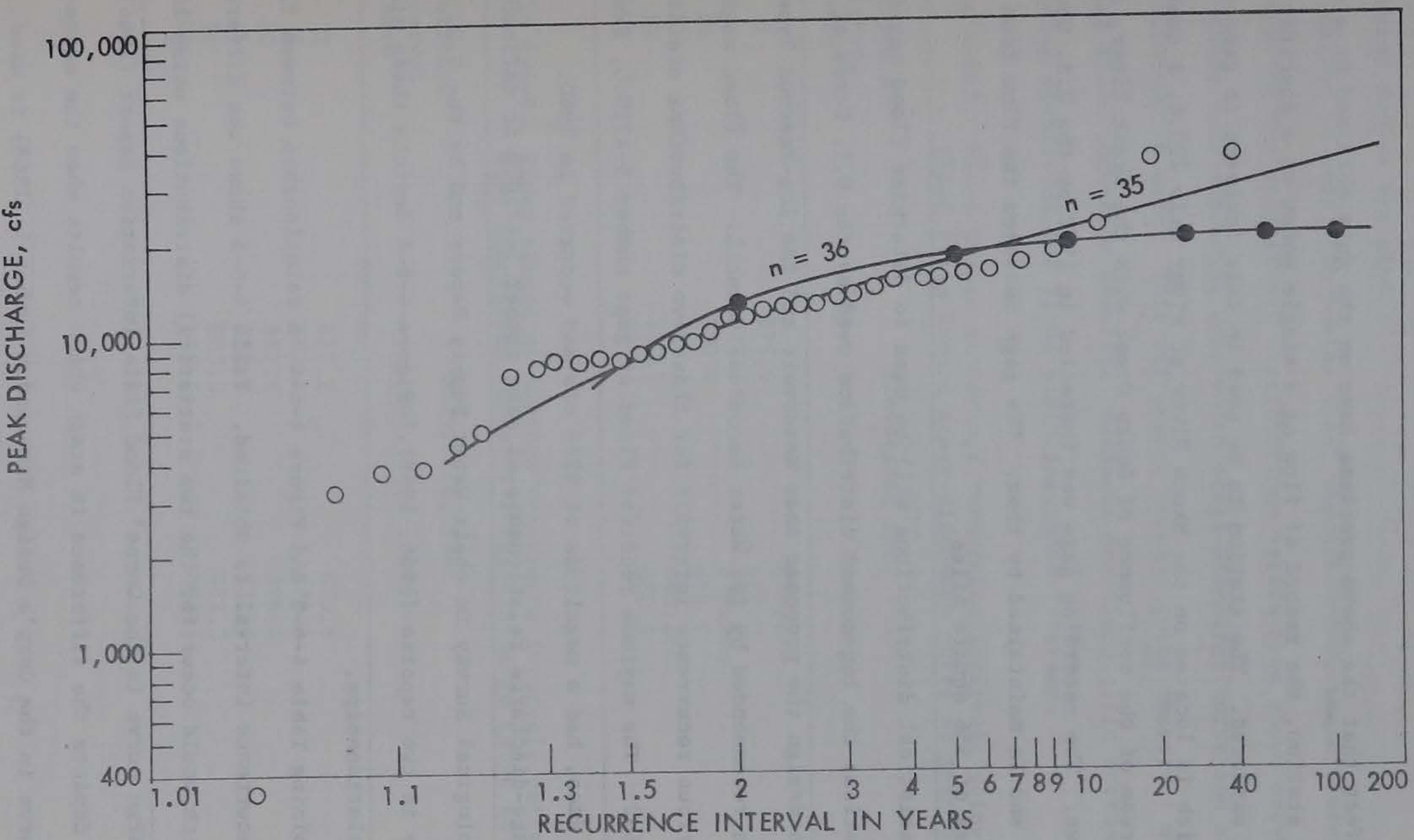

Fig. 4-6-3. Change in log-Pearson Type III cumulative probability curve when lowest event is removed — East Nishnabotna River.

Gage Number 5-4710.0, Skunk River Below Ames

The effect that the above problems have on the data obtained at a streamflow gaging station, the record of flow at a single point on a specific river, will now be explored. The station to be used in this analysis is gage number 5-4710.0 which is located on the Skunk River at river mile 222.6, a quarter mile downstream of the confluence of Squaw Creek with the Skunk River, south of Ames, Iowa. The recording gage was installed in 1952 by the U.S. Geological Survey and is maintained by them. The gage measures the flow from a drainage area of 556 square miles.

Two statistical distributions will be used to determine flood magnitudes at this location: the log-normal distribution used by the U.S. Corps of Engineers to design the proposed Ames Reservoir and the log-Pearson Type III distribution recommended by the Water Resources Council. The flood magnitudes at various recurrence intervals for these two distributions are listed in Table 4-6-2. The maximum recorded flood at gage number 5-4710.0, Skunk River below Ames, had a magnitude of 9260 cfs and occurred in 1960.

The stage-discharge relationship at gage number 5-4710.0 is defined by the U.S. Geological Survey in their Water Supply Papers and by the U.S. Corps of Engineers in two reports (1966, 1968). Figure 4-6-4 depicts these stage-discharge relationships.

By combining Table 4-6-2 and Figure 4-6-4, a relationship between flood stage and recurrence interval is obtained. Table 4-6-5 shows the difference in stage which would occur for the two statistical distributions using the stage-discharge curve in the Corps' Flood Plain Information Report (1966). Table 4-6-6 depicts the difference in stage which results when the stage-discharge curve in the Corp's Design Memorandum Number 1 (1968) is used. A possible maximum difference in stage is shown in Table 4-6-7 when both stage-discharge curves are used.

As can be seen from Tables 4-6-5 through 4-6-7, the difference in stage between the two statistical distributions varies from about one-half foot to over three feet depending upon which stage-discharge curve and statistical distribution is used. This difference becomes quite important when calculating flood reduction benefits, setbacks for flood plain encroachments, or building elevations for flood plain insurance programs.

Table 4-6-5. Flood stages at various recurrence intervals using the Corps' Flood Plain Report stage-discharge curve at gage number 5-4710.0

Recurrence Interval Years	Elevation, feet		Difference
	log-normal	regional	feet
2	876.8	875.2	1.6
5	879.7	878.0	1.7
10	880.2	879.2	1.0
25	880.5	879.9	0.6
50	880.7	880.2	0.5
100	881.4	880.3	1.1

Table 4-6-6. Flood stages at various recurrence intervals using the Corps' Design Memorandum Number 1 stage-discharge curve at gage 5-4710.0

Recurrence Interval Years	Elevation, feet		Difference
	log-normal	regional	feet
2	877.2	875.6	1.6
5	880.1	878.0	2.1
10	881.5	879.4	2.1
25	882.8	880.4	2.4
50	883.3	881.3	2.0
100	883.6	882.1	1.5

Table 4-6-7. Flood stages at various recurrence intervals using both the Corps' Design Memorandum Numbèr 1 and the Flood Plain Report stage-discharge curves at gage number 5-4710.0

Recurrence Interval Years	Elevation, feet		Difference
	log-normal[1]	regional[2]	feet
2	877.2	875.2	2.0
5	880.1	878.0	2.1
10	881.5	879.2	2.3
25	882.8	879.9	2.9
50	883.3	880.2	3.1
100	883.6	880.3	3.3

[1] Using the Corps' Design Memorandum Number 1 (See Fig. 4-6-4).

[2] Using the Corps' Flood Plain Report (See Fig. 4-6-4).

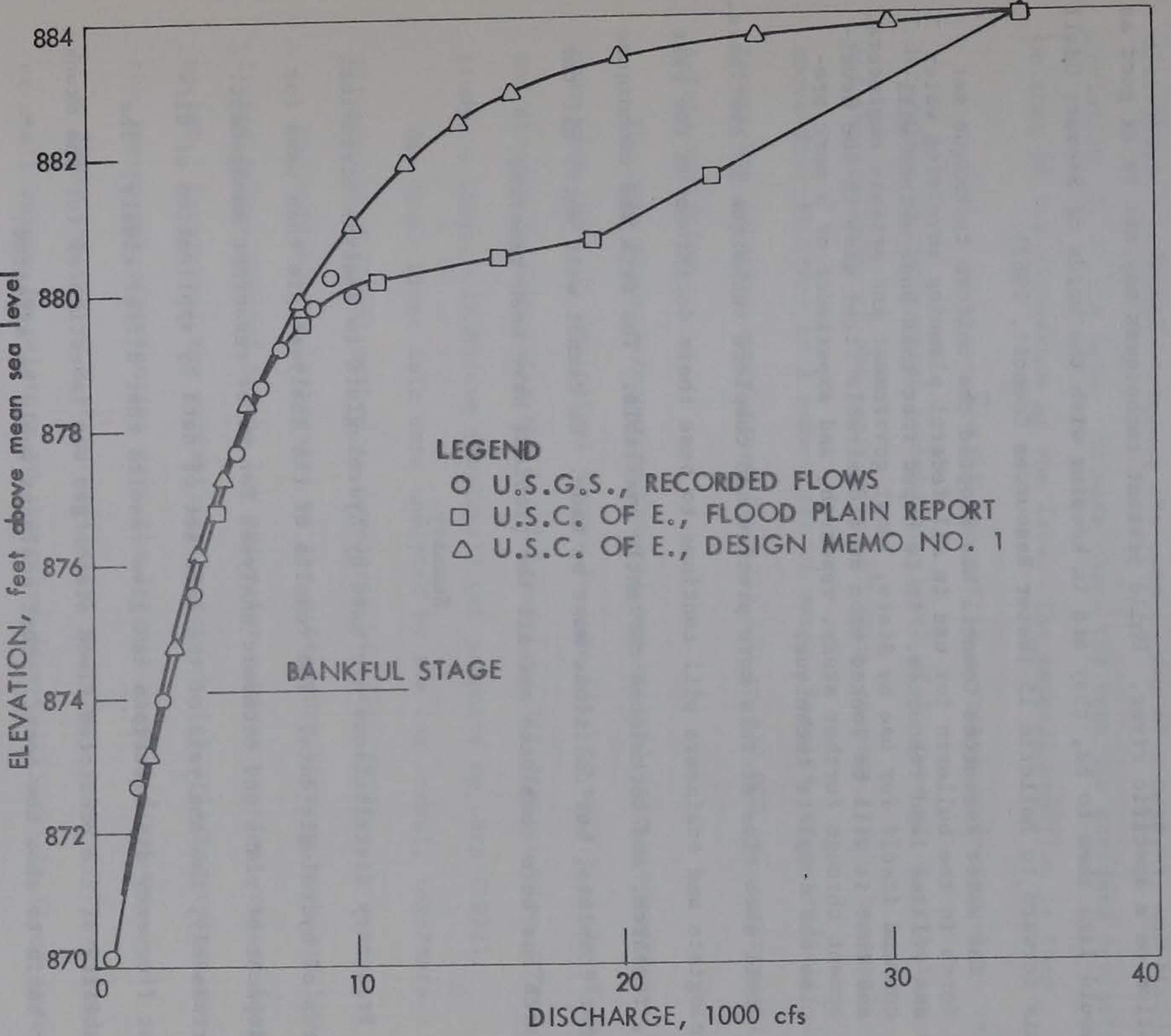

Fig. 4-6-4. Stage-discharge curves at USGS gage No. 5-4710.

General Comments

Hydrologists need to resolve their differences as they attempt to quantify the magnitudes of floods at various recurrence intervals for a particular location on a specific river. While present techniques may not be as good as we would like them to be, they are in keeping with the words of Stewart Udall in his forward to Bulletin 15 (Water Resources Council, 1967).

> The Water Resources Council has adopted the uniform technique set forth in the bulletin for use in all federal planning involving water and related land resources. It is hoped that this base method will commend itself for use by State, local government and private engineers, and that it will be looked upon as a desirable first step in the development through further study, research, and experience of a more precise and complete technique.

Until such time at this more precise and complete technique is available, hydrologists and engineers will continue to base their decisions on the best data, research, and techniques currently available. The data and techniques are not complete, but decisions must be made. We cannot wait until all the research has been completed and all the problems have been resolved.

Summary

Frequency distributions are used by hydrologists to analyze historical records of hydrologic data. The results of the analyses are then used for development of plans and economic analyses for water resources management. Unfortunately, the analysis of the same set of data by application of different frequency distributions can give results that differ widely. The variability of the predicted flood discharges was investigated for the Skunk River basin to show how benefit-cost analyses would be affected.

Some of the more frequently used frequency functions are discussed in a bulletin prepared by the Committee on Water Resources (1966). These include the log normal, gamma, extreme value functions of type I largest and type III smallest, log Pearson type III and distribution free methods. The methodology of predicting future events from a historical record, regardless of the distribution selected, involves the computation of a mean, $\overline{x}$, and standard deviation, S, of the data. In some cases the mean and standard deviation will be that of the logarithms of the data. The general equation is then

$X = \overline{X} + S\,K$ where K is a frequency factor whose value is determined by the desired probability level of X, type of distribution used and the treatment of the coefficient of skew. Benson (1968) has applied the above distributions to a common set of data. Results for a predicted 100 yr. recurrence interval event range from 213,870 to 830,000 or approximately a 4-fold variation.

The Iowa Natural Resources Council has entered into a cooperative agreement with the U.S. Geological Survey in Iowa City to make a study of the rivers and streams in Iowa using the log-Pearson type III distribution. From this study, a uniform technique (Regional) was proposed by Lara (1972).

The Skunk River data were analyzed by the log normal, log-Pearson type III and the Regional method as developed by Lara (1972).

The variability, expressed as the difference between high and low predicted values divided by the low value for a given station, ranged from 27% to 56%. In general the variability increased with a larger return period and the log-normal distribution gave the largest predicted values.

Since the use of a skew coefficient and the treatment of extremely large or small values in relation to the other data (outliers) in flood frequency analyses can significantly affect the result, an analysis of the skew coefficient of the record of 170 Iowa streams was made. Also 6 examples were computed showing the effect of outliers. Results show that Iowa streams with records from 46-75 years in length have a negative skew coefficient of approximately -0.6. When the lowest value of record is excluded from the analysis as an outlier, the coefficient of skew increases positively and reduces the variability between results obtained by different frequency distributions.

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AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIP WITH THE AGRICULTURAL SECTOR

Chapter 7

WATER CONTROL ON AGRICULTURAL LAND

by

David B. Palmer

1973

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Chapter 7

WATER CONTROL ON AGRICULTURAL LAND

David B. Palmer

Introduction

Economic losses are suffered by farm owners and operators when high stream flows occur through flood plains being used for agriculture. Above normal stages, even if the flow is not out-of-banks, cause accelerated channel erosion. The resultant sloughing of banks decreases the size of field areas and increases costs of production by increasing the curvature of field boundaries. When streams go out-of-banks additional losses occur. Field operations are stopped and decreased yields result because of untimely crop operations. Crop damage may occur due to extended periods of inundation and lodging of plants caused by flowing water. Damage to bridges, transportation rights-of-way, and farmstead structures also occurs. In addition, the life of farm machines and the comfort and health of machine operators are adversley affected by dust and delays in harvest precipitated by flooding.

Flood control represents a major impact of the Ames Lake on the Skunk River valley. Substantial crop and property damage has resulted from floods. In an effort to reduce these damages, land owners along the Skunk River and below Ames have made sizeable investments in river training works. Before 1900 a new channel for the river was constructed. Horses and scrapers were

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Palmer was an associate professor of agricultural engineering at Iowa State University and is now with Harza Engineering Company, Chicago.

used to construct a pilot channel which was then enlarged by the river flow. In the early 1920s levees were constructed along both sides of the river through Polk County. Both surface and subsurface drains have been installed in the flood plain to decrease crop damage resulting from standing water. Thus, over the years land owners have initiated projects and made substantial investments of their own funds in improving the Skunk River flood plain for agricultural production. The proposed Ames Lake Project offers the possibility of additional improvements and resulting decreases in average annual flood damages.

Flood control represents a major component of the economic justification for the Project. The Corps in its most recent economic justification shows average annual benefits of $681,100 from flood control and a total average annual benefits of $1,384,591. Thus, flood control represents 49 percent of the total benefits.

A major task of this chapter is to re-consider the assumptions that have been made in order to perform the economic justification. Components of this review include:

1. The frequency distribution selected for analysis of peak runoff rates for the river.
2. The interpretation of how the selected distribution is used in the analysis.
3. The stage - damage relation for the various reaches of the river.
4. Crop distribution, yields, costs of production and selling pieces.

Impact of Frequency Analysis on Benefits

The magnitude of flood control benefits is sensitive to the frequency analysis of the flood flows. At the same time it was recognized that a diversity of opinion exists regarding what is the "best" method for processing peak flow data. For example, should an annual flood series or a partial duration series be used? Or should both be used, the selection depending on the type of damages to be evaluated? Which of the several available frequency distributions should be used and how should it be used? Another question concerns the effect on predicted peak flows of omitting one or more of the so-called outliers, or values which are extremely large or small relative to the remainder of the data. These issues have been discussed in considerable detail in chapter 6 of this appendix.

Due to time limitations it was not possible to ascertain the impact on benefits of all the possible approaches to frequency analysis. One particular alternative to the Corps procedure however was selected to ascertain its impact on the predicted project benefits. This alternative was the introduction of the regional flood-frequency distribution as determined using the log-Pearson method now being applied to Iowa flood data by the U.S. Geological Survey for the Iowa Natural Resources Council. As shown in the previous chapter different results are obtained than with the log-normal procedures employed by the Corps of Engineers in the Ames Reservoir study and design phases.

Revised Estimates of Crop and Pasture Damages

To test the impact of an alternative frequency analysis on the benefit-cost analysis the Log Pearson Type III distribution, recommended by the Water Resources Council (U.S. Water Resources Council, 1967), was utilized to develop a damage probability curve based on the regional multiple regression analysis approach of the Iowa Natural Resources Council. Revised benefits were estimated for Reaches 3B and 4 and the resulting percentage changes were applied to the published project benefits from the remaining reaches. The procedure used to obtain the revised benefits for Reaches 3B and 4 is described below.

In order to estimate crop and pasture damages for the Skunk River valley, the valley was divided into reaches in such a manner that each reach was assigned to a specific gaging station. For the Ames Lake Project computations the "Skunk River below Squaw Creek" station was used for reaches 3B and 4. Reach 3B includes the portion of the valley in Polk County (Mile 188 to Mile 202) and reach 4 extends from the Polk-Story County line to the Ames Dam Site (Mile 221).

Discharge versus frequency relations for the "Skunk River below Squaw Creek" station are shown in Design Memorandum No. 1 (U.S. Army Corps of Engineers, 1968) as Plates 1-6 (All Year) and 1-7 (Crop Year) and are included herein as Figures 4-7-1 and 4-7-2. The "Crop Year" includes runoff events occurring between April 1 and November 30, an eight-month period. For the same station a revised discharge versus frequency relation was developed using the "annual event" series of the "all year" data, Figure 4-7-3. This revised relation was based on data developed by the U.S. Geological Survey and the Iowa Natural Resources Council using their "regional multiple regression" approach (Lara, 1972).

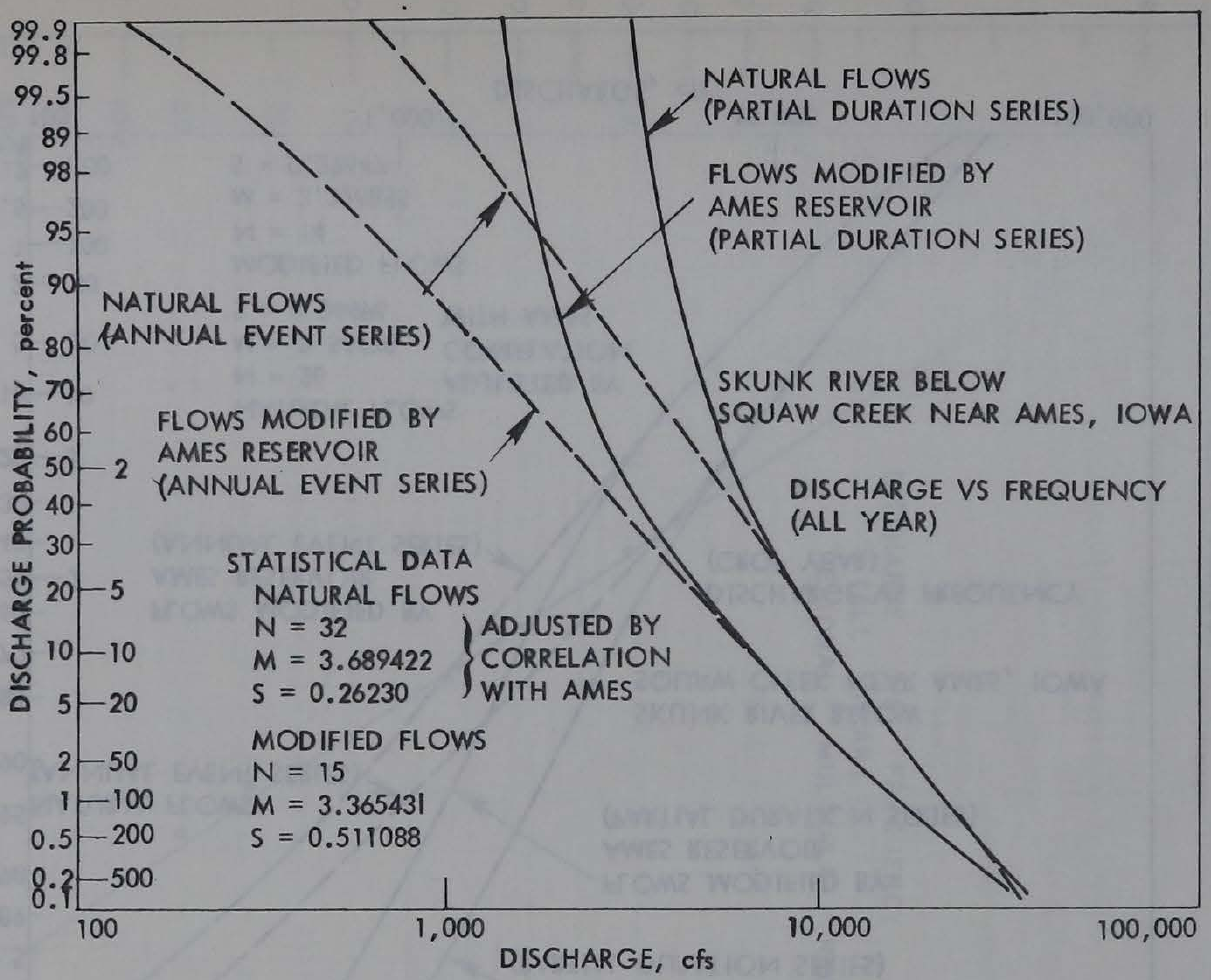

Fig. 4-7-1. Discharge and frequency (all years).

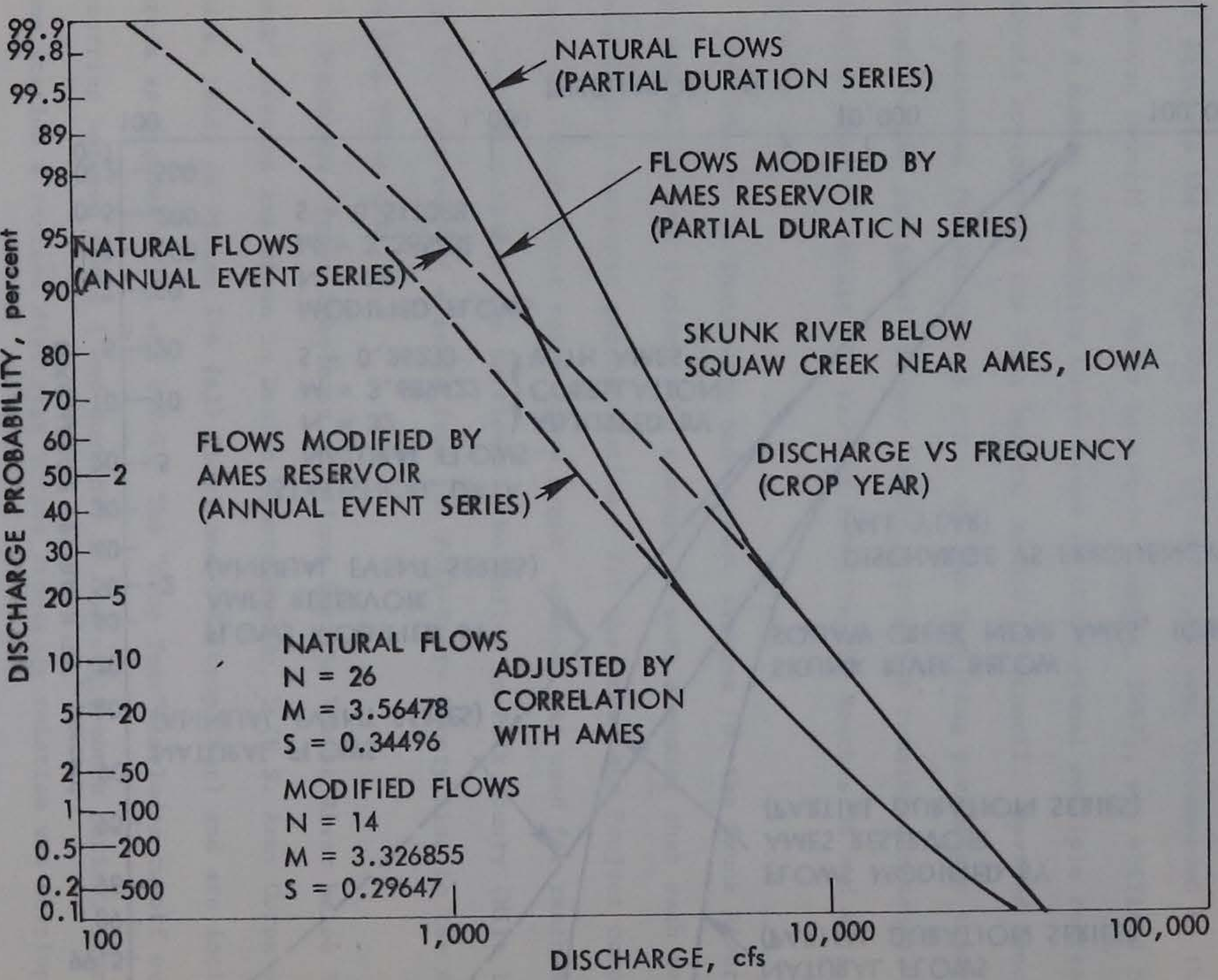

Fig. 4-7-2. Discharge and frequency (crop year).

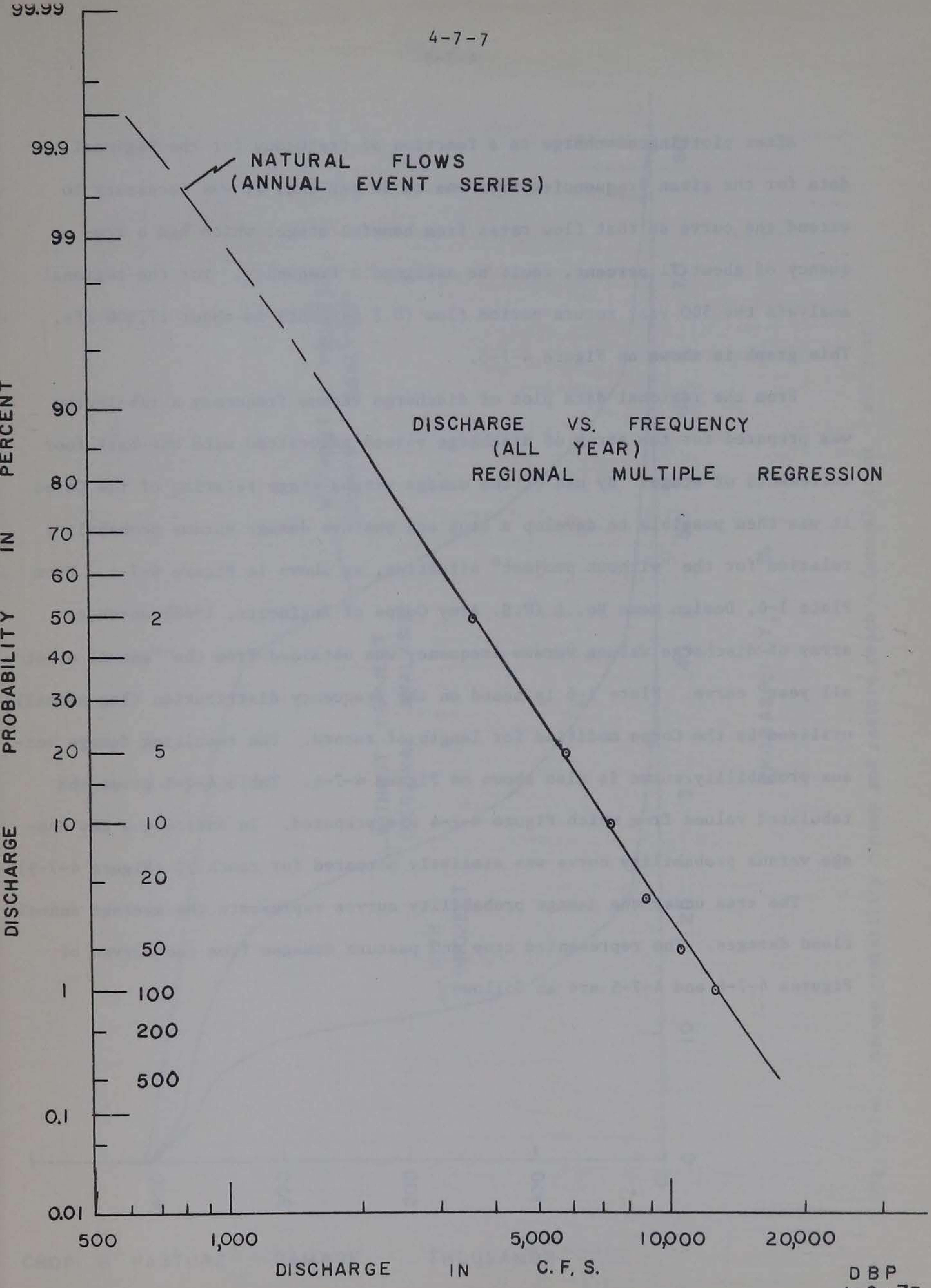

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Fig. 4-7-3. Discharge vs frequency (Skunk River below Squaw Creek near Ames).

After plotting discharge as a function of frequency for the regional data for the given frequencies from one to 50 percent, it was necessary to extend the curve so that flow rates from bankful stage, which has a frequency of about 71 percent, could be assigned a frequency. For the regional analysis the 500 year return period flow (0.2 percent) is about 17,300 cfs. This graph is shown as Figure 4-7-3.

From the regional data plot of discharge versus frequency a tabulation was prepared for the array of discharge values associated with one-half foot increments of stage. By use of the damage versus stage relation of the Corps it was then possible to develop a crop and pasture damage versus probability relation for the "without project" situation, as shown in Figure 4-7-4. From Plate 1-6, Design Memo No. 1 (U.S. Army Corps of Engineers, 1968) another array of discharge values versus frequency was obtained from the "annual event - all year" curve. Plate 1-6 is based on the frequency distribution (log normal) utilized by the Corps modified for length of record. The resulting damage versus probability curve is also shown on Figure 4-7-4. Table 4-7-1 gives the tabulated values from which Figure 4-7-4 was prepared. In addition a new damage versus probability curve was similarly prepared for reach 3B (Figure 4-7-5).

The area under the damage probability curves represents the average annual flood damages. The represented crop and pasture damages from the curves of Figures 4-7-4 and 4-7-5 are as follows:

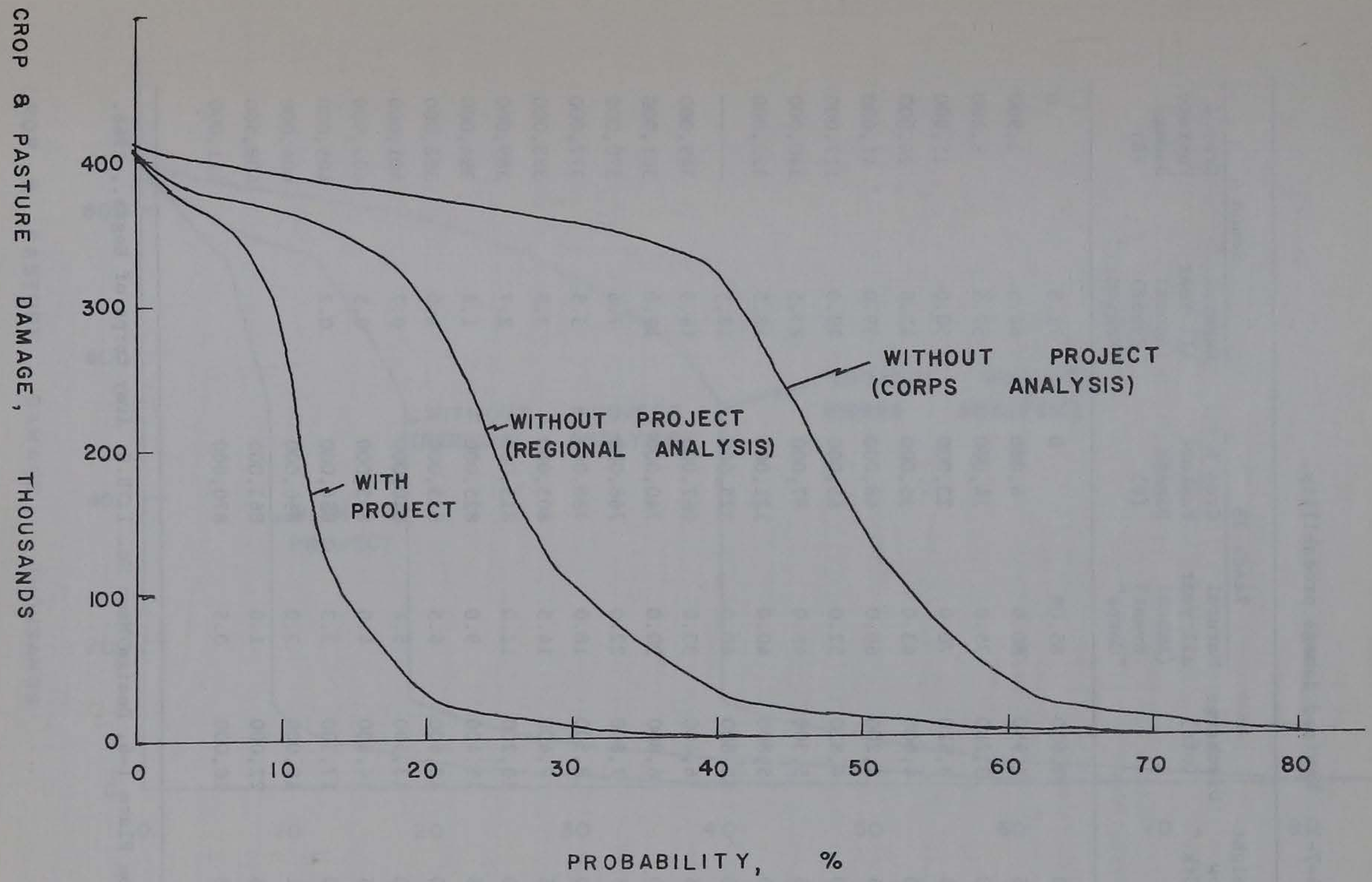

Fig. 4-7-4. Damage probability — crop and pasture reach 4 (annual event — all year).

Table 4-7-1. Revised damage probability.

Gage Height "below Squaw Crk."	Discharge (cfs)	Reach 3B		Reach 4	
		Natural all year (Annual Event) "Corps"	Crop & Pasture Damage ($)	Natural All Year (Annual Event) "Regional"	Crop & Pasture Damage ($)
7.0	2,630	85.0*	0	71.5	0
7.5	2,950	80.0	6,000	64.5	1,900
8.0	3,280	75.0	14,000	57.5	8,200
8.5	3,620	70.0	23,000	50.0	15,000
9.0	4,000	63.0	35,000	42.0	24,000
9.5	4,200	60.0	48,000	39.0	41,000
10.0	4,820	52.0	65,000	29.0	117,000
10.5	5,300	45.0	87,000	23.5	240,000
11.0	5,800	40.0	121,000	18.5	323,000
11.0	5,800	40.0	525,000	18.5	-------
11.5	6,400	33.0	667,000	14.5	349,000
12.0	6,800	30.0	740,000	12.0	361,000
12.5	7,800	22.0	768,000	7.5	370,000
13.0	8,500	18.0	788,000	5.5	377,000
13.5	9,400	14.5	803,000	3.8	383,000
14.0	10,200	12.0	815,000	2.7	389,000
14.5	11,400	9.0	825,000	1.6	394,000
15.0	12,600	6.5	835,000	1.0	398,000
15.3	13,500	5.4	840,000	0.7	401,000
15.5	14,800	4.0	845,000	0.5	402,000
16.0	17,300	2.3	854,000	0.2	405,000
16.1	18,000	2.0	856,000		406,000
16.5	22,000	1.0	863,000		408,500
16.8	26,000	0.5	870,000		411,000

*From Plate 1-6, Design Memo No. 1, U.S. Army Corps of Engrs., 1968.

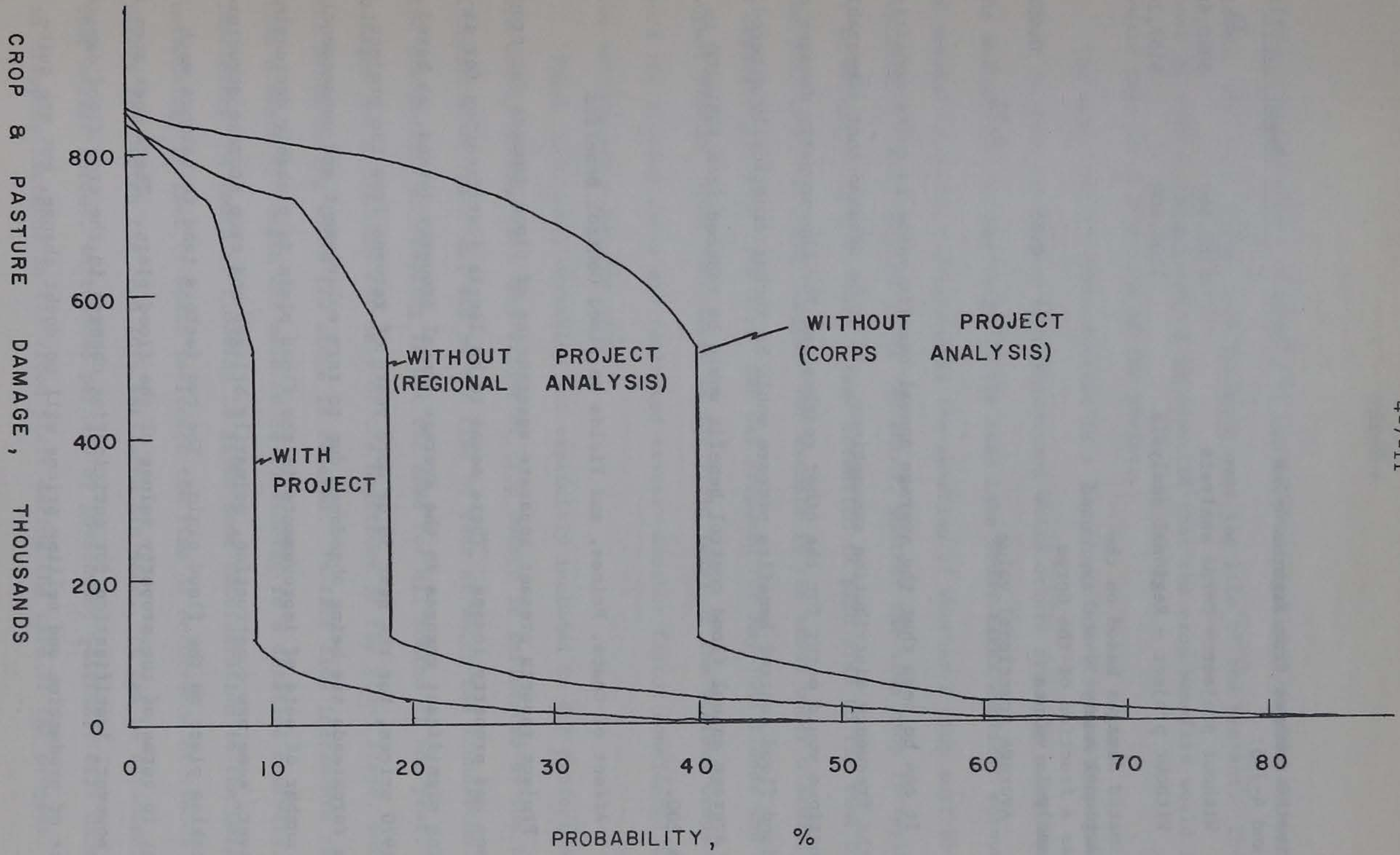

Fig. 4-7-5. Damage probability — crop and pasture reach 3B.

Estimated damages from Figures 4-7-4 and 4-7-5:	Reach	
	4	3B
Without project - Corps analysis	$185,500	$320,600
Without project - Regional analysis	$102,600	$157,200
Estimated damages based on the Regional analysis and expressed as a fraction of the Corps analysis values	0.55	0.49
Average fractional value	0.52	

It can be seen that the average annual benefit value is quite sensitive to the frequency distribution assumptions. If it be assumed that comparable reductions would occur for the other reaches and for the property damages the revised flood control benefits picture would be rather drastically altered. The average annual flood control benefit would be reduced from $681,100 to $354,200.

Affect of Costs, Prices, and Yields on Flood Control Benefits

Project reports present separate assessments of flood damages for crop losses and property losses. There seems to be little justification for assuming significant changes in the average annual property losses, as based on 1970 prices, for the next 50 or more years of returns from the project. Some farmsteads are being abandoned due to farm enlargement and consequently the number of sets of improvements in the flood plain is probably decreasing. However, some new construction, primarily bridges and crop storage structures, is taking place on the flood plain. The two factors tend to balance each other in terms of the property values of the flood plain. There does seem to be, however, justification for anticipating changes in the crop flood damages. Costs of production and selling prices will no doubt change, but are quite difficult to forecast. However, it can be predicted with considerable confidence that crop yields will increase over the life of the project. Thus, based on 1970 dollars it would be expected that the crop benefits would increase throughout the life of the project.

The magnitude of flood damages is a function of many variables; the effect of some are fairly well understood while others are only estimated. The method used by the Corps in the Ames Lake Study takes explicit account of several of these. Included is the question of whether a crop must be replanted or not, and, if it is replanted, whether the same crop is replanted or an alternate crop is used. Some attention is paid also to the time of the year when the flood occurs. For example in the study under discussion a separate per acre crop loss list was prepared for May-June floods and for August floods. Also considered is the yield level of the various crops for both the first-planted and replanted cases. Another factor considered is the selling price for the crop.

Three additional variables not explicitly included in the project method are worthy of mention. The extent of crop damage is influenced by the time of inundation of the crop, and by the time of year at which the inundation occurs. The probability of flooding is not the same for all months of the year. Thus, damages are a function not only of the magnitude of the flood stage, but also the month during which the stage is reached. In fact time increments shorter than a month in length may need to be considered in a detailed analysis. Implicitly the month of flooding is given some consideration in the Corps methodology in that it would influence the time of occurrence of floods of record from which the crop loss estimates are made. It can be anticipated that market forces, influenced perhaps by government programs, will cause changes in cropping patterns in the flood plain during the life of the project.

One set of per acre crop losses used for the Ames Lake Study and computed at 1967 price levels is shown in Table 4-7-2. For May-June floods where corn was the original crop and no replanting was done, a value of $76.69 is used for the per acre crop loss. When corn is replanted, the loss figure is $76.15. If soybeans are the replanted crop, the per acre crop loss is $67.73. A comparable value was used for buckwheat. The gross cash yield for corn of $102.85 is the product of an average yield per acre of 85 bushels and a unit price of $1.21. The value of $26.16 is an estimate of the harvest costs plus the weed control costs. Where corn is used as the replant crop, the per acre crop loss is the difference between the $76.69 and 54¢ or $76.15. The 54¢ represents the per acre profit on the replanted crop. In order to arrive at this figure, it is assumed that the yield from the replanted crop will be one-half that of the full season crop. Total production costs for the replanted crop were estimated at $50.88. Thus, 54¢ represents the difference between one-half of the gross cash yield, that is 42.5 bushels per acre times a unit price of $1.21 minus the total production costs of $50.88. Similar computations are shown for soybeans, and have been computed for the additional crops that were surveyed in the flood plain. Table 4-7-2 gives per acre crop loss values for May-June floods. Comparable values were also used by the Corps for August floods.

For the current study flood control benefits were re-estimated using revised values of yields per acre, selling costs per bushel, and production costs. The most significant change in these variables was the yield per acre. For corn a value of 135 bushels was used. It will be noted in Chapter 1 of Appendix 4 of this study that corn yields during the life of the project have been projected for some soils to a value of 165 bushels per acre by the year 2025. Interviews

Table 4-7-2. Per Acre Crop Loss (May-June Floods) (Unpublished Corps Values)

Original Crop	Replant Crop	Computations	Per acre Crop Loss
Corn	None	Gross cash yield (GCY) minus Costs not incurred (CNI) = $102.85 - 26.16 =	$76.69
	Corn	GCY - CNI = $102.85 - 26.16 = $76.69 One-half GCY - Total production costs (TPC) = ($102.85 ÷ 2) - 50.88 = $0.54	$76.15
	Soybeans	GCY - CNI = $76.69 (GCY ÷ 2) - TPC = ($80.72 ÷ 2) - 31.39 = $8.96	$67.73
	Buckwheat		$67.73
Soybeans	None	GCY - CNI = $80.70 - 10.03 =	$70.67
	Soybeans	GCY - CNI = $70.67 (GCY ÷ 2) - TPC = $80.70 ÷ 2) - 31.39 = $8.96	$61.71
	Corn	GCY - CNI = $70.67 (GCY ÷ 2) - TPC = ($102.85 ÷ 2) - 50.88 = $0.54	$70.13

with farmers and extension specialists indicate that current average yields in the Skunk River Valley are at the 125 bushel per acre level. Average farm yields over the last few years have been in the order of 150 bushels per acre for the better farmers. The selling price for corn was used as $1.25 per bushel which is the 1970 price-adjusted normalized value based on national indices. The comparable price adjusted normalized values for soybeans is $2.68, which appears to be quite low in relation to the market prices prevailing early in 1973. A yield of 135 bushels per acre times a unit price of $1.25 gives a gross cash yield for corn of $169. Production costs per acre were estimated at $65. Thus, the net cash yield per acre is $104. A harvest cost per acre of $28. was used and a weed control cost per acre of $2.00 was used. For soybeans the revised estimate is based on a yield of 52 bushels per acre and the $2.68 unit price, giving a gross cash yield of $139.00. Production costs per acre were estimated at $41.00 for soybeans giving a net cash yield per acre of $99. Harvest costs per acre were estimated at $12. Weed control costs per acre were estimated at $1.00.

Per acre crop losses were re-estimated for original crops of corn and soybeans and for replanted crops of none, corn, or soybeans. These computations are shown in Table 4-7-3. Each of the re-estimated per acre crop losses was then divided by the per acre crop losses used to compute the flood control benefits in the 1970 report. Ratios of the two loss figures vary between 1.5 and 1.8. Considering the number of acres in each of the crop categories a ratio value of 1.7 was selected for further computations.

Revised benefits from flood control were then estimated on the basis of the ratio selected and described in the preceeding paragraph. The crop benefits are shown in the 1970 report for the valley as $503,300. 1.7 times this value gives a benefit of $855,000. If the property values shown in the 1970

Table 4-7-3. Revised crop loss estimates.

Original Crop	Replant Crop	Computations	Per Acre Crop Loss	Ratio*
Corn	None	Gross Cash Yield (GCY) = 135 bushels per acre times $1.25 per bu. = $169.00. Production costs per acre = $65.00 (assumed). Net cash yield per acre = $104.00. Harvest cost per acre = $28.00. Weed control cost per acre = $2.00 (assumed). Therefore, for May-June floods, Loss = GCY - Costs not incurred (CNI) = $169.00 - (28.00 + 2.00)	$139.00	1.8
	Corn	GCY - CNI = $169.00 - 30.00 = $139.00. One-half GCY - Total production costs (TPC) = ($169.00 ÷ 2.00) - 65.00 = $18.50	$120.50	1.6
	Soybeans	GCY = 52 bu. per acre times $2.68 per bu. = $139.36. Production costs per acre = $41.00. Net cash yield per acre = $98.36. Harvest cost per acre = $12.00 (assumed). Weed control cost per acre = $1.00 (assumed). Therefore, for May-June floods, Loss = $169.00 - 30 = $139.00 and (GCY ÷ 2) - TPC = ($139.00 ÷ 2) - $41.00 = $28.50.	$110.50	1.6
Soybeans	None	GCY - CNI = $139.99 - (12+1) =	$126.00	1.8
	Beans	GCY - CNI = $126.00 (GCY ÷ 2) - TPC = $69.50 - $41.00 = $28.50		
	Corn	GCY - CNI = $126.00 (GCY ÷ 2) - TPC = ($169 ÷ 2) - $65.00 = $19.50	$106.50	1.5

*Ratio of re-computed per acre crop loss to Corps per acre crop loss. Ratio approximates 1.7 for all crops.

report are added, that is a value of $177,800 is added to $855,000, an estimate of the revised average annual flood control benefits is arrived at of $1,032,800. When this value is compared with the original $681,100 it will be noted that flood control benefits occuring to the project have increased by 52%.

Additional Indications of Flood Damages

Some additional measures of flood damages were considered. The U.S. Weather Bureau publishes estimates of flood damages from major storms. Values for the Skunk River valley are shown in Table 4-7-4 for the years 1943 to 1970, a period of 38 years.

Table 4-7-4. Skunk River flood damages; U.S. Weather Bureau Estimates

Year		Total Damages
1943		$2,093,175
1944		3,169,100
1945		1,000
1946		380,000
1947		4,194,400
1948		125,000
1950		41,200
1951		1,269,600
1954		912,900
1960		305,000
1962		185,200
	Total	$12,677,075

Dividing the total damages of $12,677,075 by the 38 years gives an average annual loss value of $333,000. It may be noted that the average annual flood control benefits used in the Ames Lake Design Memo No. 1 is $681,100. It appears that Weather Bureau estimates are not based on extensive field investigations but are compiled from surveys of officials of various government organizations, including, on occasion, the Corps of Engineers.

It would be expected that a propensity to flood would decrease the selling price of land relative to the value of nearby land with the same productive capacity, but so located that flooding does not occur. Several interviews were made in an attempt to verify this expectation. The variation in flood damages among rivers and reaches of rivers and the extent to which propensity to flood is capitalized into selling price is illustrated by a consideration of the Des Moines River in Boone County and the Missouri River along western Iowa. Bottom land along the Missouri River has experienced considerable increase in value as a result of the construction of flood control dams and channel stabilization measures. Here, as with the Skunk River valley, floods tend to inundate rather large areas to rather shallow depths.

The Des Moines River in Boone County flows through a relatively narrow valley and therefore, flooding tends to be to deeper depths than along the Skunk River. Productive land along the Des Moines River that floods sufficiently that crops must be replanted about every third year currently sells for about $400 per acre. Land of comparable productive capacity but lying at higher elevations currently sells for about $700 per acre. It should be noted that farmland in this area is currently in great demand. One interviewee noted that "farmers are so eager to buy (land) that they don't even ask the questions that they don't want to hear the answer to". He was referring specifically to the possibility of flood damages on crop land.

Another viewpoint was expressed by a land assessor with recent experience in Story County. He indicated that no flood damage along the Skunk River had been brought to his attention in the last nine years.

A review of the public record of land sales was made for Story County for a recent year to determine if the possibility of flooding was reflected in the selling price. Although a number of land sales occur each year in the Skunk River valley it was not possible to discern any tendency toward either higher or lower prices relative to nearby land. The issue is clouded by conditions leading to the transfer, such as a change from farm land to rural residences or industrial uses, the presence, or absence, of sets of improvements of varying values, and the recording of an artificial price due to other considerations of value being included in the transfer.

An excellent study of the variables which influence flood damage evaluation has been reported (Nissen, 1968).

Flood Plain Management Techniques

A broad range of techniques is available for the management of flood plains (N.Y. State Water Resources Commission, 1967). The principal categories are information, planning, regulation, public investment protection, and acquisition. The Ames Lake Project envisions the use of protection by upstream reservoir only. Lower total cost alternatives may be possible by using another technique or combination of techniques.

The preparation, distribution, and use of information concerning flood hazards and flood plain use offers the potential of reducing flood damages in the long-run. Since current damages are mainly agricultural and result from inundation of crop and farm buildings there is little likelihood of the land use significantly changing as a consequence of additional information being available. However, to the extent that future construction of homes and businesses on the flood plain is discouraged, savings would accrue in the long-run.

Planning is successful to the extent that it results in the choosing of a combination of regulatory measures protective measures, and other techniques best suited to the individual area. Applied to the Skunk River flood plain it involves determining needs and demands for land use on and adjacent to the flood plain, and the degree of flood hazard.

Regulation of land use on the flood plain could be used to limit future development and consequent flood damages. It may be desirable to impose some limitations such as channel encroachment laws, flood plain zoning, or an official map designation of open areas. A policy of restricted public investment for items such as roads, bridges, and public buildings also may be helpful in reducing flood damages.

Physical protection from floods by means other than upstream reservoirs has been used in the past and may prove to be an acceptable means of further restricting flood damages in the future. Channel improvements and levees along the Skunk River and below Ames date back to before 1900. Additional degrees of protection could be afforded in the future by further work of this nature. A comprehensive system of levees, channel stabilization works, and interior drainage and pumping facilities would be a structural, engineering works alternative to the proposed flood control reservoir. However, the study and development of this alternative on a detailed basis was outside the scope of the review study. It would, under present funding policies of the federal government, require more local landowner participation (lands, easements, rights-of way and maintenance) than would the reservoir project.

Summary

A major component of the economic justification for the Ames Lake Project is reduced flood damages. The selection of a frequency analysis and method of use thereof can have a sizeable effect on the dollar estimate of benefits. Based on the assumption and methodology of this chapter it was estimated that with the Log Pearson Type III distribution, the benefits would be 0.52 times the value originally estimated by the Corps, which was based on the log normal distribution.

Flood control benefits for flood plain lands in agricultural production are strongly influenced by costs of production, product selling prices, and yields per acre. Using what is considered to be a reasonable set of revised values for these variables it was estimated that the flood control benefits would be 1.7 times the value originally estimated by the Corps.

Additional estimates of flood damages were sought which would be independent of the Corps values. Published U.S. Weather Bureau values are included as well as impressions obtained from interviews. Results are inconclusive. Attention is called to the several flood plain management techniques that are available to reduce the economic losses from flooding, some of which may be desirable alternatives in the upper Skunk River watershed.

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The assistance of Dr. Dougal, the secretarial staff of the Agricultural Engineering Department and staff members of the Agricultural Engineering Department is recognized and much appreciated.

AMES RESERVOIR ENVIRONMENTAL STUDY

Appendix 4

PHYSICAL RELATIONSHIP WITH THE AGRICULTURAL SECTOR

Chapter 8

ALTERNATIVE LAND AND WATER MANAGEMENT PROGRAMS

by

David B. Palmer

1973

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FIGURES

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Chapter 8

ALTERNATIVE LAND AND WATER MANAGEMENT PROGRAMS

David B. Palmer

Several opportunities exist for reducing the impact of agricultural operations on the Ames Lake Project. In a like manner the impact of the Project on agricultural production can be lessened by incorporating certain modifications into the project plans. Such project features include the use of Public Law 566, drainage outlet protection, and flood-control-pool land management.

Public Law 566 Application

The Iowa Conservation Needs Inventory (1970) includes a Conservation Needs Inventory of Watersheds. Therein the U.S. Soil Conservation Service delineated lands which were thought to be "potentially feasible watersheds." These small watersheds were selected on the basis of data furnished by field technicians and were not subjected to a serious physical or economic evaluation.

Under the Public Law 566 program (Watershed Protection and Flood Protection Act, 1954), project purposes include drainage improvements, flood control, wildlife improvements, water supply and erosion control. Recreation can also be included if 50 percent financial participation can be obtained from local sponsoring groups. Water supply can be included only where local sponsoring groups underwrite the entire additional costs. Exclusive of the Squaw Creek drainage area, the Conservation Needs Inventory delineated ten subwatersheds in the Upper Skunk River Basin. If developed as projects, the subwatersheds above

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Ames would obtain their benefits from improved drainage, with a small amount of flood damage alleviation. The subwatersheds below Ames would also be primarily drainage improvements. The subwatershed in the northwest corner of Story County could also include a wildlife improvement area. The subwatersheds which were delineated are shown in Figure 4-8-1 and are described as follows:

04. Bear Creek. This watershed contains 20,000 acres, 5,520 of which are in need of project-type drainage.

03. Long Dick. This watershed contains 21,380 acres of which 190 acres are suffering flood damages. Fifteen thousand eight hundred eighty acres are in need of drainage and 9,580 acres are in need of group drainage effort.

02. Upper end of Skunk main stem. Seventeen hundred acres of this subwatershed were classed as having flood water and sedimentation problems. Twenty eight thousand two hundred ten acres have drainage problems with 16,340 acres needing project drainage improvements.

01. This subwatershed is on the tributary that goes through Jewell, Iowa. Forty eight thousand one hundred acres have a drainage problem with 23,600 acres needing project-type action.

05. Keigley Creek. Six hundred acres were delineated as having flood and sedimentation problems. Of the 16,725 acres having drainage problems in the subwatershed, 12,580 are in need of project type action.

06. Next lower section (below 02) of the Skunk River main stem. In this subwatershed 21,000 acres have flood water and sedimentation damage. Seventeen thousand five hundred acres have drainage problems with 11,400 needing project type action. There are also erosion problems in the subwatershed.

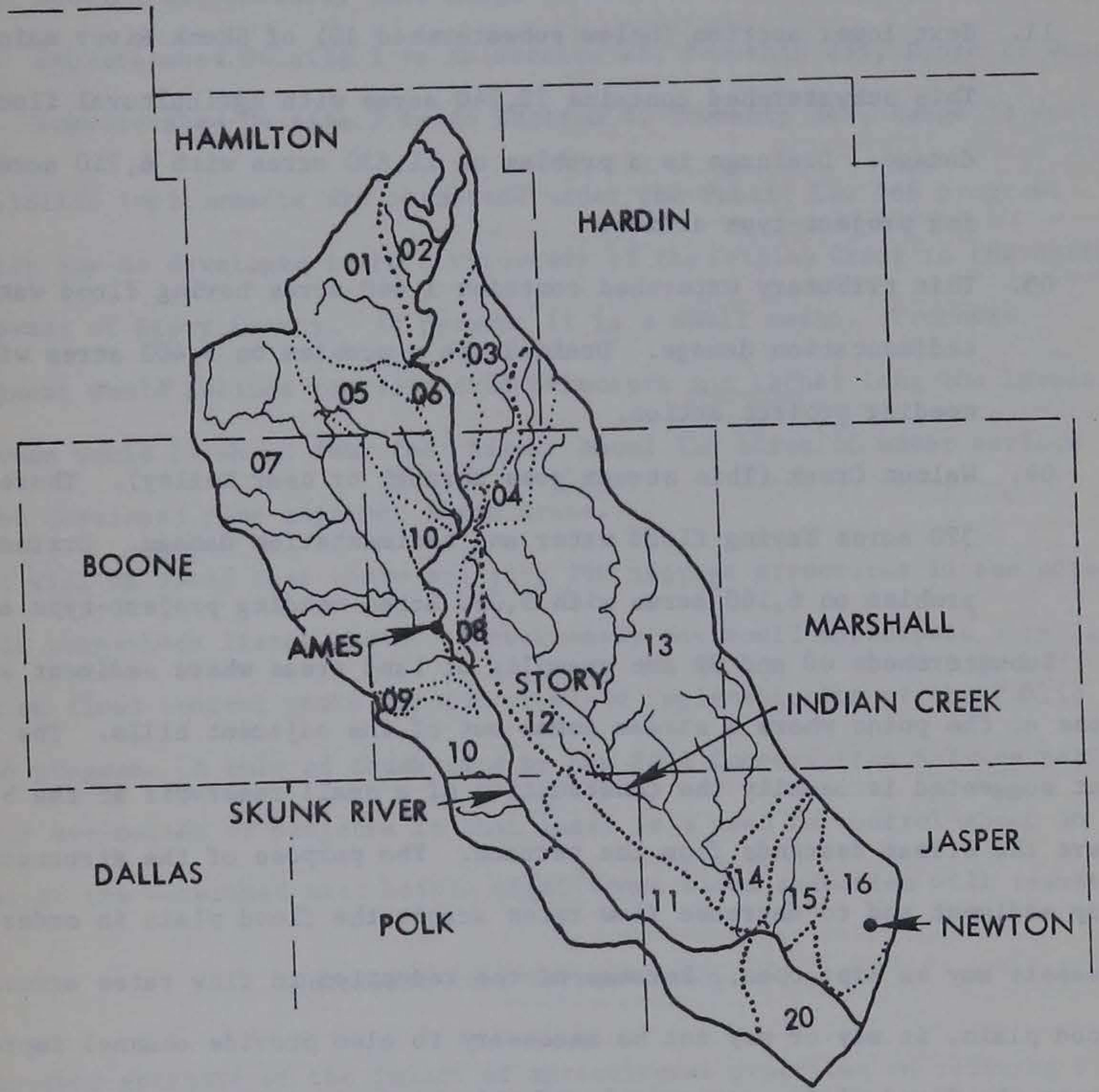

Fig. 4-8-1. Potentially feasible watersheds — South Skunk River (using Soil Conservation Service source map).

10. Skunk River main stem from Ames downstream to a line approximately between Elkhart and Loring, Iowa. In this subwatershed there are 14,570 acres with a flood problem, 31,780 acres with a drainage problem of which 18,060 acres need project-type action.

11. Next lower section (below subwatershed 10) of Skunk River main stem. This subwatershed contains 12,240 acres with agricultural flood damage. Drainage is a problem on 11,630 acres with 6,750 acres needing project-type action.

08. This tributary watershed contains 1,440 acres having flood water and sedimentation damage. Drainage is a problem on 3,400 acres with 2,400 needing project action.

09. Walnut Creek (This stream goes through or near Kelley). There are 320 acres having flood water and sedimentation damage. Drainage is a problem on 6,160 acres with 5,000 acres needing project-type action.

Subwatersheds 08 and 09 are examples of land areas where sediment accumulates at the point where a stream comes out of the adjacent hills. The improvement suggested is usually the construction of a small reservoir at the break where the stream descends from the terrace. The purpose of the structure is to trap sediment and to decrease flow rates across the flood plain in order that channels may be kept open. Because of the reduction in flow rates across the flood plain, it may or may not be necessary to also provide channel improvements across the flood plain. An example of this kind of structural control is located on Route 210 east of the Skunk River. Improvements of this type would have little or no effect on flood damage reduction in the Skunk River Basin as influenced by the Ames Lake Project since peaks on these small watersheds would likely occur at a different time than peaks for the larger watersheds.

The Soil Conservation Service identified but did not evaluate three possible structure sites:

1. Site in subwatershed 02. This would be located on County Road D, Section 25, Township 88N, Range 24 West.
2. Subwatershed 04 site 1 is in Section 28, Township 85N, Range 23 West.
3. Subwatershed 04 site 2 is in Section 4, Township 84N, Range 23 West.

Wildlife improvements are permitted under the Public Law 566 program. One which may be developed is on a tributary of the Keigley Creek in the northwest corner of Story County. At present it is a small marsh. Proposed development would include concrete drop structure and rather long low levees. The levees would be about four feet high. About 110 acres of water surface could be developed plus adjacent marsh areas.

It will be noted that there are very few storage structures in the potentially feasible watersheds listed above. Consequently one would anticipate very little effect on flood control peaks through complete implementation of the Public Law 566 program. A rule of thumb used by the Soil Conservation Service personnel in their evaluation of projects is that there is a need to control about 50 percent of the watershed area before significant flood reduction will result.

Northwest Iowa Terrace Study.

Another estimate of the impact of agricultural practices on reducing flood peaks was prepared by the Soil Conservation Service about 20 years ago for an area in northwest Iowa. Table 4-8-1 indicates the effects of level terraces in reducing runoff on the Floyd River.

Table 4-8-1. Effects of level terraces in reducing runoff on the Floyd River in Northwest Iowa**

*Our studies also show the following preliminary estimates.

Extent of runoff and Terraced Area	Peak runoff, cfs
0.9 inches runoff	
Natural Peak	10,600
17% Terraced	8,150
30% Terraced	6,300
37% Terraced	5,500
1.79 inches runoff	
Natural Peak	36,000
17% Terraced	24,300
30% Terraces	18,600
37% Terraced	15,500
2.86 inches runoff	
Natural Peak	76,000
17% Terraced	63,800
30% Terraced	54,000
37% Terraced	52,000
3.48 inches runoff	
Natural Peak	96,000
17% Terraced	84,500
30% Terraced	80,000
37% Terraced	71,000

*The reduction in peak flow indicated above is based on a maintained effective terrace capacity of 1-1/2 inch of water storage and an infiltration capacity that brings this to 1.8 inches of water storage. If a higher capacity or larger level terrace is constructed and maintained the effect on floods would be greater than shown above and, on the other hand, if smaller terraces were built the effect would be less. We believe that the figures we have presented are conservative as to the effect level terraces will have in reducing floods in the Floyd River.

**Excerpts from a STATEMENT OF SOIL CONSERVATION SERVICE at MEETING ON FLOYD RIVER WATERSHED, LeMars, Iowa, September 29, 1954 by Frank H. Mendell, State Conservationist, Soil Conservation Service.

The estimates were prepared by assuming different fractions of the watershed were level terraced. The combined affect of the terrace storage capacity and the infiltration capacity that would occur during the storm period was assumed to total water storage depth of 1.8 inches. Larger terrace storage capacities would show greater reduction in peak runoff rates for a given percentage of the watershed terrace than those shown in the table. For example, it will be noted that for a storm giving 2.86 inches of runoff that the natural peak, or the predicted peak runoff rate with no terracing, would be 76,000 cubic feet per second. As the percentage of the land increases from 17 percent to 37 percent, the estimated peak runoff rate would decrease to 52,000 cubic feet per second. At the time that the estimates were prepared the Soil Conservation Service noted their belief that the figures were conservative regarding the effect that level terraces would have in reducing floods in the Floyd River watershed.

The use of tile-outlet terraces as flow control and water storage devices has received little emphasis outside of agriculture. If properly designed, constructed, and maintained, terraces provide flood control and sediment control benefits and, concurrently, some control of movement of nutrients and pesticides. Usually two inches of storage are provided. Discharge is maintained at low rates up to 36 hours. Greater inundation time may damage the crop.

Off site benefits of terraces are:

1. Reduced sediment loads to streams (Laflen, et. al., 1972),
2. Reduced peak discharges from design of structures such as spillways and culverts,
3. Reduced flood peaks, and
4. Higher base flows in permeable soils.

Some problems with tile outlet terraces are:

1. Failure by washout the first year or two after construction, and
2. Lack of proper maintenance needed to repair washouts, remove trash from inlets, and repair other damage.

Terraces offer about the only proven method of sediment control where a large percent of the land is planted to row crop and slopes are greater than 4 percent. Much of the land in the Skunk River Reservoir Watershed has a lesser slope. Terracing the steeper cropped land which delivers water directly to the Skunk River and its major tributaries would sharply reduce the quantity of sediment delivered to the reservoir (see Chapter 3, Appendix 4, Reservoir Sedimentation).

Project Impact on Drainage Outlets

One question of considerable concern to farmers and land owners above the dam site is the affect that water in the reservoir would have on the flow from existing tile drainage systems. On several occasions the opinion has been expressed that tile drainage systems on watershed lands above the dam site would be adversely affected when the water level rises. A survey of "County" drainage district systems was made to determine the extent of the problem. Since the maximum elevation of the flood pool is at elevation 976, the location and size of all drainage outlets below that elevation was noted. After the outlets had been identified in the drainage record, a field investigation was conducted to determine the exact location of these outlets. The outlets were also examined to ascertain whether they were functional. The next step in the investigation was the location of drainage systems that drain individual farms. Since the conservation pool is at elevation 950, the location of drainage outlets between 950 and 976 were primarily concerned.

Table 4-8-2 summarizes the potential impact on drainage systems of the watershed by the operation of the reservoir. It will be noted that three zones have been delineated. Zone 1 comprises those lands lying below elevation 976. Zone 2 includes those lands which are drained and which lie above elevation 976, but whose outlet is below elevation 976. Zone 3 comprises those lands drained above 976 which also have their outlet above elevation 976. Zone 1 lands will either be purchased outright or flowage easements will be obtained. Thus, drainage systems will be considered in purchase or easement arrangements.

For lands in Zone 2 the drainage system itself would not be inundated by fluctuating water levels in the reservoir, but the outlet to the system would be periodically under water. In Zone 3 no significant problem is anticipated since both the lands being drained and the outlet are above elevation 976.

Table 4-8-2. Impact on drainage systems.

	(Flood Pool to Elev. 976)		
Zones	Drained land is below 976	Outlet is below 976	Remedial measures needed
1	Yes	Yes	None (land to be controlled by govt.)
2	No	Yes	Replace tile with open ditch to 976 contour
3	No	No	None

It is recommended that certain modifications be made as a part of the project where the outlet to the subsurface drain system is between elevations 976 and 950. The possible problem related to the proper functioning of drainage outlets in this region is that fluctuating water surfaces in the reservoir would permit the deposition of sediment in the outlet, thus restricting its flow over a long period. Even though there is relatively small likelihood of this occurring, any possible problem of this kind could be prevented by constructing a length of open channel from the existing tile outlet location to elevation 976. There is also the possibility of some backwater affect in the streams draining into the reservoir. This backwater affect at times of high flow into the reservoir would increase slightly the stages in the streams for a short distance upstream from the 976 water surface elevation. However, this backwater effect would be relatively minor in the streams of the watershed. When this is taken into account along with the infrequent rise of the reservoir surface to elevation 976, the adverse affect on the drainage systems above that elevation is negligible.

The areas of concern are in sections 32, 31, 30, 19, and 18 in Howard Township, and sections 35, 36, 25, 26, 27, 22, 24, 13, and 2 in LaFayette Township in Story County, Iowa. The remaining areas are either located below 950 feet or have systems that outlet on the valley walls above 976 feet.

The only District Drainage Systems that outlet below 976 feet are LaFayette No. 73 and LaFayette No. 106. The LaFayette No. 73 drain outlets about 300 feet away from the 976 feet contour in a 22 inch tile. The outlet is located in the NW 1/4 of SE 1/4 of section 24 in LaFayette Township. The exact location is 800 feet south of the east-west centerline and 1800 feet west of that point. The LaFayette No. 106 drain outlets directly into the Skunk River in section 12 of LaFayette Township. The outlet is located in the NE 1/4 of the SE 1/4 of that section and is a 12 inch clay tile. It extends about 500 feet laterally below the 976 foot elevation.

Some individual systems involved are:

Location	Outlet Size	Lateral Distance from 976 Foot Contour
Section 24 LaFayette SE corner NW 1/4 SE 1/4	8" CMP	200 feet
Section 24 LaFayette Middle of east edge Se 1/4 SE 1/4	4" clay tile	400 feet
Section 19 Howard Middle of SW 1/4 SW 1/4	5" clay tile	1500 feet
Section 25 LaFayette SW 1/4	Three outlets	
Section 36 LaFayette Middle of east edge NW 1/4 NW 1/4	5" clay tile	100 feet
Section 36 LaFayette Middle of south edge NW 1/4 NW 1/4	5" clay tile	300 feet
Section 12 LaFayette West of middle NE 1/4 SW 1/4	8" CMP	500 feet

REFERENCES

1. Iowa Conservation Needs Inventory. U.S. Soil Conservation Service, Des Moines, Iowa. 1970.
2. Soil Loss From Tile Outlet Terraces. Journal Soil and Water Conservation 27: 74-77. 1972.
3. Watershed Protection and Flood Prevention Act. P.L. 566, 83rd. Congress, 68 Stat. 666 and amendments thereto. 1954.

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