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THE RURAL-URBAN WATER
QUALITY INTERFACE OF WILDCAT CREEK

by

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A MASTER'S REPORT

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INTRODUCTION

This report surveys the recent literature on rural and urban runoff and compares the literature with the results of the water quality analysis obtained from Wildcat Creek and its tributaries.

Samples were taken from the creek and from the urban runoff storm sewers, during or shortly after rainfall. Several parameters were examined but the main emphasis was place on establishing relationships between organic loading of urban drainage and dissolved oxygen content of the creek. Samples were taken from the urban runoff and time and distance were allowed to insure proper mixing of the runoff and the stream. Then samples were taken from the stream.

This water quality survey points out the significance of urban runoff in the consideration of stream pollution. This can be an added load to streams which are already heavily loaded from rural pollution. This report also points out the need for further study on the portion of Wildcat Creek that does not meet the Kansas Water Quality Standards.

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LITERATURE REVIEW OF RURAL WATER POLLUTION

Rural Runoff Studies

The factors determining the effect of rural runoff on receiving streams are many. Among them are: the size of the watershed, the type of soil and cropland, the hydrological characteristics of the watershed and stream, the amount of additives applied to the soil and the chemical and biological characteristics of the stream.

Weidner, et al (1) attempted to correlate the quality of runoff with soil losses for different types of crops. Table 1 contrasts land management practices and Table 2 gives the average soil loss over a period of several years.

Table 3 compares the average annual loads from the various types of watersheds. Watershed 113 used the improved practice of land management while watershed 118 used the prevailing practice.

Table 1 (1)

—Contrast of Land-Management Practices

Prevailing Practice	Improved Practice
Straight-row tillage across the slope	Contour tillage
Low level of fertilizing	High level of fertilizing
Liming to pH 5.4	Liming to pH 6.8
Alsike-red clover-timothy mixture for meadow	Clover-alfalfa-timothy mixture for meadow

Table 2 (1)

—Average Soil Loss by Crops in 4-Year Rotation, Coshocton, Ohio, 1945–1956

Crop	Time on Land	Soil Loss (tons/acre)	
		Pre-vailing	Im-proved
Corn	May 1–Oct. 10	7.70	2.03
Wheat	Oct. 11–Apr. 30	0.88	0.14
Meadow	33 months	Trace	Trace
Total for 4-year rotation	—	8.58	2.17

Table 3 (1)

—Calculated Average Annual Loads

Watershed No.	Cover	TS (lb/acre)	BOD (lb/acre)	COD (lb/acre)	PO_4 (lb/acre)	Total N (lb/acre)
113	Corn	3,660	27.5	480	8.4	88
118	Corn	13,200	120.0	1,300	27.7	237
113	Wheat	480	3.7	64	1.1	11
118	Wheat	1,730	15.5	170	3.6	31
113	Meadow	Trace	—	—	—	—
118	Meadow	Trace	—	—	—	—

This shows that there appears to be some means available for reducing the pollution load. Despite an increase in the amount of fertilizers and manure applied under improved practices, there is a marked decrease in the amount of pollutants that come from the watersheds of the improved practices as contrasted to loads from watersheds using prevailing practices.

Table 4 shows the mean concentrations of the parameters per storm, however no reason was given for the high BOD and COD concentrations of the improved practices watersheds.

Table 4 (1)

—Mean Concentrations of Constituents per Storm, with Land in Wheat

Constituent	Concentration in Given Watershed (mg/l)	
	118	113
TS	500	540
BOD	2.9	7.2
COD	40	80
Total N	6.0	9.0
PO_4	1.3	1.8

Table 5 (1)

—Bacterial Counts in Stormwater Runoff Samples from a Rural Area*

Kind of Organism	Watershed No.	Counts Exceeded in Designated Percent of Samples (Storm Composites) (counts/100 ml)		
		90%	50%	10%
Coliform†	113 Imp.	220	3,000	36,000
	118 Prev.	80	2,500	42,000
	185 Imp.	1,800	3,000	70,000
	192 Prev.	100	4,400	110,000
	196 M. prev.	1,300	8,100	180,000
Fecal coliform†	113 Imp.	<2	8	80
	118 Prev.	<2	<2	80
	185 Imp.	<2	20	1,100
	192 Prev.	<2	18	4,600
	196 M. prev.	22	1,200	56,000
Fecal strep.‡	113 Imp.	320	1,500	21,000
	118 Prev.	38	610	5,800
	185 Imp.	24	3,700	4,800
	192 Prev.	90	1,100	150,000
	196 M. prev.	1,200	8,400	19,000

* Samples taken during 1964 at Coshocton, Ohio.
† Coliform organisms and fecal coliform organisms were determined by MF techniques using M-Endo and M-FC media, respectively.
‡ Fecal Streptococci were detected by KF Streptococcus agar pour plates.

Table 5 lists the microbial densities found in the runoff from some of the watersheds surveyed by Weidner. As would be expected, the fecal streptococci exceeded the fecal coliform organisms, therefore one could conclude that the source of pollution is from animals rather than humans (2).

Fertilizer Usage

Much has been written about the effects of fertilization and runoff in regard to the water quality of lakes and streams. Sawyer (3) attributes the amount of eutrophication of lakes to primary production, which can increase as the critical limiting nutrients increase. Eutrophication, described briefly, is the process whereby lakes become enriched with nutrients resulting in water quality characteristics undesirable for man's use of the water (4).

The major critical limiting nutrients are regarded as nitrogen and phosphorus. When these nutrients are abundant, excessive weed growth in shallow water inhibits swimming, boating, and fishing. Excessive algal growth imparts tastes and odors to the waters and results in the accumulation of dead organic matter on the lake bottom. During prolonged periods of lake stratification, metabolism of the organic matter by bacteria depletes the oxygen supply near the bottom, resulting in the loss of desirable fish species. Perhaps the most devasting aspect of eutrophication is that the process is irreversible, except in rare and unusual cases. When a lake has become eutrophic, it remains so for a very long time even if the source of extra nutrients is cut off.

It has been estimated that each pound of phosphorus (other nutrients being available) results in the production of about 30 lb. dry weight of algae (4). It is claimed that some species of algae cause gastric disturbances in humans who consume such infested waters. Several species of blue-green algae produce, under certain conditions, toxic organic substances that kill fish, birds, and domestic animals (5).

Because nitrogen is highly soluble, many are quick to associate statistics on the rapid expansion of fertilizer use with suspected increases in water pollution from nitrates; however, the behavior of nitrogen in soil is highly complex. Besides the nitrogen added to soil in the form of fertilizers, one must consider the organic matter in the soil and the rate at which it is mineralized, the atmospheric nitrogen that is fixed either symbiotically or nonsymbiotically, the nitrogen involved in crop utilization and leaching, the nitrogen assimilated by micro-organisms, and the nitrogen returned to the atmosphere (6).

Phosphorus, when it is added to soil in the form of fertilizer, is rapidly immobilized through adsorption on clays or precipitation as iron or aluminum phosphates. Because of this low solubility, the loss of fertilizer phosphates in water is not significant, expecially in relation to the quantities released from municipal and industrial wastes. Phosphorus additions to water bodies from agricultural lands are almost wholly associated with erosion (6). Thus, erosion control practices, which include high levels of fertilization to provide good plant cover, will tend to control water pollution from phosphorus.

Attempts have been made to relate the rate of eutrophication of a lake with amount of macronutrients available, but the fact that algae will store phosphorus if it is present in amounts in excess of immediate growth requirements, has complicated these relationships (7).

Sawyer (3) recommends the control of phosphorus as an aid to inhibition of eutrophication because removal methods have been well established and because it offers the only known hope of controlling the growth of nitrogen-fixing blue-green algae.

Viets (8) states that, although excess nitrogen and phosphorus have been blamed for eutrophication, organic pollution is essential in order to provide the CO_2 needed by algae. Furthermore, agricultural runoff is difficult to measure and present methods are only crude measurements of agricultural input in the stream. Viets (8) also reports that severe restriction or the banning of fertilizer would have serious effects on our supply and cost of food.

It appears that controls on the use of fertilizer in agricultural areas will eventually be implemented. This control will strictly depend on the area, type of crops, watershed and erosion as well as the findings from close monitoring of the lakes and streams in the area.

The Federal Water Pollution Control Administration (5) has set guidelines that serve as indicators that eutrophic conditions could possibly be proceeding. These indicators are listed on page 7.

Indicators of Initial Eutrophic Conditions (5)

(1) A slow overall decrease year after year in the dissolved oxygen in the hypolimnion as indicated by determinations made a short time before the fall overturn and an increase in anaerobic areas in the lower portion of the hypolimnion.

(2) An increase in dissolved solids—especially nutrient materials such as nitrogen, phosphorus, and simple carbohydrates.

(3) An increase in suspended solids—especially organic materials.

(4) A shift from a diatom-dominated plankton population to one dominated by blue-green and/or green algae, associated with increases in amounts and changes in relative abundance of nutrients.

(5) A steady though slow decrease in light penetration.

(6) An increase in organic materials and nutrients, especially phosphorus, in bottom deposits.

Recommendation: The Subcommittee wishes to stress that the concentrations set forth are suggested solely as guidelines and the maintenance of these may or may not prevent undesirable blooms. All the factors causing nuisance plant growths and the level of each which should not be exceeded are not known.

(1) In order to limit nuisance growths, the addition of all organic wastes such as sewage, food processing, cannery, and industrial wastes containing nutrients, vitamins, trace elements, and growth stimulants should be carefully controlled. Furthermore, it should be pointed out that the addition of sulfates or manganese oxide to a lake should be limited if iron is present in the hypolimnion as they may increase the quantity of available phosphorus.

(2) Nothing should be added that causes an increased zone of anaerobic decomposition of a lake or reservoir.

(3) The naturally occurring ratios and amounts of nitrogen (particularly NO_3 and NH_4) to total phosphorus should not be radically changed by the addition of materials. As a guideline, the concentration of total phosphorus should not be increased to levels exceeding 100 $\mu g/l$ in flowing streams or 50 $\mu g/l$ where streams enter lakes or reservoirs.

(4) Because of our present limited knowledge of conditions promoting nuisance growth, we must have a biological monitoring program to determine the effectiveness of the control measure put into operation. A monitoring program can detect in their early stages the development of undesirable changes in amounts and kinds of rooted aquatics and the condition of algal growths. With periodic monitoring such undesirable trends can be detected and corrected by more stringent regulation of added organics.

Pesticide Usage

Lichtenstein and Schultz (9) found that persistance of hydrocarbon insecticides was influenced by soil types, rate of application and temperature.

Pesticides are transported in the air and deposited on areas remote from the area of original application. If high winds are coincident with dust clouds, even a trace of precipitation may deposit unusually large amounts of contaminants on sites far from the source of the contaminant. DDT has been found in rain collected in a rural environment, near Riply, Ohio, in amounts of 0.06 ug/l some 500 feet from a vineyard in which the DDT was applied (10).

In the U.S., all of the different chlorinated hydrocarbon insecticides have been reported in rivers, sometimes in large quantities (11). DDT can induce behavioral changes in fish that could lead to reproduction problems. DDT also affects the mortality rate of the young fish and causes changes in the physiology of fish-eating birds (12).

Since many pesticides and herbicides contain organic chlorine, measures of this constituent can be used as an index to the quantities of the chemicals employed (13), however caution should be exercised since organic chlorine can originate from other sources.

Realizing the potential hazards involved with the use of pesticides, the United States Public Health Service has set up Community Pesticide Laboratories throughout the nation (14). The primary purpose of these laboratories is to monitor pesticide levels in man and his environment and to determine if any relationships exist between certain human disorders and pesticide residues in man.

Table 6 gives the toxicity of several organic phosphorus and chlorinated hydrocarbon insecticides to bluegills.

Table 6 (15)

Comparative Toxicity of Several Organic Phosphorus and Chlorinated Hydrocarbon Insecticides to Bluegills in Soft Water at 25°C.

Organic Phosphorus Insecticides	96-hour TLm mg/L	Chlorinated Hydrocarbon Insecticides	96-hour TLm mg/L
Guthion	0.0052	Endrin	0.0006
Delnav	0.0340	Toxaphene	0.0035
Di-Syston	0.0630	Dieldrin	0.0079
Malathion	0.0900	Aldrin	0.0130
Parathion	0.0950	DDT	0.0160
EPN	0.1000	Heptachlor	0.0190
Chlorthion	0.7000	Chlordane	0.0220
Methyl Parathion	1.9000	Methoxychlor	0.0620
Dipterex	3.8000	BHC	0.7900

Animal Wastes

The practice of raising large numbers of animals in a small area has complicated the process of disposing of the animal waste and has increased the chance of water pollution. In recent years it has become common practice to spread manure on frozen ground or even on snow cover. When the snow melts or the rains come, soluble nutrients are leached from the manure and are carried to the nearest watercourse whenever surface runoff occurs, which is 100% certain if the ground is frozen. An appreciation of the magnitude of the problem can be estimated from the knowledge that the wastes of one dairy cow are equivalent to those of 17 people (3).

About 2/3 of the U.S. beef output now comes from feedlots. A single beef feedlot containing 10,000 head produces 200 tons of solid waste plus 100 tons of liquid waste daily, an amount equal to that of a city of 160,000 people (16).

The three components of feedlot runoff which are of greatest concern are the organic matter, nitrogen, and microorganisms as outlined by Miner (17). The decomposition of the organic matter causes a decrease in the dissolved oxygen of the stream, which may proceed to anaerobic conditions. Under anaerobic conditions, nitrogen is converted to ammonia, while under aerobic conditions nitrate is formed. The microorganisms present may be important in the spread of disease, especially where the receiving stream is tributary to a water recreation area.

During the initial planning and location of cattle feedlots, water pollution problems can be minimized. The following control measures are outlined by Miner (17):

1. Runoff from adjacent areas should not be allowed to flow across the feedlot.
2. Feedlots should be located in areas with good drainage.
3. Lots should be designed as small as feasible.
4. Feedlots should be located and designed so there is space for pollution control facilities.

Silt Pollution

Sediment is considered the greatest pollutant coming from agricultural land (18). A report of the Senate Select Committee on Water Resources indicated that by volume, suspended solids in the nations streams amount to at least 700 times the loadings caused by sewage discharge (16). A major problem by itself, sediment also carries other pollutants. As stated previously, virtually all of the phosphates and most of the pesticides carried in streams are carried on sediment.

The detrimental effects of sediment in water are that stream channels are filled and this causes physical and biological changes in the stream. These changes include blanketing of bottom dwelling flora and fauna, alteration of the flora and fauna as a result of changes of light transmission and abrasive effects of sediment, and alteration of the species of fish as a result of changes produced in the flora and fauna upon which the fish depend.

Erosion and sedimentation also pose a severe problem for downstream property owners.

Proper soil conservation practices have the greatest potential of controlling agricultural silt pollution.

Salinity in Relation to Agriculture

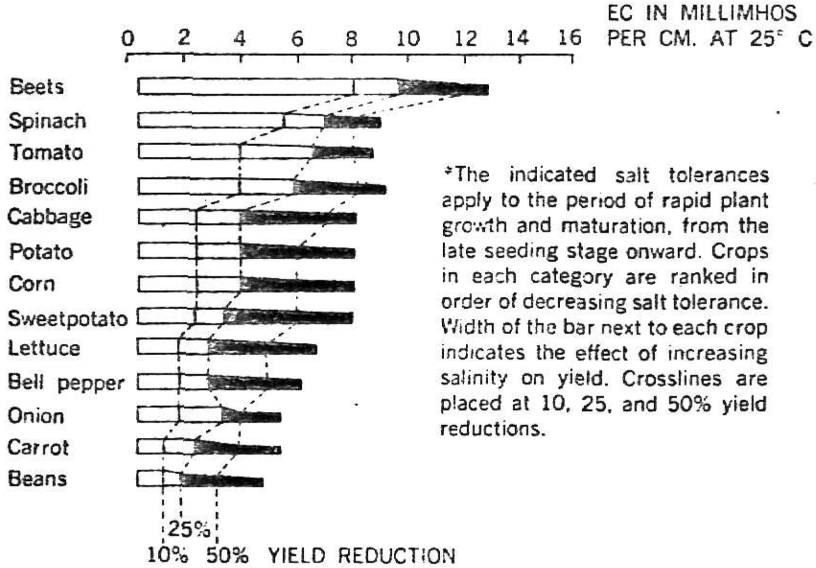
One of the most serious long-term effects of increased salinity of waters involves the use and re-use of water in irrigation. It has been estimated that about 25% of the irrigated land of the U.S. is now affected to some degree by water salinity (12). Irrigation water brought onto a field always contains some dissolved salts. The concentration of these salts is in the range of 25 to 8000 mg/l. Plants extract water from the irrigated field, but most of the dissolved salts are excluded by the roots. Water that evaporates from the soil surface leaves dissolved salts behind. These two processes cause residual salts to accumulate in the soil.

Table 7 (12)

SUGGESTED GUIDELINES FOR SALINITY IN IRRIGATION WATER

CROP RESPONSE	TDS mg/l	EC[1] mmhos/cm
Water for which no detrimental effects will usually be noticed	<500	<0.75
Water which can have detrimental effects on sensitive crops	500-1,000	0.75-1.50
Water that may have adverse effects on many crops and requiring careful management practices	1,000-2,000	1.50-3.00
Water that can be used for salt-tolerant plants on permeable soils with careful management practices	2,000-5,000	3.00-7.50

[1]Electrical conductivity.



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seeding stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10, 25, and 50% yield reductions.

SALT TOLERANCE OF VEGETABLE CROPS

Figure 1 (12)

Table 7 and Figure 1 give crop responses to various concentrations of total dissolved inorganic solids (TDS) in irrigation water. In order to put these figures into perspective, it is worth noting that the Colorado River has a TDS of 750 mg/l by the time it reaches the Imperial

Dam in California. A farmer who applies 5 feet of water during the growing season in the Imperial Valley in California, also applies 6 tons of dissolved salts/acre.

The recommended TDS level for drinking water is 500 mg/l. The salinity is also expressed in terms of electrical conductivity (EC).

Water Quality Surveys in Agricultural Watersheds

Stream Surveys

Two surveys in small agriculture watersheds are reported by Cherryholms (14) and Stoltenberg (19). Stoltenberg reported on Soldier Creek in northeastern Kansas and Cherryholmes reported on the Clear Creek drainage basin in Iowa. Soldier Creek basin is predominately agricultural and there are no point sources of pollution located within the watershed. Approximately 80 percent of the Clear Creek basin area is cultivated fields, however two towns, one of population 311 and the other of population 633 both discharge their secondary treated sewage into the creek.

Flows

Soldier Creek has a 35 year average discharge of 124 cfs at Topeka and Clear Creek has an average of 53.5 cfs.

Phosphate Levels

Stoltenberg detected phosphate levels from 0.18 to 4.0 mg/l (as PO_4). Cherryholmes had a maximum concentration of 1.5 mg/l of orthophosphate.

Nitrate Nitrogen

Stoltenberg observed nitrate levels from 0.05 to 10 mg/l (as N), while Cherryholmes's values ranged from 0.05 to 2.5 mg/l.

Ammonia Nitrogen

Cherryholmes's values of ammonia nitrogen varied from 0.05 mg/l (as N) to 1.86 mg/l. Stoltenberg's values ranged from 0.16 to 0.30 mg/l at low flow with maximums up to 1.8 mg/l during runoff.

BOD and DO

Stoltenberg observed BOD values from 2 to 14 mg/l while Cherryholmes's spring runoff values ranged from 1.3 to 23.2 mg/l.

Stoltenberg had DO values above 5 mg/l the entire year.

Biological Observations

Stoltenberg found summer values of total coliforms to be about 4200/100 ml at a flow of 73 cfs. Cherryholmes's values of total coliforms never dropped below 1300 organisms/ 100 ml and reached 1,000,000/100 ml during flood conditions.

LITERATURE REVIEW OF URBAN WATER POLLUTION

Introduction

Few efforts have been made to identify and quantify the important water quality constituents of urban drainage. However it is becoming increasingly clear that drainage from urban areas can be a significant factor in the pollution of streams (13)(20).

Street Litter

Description

In general, pollutants known as street litter are introduced into storm drainage systems through inlets or open channel sections. Storm water inlets often become depositories for lawn clippings, papers, sticks, rubble and other items of refuse. These materials often tend to fill inlets causing partial or total bypass of flow, create stagnant pools, decompose, or become lodged in downstream points and retard flow. A field survey conducted by the American Public Works Association (15) showed that the average amount of street refuse ranged from 2.4 lb/day/100 foot of curb for residential areas to 4.7 lb/day/100 foot of curb for commercial areas. The amount of the dust and dirt fraction of the litter varied from 45 to 83 percent of the total litter.

Pollution Potential of Street Litter

The following page reviews the findings of the American Public Works Association Survey (15) with respect to the average amount of soluble matter in dust and dirt samples. It also goes through an example of how to compute the pollution potential of street litter.

Table 8 (15)

Amount of Pollutant by Type of Land Use

Item	Single Family	Multiple Family	Commercial
Water Soluble (mg/g)	6.0	5.6	12.4
Volatile Water Soluble (mg/g)	3.8	3.4	6.9
BOD (mg/g)	5.0	3.6	7.7
COD (mg/g)	40	40	39
PO_4 (mg/g)	.05	.05	.07
N (mg/g)	.48	.61	.41
Total plate counts/g (x 1000)	10,900	18,000	11,700
Confirmed coliform/g (x 1000)	1,300	2,700	1,700
Fecal enterococci/g	645	518	329

Computation of Pollution Potential of Street Litter

The following computations show the pollution potential of street litter, using the above average data for soluble BOD per gram of the dry dust and dirt fraction of the amounts of litter swept in the test areas.

Steps that can be used for any community areas and condition to determine the pollution effect of street litter are:

1. Determine the curb or gutter mileage for each category of zoning or land use
2. Determine the average pounds of dust and dirt (D/D)/unit of curb and street length (100 feet, 1,000 feet, mile) for the various types of zoning or landuse areas
3. Multiply the length of street in each category by appropriate average D/D accumulations for the different zoning or land use classifications
4. Determine the water-soluble portion of the D/D fraction, ascertain the BOD of this fraction, and compute the amount of BOD/day/unit of street length
5. Assume that this BOD of the soluble D/D is the actual pollution factor of the total street litter
6. Convert the D/D BOD potential into population equivalent on the basis of raw sanitary sewage BOD of 0.17 pound/day/person

Table 9 (15)

Amount of Dust and Dirt and Strength of BOD by Land Use

Land Use	Amt. of D/D by land use lb/day/100 ft of curb	BOD of D/D mg/g
Commercial	3.3	7.7
Industrial	4.6	3
Multiple family	2.3	3.6
Single family residence	0.7	5
Assumed weighted average	1.5	5

Then:

Average D/D in street litter	1.5 lb/day/100 ft curb
D/D soluble BOD	5 mg/dry D/D; or 5 lb/1,000 lb
D/D per mile of curb	1.5 × 52.8 = 80/lb/day
D/D per mile of street (2 curb miles)	80 × 2 = 160 lb/day
D/D BOD per mile of street	5 lb × 160/1,000 = 0.8 lb/day

D/D BOD population equivalent
0.8/0.17 = 5 persons/day/mile street

Control of Street Litter

The more street litter that can be removed from the streets before it comes in contact with precipitation or runoff, means a reduction in contaminants. Vacuum type sweepers have proven efficient when operating on level and even pavement.

Pesticides, Herbicides and Fertilizers

These were discussed in detail in the agricultural water pollution section, however it is worthy of mention that their rate of application is usually greater in urban than in rural areas.

Local public works officials must be alert to the pollution potential of these chemical formulations and govern their use in a manner that will minimize pollution.

Salt and Calcium Chloride

Salt is very effective in melting snow, preventing icing conditions and breaking the bond between the pavement and the snow at temperatures down to 20^{o}F. Calcium chloride is generally used alone at temperatures below 10^{o}F. In the temperature range of 10-20^{o}F, a combination of sodium and calcium is often used.

Typical applications of salt vary from 100 pounds to 2000 pounds/lane-mile. The average single application is from 200 to 400 pounds/lane-mile. In an American Public Works Association Survey (15), 13 states have reported damage to vegetation and 12 states have reported pollution caused by chemical intrusion into surface and groundwater sources. Street trees in the city of Chicago are reported to have been killed or stunted by the effects of salt, and there is increasing evidence that salt is changing the aquatic environment of small lakes that receive highway drainage.

It appears that in small watersheds draining highways and streets, the drainage designer must consider the possible accumulation of salt that will occur, and seek to use salt resistant grasses and vegetation as well as endeavor to bring about dilution of street runoff with flow from nonsalted areas.

Oils and Tars

In a Seattle survey (21), appreciable amounts of oil have been noted in runoff samples. A median value of 59 mg/l from 35 observations, was reported. There has been additional concern over the pollution component of hydrocarbons and tars derived from the washing of urban streets, however little quantitative data related to oils, hydrocarbons or tars is available.

Sediment

During periods of construction, large sediment yields from urban lands can occur. While only a fraction of the urban complex is under construction at any one time, there is an increasing expansion of urban centers and the construction phase for at least part of these lands can be expected to extend well into the future. The data available on sediment loads in urban areas is not extensive. It appears that a good deal of available information has been summarized by Wolman and Schick (22). Wolman and Schick state that "the equivalent of many decades of natural or even agricultural erosion may take place during a single year, from areas cleared for construction.

The public, regulatory agencies, engineers and the courts have recognized problems posed by sediment derived from construction. Wolman and Schick (22) have compiled the following table of economic evaluation of sediment damage.

Table 10 (22)

Alternative Estimates of Economics of Sediment Damage

Location of Sediment	(1967) Unit Cost or Value	Method of Estimation
Reservoir	\$100/acre-ft	Cost of storage of water: range \$60 to \$145 per acre-ft
	\$0.03/yr/acre-ft	Annual cost assuming rate of depletion of storage, Liberty Reservoir, Patapsco R., 0.03%/yr sedimentation at prevailing rates.
	\$1/yr/acre-ft	Annual cost assuming rate of depletion of storage, Liberty Reservoir, 1%/yr, urbanization: extremely high sediment yield 80,000 t/sq mi^2
Reservoir	\$4000/acre-ft	Present value of storage per acre-ft (Liberty Reservoir)
Reservoir	\$22,000 to \$78,000/yr	Loss of reservoir use: alternative sources and emergency pumping, Worcester, Mass.
Reservoir	$\$2/\text{yd}^3$	Dredging of small lake (Lake Barcroft, Va.)
	$\$1.25/\text{yd}^3$	Dredging of small reservoir (Tollgate, Md.)
Reservoir	Estimated	Recreation: dependent upon % loss capacity, turbidity, etc., at \$1.00/visitor/day
Estuary	$\$0.60$ to $\$1.25/\text{yd}^3$	Dredging: Baltimore Harbor } —much dependent on disposal
	\$0.19	Dredging: Anacostia Area }
Channel	$\$0.80/\text{yd}^3$	Removal of sediment: spoil placed adjacent to channel
	$\$1.20/\text{yd}^3$	Removal of sediment: spoil removed
Channel	Value unknown	Increase in flood damage due to channel obstruction
Channel	Value unknown	Deposition of sediment during floods
Channel	Value unknown	Fish kill, substitution of less desirable species, or recreation time lost due to poor fishing
Channel	Variable	Increased costs of water treatment, \$23,400/yr in treatment of 180 mgd (Washington, D. C.)
Riparian Lands	Damage equivalent	Legal award for damages equal to cost of restoration (if less than diminution in value) plus value of loss of use

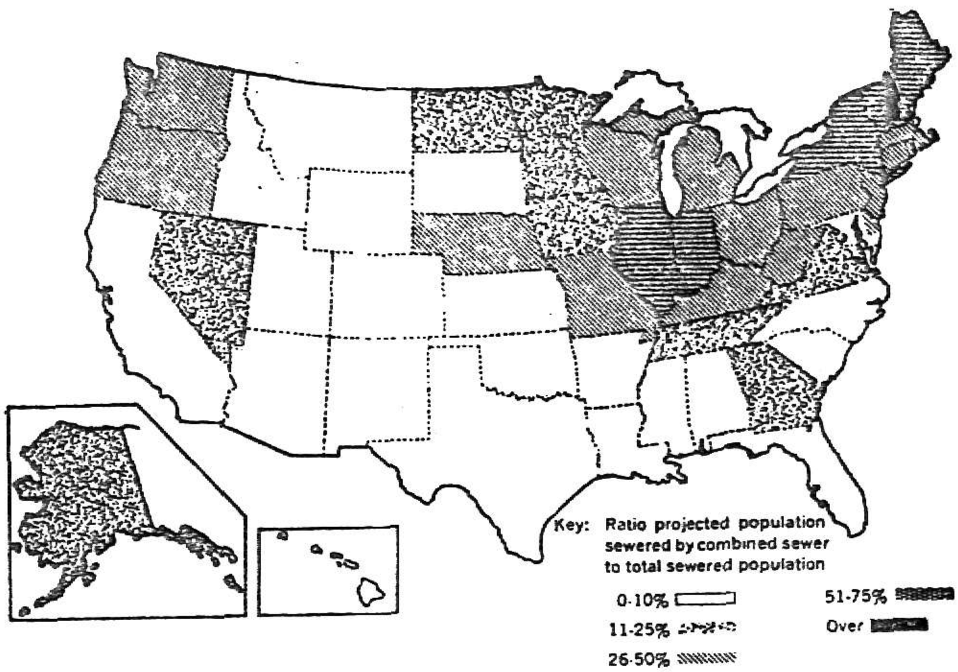
Measures can be instituted that will reduce or moderate the quantities of sediment contributed to natural environments in metropolitan regions. These include reduction of the time of exposure, vegetative traps, and diverse types of detention structures. In some areas, it should become a part of public policy to limit the quantity of sediment derived from construction activities.

Combined Sewer Overflow

Description of the Problem

Combined sewers are used by approximately 29 percent of the sewered population of the U.S., or 18 percent of the total population (23). In New York, Indiania, Illinois and the New England States, over half the sewered population is served by combined sewers. The use of combined sewers is directly interwoven with the growth and development of urban areas.

Combined sewers are those which carry storm water as well as sanitary sewage and industrial wastes. These sewers are expected to overflow and are designed to provide for such overflows (24). At one time, sanitary engineers and public health officials felt that the overflows were sufficiently small and diluted so that



—The relative use of combined sewers is compared to total sewered population by states. (Sewered population data source—"Statistical Summary 1962 Inventory, Municipal Wastes Facilities in the United States.")

Figure 2 (23)

they posed no water pollution problem. But under current conditions of urban growth which has brought about increases in runoff volumes and rates, the overflows have increased in frequency and duration and pose threats to the nations water resources. Storm water and sanitary sewage flowing in combined sewers can also flood the basements of homes, businesses and industries, and cause public health hazards.

Chemical and Physical Comparisons of Combined and Separate Sewer Discharges

In table 11, Burm et al (25) compares the characteristics of combined and separate storm sewer systems. The annual mean values of BOD for the combined sewer system

Table 11 (25)

—Annual Maximum and Mean Values—Combined and Separate Sewers

Analyses	Ann Arbor (separate)		Detroit (combined)	
	Maximum Value Observed	Annual Mean*	Maximum Value Observed	Annual Mean*
Phenols (μg/l)	70	16	8,000	312
BOD (mg/l)	62	28	685	153
NH_3-N (mg/l)	2.0	1.0	131	12.6
Organic N (mg/l)	4.0	1.0	38.4	3.7
SS (mg/l)	11,900	2,080	804	274
VSS (mg/l)	570	218	452	117
Sett. Solids (mg/l)	11,100	1,590	656	238
Vol. Sett. Solids (mg/l)	475	140	376	97
Soluble PO_4 (mg/l)	3.4	0.8	21.2	7.7
Total PO_4 (mg/l)	16.4	5.0	43.2	14.6
NO_3-N (mg/l)	3.6	1.5	2.8	0.5

* Values for extreme slugs of a particular parameter were included in the computations for the annual mean. These extremes were not included in the computation for the mean values.

are about 5 times greater than the values observed in the separate storm sewer system. The maximum BOD value in the combined system is about 10 times the maximum separate sewer values.

Bacteriological Comparison Between Combined and Separate Sewer Discharges

A study completed by Burm et al (26) gives a bacteriological comparison between combined and separate sewer discharges:

1. Total coliform densities in the overflow from combined sewers many times approach densities found in raw wastewater with the maximum observed density being 160,000,000 organisms/100 ml. Median monthly figures of the individual overflow geometric means were as high as 37,000,000 organisms/100 ml.

2. Total coliform densities in the runoff from separate storm sewers are judged to be approximately one tenth of those in combined sewers. The maximum individual count recorded was 49,000,000 organisms/100 ml on 2 occasions.

3. Fecal coliform densities in combined sewer overflows approach 100 percent of the total coliforms on individual samples. Overall fecal coliform densities are approximately 20 percent of the total coliforms with the maximum count observed to be 61,000,000 organisms/100 ml.

4. Fecal coliform densities rarely are more than 20 percent of the total coliform densities in a separate storm sewer installation. The maximum individual separate sewer count observed was 4,300,000 organisms/100 ml. The greatest differential between the combined and separate storm sewer data occurs for this parameter with the combined sewer discharge containing approximately 40 times as many fecal coliforms as are found in separate storm sewers.

5. Fecal streptococcus densities are at remarkably equal levels in both types of sewer systems. Counts rarely are in the millions and the maximum observed count of 2,900,000 organisms/100 ml occurred in the combined sewer installations. Discharges from the combined sewer system have fecal streptococcus densities only about twice as great as those in the separate system.

6. Total coliform and fecal coliform densities show significant increases in magnitude during the warmer summer months, but the fecal streptococcus counts fail to show this pattern.

7. Fecal streptococcus densities from a separate storm sewer system are generally equal to or greater than the fecal coliform counts. The fecal coliform counts in a combined sewer discharge, however, usually exceed the fecal streptococcus counts by a margin of 3:1 to 20:1. Using the rationale developed in research concerning these ratios, one can conclude that the fecal coliforms in the separate sewers are primarily of non-human origin while those in the combined sewer discharges are of human origin.

8. Initial counts from both combined and separate storm sewer discharges are either moderately higher than the rest of the results or at about the same level. This indicates that any effect of "first flushing" is minimal. In one observed instance, the first samples gave lower results.

Recent studies by Geldreich et al (27)(28) have utilized bacteriological relationships as measures of storm water and stream pollution.

Weibel et al (29) gives bacterial counts for urban runoff (table 12) and compares the quality of runoff for different seasons of the year (table 13).

Table 12 (29)

—Bacterial Counts in Stormwater Runoff Samples from an Urban Area*

	Counts Exceeded in Designated Percent of Samples (Colonies per 100 ml)		
	90%	50%	10%
Coliforms†	2,900	58,000	460,000
Fecal coli†	500	10,900	76,000
Fecal strep‡	4,900	20,500	110,000

* Samples were taken from the Cincinnati study site during 1962 and 1963.

† Coliforms and fecal coliforms were determined by the completed MPN technique during 1962, and by the MF technique during 1963.

‡ Fecal streptococci were detected by KF streptococcus agar pour plates in 1962 and 1963.

Table 13 (29)

—Seasonal Variations of Constituents

Constituent	1962 July-Sept.	1962 Oct.-Dec.	1963 Jan.-March	1963 April-June	1963 July-Sept.
	Mean Concentrations (mg/l)				
SS	180	160	260	250	190
VSS	43	41	63	62	48
COD	110	84	110	100	100
BOD	30	28	12	19	15
NO_2-N	0.07	0.03	0.06	0.05	0.07
NO_3-N	0.41	0.26	0.44	0.44	0.52
NH_3-N	0.97	0.79	0.49	0.82	0.50
Org N	1.2	1.9	1.8	2.0	2.0
PO_2	1.2	0.81	0.47	0.66	1.1

Remedial Measures for Combined Sewer Overflows

The most widely publicized remedial measure for controlling stormwater overflows is to replace the combined sewers with separate storm and sanitary sewers. The cost of this effort was estimated by the APWA to be about $48 billion (24) in 1967.

Another measure of control is the addition of storage facilities to the combined system (20). This would permit temporary storage of the stormwater, with a release to the wastewater treatment plant for treatment before discharge to a receiving body of water. The Chicago Area Deep Tunnel (30) is such a storage facility. It captures stormwater overflows from combined sewers and stores it in a large mined underground reservoir, some 800 feet below the surface. The water is then pumped, at reduced rates, to an upper reservoir, and then to an advanced waste treatment plant.

AREA AND SCOPE OF STUDY

Nature of Wildcat Creek Basin

Description

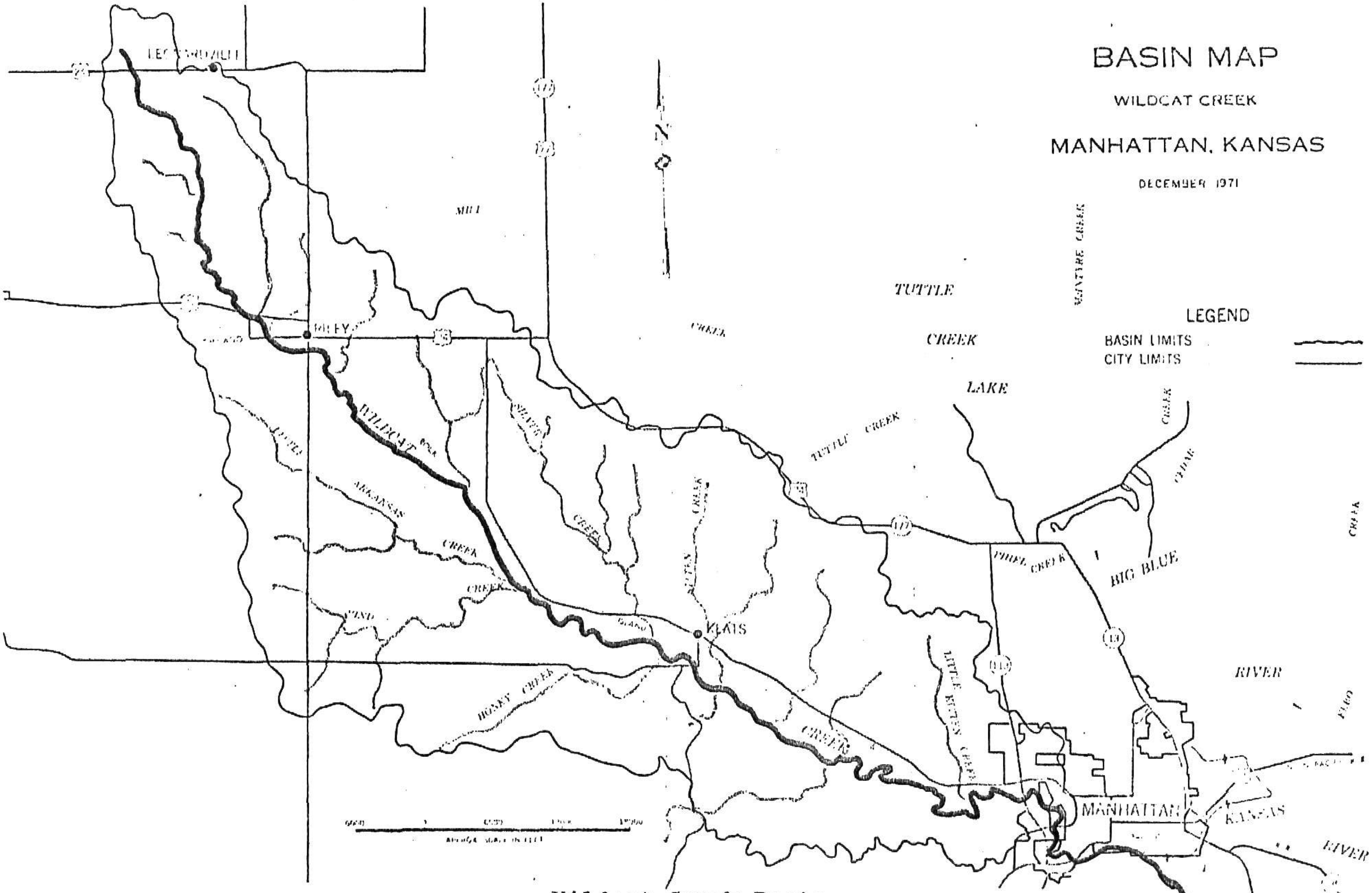
Wildcat Creek basin drains an area of 88 square miles and originates some 28 miles above the city of Manhattan, Kansas. (See Figure 3). The creek has a bottom slope of about 12.5 foot/mile. Ninety-five percent of the land usage in the basin is agricultural and approximately 5 percent is urban (31). It is estimated the flow ranges from below 10 cfs to greater than 7000 cfs. There is no gaging station on the stream but the June 1965 flood was estimated to be 6300 cfs. This was ranked as a 17 year frequency flood.

Agricultural Drainage

The soils are predominantly of the silt or sandy-loam type with the most common types being the Ivan-Kennebar Reading and the Haynie Series (32). A land use survey of the area, a few miles west of Manhattan, indicates that approximately one-third of the drainage basin is under cultivation. The remainder is grassland and vegetation. The crops common to the area are: corn, milo, wheat and alfalfa. The grassland has small herds of cattle grazing on it, and some are using the creek as a water source.

Urban Drainage

The storm drainage from approximately two-thirds of the land area of the city eventually goes into Wildcat Creek. On the west side of the city, the creek receives drainage from Little Kitten Creek (see Figure 3) and another small creek just to the west of Village Drive. Storm water from above the westloop shopping area draining through the Garden Way Apartment area eventually flows through an 8'x 9' reinforced concrete box culvert into Wildcat Creek. The creek also receives drainage from a 15" and a 21" storm sewer on Wildcat Ridge and a 15" storm sewer on Grandview Terrace.



Wildcat Creek Basin

Figure 3 (31)

The Sunset Zoo drainage eventually goes into Wildcat Creek. The Zoo has about 10 large animals and 25-30 smaller ones.

On the south side of Manhattan, a 7 foot diameter storm sewer at the end of 14th street, a 6 foot diameter storm sewer on South Manhattan Avenue, and a 2 foot diameter storm sewer at the end of 10th street, all empty into the creek.

The 7 foot sewer receives the Hunting Avenue drainage on the west side of the old stadium and runs along 16th Street and eventually down 14th Street to Wildcat Creek.

The 6 foot diameter sewer receives drainage from the university, runs along 14th Street and receives drainage from the city park, and follows South Manhattan Avenue to Wildcat Creek. There is a small flow (5-10 gpm) coming from this sewer at all times. This was traced back to the university and is believed to be coming from the cooling units of the physical plant.

The 2 foot sewer receives drainage from between the railroad tracks in south Manhattan (between Riley and El Paso streets) and flows down 10th Street, under the flood protection levee out into Wildcat Creek.

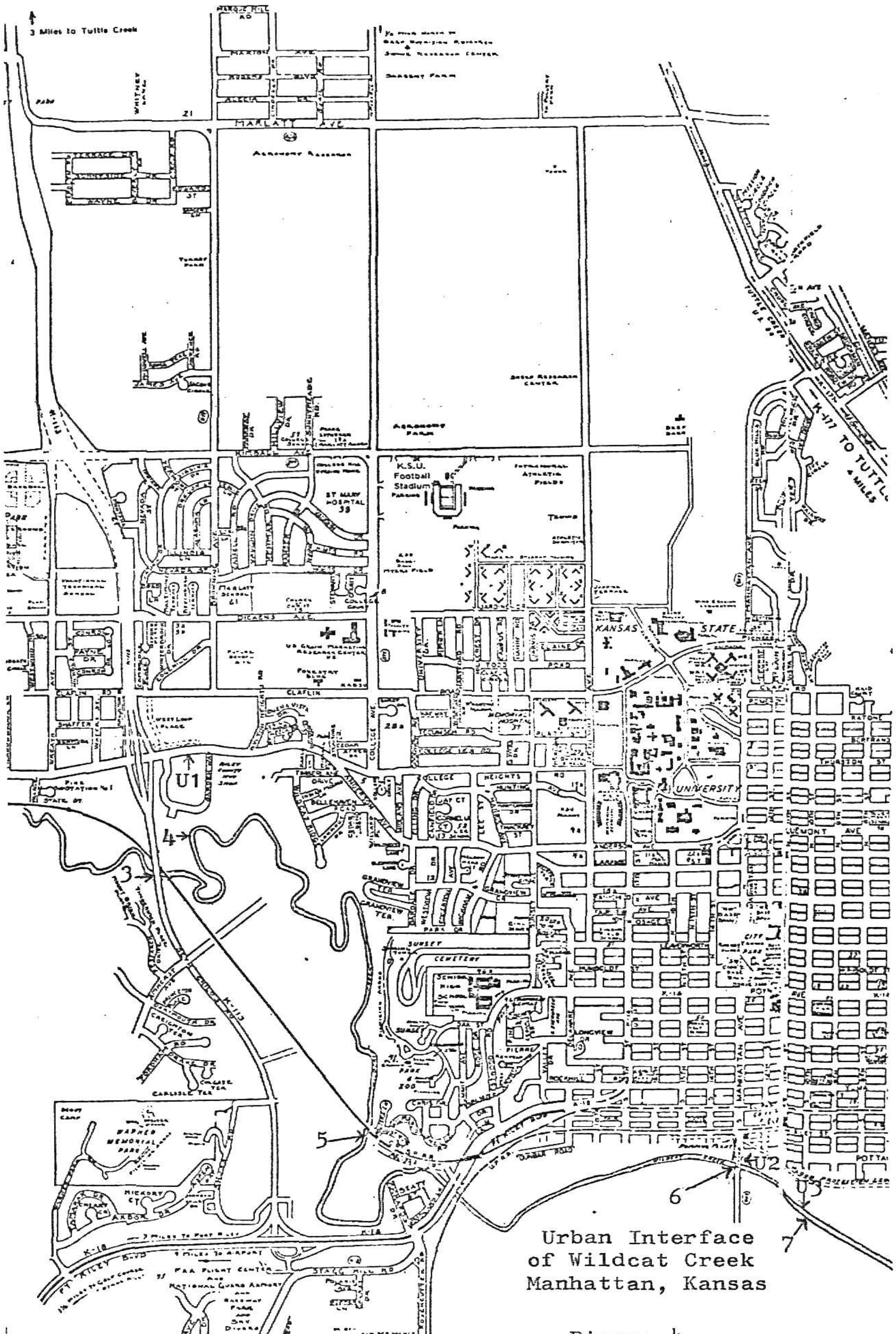
Scope of Study

Sampling Points

A total of 10 sampling points were chosen. These included 7 points where samples were taken directly out of the stream and 3 points where samples of urban drainage were taken just before the drainage entered the stream. The location of the sampling points are all noted on Plates 1-3 in the appendix and some of them are indicated on Figure 4.

Sampling Point 1---

County Road Bridge, approximately 2 miles west of Manhattan city limits. The exact location of the bridge is on the north



Urban Interface
of Wildcat Creek
Manhattan, Kansas

Figure 4

line of Section 16, Township 10S, Range 7E. This point is indicated on Plate 1.

Sampling Point 2---

Private Farm Road Bridge, one mile upstream of Kansas State Highway K-113. This bridge is located approximately one-half mile south of Manhattan Nursery. This point is indicated on Plate 2.

Sampling Point 3---

Kansas State Highway K-113 (Seth Childs Road) Bridge, just upstream of the Chicago, Rock Island and Pacific Railroad Bridge. This point is indicated on Plates 2 and 3 and Figure 4.

Sampling Point 4---

Behind Garden Way Apartments, just before the stream receives urban drainage from the west loop shopping area. This point is indicated on Plates 2 and 3 and on Figure 4.

Sampling Point U1---

Anderson Avenue at the 8'x 9' storm sewer, which receives urban drainage from above and including the west loop area. This point is indicated on Plates 2 and 3 and on Figure 4.

Sampling Point 5---

Just below the C.R.I.&P. railroad bridge near Poliska Lane. This point is below the Sunset Zoo area and is indicated on Plate 3 and Figure 4.

Sampling Point 6---

South Manhattan Avenue Bridge. This sampling point is just above the bridge, before the stream receives drainage from the 6 foot diameter storm sewer. This point is indicated on Plate 3 and on Figure 4.

Sampling Point U2---

South Manhattan Avenue 6 foot diameter storm sewer. Samples collected here are from urban drainage before it runs into the stream. This point is indicated on Plate 3 and on Figure 4.

Sampling Point U3---

South 10th Street 2 foot diameter storm sewer. Samples collected here are from urban storm sewerage before it runs into the stream. This point is indicated on Plate 3 and on Figure 4.

Sampling Point 7---

This point is the last point sampled in Wildcat Creek before it runs into the Kansas River. This point is indicated on Plate 3 and on Figure 4.

Parameters Considered

The parameters considered in the stream survey were: rainfall, flow, temperature, pH, conductivity, turbidity, suspended solids, total phosphorus, nitrate nitrogen, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total coliforms, fecal coliforms and fecal streptococci.

METHODS AND PROCEDURES

Sampling

Samples from the stream were collected every time it rained plus additional samples were taken to obtain representative stream characteristics of dry weather. Urban runoff was collected during or immediately after rainfall. A BOD bottle sampler was used to collect the samples. All samples were taken where it was considered that the stream was flowing at maximum velocity.

Flow Measurements

Flow measurements of the stream were determined by using a Gurley current meter. A trapozoidal section was determined and the flow was obtained by using the midsection method recommended by the Bureau of Reclamation (33). Flow in the sewers and through the box culverts was estimated by obtaining the depth of flow and slope and using Manning's equation (34).

Laboratory Methods

All analyses were performed in the Sanitary Engineering Laboratory at Kansas State University, except for dissolved oxygen field tests. All tests followed the procedures outlined in Standard Methods (35) with the variation that the use of reagents prepared by the Hach Chemical Company were utilized in the nitrate nitrogen test.

Turbidity was read in Jackson Turbidity Units (J.T.U.) by use of the Hach Kit colometric filter #4445.

Total phosphorus was determined by the spectrophotometer model Coleman 101, which has a path length of 1 cm.

Nitrate Nitrogen was determined by the use of Hach Chemical reagents and the colorfilter #4445.

DO, COD, and BOD (5-day) were run on all samples according to Standard Methods (35).

Total coliform bacteria, fecal coliform bacteria, and fecal streptococci bacteria were enumerated by the membrane filter techniques described in Standard Methods (35). For the total coliform bacteria and the fecal coliform bacteria, the culture medium was ordered from the Millipore Corporation. The culture medium for the fecal streptococci was prepared from KF Streptococcus broth.

Precipitation data was obtained from the Physics Dept. at Kansas State University.

RESULTS

Since the sampling was dependent upon rainfall, samples were taken after every rain.

Complete analyses were not run on every sample. After it was found that urban runoff had quite significant effects on the stream, the emphasis was centered on the oxygen demand, ie COD & BOD.

Flow was measured by use of the Gurley current meter at sampling points 2 and 6 in the stream. A rectangular section was assumed at Point 2 (bridge abutments), while Point 6 was trapezoidal. Velocities of flow were taken at 0.2 and 0.8 depth and the midsection formula (33) was used to calculate the flow.

At Point U1 an 8'x 9' storm sewer serves as a drain under Anderson Avenue. The slope of the storm sewer is 1 percent. Flow was calculated by assuming uniform flow and using the Mannings equation. Similar calculations were made for the 6 foot diameter concrete storm sewer at Point U2, which has a slope of 0.3 percent.

The following pages give the results of analyses from the stream and the urban runoff.

Date ---------------------------------- June 7, 1972

Weather Conditions:

Clear and Sunny.

Sampling Point 2

Water Temperature (C^o)	--------------	26
Suspended Solids (mg/l)	--------------	68
DO (mg/l)	--------------	7.6
COD (mg/l)	--------------	20
BOD (mg/l)	--------------	6
Flow (cfs)	--------------	20

Remarks:

No rain was previously recorded for several days before this sample was taken. The sample was taken to show typical water quality characteristics at normal flow.

Date ---------------------------------- June 14, 1972

Weather Conditions:

Approximately 2.4 inches of rain had fallen about 8 or 9 hours before the samples were taken.

Sampling Points	1	U1	U2
Water Temperature (C^o)	25	23	23
pH -----------	7.4	6.7	6.7
Conductivity (umhos) --	620	770	620
Turbidity (J.T.U.) --	120	800	450
Suspended Solids (mg/l)	172	535	274
Total Phosphorus (mg/l as PO_4) --	1.6	7.2	4.2
Flow (cfs) -----------	70	1	1
Oxygen Relationships:			
DO (mg/l) ------------	5.9	6.8	7.0
COD (mg/l) ------------	56	68	71
BOD (mg/l) ------------	19	--	18
Bacteriological Analysis:			
Total Coliforms (organisms/100 ml)	1860	----	22,300

Remarks:

Samples were taken at Point 1 to obtain an indication of the agricultural runoff. Samples taken at U1 and U2 were taken too late to obtain true representation of urban runoff, from the storm.

Date -- June 22, 1972

Weather Conditions:

Clear and cool, which was preceded by 0.10 inch of rain shortly before the sample was taken.

Sampling Point	U2
Water Temperature (C^o) --------	21
pH ----------	8.2
Conductivity (umhos) --------	1420
Total Phosphorus (mg/1 as PO_4) --	2.2
Nitrate (mg/1 as N) -------------	4.0
Flow (cfs) ------------------	1.0

Oxygen Relationships:

COD (mg/1) ---------------------	20

Remarks:

The 0.10 inch of rain fell lightly and intermittently.

Date ---------------------------------- June 30, 1972

Weather Conditions:

Clear and Sunny. No rain previously.

Sampling Point		7
Water Temperature (C^o)	-------	25
pH	-------	8.1
Conductivity (umhos)	-----------	750
Turbidity (J.T.U.)	------------	120
Suspended Solids (mg/l)	---------	115
Total Phosphorus (mg/l as PO_4)	---	3.1
Nitrate (mg/l as N)	-----------	2.0
Flow (cfs)	----------------	10
Oxygen Relationships:		
DO (mg/l)	----------------------	7.0
COD (mg/l)	----------------------	28
BOD (mg/l)	----------------------	3
Bacteriological Analysis:		
Total Coliforms (organisms/100 ml)	-----------	215

Date ---------------------------------- July 11,1972

Weather Conditions:

Raining. Just before the samples were taken 0.20 of rain had fallen.

Sampling Points	U1	U2	5
Water Temperature (^{o}C) ---	23	24	26
pH --------	6.9	6.9	8.2
Conductivity (umhos) -----	110	230	680
Turbidity (J.T.U.) ------	500	400	70
Suspended Solids (mg/l) --	686	450	51
Total Phosphorus(mg/l PO_4)	5.4	5.2	0.6
Nitrate (mg/l as N) -----	3.0	4.0	4.5
Flow (cfs) ------	3.0	3.0	10.0 (est)
Oxygen Relationships:			
DO (mg/l) --------	--	--	7.4
COD (mg/l) --------	65	417	40
BOD (mg/l) --------	28	228	4

Bacteriological Analyses:			
(organisms/100 ml)			
Total Coliforms --------	23,750	60,000	1,286
Fecal Coliforms --------	8,750	12,500	1,200
Fecal Streptococci -----	--	51,000	--

Remarks:

Previous results have shown DO values of urban runoff to be near saturation, therefore DO was not analyzed.

Date ------------------------------------- July 15, 1972

Weather Conditions:

Cloudy and rainy. It had been raining intermittently for approximately 3 hours before the samples were taken. About 0.15 inch of rain had fallen.

Sampling points	U2	7
Oxygen Relationships:		
DO (mg/l)	--	4.7
COD (mg/l)	96	214
BOD (mg/l)	37	102
Flow (cfs) ----------	6	18 (est)

Remarks:

These samples were taken 2 hours after the most intense rainfall. This was to allow complete mixing of the urban runoff with the stream. Point 7 is about 1500 feet downstream of Point U2.

Date -- July 17, 1972

Weather Conditions:

It had rained 1.22 inches in about 5 hours and the rain was beginning to cease at the time the samples were taken.

Sampling Points	4	5	6	U2
COD (mg/l)	40	95	24	183
Flow (cfs)	--	--	25	13

Remarks:

Three samples were taken to detect high organic loads from agricultural runoff (4, 5 & 6). It appeared the agricultural runoff load was low, and the higher loading at 5 was probably from Sunset Zoo.

Date -- July 27, 1972

Weather Conditions:

It had rained over an inch in 2 hours and had stopped raining for about one-half hour before the samples were taken.

Sampling Points	3	U3	7
Oxygen Relationships:			
COD (mg/l) ------	28	138	96

Remarks:

It was intended to obtain BOD values at these points, but the dilution water mixture yielded poor results.

DISCUSSION

Rainfall and Runoff

Most of the rains that fell during the months of June and July, in the survey area, were generally of low intensity. These rains produced significant urban runoff but tended to provide a relatively smaller amount of agricultural runoff.

Flows

Flows in the river ranged from 10 to 70 cfs. While it is generally considered that the current meter is quite accurate in measuring velocities, the accuracy of the flow very much depends on the assumptions about the cross-sectional areas. The practice used in the survey was to measure depths at 5 ft. sections across the stream.

Flows in the concrete sewers ranged from 1 to 13 cfs. These flows were estimated by measuring the depth of flow and use of the Manning's equation. It should be noted that this equation assumes uniform flow.

During stream low flows, the urban runoff may produce a flow greater than half that of the stream. Therefore a high organic loading from the urban runoff can quite significantly effect the stream loading .

Temperature

Temperature of the stream was about 25°C, while the temperature of the urban drainage ranged from 21 to 24°C. This is naturally expected since rainwater temperature is cooler.

pH

The pH of the streamwater varies from 7.4 to 8.2, while the values of the urban runoff ranged from 6.7 to 8.2.

Conductivity

Conductivity values for the river ranged from 620 to 750 umhos. This would be less than 500 mg/l of TDS and would have no detrimental effects on crops if used for irrigation. This also is a permissible level which is believed harmful to fish and fauna life.

The urban runoff values of conductivity were lower than that of the stream except for one value of 1,420 umhos of a sample taken from the 6 ft. diameter storm sewer on South Manhattan Avenue.

Turbidity

Turbidity for the stream ranged from 70 to 120 J.T.U. while the turbidity from the urban drainage covered the range from 400 to 800 J.T.U. Literature surveys indicate that turbidities as high as 200 J.T.U. are not harmful to fish (37).

Suspended Solids

Suspended solids values for the stream were commonly in the 100 to 200 mg/l range. This is low compared to the 274 to 535 mg/l from urban drainage. The highest value of SS came from the urban drainage in the Westloop area and probably could be attributed to construction in that area.

The literature indicates that SS values of more than 270 mg/l can have significant effects on fish life.

Total Phosphorus

Total phosphorus values for the stream ranged from 0.6 to 3.1 mg/l (as PO_4). This is less than the levels found by Stoltenberg (19).

Total phosphorus values for urban runoff ranged from 2.2 to 7.2 mg/l (as PO_4). This compares with the values of the storm sewer in Ann Arbor, Michigan (25), however it is higher than the values obtained in the District of Columbia survey. (36).

Nitrate Nitrogen

Stream values of nitrates were from 2.0 to 4.5 mg/l (as N). These values compare with the literature of Stoltenberg (19) and Cherryholmes (14).

Urban runoff values of nitrates were about 4.0 mg/l (as N). These appeared to be higher than the values found in the literature.

The USPHS has set a safeguard limit of 45 mg/l (as N), for drinking water purposes, however it is recommended that water containing over 10 mg/l not be used for infant feeding.

Because of the velocity of Wildcat Creek, it is doubtful that algal blooms will be a problem in the near future.

Dissolved Oxygen

DO values for the stream ranged from a low of 4.7 mg/l to a high of 7.6 mg/l. It is recommended that the DO content of warmwater fish habitats be not less than 5 mg/l during at least 16 hours of any 24 hour period (37). The Kansas Water Quality Standards set 5 mg/l as a minimum DO content.

The low (4.7 mg/l) sample was taken 2 hours after the light rain fell, causing urban drainage. It was taken about 1500 ft. downstream from where the storm drainage entered the creek, to provide thorough mixing with the low flowing stream. Two samples were taken from the middle of the stream, both were field tested following Standard Methods (35) procedures, and both yielded the 4.7 mg/l of DO. It should be noted that the mean BOD of the sample was 102 mg/l.

Biochemical Oxygen Demand

The stream had BOD values ranging from 3.0 mg/l to 102 mg/l. As was mentioned previously, the high BOD (102 mg/l) was obtained from the same sample that yielded the low DO (4.7 mg/l). This was obtained on the last sampling point before the creek runs into the Kansas River. The following paragraph explains why it was decided to sample at this point.

Referring to the samples taken on July 11, it is noted that 0.20 inches of rain fell, producing urban runoff. This rain fell rapidly producing an increasing flow in the 6 ft. diameter sewer. The sample at U2 was taken just as the sewer was beginning to flow rapidly. This sample had a BOD of 228 mg/l which is comparable, at times, to the influent flow of domestic sewage at the Manhattan Sewage Treatment Plant. The BOD of the urban drainage at point U1 was 28 mg/l, while the BOD at Sampling Point 5 was 4 mg/l. This showed that the urban drainage from U1 was significantly diluted by the time it reached point 5.

It was then decided to take samples below Point U2 to see what effect the urban drainage had on the stream. Referring to the samples taken on July 15, the BOD of the sample taken at Point 7 was 102 mg/l. This sample was taken 2 to 3 hours after the most intense rainfall to allow mixing. A sample was then taken at U2 and the BOD of the urban drainage was 37 mg/l. This lower value could be explained by the fact of the flushing effect of the storm, as this sample was taken later.

There can be little doubt that urban drainage running into Wildcat Creek at Point U2 has significant effect on the dissolved oxygen content of the stream.

Chemical Oxygen Demand

COD values for the stream ranged from below 50 mg/l to 214 mg/l. The high value was obtained from the sample that yielded the low DO of 4.7 mg/l.

The COD values from the Westloop urban drainage area were about 65 mg/l. The urban drainage from the 6 ft. diameter storm sewer running into Wildcat Creek at South Manhattan Ave., had COD values ranging up to 417 mg/l. These values appear high compared to those found in the literature (29). The 2 ft. diameter storm sewer running into the creek from South 10th Street also had a comparatively high value (138 mg/l) for its limited drainage area.

The COD/BOD ratio for the urban drainage is approximately 2:1. Using this ratio and knowledge of flows, one could conceivably predict the load on the stream by taking a COD sample of the urban drainage.

Coliforms

Total coliforms in the stream ranged from 215/100 ml to 1860/100 ml. This range appears to be near the observations found by Cherryholmes (14) and Stoltenberg (19). Total coliforms from urban runoff ranged from 22,000/100 ml to 60,000/100 ml. These values are common according to the stormwater runoff literature (26)(29).

The fecal coliform/fecal streptococci ratio for the urban runoff is less than 0.3, so it is assumed that the organisms are from warmblooded animals (27)(28)(38).

CONCLUSIONS AND RECOMMENDATIONS

This report focused on a broad water quality survey of the rural-urban interface of Wildcat Creek.

It can be said that the moderately light rains that fell on the area during the months of June and July of 1972, produced agricultural runoff which had very little effect on the stream. However, these same light, long duration rains produced the type of urban runoff which had a significant effect on the water quality of Wildcat Creek. The light rains added very little runoff to the stream to dilute the urban drainage. The urban runoff entered the stream which was flowing at the usual slow velocity, thereby significantly affecting the water quality.

This water quality survey points out the following:

1. The urban drainage coming from the 6 ft. diameter sewer at South Manhattan Avenue, is a significant pollutant of the stream, for a "period of time". Just how long the "period of time"is, has yet to be determined.
2. The dissolved oxygen level of the stream falls below the Kansas Water Quality Standards.
3. The fecal coliform/fecal streptococci ratio is about 0.3, so the organisms are most probably not coming from domestic sewage.
4. The higher PO_4 levels from the urban drainage in the West Loop area could possibly be due to the high fertilization of lawns in the relatively new housing development areas.

In order to determine the effect of the pollution on the stream, it will be necessary to conduct further studies. It is recommended that these studies be conducted on the portion of the stream receiving heaviest urban drainage, which is primarily the part of the stream from just above South Manhattan Avenue bridge, to the confluence of the Kansas River.

One step would be, to obtain additional, sufficient data to model the runoff effects on the DO of the stream, which could be done in a manner similar to studies by Wallace (39). In order to do this it would be necessary to set up a stream gaging station on the creek. Storm sewer flows could also be monitored and a sampler which could be activated when the sewer starts to flow, to collect samples periodically during the runoff period. It is the author's belief that the 6 ft. diameter storm sewer carries the major organic load into the stream and that initially, additional studies should be concentrated on this source.

In setting water quality standards, the regulatory agencies accepted the fact that large rivers have to be able to handle some waste loads, however the standards were to keep the smaller streams from having to take the wastes. It is in this light that this author recommends further studies, supported by a public agency, of this stream.

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APPENDIX

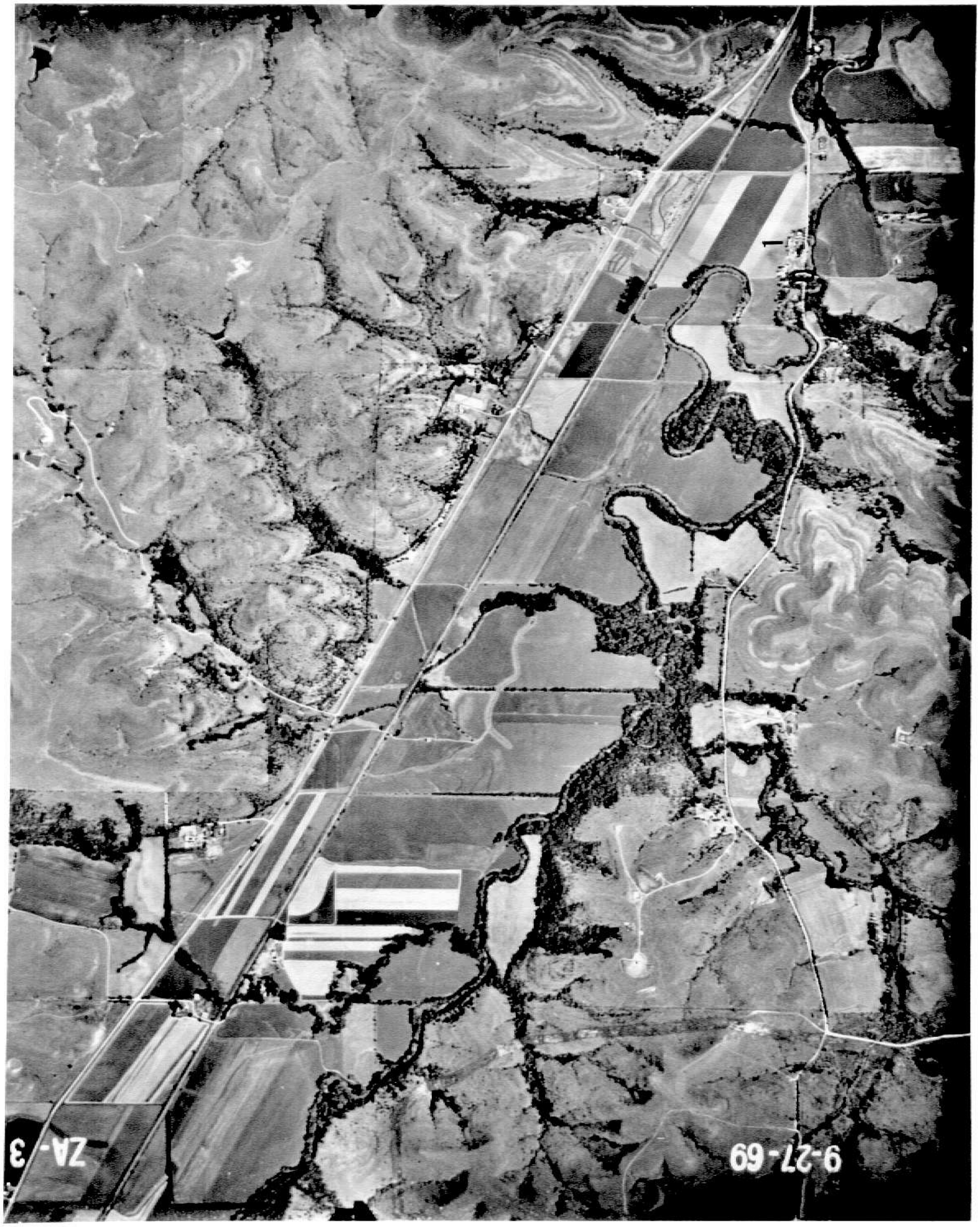

Plate 1

Plate 2

Plate 3

THE RURAL-URBAN WATER QUALITY
INTERFACE OF WILDCAT CREEK

by

KEITH M STUTTERHEIM

B.S., Kansas State University, 1971

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

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MASTER OF SCIENCE

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A literature review of recent rural and urban runoff studies, points out their effects on the water quality characteristics of small streams. Some of the sources of pollution considered in the review were: fertilizers, pesticides, insecticides, animal waste, sediment, salts, street litter and combined sewers. The rural runoff literature review also relates water pollution to various land management practices. Remedial measures for urban runoff pollution are also discussed.

The water quality of Wildcat Creek, Manhattan, Kansas, is analyzed considering the following parameters: temperature, pH, conductivity, turbidity, suspended solids, total phosphorus, nitrate, flow, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, fecal streptococci, fecal coliforms and total coliforms. Sampling points were chosen to indicate rural runoff pollution, urban runoff pollution or a combination of both.

Samples were collected after, or during every rainfall during the months of June and July. It was found that the rural runoff from light rains had very little effect on the water quality of Wildcat Creek. However, the urban runoff had a very significant effect on the water quality of the stream, which runs directly into the Kansas River. Thorough mixing of urban runoff, from light rains, with the stream, produced dissolved oxygen values below the Kansas Water Quality Standards. BOD values taken across the stream were as high as 102 mg/l.

It is recommended that further studies of the effects of urban runoff on Wildcat Creek be conducted.