JORDAN RIVER FISHERY

APRIL, 1980

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ABSTRACT

Pursuant to the Federal Water Pollution Control Act as amended (PL 92-500), all waters in the United States will be "fishable and swimmable" by 1983. This study was directed toward investigating the fishery potential of the Jordan River as affected by wastewater treatment alternatives which were developed during the Salt Lake County 208 Water Quality Project. The study develops instream species specific safe levels of temperature, dissolved oxygen, chlorine, ammonia, and detergent (surfactant) for seven species of fish that are considered as being representative of the fishes that could comprise the future fishery. Warmwater species investigated were Bluegill, Channel Catfish, Largemouth Bass, Perch and Yellow Perch. Coldwater species investigated were Brook, Brown and Rainbow Trout.

Future water quality constituent levels in the Jordan River are projected in the study and result in similar concentrations for all cases except for spatial considerations. Future habitat of the Jordan River is also investigated.

It is concluded that a coldwater and a warmwater fishery in the upper and lower river respectively would not be constrained by the future water quality of the river if nitrification and dechlorination were included in the future treatment scheme that is adopted. The upper river is considered as that river reach upstream from the Little Cottonwood Creek-Jordan River confluence. The lower river is that river reach downstream from the confluence to the Great Salt Lake. A coldwater fishery could be developed in the entire river reach in Salt Lake County but at a greater cost due to the more stringent requirements of these fishes.

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LIST OF ABBREVIATIONS

BOD	Biochemical oxygen demand
BOD_5	Biochemical oxygen demand - 5 day
CBOD	Carbonaecous biochemical oxygen demand
cfs	Cubic feet per second
DWR	Division of Wildlife Resources, State of Utah
fps	Feet per second
$g/cm^2/day$	Grams per square centimeter per day
mg/l	Milligrams per liter
MPN/100 ml	Most probable number per 100 milliliters
NBOD	Nitrogenous biochemical oxygen demand
NPDES	National Pollutant Discharge Elimination System
ppm	Parts per million
STP	Sewage treatment plant
TDS	Total dissolved solids
TSS	Total suspended solids
VSS	Volatile suspended solids
$\#/ft^2/day$	Pounds per square foot per day
$\mu g/l$	Micrograms per liter

SECTION I

INTRODUCTION

Background

The Jordan River, the major waterway in Salt Lake County, is the only natural outlet from Utah Lake in Utah County. After leaving Utah Lake the river flows northward approximately 15 miles before entering Salt Lake County through what is known as the Jordan Narrows. The river then continues northward through Salt Lake County approximately 41 miles before entering a marshland at the inlet to Great Salt Lake. Along the 41 miles through Salt Lake County, seven sewage treatment plants, five major tributaries, and numerous agricultural return and urban runoff flows augment the flow but major irrigation diversions substantially deplete the flow. About 16 miles upstream of Great Salt Lake a major portion of the river flow is diverted into the surplus canal which conveys high flow waters directly to Great Salt Lake in order to alleviate flooding problems on the lower Jordan River.

As the Jordan River flows downstream, the quality of the water is continually degraded, primarily by agricultural return flows, sewage treatment plant effluents, and urban runoff.

Between Utah Lake and the Jordan Narrows (approximately the Utah-Salt Lake County line), the water is very turbid and supports few fish species. Proceeding farther north (to approximately 12400 South - Salt Lake County), turbidity lessens and the number of species found increases. From this point downstream to the Great Salt Lake, water quality generally deteriorates and the natural channel has been altered more and more, resulting in declining numbers of fish species and individuals per species.

Past accounts report that the streams in Salt Lake Valley were filled with numerous trout in 1841.(1) In 1872, trout were the most numerous fish species in Utah Lake and were commercially seined from 1847 to 1880. Largemouth bass were so abundant that a natural hatchery was established at Powell Slough on Utah Lake in Utah County and operated until 1913.(2) In a recent survey of the fish species in the Jordan River, brown trout, yellow perch and white bass comprised less than two percent of the total fish population collected while carp, Utah suckers, and mountain suckers comprised 87 percent of the population.(3)

The need to develop the Jordan River fishery to its potential is demonstrated by the fact that in 1973, 45 percent of the State's population lived in the Bureau of Outdoor Recreations' Planning District 3 (Salt Lake and Tooele Counties) which contained about 10 percent of the State's recreation sites and less than one percent of the fishing sites. When asked to rank outdoor recreation activities as to preference, the population of the State then ranked fishing as the number one favored activity.(4) These facts strongly suggest the development of the Jordan River fishery to its potential.

The Salt Lake County 208 Water Quality Management Project investigated alternative wastewater treatment management schemes for Salt Lake County including those which presently discharge to the Jordan River. Many of the decisions concerning levels of treatment and process selection were developed from requirements stipulated in the State's surface water classification system. However, it was deemed advisable to make a more detailed analysis of one of the more important components of the Jordan River ecosystem, specifically the fishery.

It was recognized that certain of the State's requirements could most likely be achieved only through extremely expensive construction programs, e.g., instream ammonia concentrations. Consequently, a clear need existed for a comprehensive analysis of the fisheries potential of the Jordan River to be used as a major element in the final review of waste treatment alternatives for the Upper and Lower Jordan River Planning Areas. This analysis also held promise for guidance in the development of the river's fishery by wildlife and outdoor recreational interests.

Objectives

The overall objective of this study was to determine the potential of the Jordan River to support a fish population as constrained by wastewater treatment alternatives. The constraints imposed by sewage treatment are generally in the form of toxicants in plant effluents but habitat considerations were also evaluated. Both of these constraint concepts were included in this study.

To achieve this overall objective, three specific goals were addressed:

(1) To determine what levels or concentrations of certain substances (toxicants) in sewage treatment plant effluents impose species specific constraints on selected fishes. Specifically, these water quality constituents are temperature, dissolved oxygen, chlorine, ammonia, detergent, and suspended solids. Pesticides, herbicides, and heavy metals, which are very toxic to fish in minute quantities, were not investigated in this study as the topic is large enough to warrant a major multi-year study and little investigation as to the concentration of these toxicants in the Jordan River has been undertaken.

(2) To determine what future levels or concentrations of the above mentioned constitutents will occur in the Jordan River. The levels and concentrations will be affected by different wastewater treatment alternatives and were evaluated in light of such. The null case, i.e., the case in which no treatment alternative is implemented, was not investigated because something will have to be done to upgrade county sewage effluents to attain water quality standards.

(3) To determine what type of fishery could be maintained in the future Jordan River. The aspect of future physical habitat is an important consideration and was also investigated.

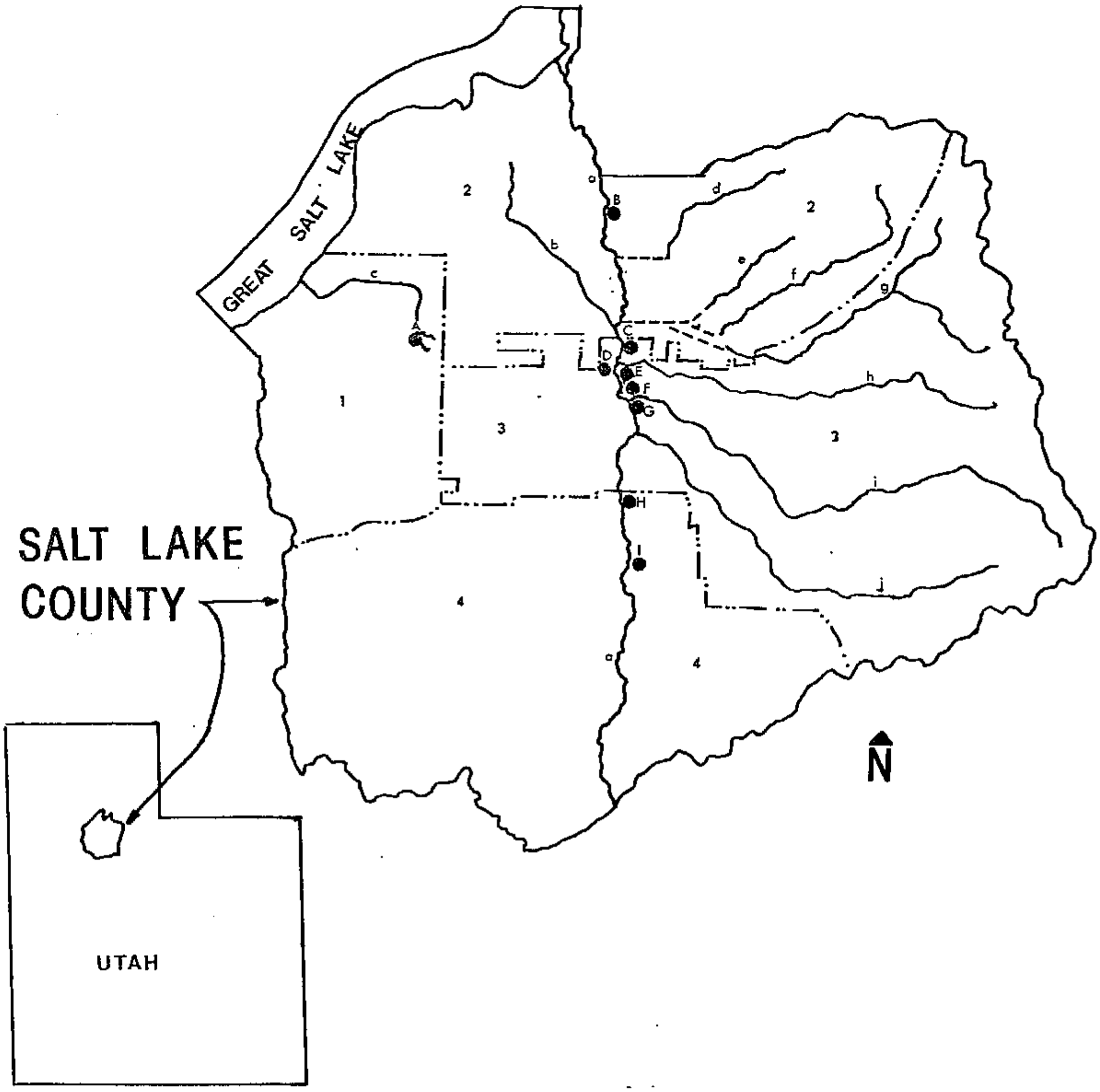
Definitions

Throughout this report there are terms that are frequently used and need some definition. Presented here are definitions of the study area, cold-and warmwater fisheries, and wastewater alternatives. Other terms are defined in detail as they are used.

The study area investigated in this study is the Jordan River as it flows northward through Salt Lake County. Figure 1 shows the study area, the location of major tributaries to the river and the location of the present seven county sewage treatment plants (STP) discharging to the Jordan River.

The term "fishery" as used in this study, is defined as those fish species and associated biota that comprise the fish population of the waters of concern (the Jordan River). A fishery can be of two types; natural or managed. A natural fishery is one which has not been manipulated by man. Usually this manipulation is in the form of stocking (planting) fishes to augment any natural reproduction. Throughout this report, the term "fishery" when applied to the Jordan River will imply "managed fishery". It should be noted that in Utah, essestially all fisheries in accessible waters fall into the managed fishery category. A coldwater fishery as used in this study means a trout fishery (e.g., Brown, Brook and Rainbow Trout). A warmwater fishery means those fisheries not comprised of trout as the dominant fishes (e.g., Bluegill, Perch, Yellow Perch, Channel Catfish and Largemouth Bass).

There were many alternatives for treating wastewater in Salt Lake County that were proposed and partially accepted. These alternatives were upgrading the present seven small area plants and regionalizing these plants into one, two, three, four and five subregional



Sewage Treatment Plants

A. Magna
B. Salt Lake City
C. South Salt Lake City
D. Granger-Hunter
E. SLC SSD #1
F. Cottonwood
G. Murray
H. Midvale
I. Sandy

Surface Water

a. Jordan River
b. Surplus Canal
c. Kersey Creek
d. City Creek
e. Red Butte Creek
f. Emigration Creek
g. Parley's Creek
h. Mill Creek
i. Big Cottonwood Creek
j. Little Cottonwood Creek

Planning Area

1. Magna
2. Salt Lake City
3. Lower Jordan
4. Upper Jordan

Figure 1. The Study Area, Planning Areas and Locations of Major Jordan River Tributaries and Existing Sewage Treatment Plants.

plants. It was determined early in the 208 Project study that some sort of regionalization will be made. Therefore, only the regionalization alternatives were evaluated for future water quality impacts to the Jordan River. Figure 2 schematically shows the configuration of these alternatives. Nomenclature used in Figure 2 will be used throughout this report to designate the alternative being evaluated.

Scope

Determination of constraining levels or concentrations of the selected pollutants was accomplished by means of a literature search. The results of this search are discussed in the text with detailed tables of species specific results appearing in Appendix B.

Determinations of future levels of toxicants were made by three means; a literature review, mass balance modeling, and judgement. Those constituents which had not been investigated by earlier authors were modeled by mass balance equations when applicable (e.g., chlorine) or by judgement when modeling was beyond the scope of this study (e.g., temperature). Documentation is provided wherever it exists and rationale for judgement decisions is provided when needed.

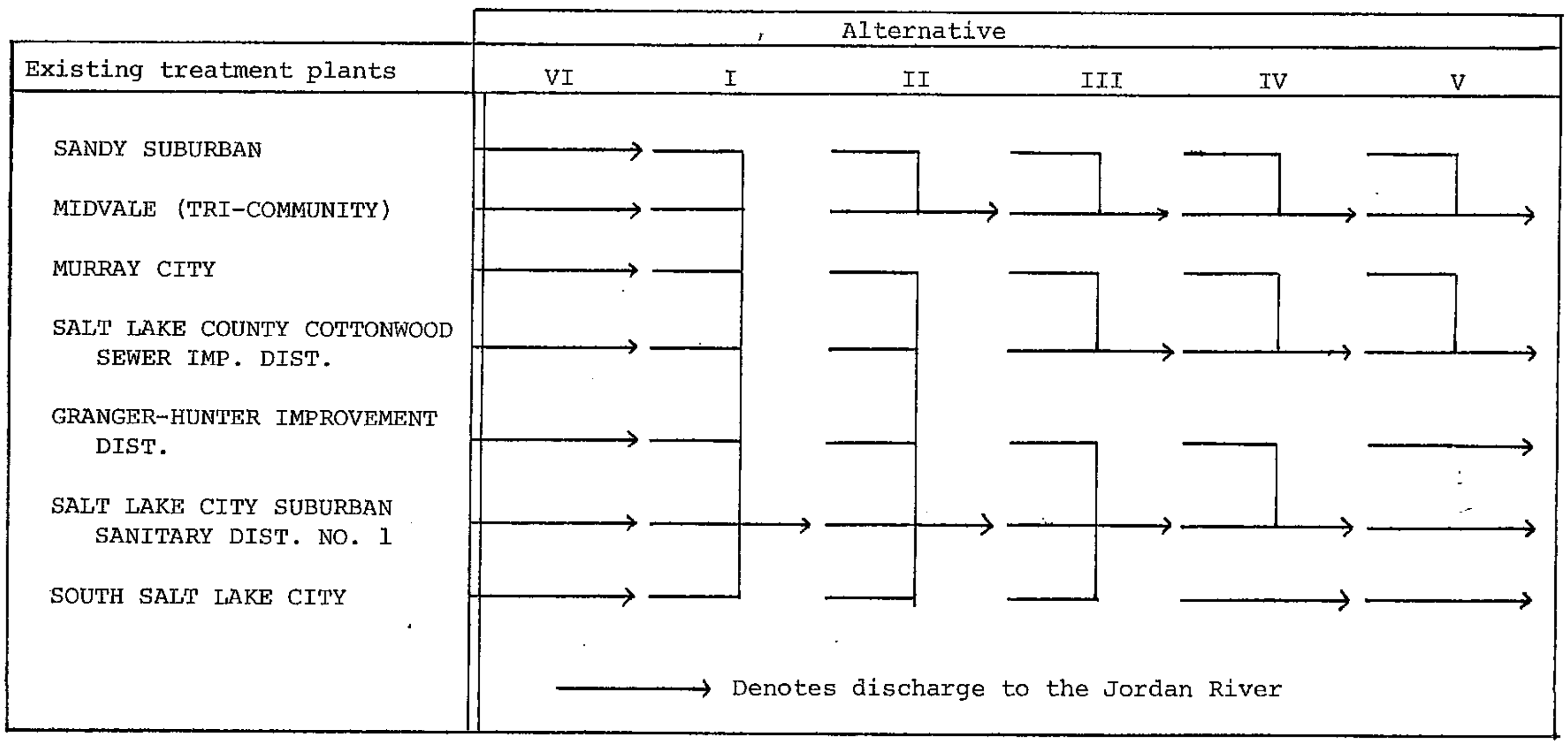


Figure 2. Schematic and Nomenclature of Sewage Treatment Alternatives

SECTION II

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

In order to reduce the scope of this study to a reasonable limit, only a restricted number of species of fish were investigated. Warmwater species include Bluegill, *Lepomis machrochirus*; Channel Catfish, *Ictalurus punctatus*; Yellow Perch, *Perca flavescens*; Largemouth Bass, *Micopterus salmoides*; and Perch, *Perca fluviatilis*. Coldwater species are: Brown Trout, *Salmo trutta*; Rainbow Trout, *Salmo gairdneri*; and Brook Trout, *Salvelinus fontinalis*.

The 208 Project examined many alternatives to waste treatment in Salt Lake Valley which included upgrading seven small-area treatment plants to meet design flows and future water quality standards (for cost comparison purposes) and consolidating these seven sewage treatment plants into one regional or two, three, four or five subregional sewage treatment plants. These alternatives were used to estimate water quality conditions for purposes of evaluating impacts on a fishery in the Jordan River.

Present fishing pressure in the Jordan River has been described as "light" in the lower reaches of the river to "heavy" in the upper reaches of the river. The primary "target" fish in the Jordan River is the Channel Catfish. However, trout fishing has been improving the last few years in the river.

Fishing in Utah Lake has been improving in the past few years. Fishermen report success in fishing for Walleye, White Bass, and Channel Catfish. Because Utah Lake is the major source of the Jordan River, some conclusions concerning water quality conditions in Utah Lake and the Jordan River can be made, although different habitat conditions preclude direct comparisons for all factors.

Safe Constituent Levels

Water quality parameters related to wastewater treatment that have been shown to be toxic and/or important and were therefore investigated are temperature, dissolved oxygen, chlorine, ammonia, detergents, and suspended solids. Others, such as pesticides, organics, and heavy metals were not investigated as they are outside of the scope of this study.

The temperature range of the Jordan River ($7^{o}C$ to $25^{o}C$) should not limit growth or survival of any of the warmwater species investigated. The upper portions of this temperature range would be marginal for growth and would inhibit spawning of the coldwater species.

Dissolved oxygen (DO) requirements of the species investigated followed fairly closely the standards of 5.5 mg/l DO minimum for warmwater species and 6.0 mg/l for coldwater species. A minimum safe concentration for all species is about 5.0 mg/l DO, but it should be noted that at this and lower concentrations, sublethal effects stress the fish and lead to shorter survival times, especially among juveniles of all species.

Historically, for other water quality parameters, safe concentrations have been estimated to be 1/100 to 1/10 of the 96 hour Median Tolerance Level, TL 50. TL 50 is defined as the concentration that is lethal to 50 percent of the test organisms. Safe concentrations developed in this study are defined as 1/20 of the 96 hour TL 50.

Chlorine is toxic to fish at very low concentrations. Safe concentrations for all fish species of total residual chlorine (TRC) are in the vicinity of 0.02 mg/l and less.

The un-ionized fraction of total ammonia concentrations (NH_3 as opposed to NH_4^+, ammonium ion) is that which is toxic to fish. The species specific toxic range of un-ionized ammonia is approximately 0.04 mg/l to 0.17 mg/l. The general guideline of 0.02 mg/l un-ionized ammonia is preferable owing to the safety factor requirements. Temperature and pH are prime factors influencing the amount of ammonia that is un-ionized. Total ammonia concentrations at Jordan River temperatures and pH that correspond to these un-ionized toxic concentrations are shown in Table 1.

Detergents and suspended solids show somewhat lesser toxicities toward fish. Detergent was found to be less toxic when in the non-biodegradable forms (ABS, DBS) than when in the biodegradable form (LAS). Suspended solid generally show no significant effects upon fish when the concentration is 30 mg/l or less.

A summary of the safe levels and concentrations for the water quality constituents investigated is shown in Table 2.

TABLE 1

TOTAL AND UN-IONIZED AMMONIA AT VARIOUS TEMPERATURES AND pH LEVELS

Temperature (°C)	Un-ionized Ammonia (mg/l)	Total Ammonia* (mg/l)	
		pH = 7.5	pH = 8.0
7	0.02	4.33	1.38
	0.04	8.65	2.76
	0.17	36.76	11.74
25	0.02	1.13	0.37
	0.04	2.26	0.74
	0.17	9.62	3.16

*As calculated from methods given in Ref. (41).

Projected Constituent Levels

Throughout this study primary alternatives investigated were the combining all county sewage treatment services into one regional plant (Alternative I) and combining county sewage treatment facilities into two, three, four and five subregional plants (Alternative II, III, IV and V respectively). Another alternative, investigated, but in lesser detail, was the upgrading of the seven present plants (Alternative VI).

The temperature of the Jordan River is not expected to change significantly in the future, with the exceptions of the areas around the discharges from proposed reservoirs on the upper river (cooler) and around the areas of the outfalls from the future treatment plants (warmer). Temperatures should remain within the historical averages of 7°C minimum and 25°C maximum.

TABLE 2

SAFE CONCENTRATIONS OF VARIOUS WATER QUALITY CONSTITUENTS FOR FRESHWATER FISHES

Species[a]	Water Constituent					
	Temperature Range[b] (°C)		Dissolved Oxygen[c]	Chlorine[d] (Cl_2)	Ammonia[d] (un-ion)	Detergent[d]
	Growth	Repro.[i]	(mg/l)	(mg/l)	(mg/l)	(mg/l)
WARMWATER						
Bluegill	8.1-31.6	25.0 - 34.0	5.5	0.013	0.170	0.200[f] 0.880[g]
Largemouth Bass	e-34.5	21.0 - 27.0	6.0	0.013	e	e
Channel Catfish	3.0-31.9	27.0 - 29.0	5.8	0.008	0.150	e
Perch	e-26.6	e	5.6	e	0.150	e
Yellow Perch	e-30.9	12.0 - 20.0	4.8	0.010	e	e
COLDWATER						
Brook Trout	3.0-24.6	9.0 - 13.0	6.5	0.013	0.100	0.250[h]
Brown Trout	e-25.1	e	5.7	0.011	0.108	e
Rainbow Trout	e-31.2	9.0 - 13.0	6.2	0.017	0.040	e

a. For fish species investigated in this report.
b. Safe temperatures for growth are those safe for juveniles or fry. temperatures must be reported as a range as there are two temperature limits for growth, i.e., an upper and a lower limit.
c. Safe concentrations were determined as 96 hr. TL 50 divided by 10 percent to 15 percent or as the average toxic value reported in Table IX divided by 10 percent to 15 percent if no 96 hr TL 50 was reported.
d. Safe concentrations were determined as 5 percent of the 96 hr. TL 50 or as 5 percent of the average of the range of toxicity as reported in Table IX if no 96 hr. TL 50 was reported.
e. No reliable toxicity data found in the literature.
f. LAS.
g. ABS.
h. DBSO.
i. This range is the optimum spawning temperature to the upper temperature for successful incubation and hatching.

Winter dissolved oxygen concentrations will approach 6.0 mg/l in the lower river while summer dissolved oxygen concentrations will approach 3.5 mg/l in the lower river even with STP effluent limitations of 10 mg/l BOD_5, 10 mg/l SS, 5 mg/l NH_3 and 4.9 mg/l DO for all alternatives. At higher BOD_5 loads, instream DO will be even less. A summary of dissolved oxygen concentration is shown in Table 3.

Future concentrations of total residual chlorine were projected using effluent concentrations of 1.0 mg/l, 0.4 mg/l and 0.04 mg/l and decay coefficients of 0.0/day (conservative case) and 1.0/day and 5.0/day (non-conservative case). The maximum concentration of chlorine

TABLE 3

SUMMARY OF PROJECTED DISSOLVED OXYGEN CONCENTRATION FOR VARIOUS ALTERNATIVES (From Study Projections)

Season	Waste Treatment Alternative	Effluent NH_3 Concentration* (mg/l)	Minimum Instream Concentration (at end of segment)**		
			10	24	27
Summer	II	20	6.42	4.77	3.11
		5			
	III	20	6.42	4.73	3.13
		5	6.48	4.95	3.57
	IV	20	6.42	4.66	2.97
		5	6.48	4.90	3.44
	V	20	6.42	4.66	2.97
		5	6.48	4.89	3.44
Winter	II	20	8.64	7.17	6.07
		10	8.65	7.23	6.20
	III	20	8.64	7.15	6.07
		10	8.65	7.22	6.20
	IV	20	8.64	7.04	5.88
		10	8.65	7.11	6.03
	V	20	8.64	7.04	5.88
		10	8.65	7.11	6.03

*Effluent DO = 4.9 mg/l, $CBOD_5$= 10 mg/l

**From the end of segment 10 upstream, the river is designated as a coldwater fishery; between segment 10 and 24 it's designated as a warmwater fishery; from segment 25 downstream it's designated as a nongame fishery as per State Water Quality Standards.[20]

in the river will be 3.13 mg/l for the conservative case and 1.0 mg/l effluent concentration in the lower river using the assumption for Alternatives IV and V. The lowest maximum concentration for all alternatives would be about 0.001 mg/l in the lower river assuming the non-conservative case. Alternatives II and III maximum chlorine concentrations were close to that of Alternatives IV and V (3.10 mg/l). A summary of projected chlorine concentrations for selected cases is shown in Table 4.

Without nitrification, ammonia concentrations are projected to exceed 6.0 mg/l for short reaches in the river. With ammonia nitrification to 10 mg/l and 5 mg/l for winter and summer conditions the resulting concentrations in the Jordan River would be lowered to less than the toxic levels. Maximum ammonia concentrations for the alternatives are 6.4 mg/l. With ammonia reduction to 10 mg/l winter and 5.0 mg/l summer the maximum concentrations expected are 2.60 mg/l and 1.62 mg/l respectively. This constituent has a point and a distributed source (non-point) and was treated as such in the projections. The decay coefficient used was 0.15/day. A summary of projected ammonia concentrations is shown in Table 5.

Suspended solids concentrations were also projected on a first estimate basis. Factors influencing a change in the suspended solids concentration of the river are the construction of desilting basins on tributaries and storm drains, construction of the proposed reservoirs, and channel alteration. With the construction of desilting basins, it was projected that the increase in the concentration of suspended solids of the lower river due to storm water loads could be reduced by a factor of eight, resulting in maximum concentrations of 360 mg/l and 370 mg/l for short reaches directly following storms in the two storm areas. Projections other than storm runoff for suspended solids were estimated by judgment, due to the extraneous nature of the problem.

Detergent concentrations directly below outfalls of sewage treatment plants is expected to be close to 0.2 mg/l MBAS. This estimate is based upon limited data and should be taken as a first estimate of future concentrations. Detectable concentrations of detergents are

TABLE 4

SUMMARY OF PROJECTED TOTAL RESIDUAL CHLORINE CONCENTRATIONS FOR VARIOUS ALTERNATIVES (From Study Projections)*

Season	Waste Treatment Alternative	Effluent Cl_2 Conc. (mg/l)	Maximum Instream Conc. (mg/l)	Milepoint (river mile)
Summer	II	1.00	0.310	18.0
		0.04	0.012	18.0
	III	1.00	0.310	18.0
		0.04	0.012	18.0
	IV	1.00	0.313	15.6
		0.04	0.012	15.6
	V	1.00	0.313	15.6
		0.04	0.013	15.6
Winter	II	1.00	0.252	18.0
		0.04	0.010	18.0
	III	1.00	0.252	18.0
		0.04	0.010	18.0
	IV	1.00	0.255	15.6
		0.04	0.010	18.0
	V	1.00	0.255	15.6
		0.04	0.010	18.0

*Decay coefficient = 0.0/day

TABLE 5

SUMMARY OF PROJECTED AMMONIA CONCENTRATIONS FOR VARIOUS ALTERNATIVES

Season	Wastewater treatment alternative	Effluent ammonia conc. (mg/l)	Maximum instream conc. (mg/l)	Milepoint (river mile)
Summer	II	20	6.40	18.0
	III	20	6.38	18.0
	IV	20	6.31	15.7
	V	20	6.31	15.7
	II	5	1.62	18.0
	III	5	1.62	18.0
	IV	5	1.60	15.7
	V	5	1.60	15.7
Winter	II	20	5.11	18.0
	III	20	5.10	18.0
	IV	20	5.09	15.7
	V	20	5.09	15.7
	II	10	2.60	18.0
	III	10	2.60	18.0
	IV	10	2.59	15.7
	V	10	2.59	15.7

expected to disappear within two miles below outfalls from sewage treatment plants.

Conclusions

It is apparent that the future of the Jordan River fishery is largely dependent upon future sewage treatment strategies and physical development of the river itself. According to the determinations of safe water quality constituent levels, projection of future levels of these constituents, and the development plans for the Jordan River, it is concluded that a coldwater and a warmwater fishery could be established, managed, and maintained in the upper and lower reaches of the Jordan River respectively. This would be accomplished by the removal of rough fish (carp, suckers, etc.) and the stocking/planting of catchable game species, such as those investigated in this study.

Future water quality impacts to the Jordan River are not expected to be significantly different for any of the sewage treatment alternatives, except for spatial considerations. This means that although maximum pollutant levels for the alternatives would be approximately the same, the affected reaches of river would differ. Sewage treatment plant effluent from Alternative I would not affect the quality of the Jordan River until the water reached milepoint 18 whereas effluent from Alternatives II through V would affect the quality of the river downstream from milepoint 26.5. Therefore, it is concluded that the adopted strategy of treating sewage will affect the Jordan River fishery, with the most preferred alternative being Alternative I and Alternatives II through V being less desirable in that order.

Stocking with catchables would be necessary because of expected fishing pressure, i.e., natural reproduction would not be sufficient to propagate the species due to an expected high removal rate of adults by fishing. Natural reproductions could take place if suitable habitat were made available (some reproduction does currently take place). It should be noted that essentially every fishery in the state of Utah is a managed fishery, i.e., the fishery is maintained by periodic stocking/planting with fishes. Maintenance of virtually any fishery in Utah by natural reproduction alone is nonexistent.

Because of the more stringent water quality and physical habitat requirements of coldwater fishes, it is concluded that the establishment of a coldwater fishery along the entire Jordan River would be too costly to be economically feasible. There are reaches of the river in Salt Lake County that do support trout and will even if water quality was not improved. However, improvement of the entire Jordan River to meet coldwater fishery standards would not be desirable.

Recommendations

It is the overall recommendation of this study that a warmwater fishery be established and maintained in the lower Jordan River and a coldwater fishery be established and maintained in the upper Jordan River in accordance with the conclusions stated above. This overall recommendation is qualified by the following recommendations.

First, it is recommended that ammonia removal/reduction to 5 mg/l and 10 mg/l for summer and winter conditions respectively be integrated into the future sewage treatment concept that is adopted by way of NPDES permit conditions. This would serve to lower instream ammonia concentrations to acceptable non-toxic levels and would also significantly increase dissolved oxygen levels in the Jordan River.

Second, it is recommended that total residual chlorine be removed from future sewage treatment plant effluents that discharge to the Jordan River. This recommendation is made in light of the current occurence of fish in the lower Jordan River where the concentration of chlorine should be unacceptable for growth (even though these fishes are rough fishes). This recommendation should be the impetus for more study into the reactions of chlorine in the Jordan River specifically. These studies should concentrate on the aspect of chlorine die-away (decay coefficients, etc.) as affected by organic, ammonia, and suspended solids loadings and temperature.

Third, it is recommended that the habitat of the Jordan River be improved in conjunction with the Jordan River Parkway and the Jordan River Development plans. The outcome of projects such as these and others would be to improve the habitat of the Jordan River for the fishery as well as for the fisherman!

SECTION III

PREVIOUS RELATED STUDIES

Present Jordan River Fishery

To date, two major studies concerning the fishery of the Jordan River have been completed; a stream classification performed by the State Division of Wildlife Resources and an intensive June to August study performed by EPA in 1973. A study of Utah Lake and its associated fishery were investigated in a thesis primarily concerned with Walleyes in turbid waters. Since there is a close relationship between Utah Lake and the Jordan River, the results of that study are discussed.

State of Utah Classification

Periodically the State Division of Wildlife Resources surveys and classifies the fisheries of all surface waters in the State. The more important the fishery, the more often the stream is classified. In a report to the 208 Project (1975), the Division divided the river into five somewhat homogenous sections, four of which are in Salt Lake County.

Sections one and two, from the Great Salt Lake south to 6400 South Street (28.4 river miles) were designated a Class V fishery (Class I is the highest classification on the scale and Class VI is the lowest). The classification prodedure is included in this report as Appendix A. The principal factors limiting the fishery were reported as water pollution and channelization.

Section three extends south from section two to 12300 South Street (9.3 river miles) and was designated a Class IV fishery due to water pollution and channelization. If this section had not been channelized, it would have been designated Class III.

Section four extends south from section three to the Utah County line (6.5 river miles). This section was designated Class III with water pollution slightly limiting aquatic production.

Section five, south from the Utah County line to Utah Lake (10 river miles) was designated a Class III warmwater fishery.

The fishing pressure on the Jordan River is described as light in sections one and two, moderate in Section three, and heavy in sections four and five during spring and summer for channel catfish by the Division in a more recent survey. However, trout fishing in sections three and four has been improving and as occasional large trout (greater than five pounds) is being taken.

Overall, the Division reports that although an aedquate data base is lacking for this non-major fishery, the proncipal factors limiting fish production in the Jordan River are dewatering, channelization, water pollution, and the lack of suitable spawning habitat.[5]

EPA Survey

The second related investigation into the fishery of the Jordan River was conducted from June to August, 1972 by the Surveillance and Analysis Division of the Region VIII EPA office and published in 1973.[3] This report was written to provide baseline water quality data but also included data collected on the benthic communities and fish populations of the Jordan River.

A diverse community structure, indicated by the presence of many species including relatively large numbers of individuals per species, indicates a healthy environment. A value defined as a Diversity Index is a measure of this phenomena, incorporating numbers of individuals and numbers of species. A general form of the Diversity Index can be given by equation (1).

$$\overline{H} = -\sum(P_i \cdot \ln P_i) \qquad (1)$$

where: H = diversity index

$P_i = \dfrac{\text{number of organisms in the } i^{th} \text{ species}}{\text{total number of organisms in the sample}}$

ln = natural logarithm (base e)

Relatively poor areas have diversity indicies ranging between 0.0 and 1.0. More diverse areas, therefore relatively better areas, have diversity indicies greater than 1.0. It should be noted that diversity indicies are an indicator of community structure and provide a rough measure that can be used in comparing different areas.[6] Table 6 lists the fish species and numbers of individuals as reported in the EPA study. Figure 3 shows the diversity index of the fish population plotted against river mile (sample station) as reported in the EPA study. For comparison, fish diversity indicies for a survey of the Jordan River fishery completed December 1976 to January 1977 are also shown in Figure 3.[7] It should be noted that this latest study was made in the winter and sampling problems were encountered. It is, however, the most up-to-date study on the Jordan River fishery.

Utah Lake

The study of the Utah Lake population of Walleyes contains much historical data on Utah Lake and some quantitative data of fish populations and water quality.[2] Relative abundance of fish species in Utah Lake is very near to that of the Jordan River as would be expected. Carp and chub comprised 71.6 percent of all fish taken in gill netting (per hour) from May 1958 to October 1959. Channel catfish, perch and white bass constituted only 15 percent of the population. Shiners, largemouth bass and trout collectively accounted for only 0.3 percent of the population.

The present fishery in Utah Lake is apparently getting better than it was a few years ago. Personal interviews with fishermen who fish Utah Lake disclose good success for walleyes and fair success for white bass and catfish.

Water quality in the upper Jordan River and in Utah Lake is very similar since the lake is the source of the River. Some cross generalizations about critical pollutant concentrations can be drawn from this but the different habitat (lake versus stream) make these generalizations of little practical use. Water quality of two proposed reservoirs on the upper Jordan River (south of 9800 South

TABLE 6

JORDAN RIVER: NUMBER AND KINDS OF FISH, 1973*

Station # and Location--1. Saratoga Springs
2. Lehi-Fairfield
3. Bluffdale Road
4. North Prison Road
5. 12400 South
6. 9000 South
7. 5770 South
8. 4800 South
9. 3300 South
10. 2100 South
11. 300 South
12. 1800 North
13. State Canal

Station #	Distance Fished	Hours Fished	Carp *Cyprinus carpio*	Utah Sucker *Catostomus ardens*	Brown Trout *Salmo trutta*	Dace *Rhinichthys sp.*	Redside Shiner *Richardsonius balteatus hydrophlox*	Utah Chub *Gila atraria*	Green Sunfish *Lepomis cyanellus*	Yellow Perch *Perca flavescens*	Goldfish *Carassius auratus*	White Bass *Morone chrysops*	Black Bullhead *Ictalurus melas*	Mountain Sucker *Catostomus platyrhynchus*	Total #	# of Kinds	$\bar{H}$
1	0.2 mi	0.5	185						2	1		15			203	4	0.35
2	0.1 mi	0.6	10						1			3	4		18	4	1.12
3	0.1 mi	0.5	10	37		26								82	155	4	1.16
4	300 ft	0.3		3	1	35	11							10	60	5	1.14
5	800 ft	0.6	56	16		11	9					1		66	159	6	1.34
6	300 ft	0.3	16	13					1					27	57	4	1.10
7	400 ft	0.4	56	75								1		15	147	4	0.98
8	300 ft	0.2	40	50										5	95	3	0.86
9	0.2 mi	0.5	150	75										10	235	3	0.79
10	0.1 mi	0.4	60	1											61	2	0.08
11	0.1 mi	0.4	50	3				6			24				85	4	0.97
12	0.1 mi	0.4	64				20	20							104	3	0.93
13	0.1 mi	0.4	24					1							26	2	0.16

* Adapted from Ref. (3)

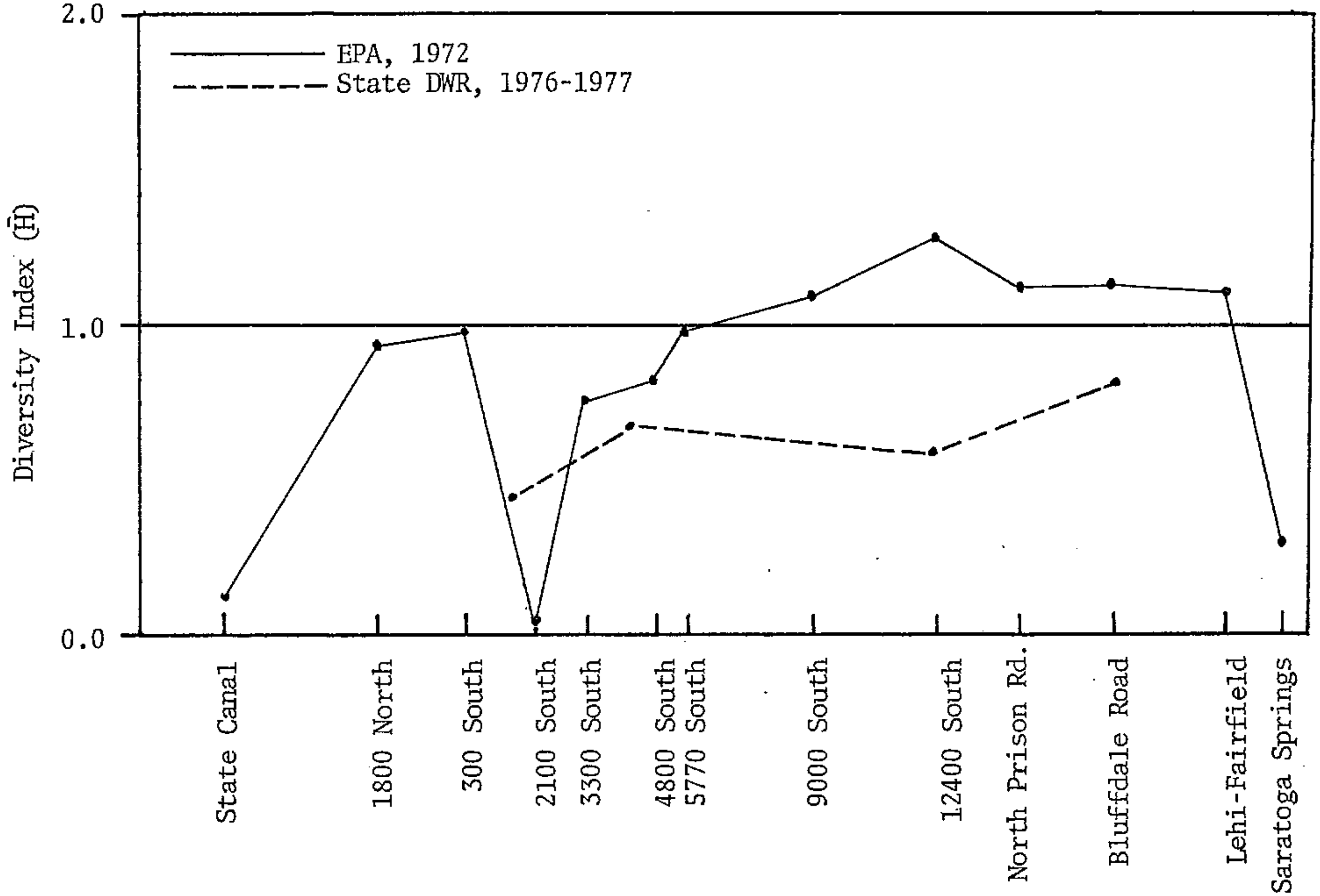


Figure 3. Fish Diversity Indices in the Jordan River, 1972[3] and 1976-1977[7]

Street)[8] would very likely be similar to that in Utah Lake. At the present time it is doubtful that these reservoirs will be built even though some sources predict they will exist within 15 years.[9]

Others

Two other studies on the Jordan River that deal with the fishery have been completed. Hinshaw, 1966, completed a study on the pollutional degradation of the Jordan River using aquatic invertebrates as indicator organisms. It is important to note that there is a striking similarity between the diversity indicies of aquatic invertebrates as reported by Hinshaw and the fish diversity indicies as reported earlier.[10]

The other study on the Jordan River was completed as required by Section 303(e) of the 1972 Federal Water Pollution Control Act as amended (PL 92-500). The 303(e) Plan in itself did not provide any new information on the Jordan River fishery but did tie together material discussed earlier. Therefore, the 303(e) plan is not discussed here.[11]

Safe Constituent Levels

There have literally been thousands of studies done on the development of safe water quality constituent levels for fishes. These studies are not considered here but are in the text in the "Results" section.

Projected Constituent Levels

Two 208 Project technical reports on the future water quality of the Jordan River were completed by Hydroscience, Inc. The 1976 report dealt with the effects on dissolved oxygen and other parameters as affected by the upgrading of the seven sewage treatment (existing condition) or the construction of one regional or two subregional treatment plants to replace the seven. They also prepared an extensive report on the future water quality of the Jordan River which examines the effects of the single regional sewage treatment plant (1977).

Hydroscience, Inc., 1976

As a Task under contract to the Salt Lake County 208 Water Quality Project, Hydroscience, Inc. developed a model and evaluated the effects of Alternatives I, II, and VI on future dissolved oxygen levels and other constituents in the Jordan River.[12] Flow data used in this report is somewhat less than is currently projected and is shown in Table 7. Loading data used were an effluent dissolved oxygen of 5.0 mg/l, effluent oxidizable nitrogen of 20.0 mg/l, and effluent $CBOD_5$ of 25.0 mg/l.

TABLE 7

WASTEWATER FLOWS USED FOR HYDROSCIENCE PROJECTIONS AND CURRENT PROJECTIONS OF YEAR 2000 FLOWS

Flow contributory to:	Flow (mgd)	
	Hydroscience projection (13)	Current projection (94)
Sandy Suburban Sanitary Dist.	6.5	12.5
Midvale City	10.5	19.5
Salt Lake County Cottonwood Sanitary Dist.	13.0	11.0
Murray City	6.0	4.0
Salt Lake City Suburban Sanitary Dist. #1	21.0	19.0
Granger-Hunter Improvement Dist.	12.0	11.0
South Salt Lake City	6.0	6.0
Total	75.0	83.0

The river was segmented into 27 reaches. Sewage treatment plant point sources and combined tributary, agricultural returns, and groundwater nonpoint sources were inputs to the system.

Benthal oxygen demand was determined from laboratory analysis of samples collected during the summer of 1975. These analyses showed this demand above the surplus canal to be negligible and below the surplus canal to be 1.3 $g/m^2/day$. Algal productivity and respiration was assumed to be negligible. This was substantiated by the non-existence of any discernible diurnal fluctuation of dissolved oxygen and a low concentration (10 μg/l) of chlorophyll a.

The atmospheric reaeration rate (K_a) was computed using the O'Connor-Dobbins formula.[14] Values ranged from 12.7/day in the faster, shallower upper river to 2.4/day in the sluggish, deeper lower river. The nitrification rate (K_n) was assumed to be 0.15/day and the deoxygenation rate (K_d) was assumed to be 1.0/day. This value proved to be a fair assumption from the simulation produced based on 1972 and 1975 data.

In all, 18 cases were investigated. Selected results of the projections using an effluent BOD_5 of 10 mg/l are shown in Figure 4.

Hydroscience, Inc., 1977

As another task under contract for the Salt Lake County 208 Water Quality Project, Hydroscience, Inc. used the model developed in Ref. (12) to predict the future water quality of the Jordan River.[15] This model is developed and calibrated in Ref. (16) using data collected by Hydroscience in 1975 and the EPA in 1972.[3] This report presents projections of ammonia, TDS, TSS, coliform bacteria, and dissolved oxygen concentrations as affected by east-side urbanization of Salt Lake Valley, improving irrigation efficiency by 50 percent, low flow conditions, and storm runoff. All of these combinations were evaluated using the concept of one regional treatment plant (Alternative I). The eutrophication potential of the proposed upper Jordan River reservoirs was also investigated.

Of importance in this study are the ammonia, dissolved oxygen, and suspended solids projections and the plankton relationships of the proposed reservoirs. Resultant ammonia concentrations for the Jordan River are shown in Figure 5. This report indicates that nitrification will be necessary to keep the concentration of ammonia below the toxic level of 0.02 mg/l un-ionized ammonia (the

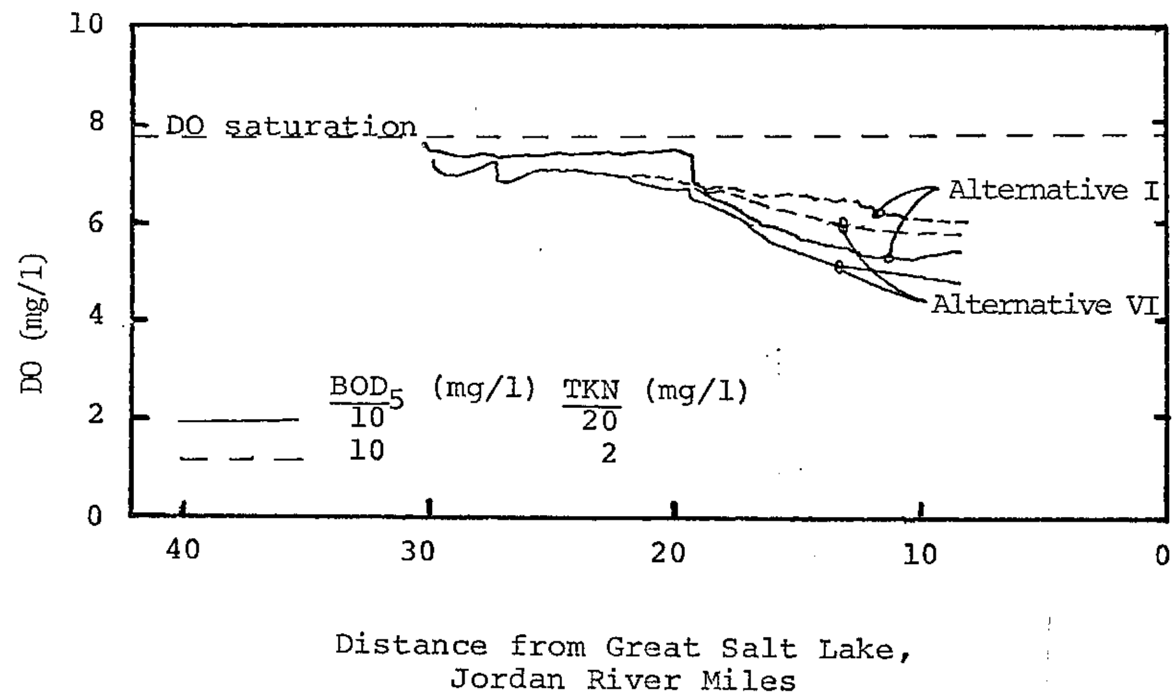


Figure 4. Projected Dissolved Oxygen Distributions, Hydroscience, 1976.[12]

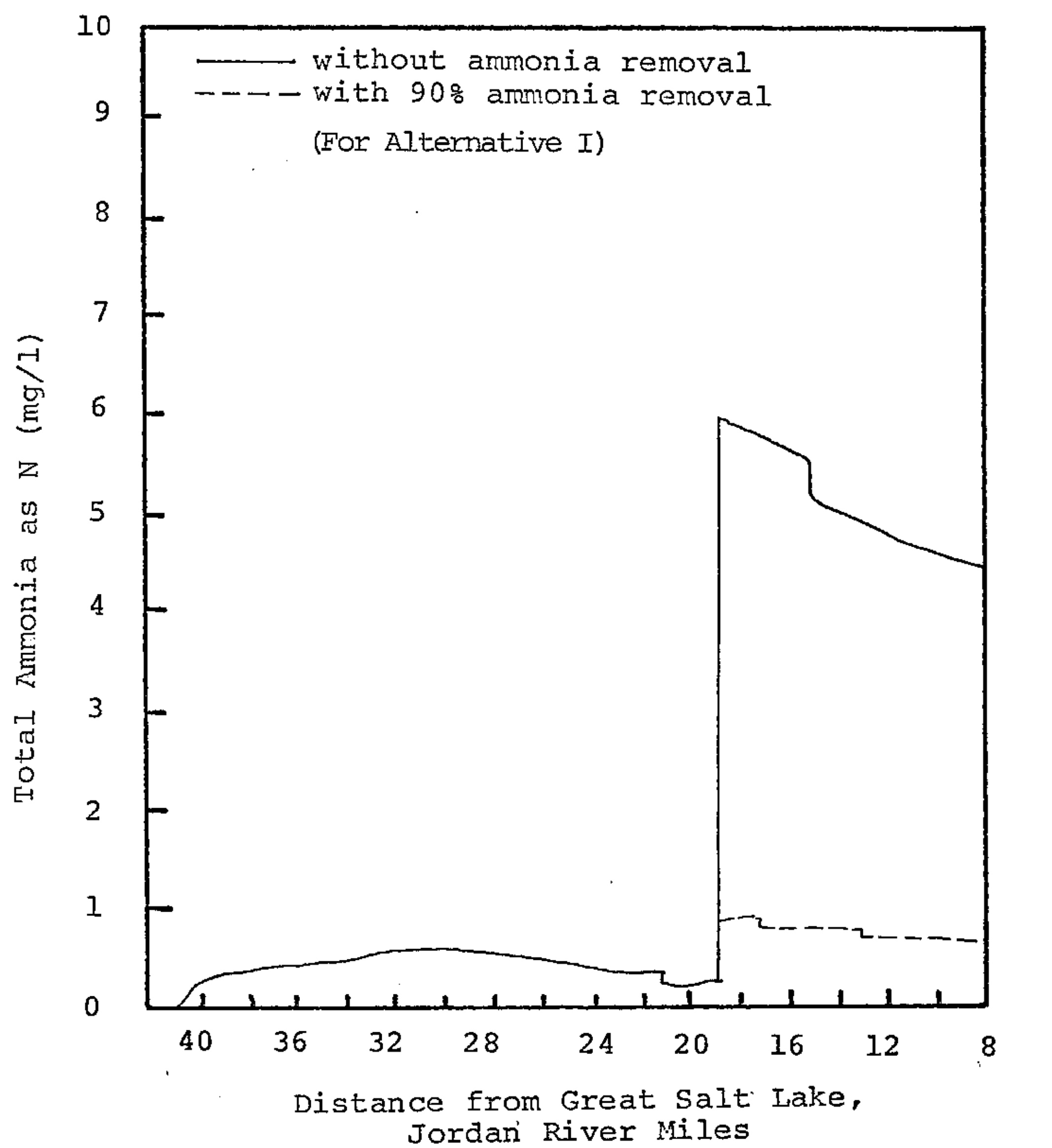


Figure 5. Total Ammonia Projections, Hydroscience, 1977.[15]

toxic portion - discussed later). Resultant ammonia concentrations for the Jordan River with 90 percent ammonia conversion in the regional treatment plant are also shown in Figure 5. Ammonia concentrations in return flows other than from the treatment plant were determined by stream reach. Figure 6 shows the various nonpoint source areas used throughout the report. Table 8 lists nonpoint ammonia loadings for the projections. The decay coefficient for NH_3-N used in all reaches was 0.15/day.

TABLE 8

NONPOINT AMMONIA LOADINGS FOR HYDROSCIENCE PROJECTIONS

	Groundwater				Agricultural Returns			
Reach*	1	2	3	4	1	2	3	4
Flow (cfs/mile)	3	18	6	0	8	11	6	0
NH_4-N (mg/l)	0	0	0	0	0.9	0.9	0.9	0
(#/day/mile)	0	0	0	0	39	54	29	0

*Reach 1 milepoints 40.8-30.0 (Utah-Salt Lake County line)
2 milepoints 30.0-25.0
3 milepoints 25.0-16.7
4 milepoints 16.7- 8.0 (Davis-Salt Lake County line)

Projected dissolved oxygen concentrations in the Jordan River are shown in Figure 7. These projections were based on polished secondary treatment at one regional wastewater treatment plant and a stream oxidation rate of 1.0/day. It was noted that BOD loads from this polished secondary plant may be more "resistive" to stream oxidation and could reduce the stream oxidation rate. For comparison, dissolved oxygen concentrations for a stream oxidation rate of 0.5/day were projected and are also shown in Figure 7. The minimum projected dissolved oxygen concentrations are 5.5 mg/l and 5.9 mg/l for K equal to 1.0/day and 0.5/day respectively.

Dissolved oxygen concentrations resulting from summer storm loads to the Jordan River were investigated. Assumptions made were

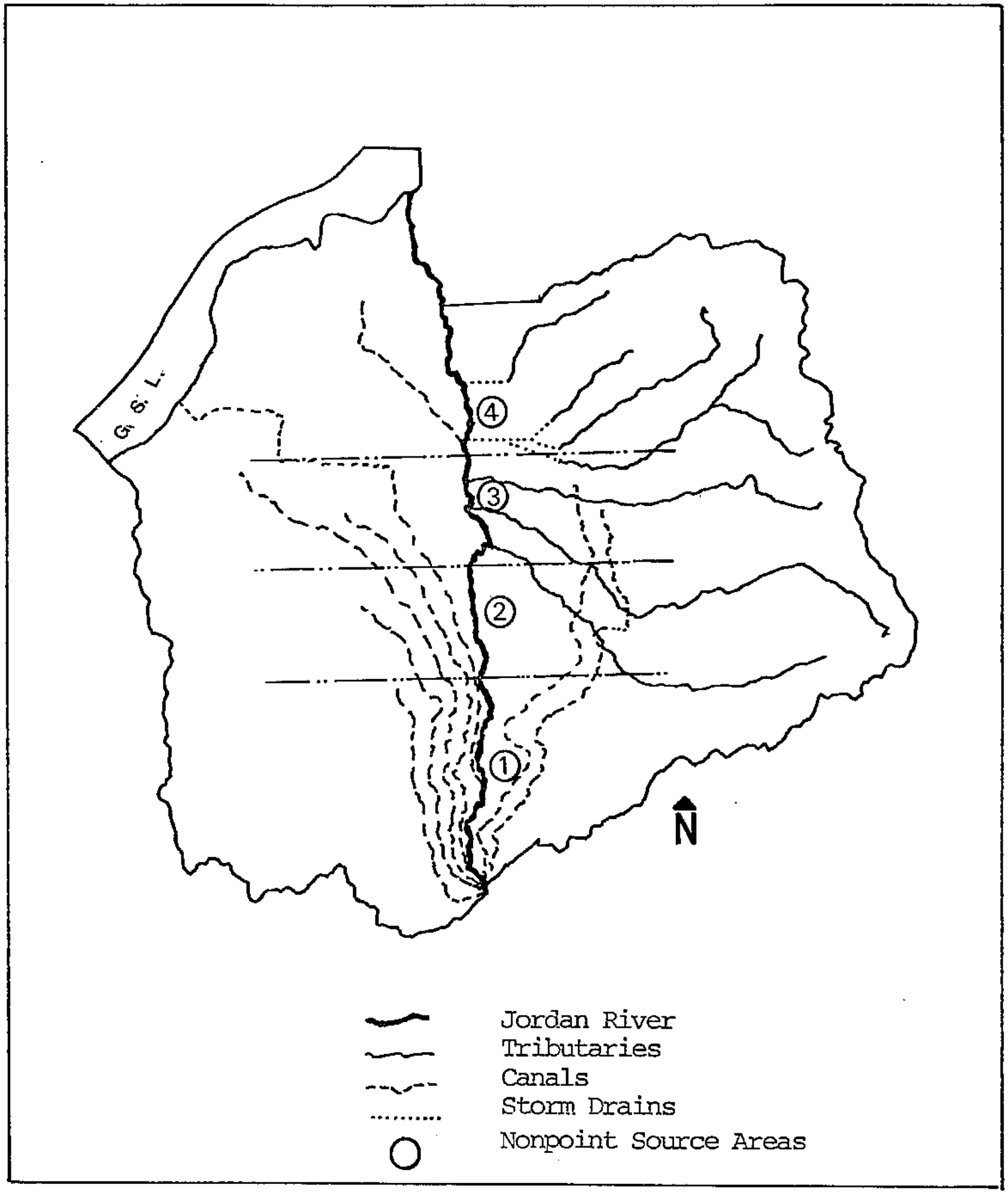


Figure 6. Nonpoint Source Areas; Hydroscience, 1977.[15]

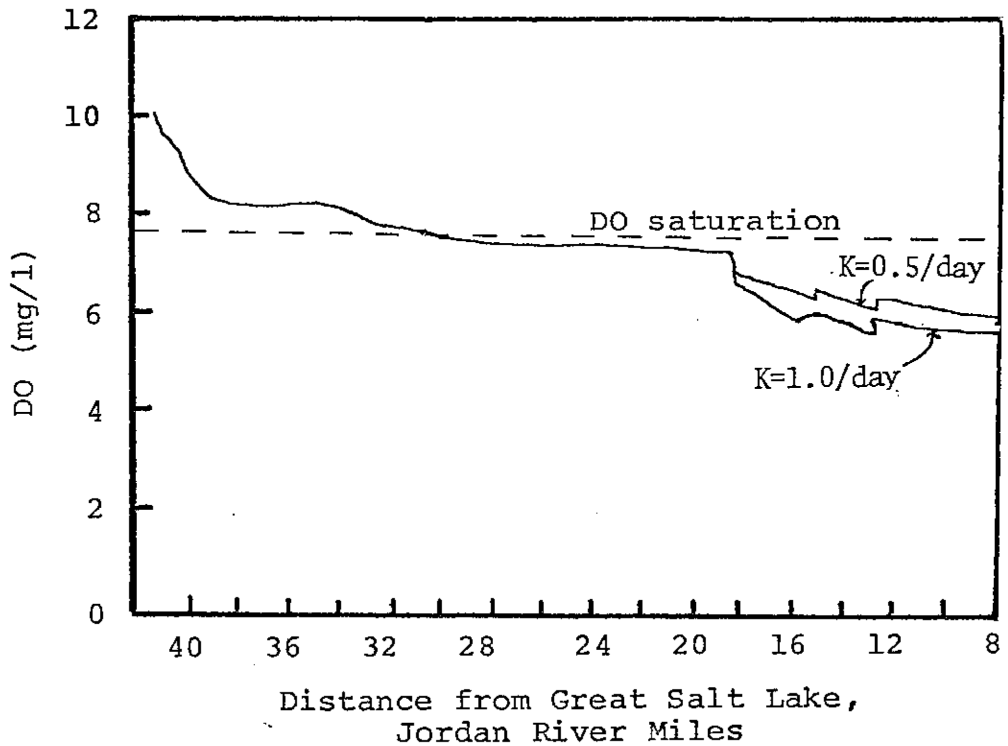


Figure 7. Projected Dissolved Oxygen Distributions, Hydroscience, 1977.

that all stormwater flows enter the river simultaneously and that the flows continue discharging until the river reaches steady state. Figure 8 shows projected dissolved oxygen concentrations resulting from stormwater loads from two storm areas (maximum impact).

Projected suspended solids concentrations resulting from storms are also shown in Figure 8. The assumptions discussed above applied for suspended solids projections.

Also investigated, on a first estimate basis, was the problem of algal blooms and dissolved oxygen depletion and removal of suspended solids in one of the two reservoirs proposed for the upper Jordan River. The Riverton Reservoir, shown schematically in Figure 9, was investigated primarily because of its potential use for recreation. Since final design has not yet been accomplished for this reservoir (or for the Lampton Reservoir), the results could only give a first estimate of what is to be expected. The conclusion was that the Jordan River downstream from the reservoirs will not be affected by blooms to any extent because of the large irrigation to the North Jordan Canal located less than one mile downstream of the proposed Lampton Reservoir site.

Water quality of the proposed reservoirs was measured as a function of the amount of chlorophyll a. It was estimated that the maximum concentration of chlorophyll a to be expected during the simulation period (May 15 to October 15 - the principal season for phytoplankton growth and relatively constant hydrological conditions in the reservoir) would be about 58 μg/l. Compared to the EPA eutrophic classification of 10 μg/l to 100 μg/l chlorophyll a, it can be seen that this reservoir has a high potential for eutrophication. The analysis did not delve into more specific projections because of the lack of data.

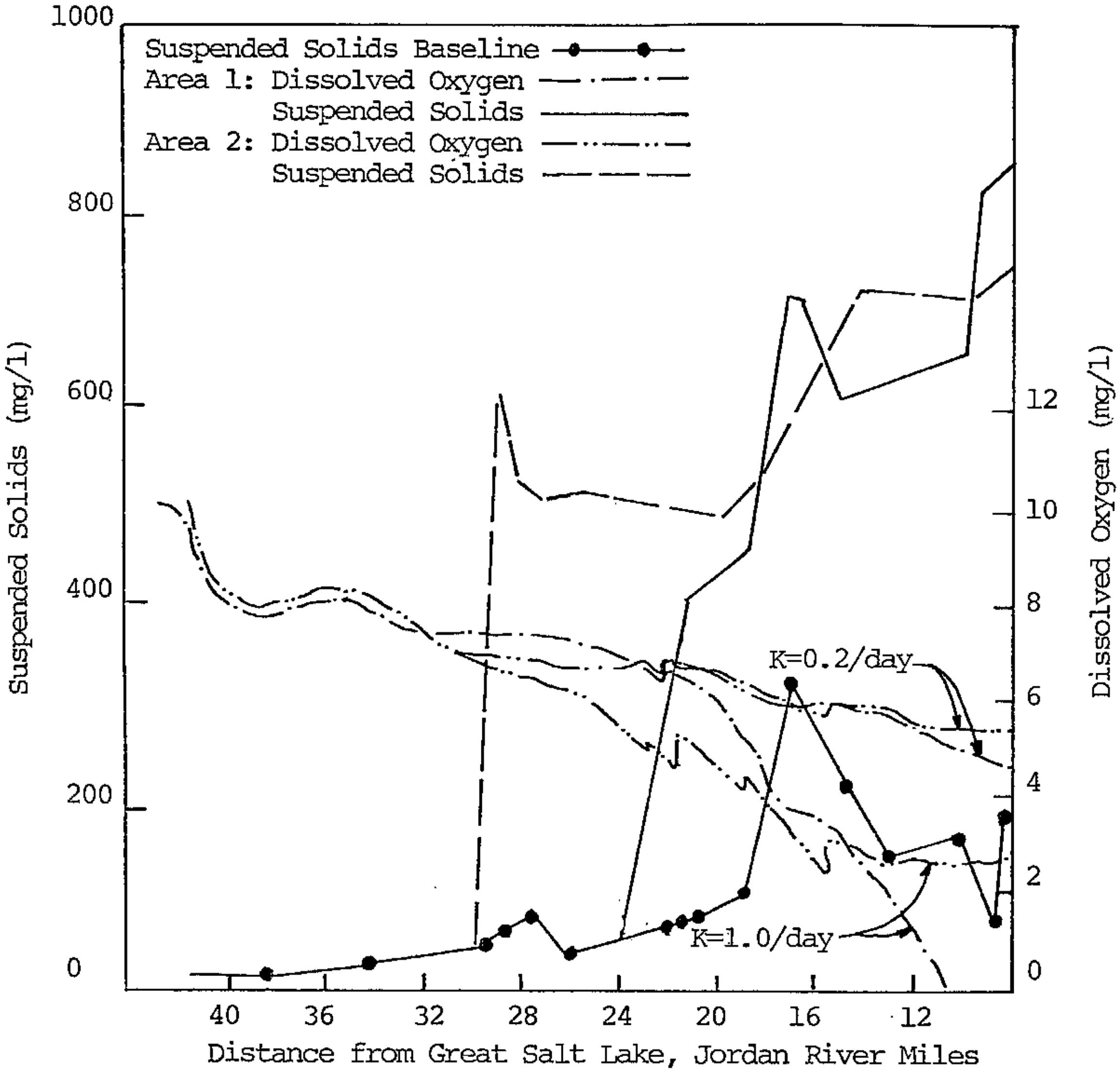


Figure 8. Dissolved Oxygen and Suspended Solids Response to Storm Areal Distributions, Hydroscience, 1977.(15)

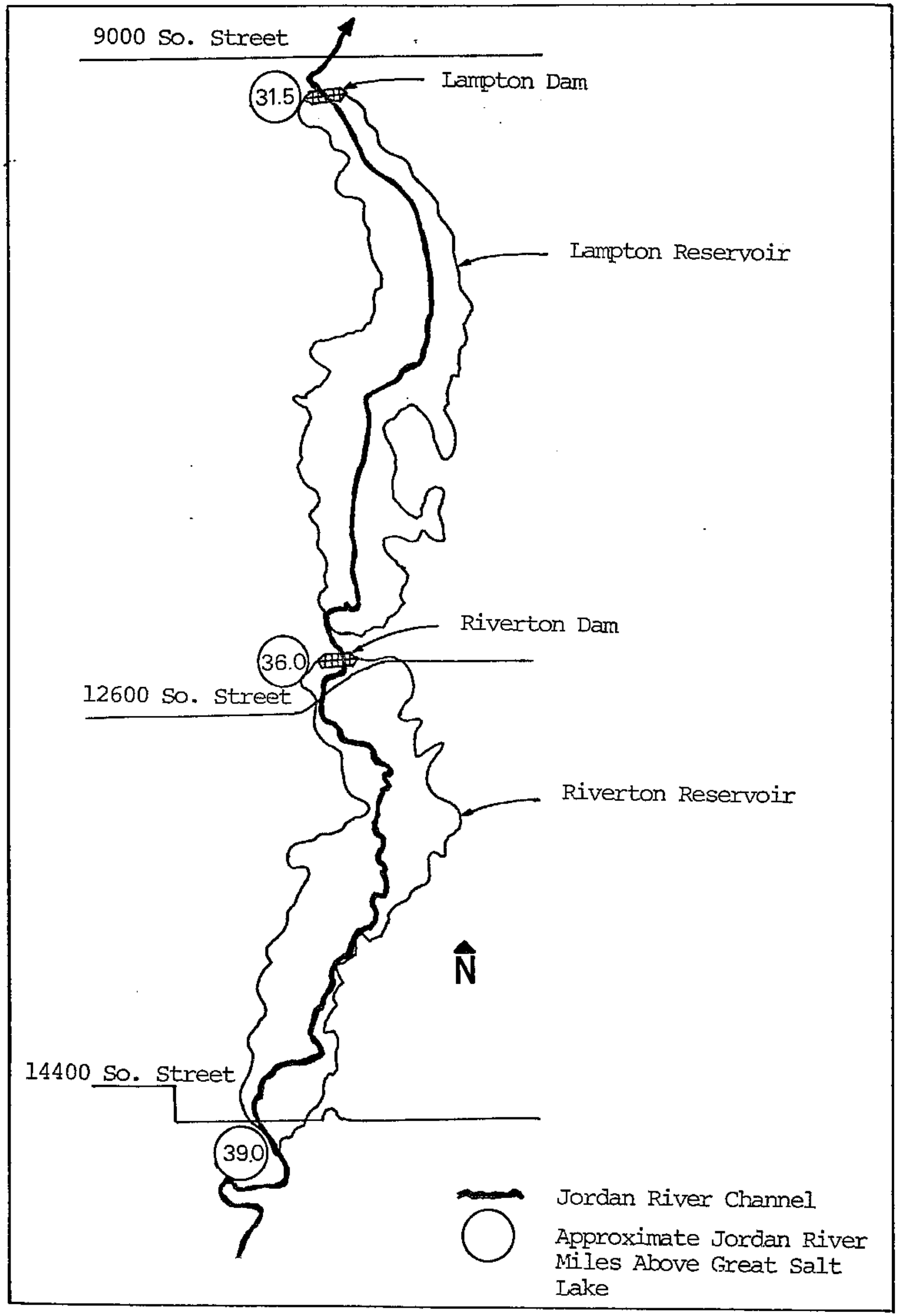


Figure 9. Location of Proposed Jordan River Reservoir.

SECTION IV

METHODOLOGY

Safe Constituent Levels

To determine species specific safe levels of temperature, dissolved oxygen, chlorine, ammonia, detergent, and suspended solids, a literature search was employed coupled with interviews of experts in the field, namely the Utah State Division of Wildlife Resources.

The amount of literature written on this subject is voluminous, describing limiting water constituent levels from literally thousands of experiments. With few exceptions, water constituent levels that were toxic to a species was determined for all fish species investigated.

A general reference of water quality criteria for freshwater aquatic life was used where little species specific reference data could be found.[17] This information source references work accomplished and reported by earlier authors. In most cases where this work was referenced, an effort was made to obtain original reports to gain an understanding of the background conditions of the reported experiment. Many reports do not define experimental conditions which limits the practical use of the work.

Projected Constituent Levels

To determine the future concentrations of chlorine and ammonia in greater detail than presented in Ref. (15), mass balance type models were employed. These models are discussed below.

Model Development

To develop projection models, essentially three mass balance equations are needed and are listed below:

$$C_2 = \frac{1}{Q_2}\left[Q_1C_1 + Q_IC_I - Q_o\left(\frac{Q_1C_1 + Q_IC_I}{Q_1 + Q_I}\right)\right] \tag{2}$$

$$C_2 = \frac{1}{Q_2}\left[Q_1C_1 + Q_IC_I - Q_o\left(\frac{Q_1C_1 + Q_IC_I}{Q_1 + Q_I}\right)\right]e^{-KT} \tag{3}$$

$$C_2 = \frac{1}{Q_2}\left[Q_1C_1 + Q_IC_I - Q_o\left(\frac{Q_1C_1 + Q_IC_I}{Q_1 + Q_I}\right)\right] e^{-KT} + \frac{S}{K}\left[1-e^{-KT}\right] \tag{4}$$

where

C_2 = concentration at downstream end of section

Q_2 = flow at downstream end of section

C_1, Q_1 = concentration and flow at upstream end of section

C_I, Q_I = concentration and flow of any inflow to the section

Q_o = flow of any outflow from the section

K = reaction coefficient of substance

T = time of flow through the section

S = total distributed source

e = base e

Conservative, non-distributed source pollutants can be modeled using Equation (2). Non-conservative, non-distributed source pollutants can be modeled by using Equation (3). Non-conservative, distributed source pollutants can be modeled using Equation (4).

The models utilize more complex mathematics but the basis is given in Equations (2), (3), and (4). A listing of the projection models can be found in Ref. (96).

Chlorine projections are developed according to Equations (2) and (3) and ammonia concentrations are projected according to Equation (4). When using the mass balance Equations (2), (3) and (4), certain assumptions must be made. Since the models are of the variable parameter-steady state input type as defined by Ref. (14), they will be advective models with the following assumptions:

1. The system is a single system; there is a functional relationship between the input and the output.
2. The system is one dimensional; there is longitudinal gradient (along the river), no lateral or vertical gradients.
3. The system is a non-dispersive medium (plug flow); pulse discharges retain their identity downstream and spreading is negligible.
4. The system follows first order reaction kenetics.

As with all subjective decisions, there will be as many different opinions regarding the validity of the results as there are readers. Documentation is provided wherever it exists.

Input Data

Typical summer and winter flow data used in this report for baseline computations was obtained from Ref. (18) and is shown in Figures 10 and 11. As can be seen, summer flows are the critical flows due to lower flowrate and dilution ratios. Seven day-ten year low flows (Q_{7-10}) were not used as they are not available from the USGS for the Jordan River. The complexity of the canal diversion system with its associated returns are the principal reason for the absence of Q_{7-10}. Flow data used as input to the projections appear in Ref. (96).

The primary source of free chlorine to the Jordan River is from sewage treatment plant effluents. Ref. (19) reports that even though some chlorine species when formed are relatively stable, they are not formed in significant amounts in natural waters. It is therefore assumed that any chlorine found in the Jordan River will originate from some point source. Point sources other than municipal sewage treatment plants that are a source of TRC input to the Jordan River are the Gadsby and Jordan power plants owned by Utah Power and Light Company. No input of TRC was assumed from these sources.

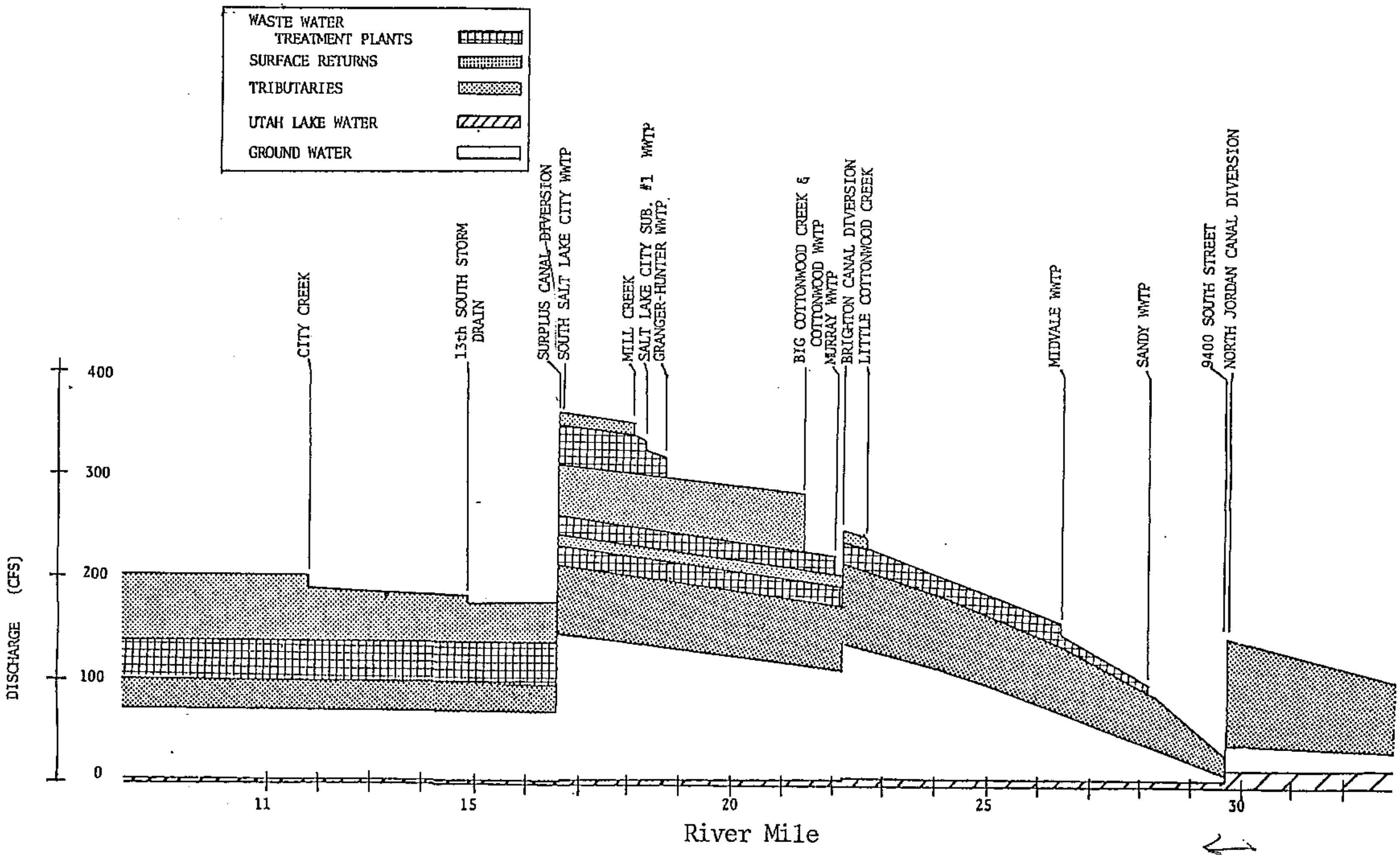


Figure 10. Typical Summer Flows, Jordan River.(18)

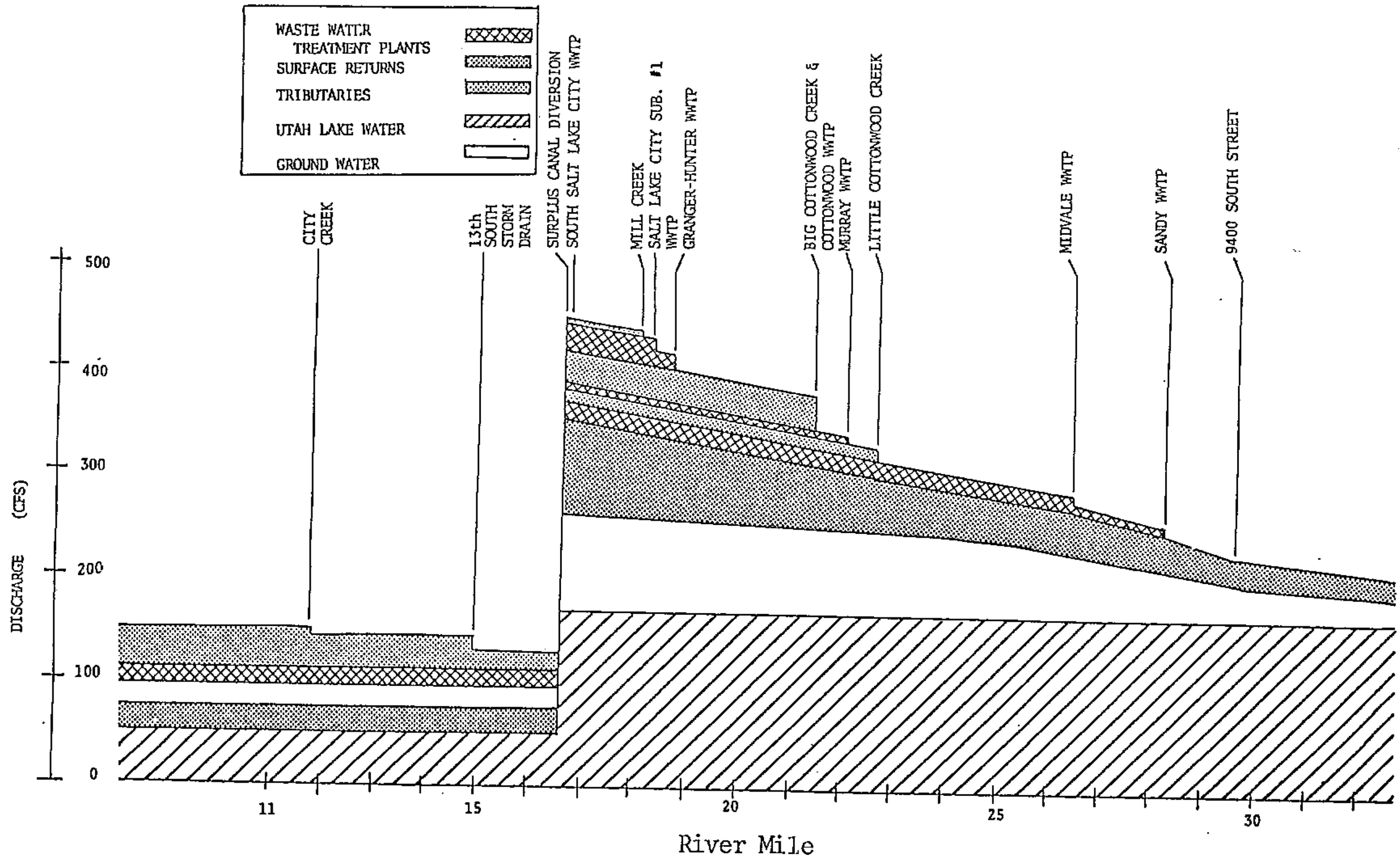


Figure 11. Typical Winter Flows, Jordan River.(18)

The State of Utah recommends that all sewage treatment plants maintain a residual chlorine level of 1.0 mg/l total residual chlorine (TRC) in their effluents.[20] However, NPDES discharge permits for all sewage treatment plants limit TRC in effluent near 0.5 mg/l. At the present time, the TRC recommendation is not being met by many plants. In a recent study, it was shown that effluent MPN coliform levels were affected by effluent suspended solids, BOD_5 concentrations and chlorine dosage.[21] In that study, it was shown that chlorine dosage of 3 mg/l at a suspended solids concentration of 10 mg/l would yield an effluent MPN level of 200 org./100 ml, the future standard.

To estimate what TRC concentration could result from this level of treatment, a multiple regression analysis was run on the data reported in Ref. (21). The resulting equations are shown below:

$$TRC = 0.098(Cl)^{0.07}(BOD)^{0.53}(MPN)^{-0.14} \quad (5)$$

$$TRC = 0.049(Cl)^{0.52}(BOD)^{0.55}(SS)^{0.54}(MPN)^{-0.23} \quad (6)$$

where

TRC = total residual chlorine in effluent

Cl = chlorine dosage

BOD = BOD_5 in effluent

MPN = MPN org./100 ml in effluent

SS = suspended solids concentration in effluent.

The multiple r's for the equations (5) and (6) are 0.885 and 0.895 respectively. Using the values of 3 mg/l chlorine dosage, 10 mg/l BOD_5, 200 org/100 ml MPN coliforms, and 10 mg/l SS, the resulting total residual chlorine values obtained from Equations (5) and (6) are 0.34 mg/l and 0.32 mg/l respectively. Therefore, the baseline chlorine concentration for model iterations in this study will be 0.4 mg/l TRC.

Chlorine is relatively stable when combined with other substances and would therefore tend to act like a conservative substance. The Jordan River, however, has a high organic (BOD) loading that would lead to chlorine compounds acting in a non-conservative manner. Since chlorine is a strong oxidizer, organic material in the river would be oxidized by chlorine with the chlorine being reduced to another, non-toxic state. Since there is essentially no data relating to this aspect, chlorine is also projected as a non-conservative substance.

The principal source of ammonia to the river is from municipal sewage treatment plant effluents. Lesser contributions arise from agricultural return flows and urban runoff. Values for STP effluents for initiation of model iterations were 20.0 mg/l from all plants, the average NH_3-N value reported from plant self-monitoring data.[50]

Non-point (distributed source) concentrations of ammonia used for all projections was assumed to be negligible. This is, however, not the case. Other pollutant sources were determined, applied by stream segment and remained constant throughout the projections (i.e., no reduction in non-point source loads). These values are shown in Table 9.

Reaction coefficients for various non-conservative reactions used as model parameters are shown in Table 10. These values, except for the chlorine decay coefficients and the different summer and winter values also remain constant throughout the projections.

Initial instream concentrations of CBOD, NBOD, DO and NH_3 were based on data from City-County Health Department monitoring data for the past year. These values for the upstream segment boundary are also shown in Table 11.

Effluent CBOD values for input were derived from State polished secondary effluent standards.[20] Initial effluent values were 15 mg/l BOD_5 and 4.9 mg/l DO.

TABLE 9

POLLUTANT VALUES USED IN PROJECTIONS

Season	Uniform Loads			Benthic Demand		Tributaries		
	Mile-point	CBOD #/day/mile	DO (mg/l)	Mile-point	($\#/ft^2$/day)	Mile-point	CBOD (#/day)	DO (#/day)
Summer	29.1 to 25.3	547.0	7.1	29.1 to 16.7	0.0	22.0	486.0	405.0
	25.3 to 16.7	474.0	7.4	16.7 to 0.0	4.94×10^{-5}	21.2	596.0	1823.0
	16.7 to 14.7	0.0	0.0			17.7	170.0	608.0
	14.7 to 11.8	400.0	5.0			16.6	408.0	729.0
	11.8 to 0.0	0.0	0.0			14.7	54.0	243.0
Winter	29.1 to 25.3	547.0	9.4	29.1 to 16.7	0.0	22.0	930.0	1090.0
	25.3 to 16.7	474.0	9.8	16.7 to 0.0	4.94×10^{-5}	21.2	308.0	1019.0
	16.7 to 14.7	0.0	0.0			17.7	70.0	257.0
	14.7 to 11.8	400.0	6.6			16.6	975.0	696.0
	11.8 to 0.0	0.0	0.0			14.7	49.0	328.0

TABLE 10

REACTION COEFFICIENTS FOR NON-CONSERVATIVE POLLUTANT PROJECTIONS

Parameter	Rate Constant (day^{-1})	
	Summer	Winter
CBOD	1.000	0.550
NBOD	0.150	0.080
Cl_2	Variable	Variable
NH_3-N	0.15	0.15

TABLE 11

INITIAL INSTREAM PARAMETER VALUES USED IN PROJECTIONS

Season	Instream Concentrations		
	CBOD (mg/l)	NBOD (mg/l)	DO (mg/l)
Summer	10.00	1.10	7.60
Winter	10.10	1.10	8.80

SECTION V

RESULTS

The first part of this section will describe the results obtained in a literature search aimed at determining species specific toxic levels of various water quality constituents to selected fishes. The most sensitive results, i.e., the lowest lethal concentrations for a species, will be determined as the species specific critical level of each pollutant (allowing for experimental error and procedures).

Warmwater species investigated include Bluegill, *Lepomis macrochirus;* Channel Catfish, *Ictalurus punctatus;* Largemouth Bass, *Micopterus salmoides;* Perch, *Perca fluviatilis;* and Yellow Perch, *Perca fluvescens*. Coldwater species include Brook Trout, *Salvelinus frontinalis;* Brown Trout, *Salmo trutta;* and Rainbow Trout, *Salmo gairdneri*. This section will present the results in discussion format. Tabular results are given Appendix B for reference.

Safe Constituent Levels

Temperature limits for a fish species can be of two types; the limit for growth (upper and lower limits) or the limit for reproduction, the spawning and the survival of fry. Temperature death points and optimal growth temperature ranges are dependent upon acclimation temperature. This can be shown by the rise in thermal death points for the Bluegill from 30.7°C to 33.8°C when the acclimation temperature is raised from 15°C to 30°C. [22] Acclimation temperature here will be considered as the ambient temperature of the Jordan River which ranges from about 5°C to 25°C. [18]

Most warmwater species were found to have optimal growth rates occurring in the temperature range of 24°C to 29°C when the acclimation temperature ranged from 5°C to 25°C.[22,23,24] Higher acclimation temperatures reflected higher upper and lower thermal death points.[25] Thermal death points for the above specified acclimation temperatures ranged from 3°C to 34°C with most values in the range of 6°C to 30°C. Maximum weekly average temperatures for growth of warmwater species range from 29°C to 32°C with maximum temperatures for survival of short-term exposures of 34°C to 35°C[55]

Coldwater species, on the other hand, showed optimum growth rates in the temperature range of 7°C to 17°C.[25,26] Thermal death points ranged from 3°C to 34°C with most values in the range of 3°C to 23°C at the specified acclimation temperatures.[23] Maximum weekly average temperatures for growth of coldwater species range from 17°C to 19°C with maximum temperatures for survival of short-term exposures of 13°C to 15°C.[55]

Reproduction temperatures for warmwater species are higher than are those for coldwater species. Optimum spawning temperatures for the Bluegill, Channel Catfish, Largemouth Bass, and Yellow Perch have been reported as 25°C, 27°C, 21°C, and 12°C, respectively, while spawning temperatures for Brook and Rainbow Trout have been reported as 9°C.[17] Maximum weekly average weekly temperatures for spawning of warmwater and coldwater fishes range from 12°C to 27°C and from 8°C to 9°C respectively.[55]

Maximum temperatures for successful incubation and hatching of eggs of warmwater species are also higher for warmwater species. These temperatures for the Bluegill, Channel Catfish, Largemouth Bass, and Yellow Perch are 34°C, 29°C, 27°C, and 20°C. The corresponding temperatures for coldwater species is about 13°C.[17] The maximum temperature for survival of embryos for short-term exposures range from 20°C to 34°C for warmwater fishes and from 13°C to 15°C for coldwater fishes.[55]

Dissolved Oxygen

Dissolved oxygen requirements of fishes is perhaps the most investigated water quality condition of all. Dissolved oxygen requirements are closely related to ambient temperature, as is the toxicity of most all other substances. This can be attributed to the linkage of metabolism of coldblooded organisms (poikilotherms) with temperature. A discussion of this "synergistic" effect of dissolved oxygen and temperature and other toxic substances and temperature follows in the next section and will not be given here. Dissolved oxygen concentrations are also related to temperature via the pressure (temperature) - dissolved gas relationship.

Warmwater species, as a general rule, can survive in low levels of dissolved oxygen for extended periods. An example of low dissolved oxygen tolerance is demonstrated by the reports of two authors who placed Mirror Carp, *Cyprinus carpio*, along with other carp species in sewage lagoons to control algae, thereby stabilizing the dissolved oxygen content by preventing algae blooms (carp are herbiverous). Dissolved oxygen content in these waters was very near 0.0 mg/l.[27,28]

Within the temperature ranges of the Jordan River ($5^{o}C$ to $25^{o}C$) most warmwater species can tolerate dissolved oxygen levles of 0.8 to 3.1 mg/l for short periods.[22,24,29,30] Some experiments were controlled to the point where fish were or were not allowed access to the surface of the water. Fish that were allowed access to the surface had lower dissolved oxygen tolerance limits than those that were not.[31] This implies that somehow fish can obtain oxygen directly from the atmosphere.

Coldwater species, on the other hand, require more dissolved oxygen than do warmwater species. The minimum dissolved oxygen range for survival of coldwater species in the ambient temperature range ($5^{o}C$ to $25^{o}C$) is from 2.5 to 3.4 mg/l for short periods.[23,32,33] Some observations showed that in the field, no trout were found at dissolved oxygen less than 3.4 mg/l.[32]

The fry and newly hatched young of both warmwater and coldwater species were found to be more susceptible to depressed dissolved oxygen levels than were juveniles or adults.[34]

Chlorine

Only recently has interest in chlorine toxicity toward fishes been aroused even though chlorine is toxic at very low levels. The concentrations of chlorine in this study denote total residual chlorine (free and combined residuals) unless otherwise specified. Again, temperature is linked to the toxicity of chlorine and is discussed in the next section.

Warmwater species are susceptible to chlorine at less than 0.1 mg/l[35] with most toxic values in the range of 0.09 to 0.6 mg/l.[17,24,36,37,38,84,86,87] Some authors make no distinction between free chlorine and combined residuals while others made quite detailed analyses of the test water and reported results to $\pm$ 0.001 mg/l.

Chlorine toxicity to coldwater species is greater than it is to warmwater species. Threshold concentrations (concentrations at which no death occurred at "infinite" exposure time) ranged from 0.06 to 0.004 mg/l total residual chlorine.[25,39] At elevated temperatures, the toxicity appears to be higher than values reported. Toxic values of chlorine range near 0.2 mg/l for 96 hour tests.[17,84]

Ammonia

Ammonia toxicity to freshwater fish has also been an area of recent investigation. It has been shown that un-ionized ammonia (NH_3), not ionized ammonia (NH_4^+, NH_4OH, etc.) is the toxic portion of total ammonia.[40,41] Some authors report high levels of ammonia that have experimentally shown to be toxic. It is assumed that these high values are for total ammonia, not the un-ionized, toxic fraction. When compared to other results and compensating for pH and temperature, the correlation is good. Again, toxicity is synergistically associated with temperature and dissolved oxygen and perhaps antagonistically with chlorine.

Warmwater species appear to be less susceptible to ammonia than are coldwater species. However, at summer temperatures, 0.35 to 2.0 mg/l un-ionized ammonia appear to be toxic to warmwater species.[24,42] Some authors report a range of toxicity to 4.0 mg/l at pH $>$ 8.5.[24]

Coldwater species are more susceptible to ammonia toxicity but this fact is hidden in the experimental methodology used by some investigators. The threshold level for trout fry of un-ionized ammonia is reported as 0.5 mg/l,[42] but this value does not correspond to other reports investigated. Prolonged exposure (1,008 hr.) to 0.005 mg/l un-ionized ammonia caused gill hyperplasia to trout in one experiment.[43] Toxic limits appear to be in this range (0.005 mg/l).

Suspended Solids

Suspended solids have a more direct effect upon the benthic community than on fishes per se. It has been shown that trout, when exposed to high concentrations of suspended materials (810 ppm diatonaceous earth), died in 13 days. Similar results were obtained at 270 ppm. At 90 ppm, "reduced survival" was observed and at 30 ppm there was no apparent effect.[25] Other authors exposed "fish" to extremely high levels of suspended sediment, 100,000 ppm and 175,000 to 225,000 ppm, and obtained survival times of one week and "a few hours", respectively. The action of suspended material on fishes is physical, acting primarily on the gills, causing irritation and/or destroying the gill epithelium. Irritation of the gills elicits a mucus-producing response, inhibiting respiration. The utlimate result of either of these actions is suffocation.

Two reports investigated another aspect of the effects of suspended solids, i.e. turbidity and reduced light intensity, on fishes-feeding. High turbidity resulted in reduced reactive distances of Bluegills for all prey sizes for feeding.[90] Light reduction resulting from turbidity and turbidity itself reduced the capacity of the visual feeding Bluegill to find and thus obtain food.[88] This was proposed as one reason a non-visual feeder (Gizzard Shad) has a competitive advantage over Bluegills under turbid conditions.

Detergent

Detergent in waters and its effect upon fishes have been studied by a few authors. ABS (alkyl benzene sulfonates) and LAS (linear alkyl sulfonates) have been reported as being toxic to

Bluegills at levels from less than 4.0 mg/l[23,25,44,45,46] down to levels of 0.2 mg/l.[47,85] Principal action of detergent is the destruction of gill epithelium with the end result being suffocation.[48] Detergents also act "synergistically" with depressed dissolved oxygen concentrations and is discussed in the next section.

Organic compounds and inorganic salts are toxic to fishes, producing damaged gills[22] and a taint in fish flesh.[49] Organic compounds are not monitored in the Jordan River on a regular basis at present and it appears that they will not be monitored in the future. Therefore, these compounds along with pesticides, herbicides and heavy metals were not studied as to their toxicity toward fishes.

Projected Constituent Levels

At the time of this writing it has been decided that the Sandy STP will consolidate with the Midvale STP and preliminary work is being undertaken on the Step I 201 Facilties Plan by a local consultant. Therefore, only projections for Alternatives II through V are presented below.

Ammonia

The maximum instream ammonia concentration ("worst case") resulting from the projections is 6.40 mg/l occurring at milepoint 18 for Alternative II (summer conditions). No removal or reduction of STP effluent NH_3-N was assumed. The maximum instream concentrations of NH_3 resulting from projections using 5.0 mg/l and 10 mg/l STP effluent NH_3 for summer and winter conditions are 1.62 mg/l and 2.60 mg/l NH_3 respectively occurring at milepoint 18 for both Alternatives II and III. Projection results are shown in Figures 12 through 15.

Chlorine

Chlorine projections as presented here are first estimate projections indicating much more work needs to be done on the decay characteristics of this toxic substance in the Jordan River. All these projections are made using an effluent total residual chlorine concentra-

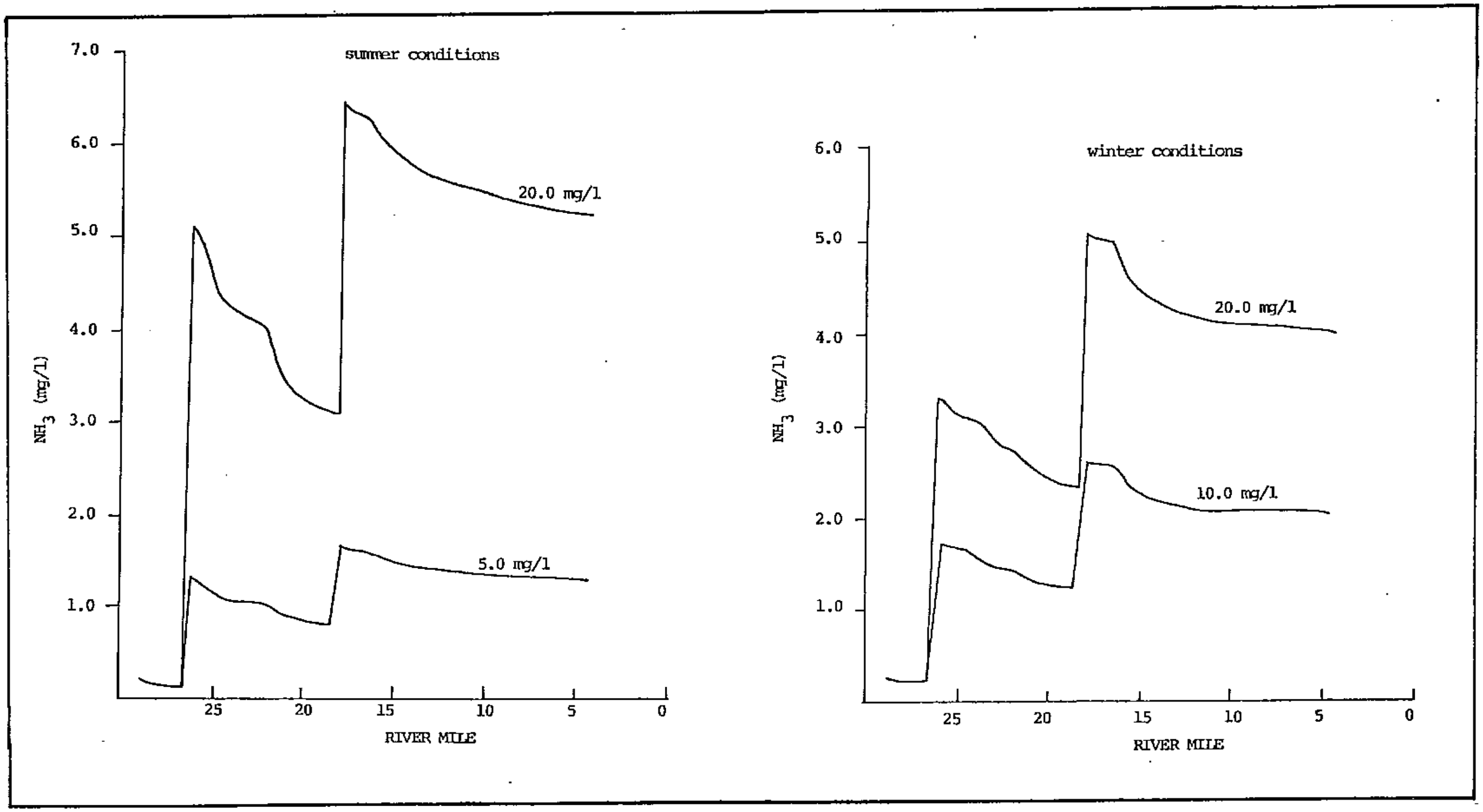


Figure 12. Resultant Ammonia Concentrations; Two Regional Plants.[96]

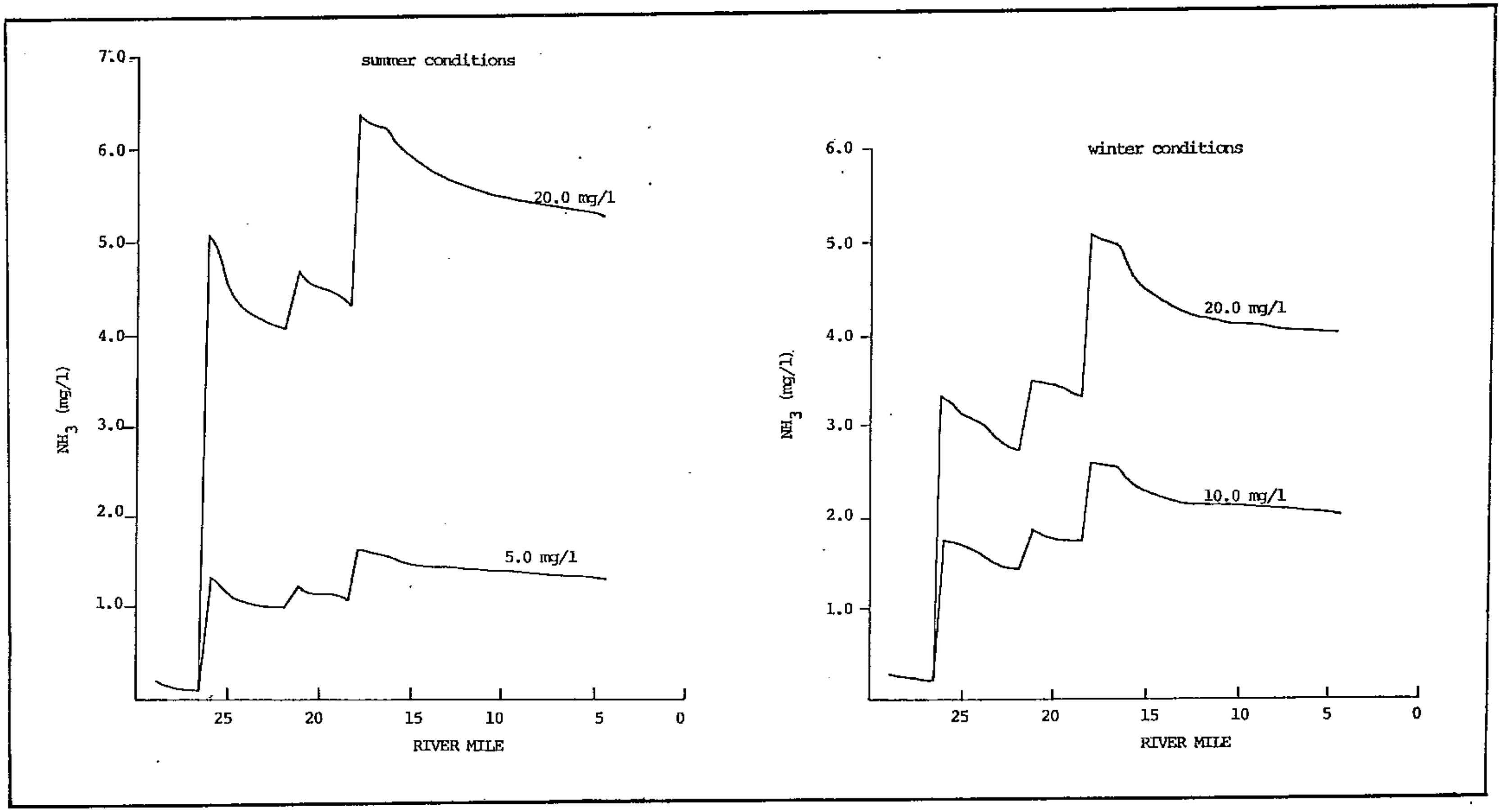


Figure 13. Resultant Ammonia Concentrations; Three Regional Plants.[96]

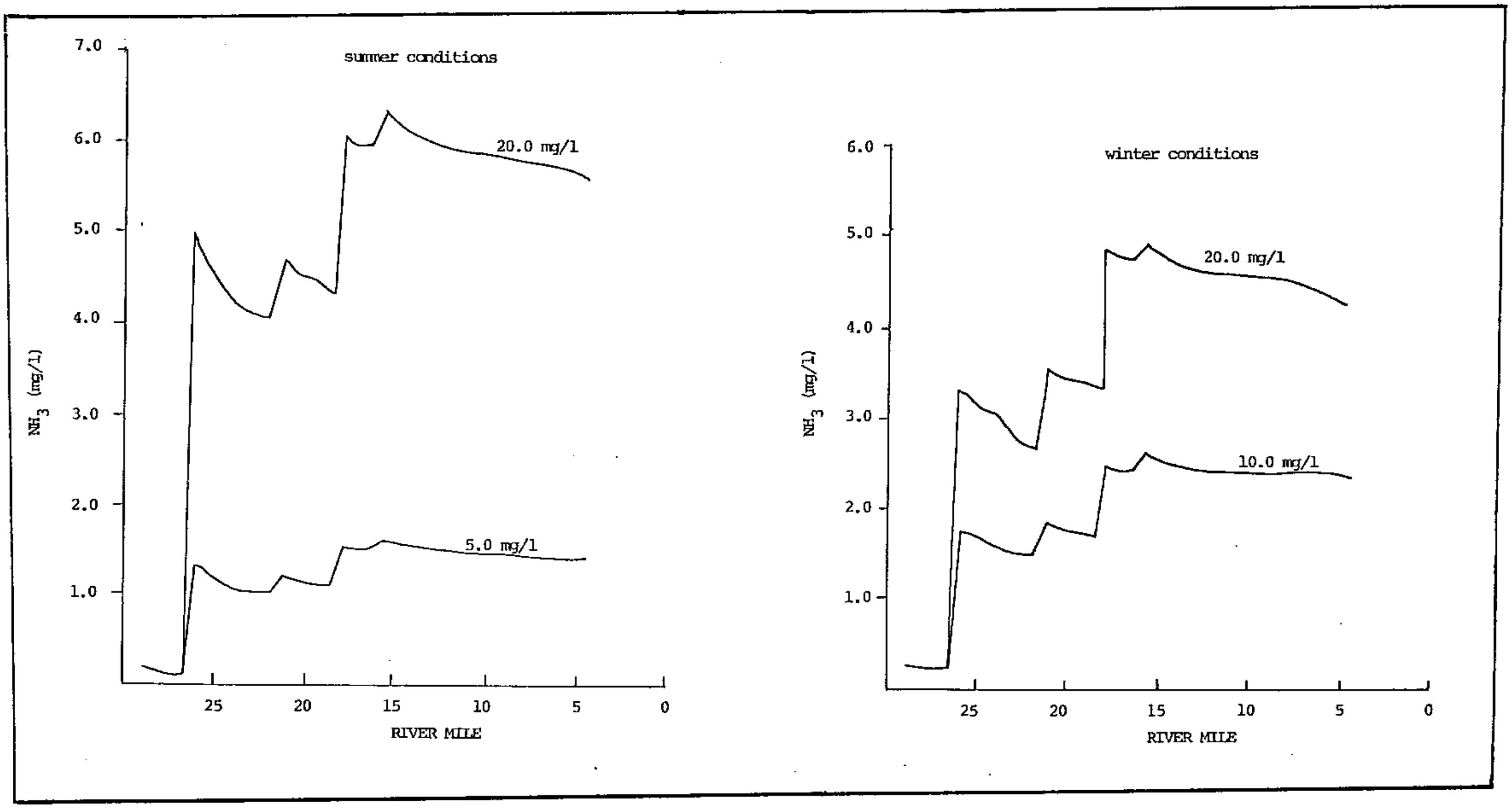


Figure 14. Resultant Ammonia Concentrations; Four Regional Plants.[96]

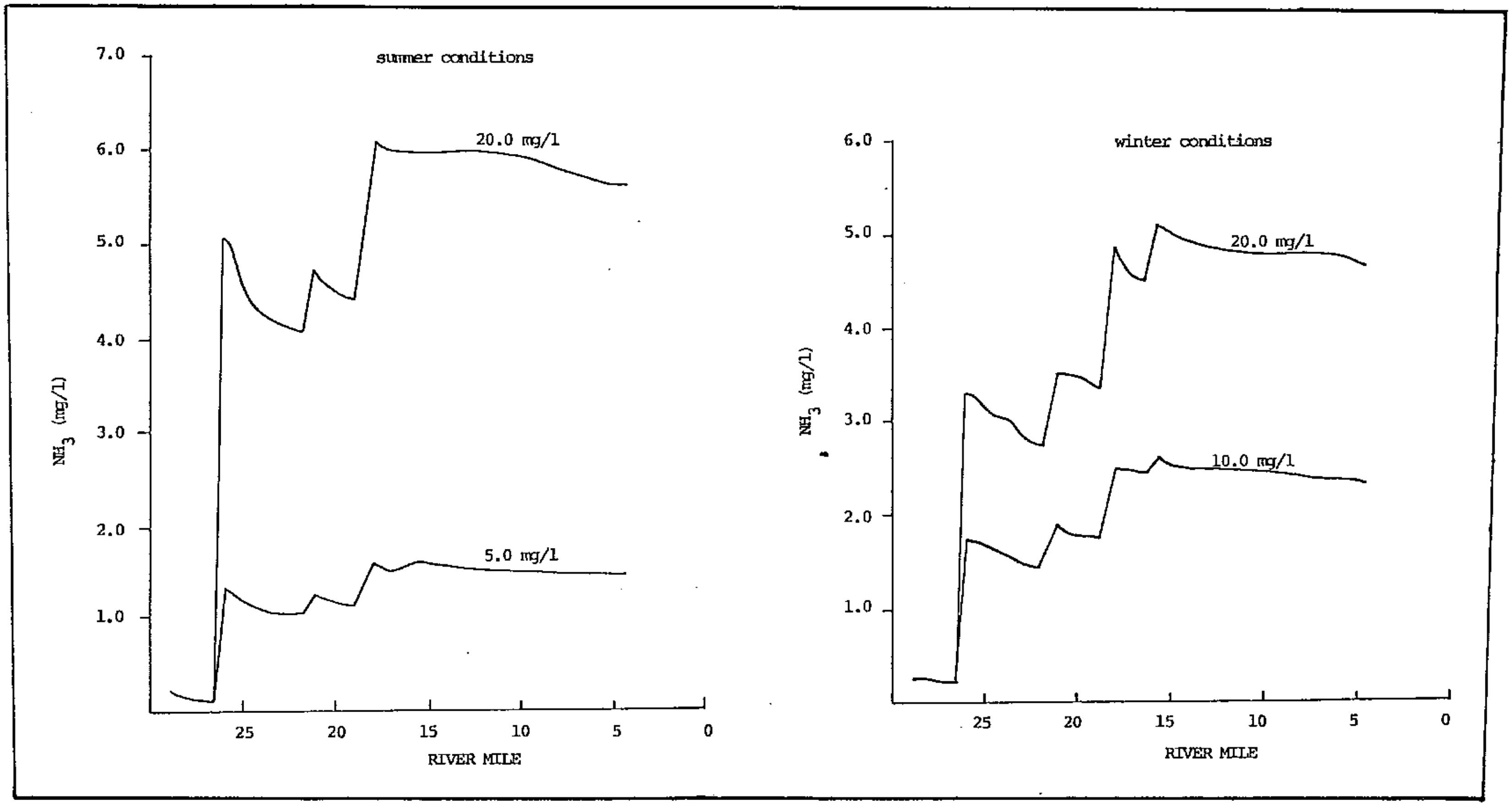


Figure 15. Resultant Ammonia Concentrations; Five Regional Plants.[96]

tions of 1.0 mg/l, 0.40 mg/l and 0.04 mg/l and decay coefficients of 0.0/day, 1.0/day and 5.0/day.

The highest instream concentration ("worst case") of chlorine projected was for Alternatives IV and V at milepoint 14.7 (3.13 mg/l). Alternatives II and III showed fairly close maximum concentrations of 3.10 mg/l. Results of chlorine projections are shown in Figures 16 through 23. Because of the lack of knowledge about chlorine reaction kinetics, it is noted that these projections are first estimates. Note also that sources other than sewage treatment plant effluents are not expected to appreciably affect the chlorine concentration in the Jordan River and were not included in the analysis.

Dissolved Oxygen

In order to evaluate effects of ammonia reduction on instream dissolved oxygen (DO) levels, projections of resultant insteam concentrations were also made. In all winter projections, instream DO concentrations remained greater than 6.0 mg/l throughout the entire length of the Jordan River in Salt Lake County. Summer projections, however, resulted in instream concentrations approaching 3.5 mg/l in the lower reaches of the river in the county. Concentrations dropped below 5.0 mg/l for all summer projections at approximately milepoint 15. Results of dissolved oxygen projections are shown in Figures 24 through 27.

Temperature

As was indicated before instream temperatures were not projected. The principal reason for this is that the river is a shallow, relatively fast moving river with few large tributaries that would change the temperature drastically. Projecting future instream thermal conditions was beyond the scope of this study. Additional information concerning temperature modeling can be found in Ref. (95) among others. Point source discharges from the sewage treatment plants would tend to be higher than the river temperature but by an insignificant amount in the range of concern. It is expected that the temperature of the Jordan River will remain within the historical maximum and minimum limits of 25°C to 7°C, respectively.

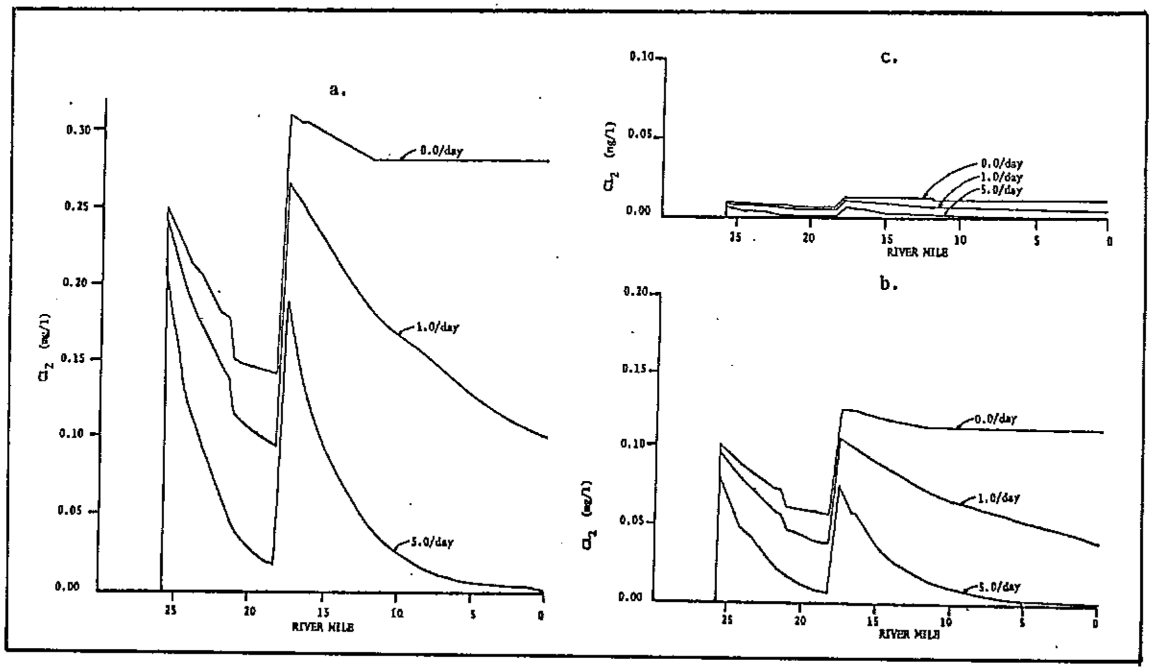


Figure 16. Resultant Chlorine Concentrations - Two Regional Plants, Summer Conditions (effluent concentrations; a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

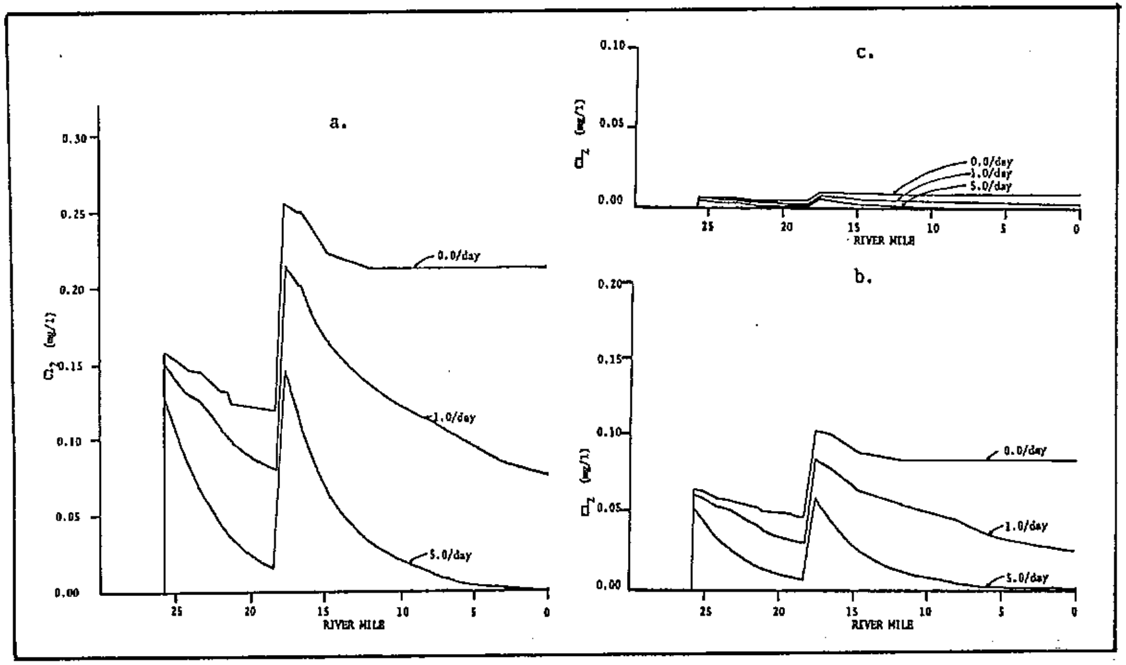


Figure 17. Resultant Chlorine Concentrations - Two Regional Plants; Winter Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

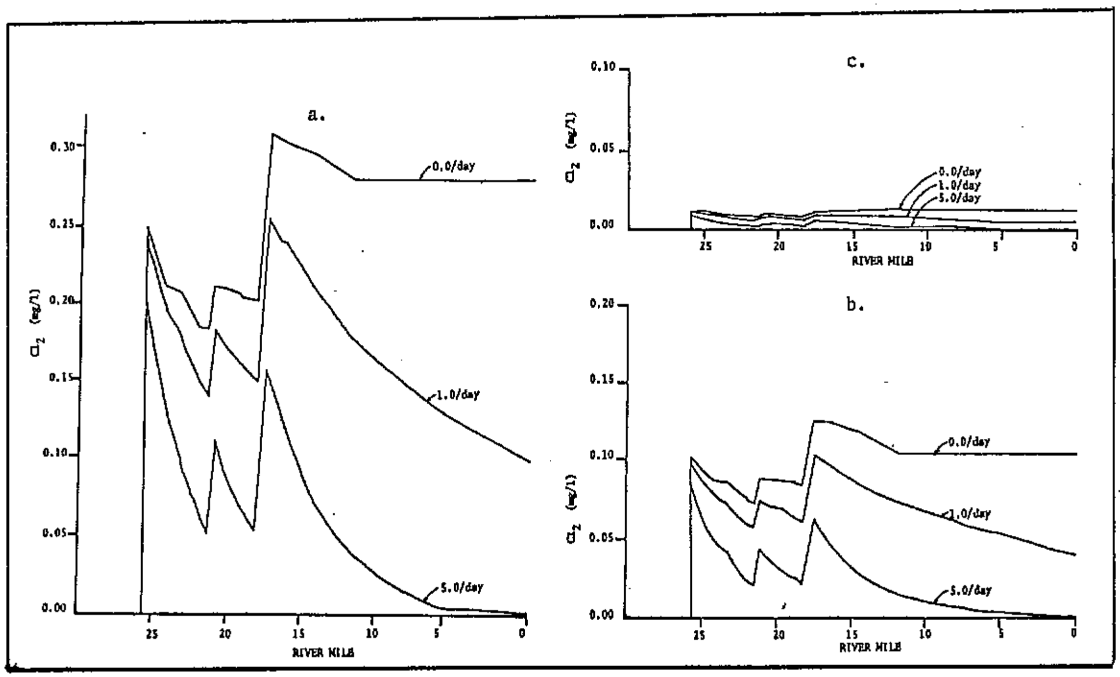


Figure 18. Resultant Chlorine Concentrations - Three Regional Plants; Summer Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

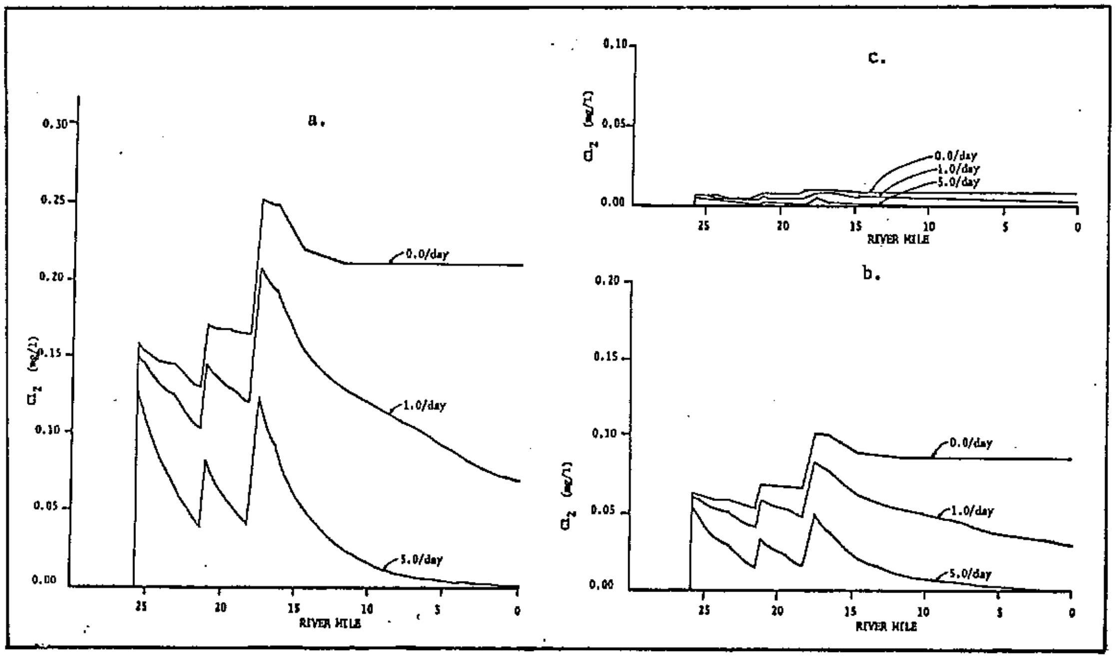


Figure 19. Resultant Chlorine Concentrations - Three Regional Plants; Winter Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

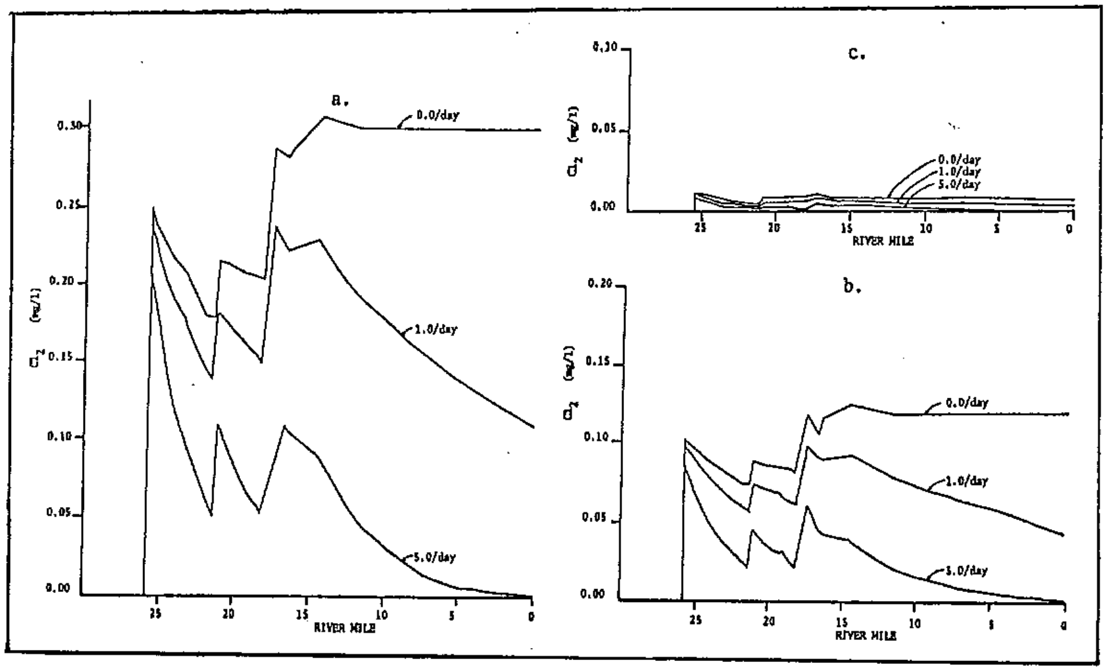


Figure 20. Resultant Chlorine Concentrations - Four Regional Plants; Summer Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

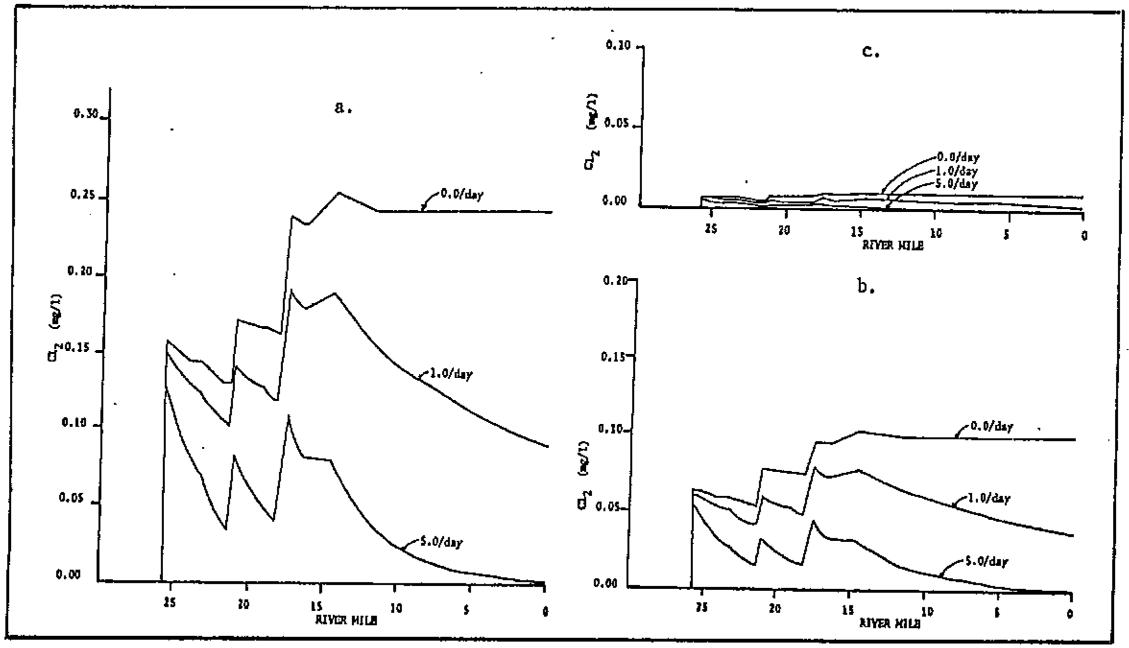


Figure 21. Resultant Chlorine Concentrations - Four Regional Plants; Winter Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

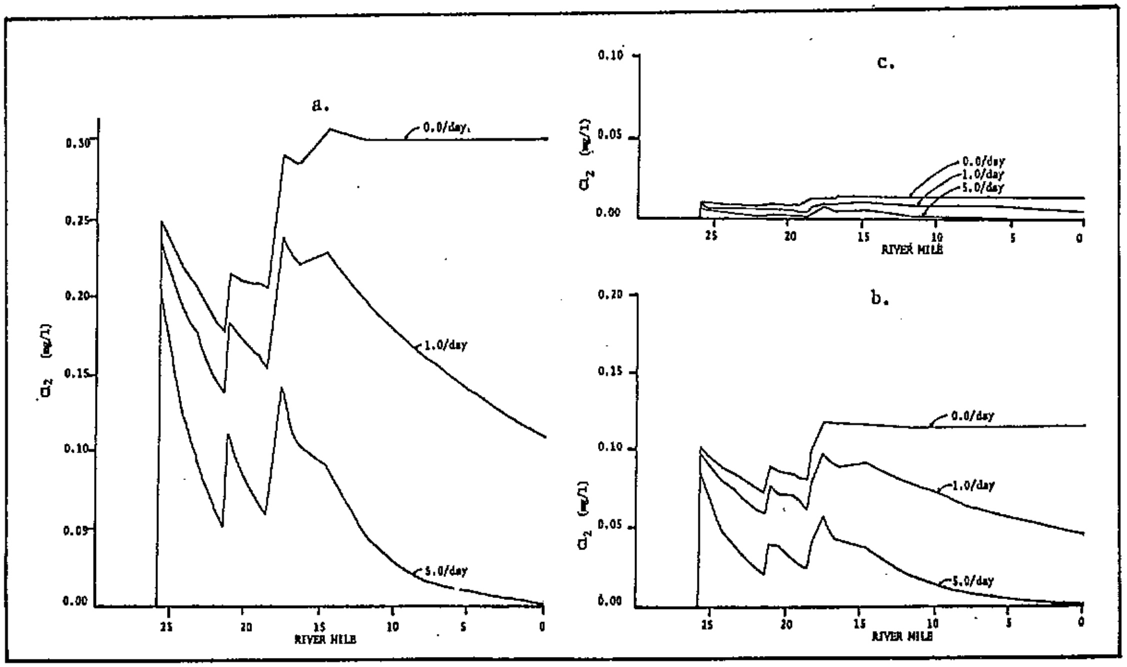


Figure 22. Resultant Chlorine Concentrations - Five Regional Plants; Summer Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

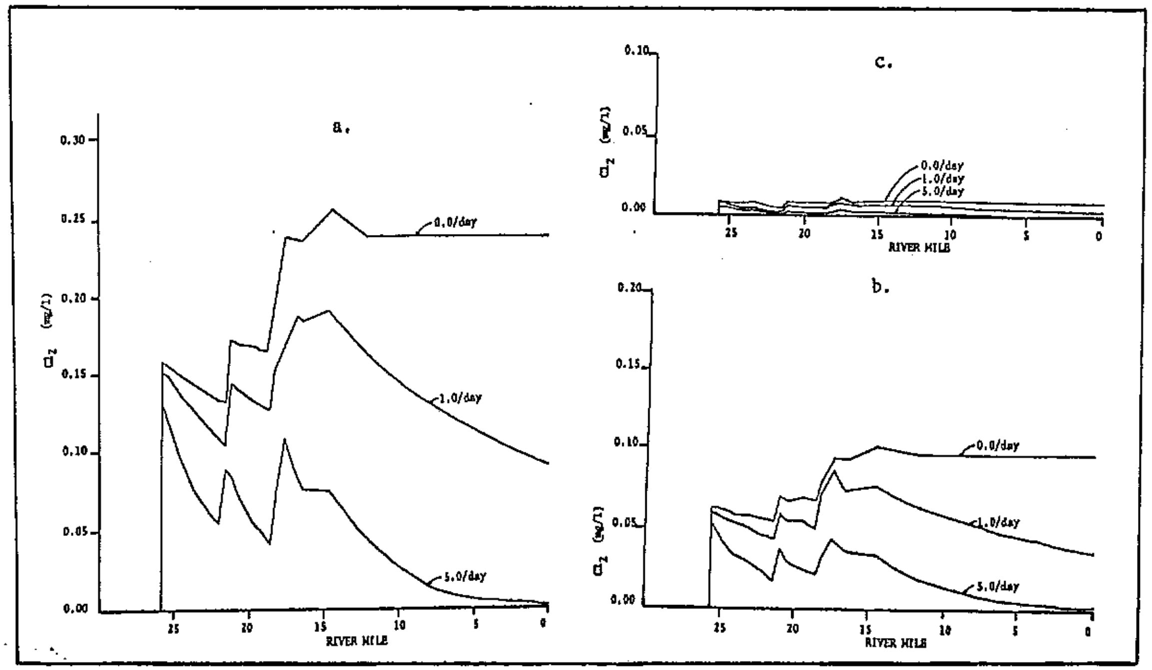


Figure 23. Resultant Chlorine Concentrations - Five Regional Plants; Winter Conditions (effluent concentrations: a - 1.00 mg/l, b - 0.40 mg/l, c - 0.04 mg/l).(96)

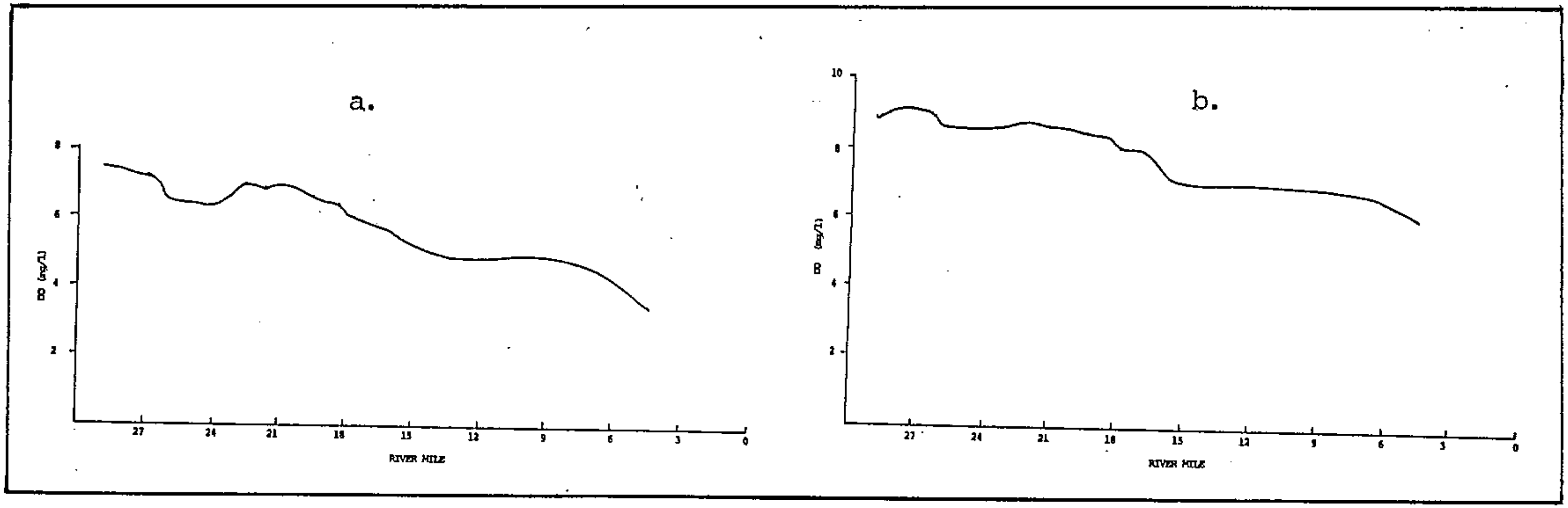


Figure 24. Resultant Dissolved Oxygen Concentrations; Two Regional Plants.
(a. summer conditions; b. winter conditions)

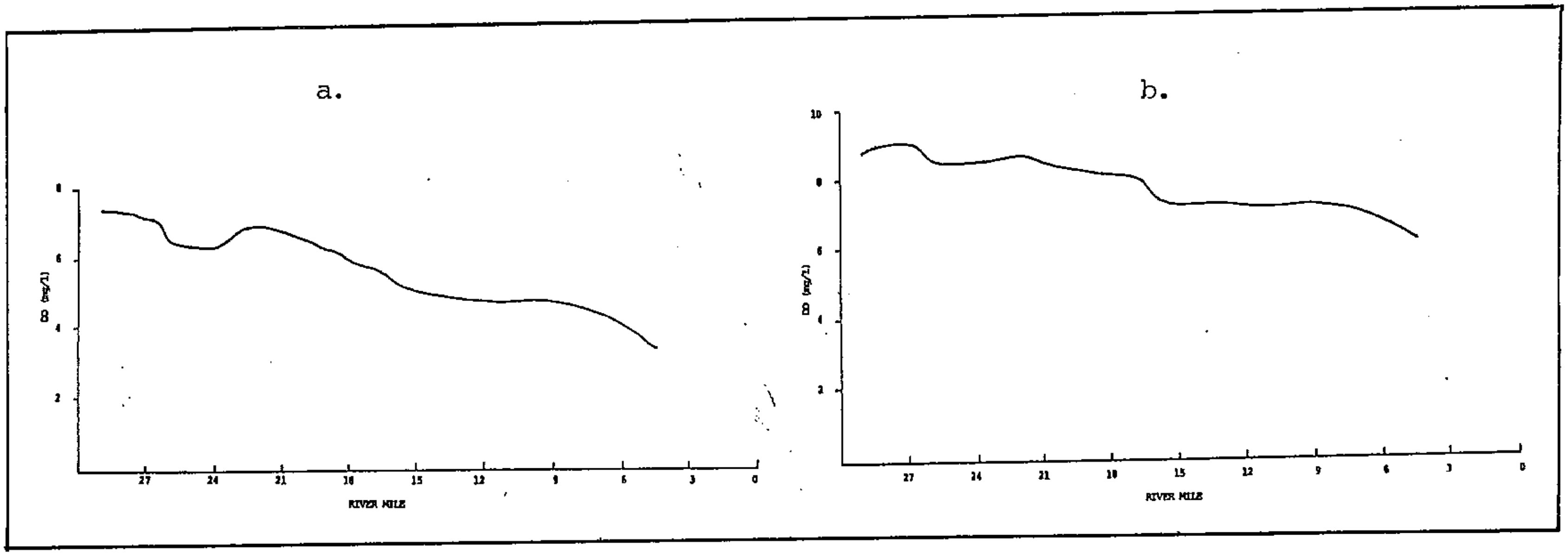


Figure 25. Resultant Dissolved Oxygen Concentrations; Three Regional Plants. (a. summer conditions; b. winter conditions)

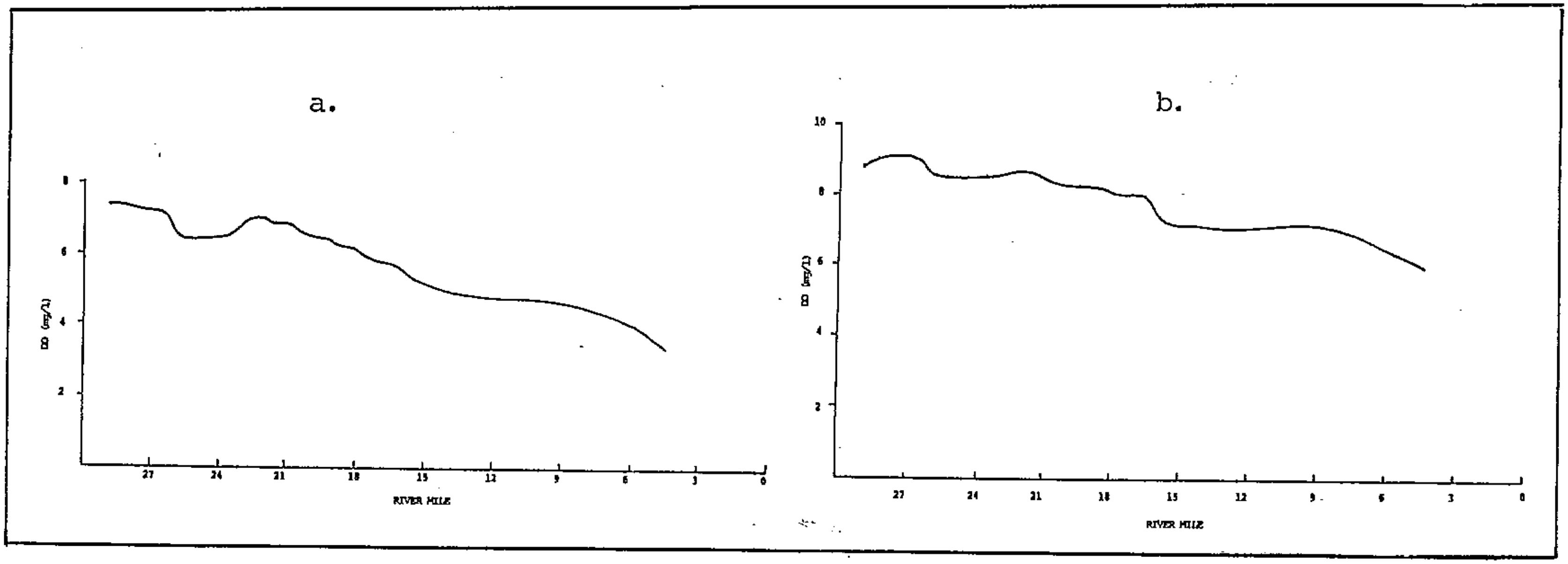


Figure 26. Resultant Dissolved Oxygen Concentrations; Four Regional Plants.
(a. summer conditions; b. winter conditions)

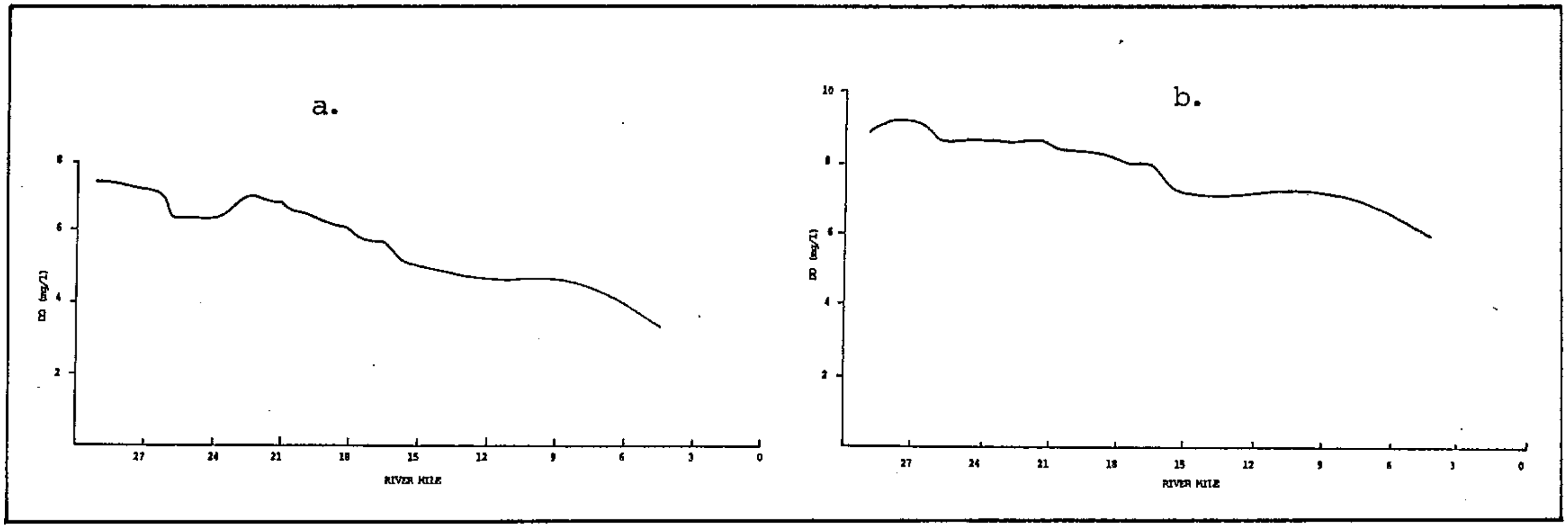


Figure 27. Resultant Dissolved Oxygen Concentrations; Five Regional Plants.
(a. summer conditions; b. winter conditions)

It is reported that the Riverton Reservoir will be stratified during summer conditions.[15] This was evaluated by the computation of a densimetric Froude number (F_o) that was less than $1/\pi$. The reservoir will, if constructed, spill out the base of the dam which will be in the cooler hypolimnion (depth of the epilimnion will be about 3.5 meters). This will be beneficial to downstream aquatic populations as cooler water might induce reproduction of stream spawners and cooler water can carry more dissolved oxygen. But with the large diversions downstream from the proposed reservoirs (North Jordan Canal) any effect will be negligible.

Detergent

Detergent concentrations in the Jordan River were compiled from unpublished data and are listed in Table 12.[50] The average sewage treatment plant effluent in 1976 was 0.39 mg/l detergent as MBAS (Methyl Blue Active Substance). It is not possible to differentiate between ABS, LAS, or other isomers of these types of compounds with the MBAS test but ABS has essentially been removed from the market as a surfactant.[51] Therefore, these values will be interpreted to represent LAS. As can be seen in Table 12, the detergent from sewage treatment plant effluents essentially disappears in less than two river miles. It is assumed that the detergent concentrations in the future sewage treatment plant(s) effluent(s) will be approximately 0.39 mg/l MBAS and that this concentration will essentially disappear in less than two stream miles. With advanced treatment, i.e., polished secondary level, this concentration will be even less. The critical dilution point, i.e., the point of discharge where the dilution is the least, will occur at the discharge from the upstream subregional plant of Alternative II. This dilution ratio will be in the range of 1:2. Therefore, the critical concentration of MBAS will occur at this point and will approximate 0.2 mg/l MBAS. The discharge from the downstream subregional sewage treatment plant of Alternative II will be diluted to about 1:3 and will therefore produce an in-stream concentration of about 0.13 mg/l MBAS for a relatively short time.

TABLE 12. SOURCES OF DETERGENT (AS MBAS) TO THE JORDAN RIVER[50]

Sample Source	Date	MBAS (mg/l)
Bluffdale Road at Jordan River	3/03/76 5/26/76 8/36/76 9/28/76 10/20/76	0.00 0.00 0.00 0.00 0.00
90th South above Sandy STP	9/28/76	0.00
Sandy STP Effluent	9/29/76	0.73
50 ft. above Midvale STP	9/29/76	0.00
Midvale STP Effluent	?	0.44
50 ft. above Murray STP	9/29/76	0.00
Murray STP Effluent	9/29/76	0.17
42nd South above Cottonwood STP	9/29/76	0.00
Cottonwood STP Effluent	9/28/76	0.68
Granger-Hunter STP Effluent	9/27/76	0.30
Salt Lake City Suburban #1 STP Effluent	9/28/76	0.38
South Salt Lake STP Effluent	9/29/76	0.30
21st South Storm Drain on Jordan River	4/27/76	0.00
13th South Storm Drain on Jordan River	4/27/76 7/28/76	0.00 0.00
8th South Storm Drain on Jordan River	4/27/76 7/28/76	0.00 0.00
6th South Storm Drain on Jordan River	4/27/76 7/28/76	0.00 0.00
City Creek on Jordan River	4/27/76 7/28/76	0.00 0.00
50 ft. above Salt Lake City STP on Sewage Canal	9/29/76	0.17
State Canal at Jordan River	2/03/76 8/24/76 10/21/76	0.00 0.00 0.00

Suspended Solids

Concentrations of suspended solids in the Jordan River will be less than what they are today when 1) polished secondary treatment is instituted, 2) desilting basins are constructed on tributaries and storm drains, 3) one or two reservoirs are constructed on the upper river, or 4) any combination of these.

In general, the sewage treatment plants discharging to the Jordan River meet Federal secondary standards (30 mg/l SS) in effluents. State polished secondary treatment is considered necessary to lower these effluent concentrations to acceptable levels for health reasons. A polished secondary effluent requirement of 10 mg/l SS will reduce the accumulation of sludge near outfalls (sludge beds) which will have a direct effect on oxygen demand, the bottom substrate, and the aesthetics of the area.

Desilting basins are proposed for the major tributaries and storm drains to the Jordan River and tributaries in a development plan for the upper Jordan River prepared by a local consulting firm[52] and in the Area-wide Water Quality Management Plan[94] Specifically, proposed for direct Jordan River discharges are basins for Little Cottonwood Creek, Big Cottonwood Creek, Mill Creek, the 1300, 900, 800, 600, and 200 South storm drains and the North Temple storm drain. From the settling data presented in Table 13 and shown graphically in Figure 28, it was calculated that these basins, with an average depth of 10 feet and a flow through velocity of 1 fps, could reduce the load entering the Jordan River to about 30 mg/l SS.[52] Figures 29 and 30 show that suspended solids concentration resulting from storms in Salt Lake Valley in two over-lapping storm distribution areas reach exceedingly high levels due to runoff from urban areas.[15] From the data given in Ref. (15), it is estimated that the suspended solids concentrations in the river resulting from storm runoff that is detained in desilting basins could be effectively reduced by a factor of eight. This is also shown in Figures 29 and 30. It should be noted that the figures do not account for the settling characteristics of the river. Therefore, expected suspended solids concentrations resulting from storms in these two areas are less than that presented in Figures 29 and 30.

TABLE 13.

SETTLEABILITY OF JORDAN RIVER SOLIDS*[6]

Station	Suspended Solids Remaining (mg/l)			
	Time (hrs)			
	0	4	8	12
14600 South	80	11	10	8
13560 South	148	23	20	19
12800 South	108	35	24	11
12500 South	62	28	22	21
9900 South	41	17	13	10

*Approximately 75 percent VSS

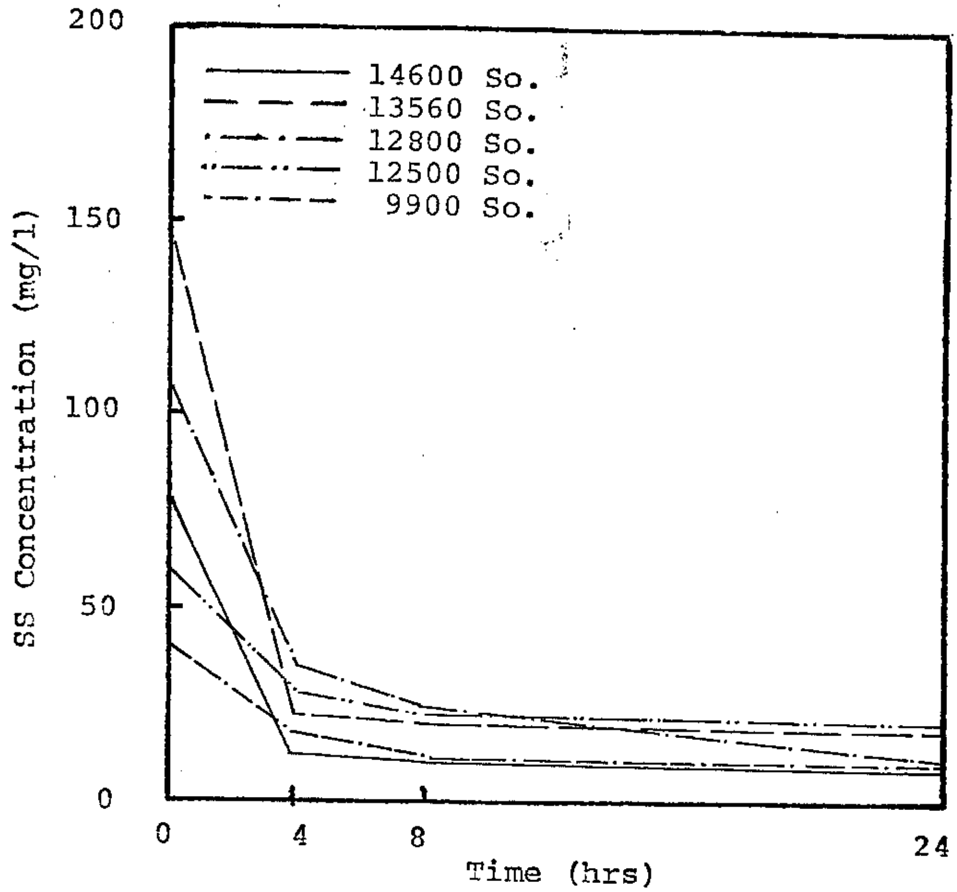


Figure 28. Settling Characteristics of Jordan River Solids.(52)

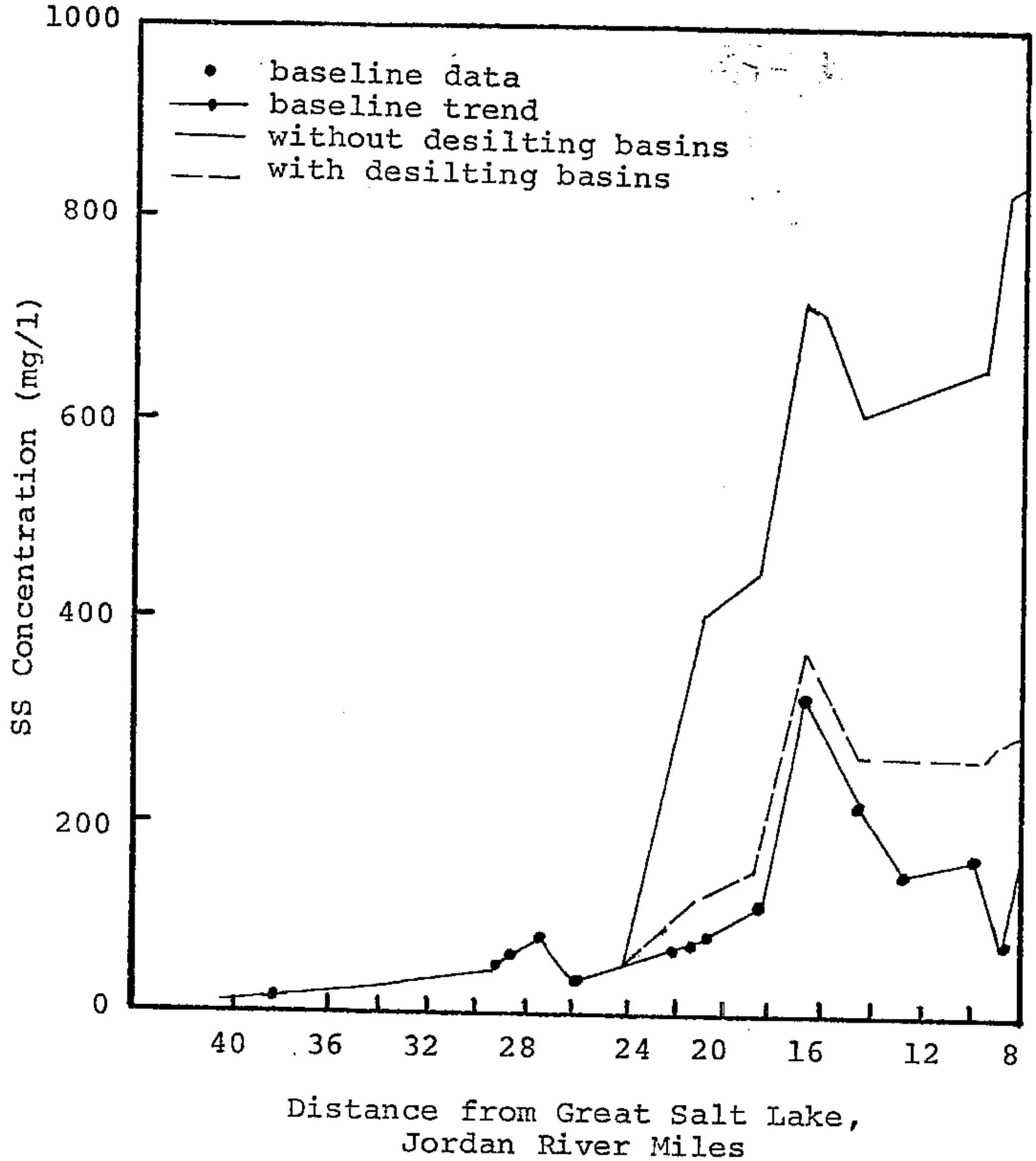


Figure 29. Suspended Solids Response to Areal Storm Distribution No. 1, 1995 Flows.(15)

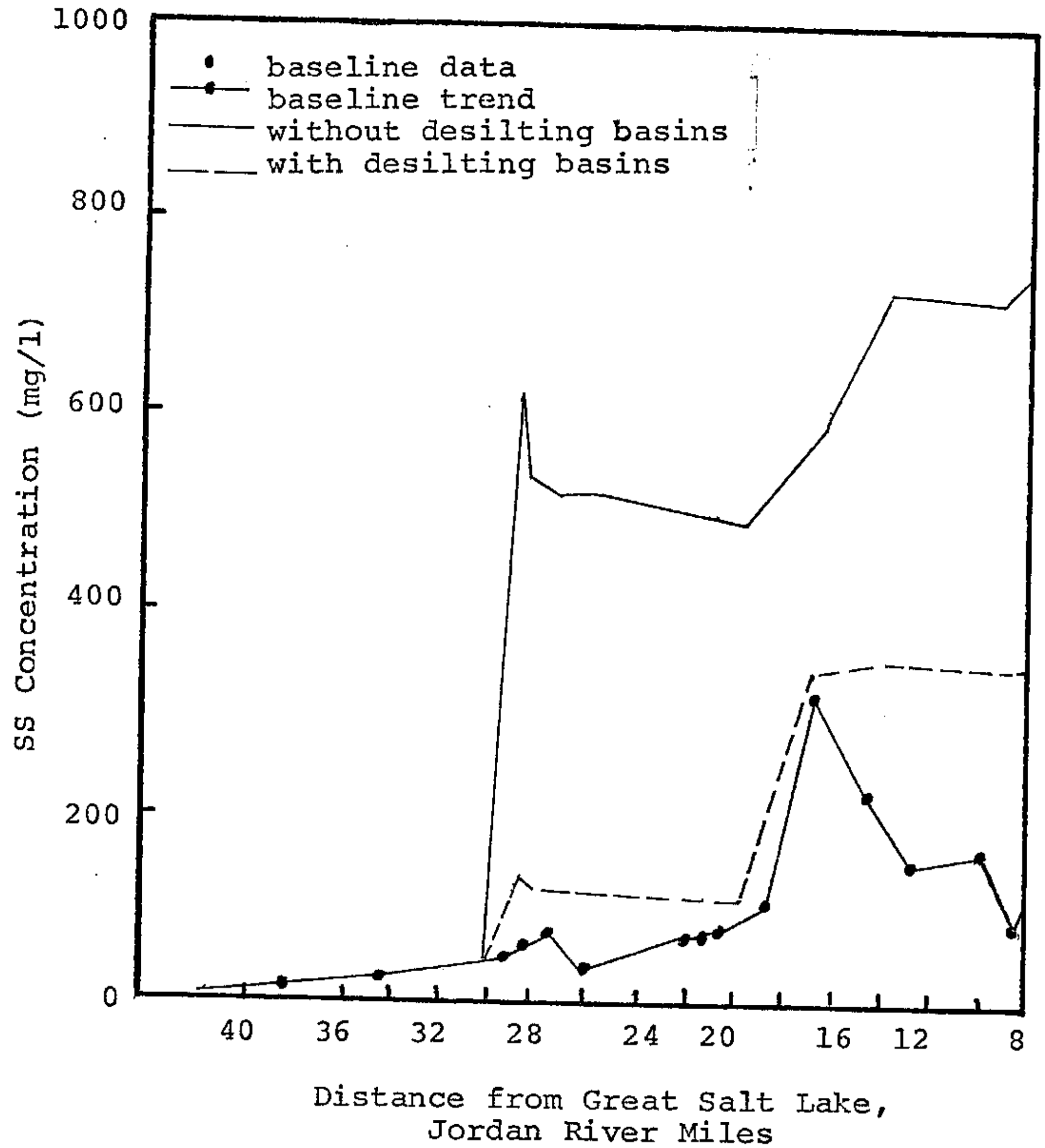


Figure 30. Suspended Solids Response to Areal Storm Distribution No. 2, 1995 Flows.(15)

SECTION VI

DISCUSSION

Safe Constituent Levels

General

Dose-Response. The concentration of a substance necessary to produce a response in an organism is dependent upon a number of variables, among which are time of exposure, method of administration of the substance, and ambient conditions, such as water temperature and dissolved oxygen concentrations (in the case of aquatic organisms).

Water pollutants in sublethal concentrations, when experimentally administered to fishes, usually produce results that follow a dose-response curve. The form of this curve is a rectangular hyperbola, illustrated in Figure 31. The general function for this curve is shown as equation (7).

$$C = (X - a)\ (Y - b) \qquad (7)$$

where a, b, and C are unknown constants and X and Y are the coordinate axes. Determination of the constants requires rigorous mathematical exercises. However, a simple approximate method has been devised which employs estimation to facilitate curve fitting.[54]

Time of exposure to a substance to produce a response is an important consideration. Without reporting exposure times, many investigators have voided the usefulness of their results. For example, a lethal concentration of 2.0 mg/l is meaningless. Time of exposure is, in essence, a qualifier used to denote a dosage. Reporting of exposure time is usually done on a 24-hour or 96-hour basis, such as concentration lethal to organisms in 24 or 96 hours. Sometimes concentrations are reported as threshold or safe concentration, meaning an infinite exposure time.

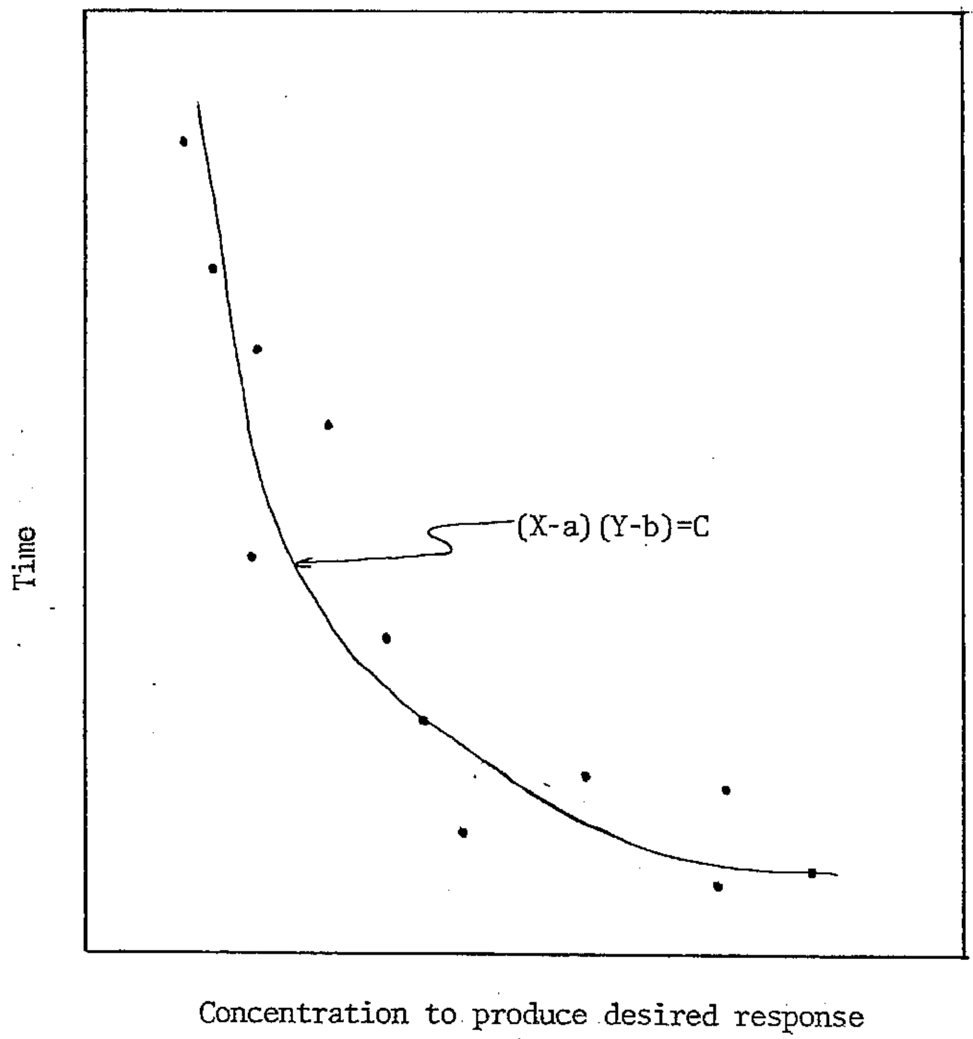


Figure 31. The Rectangular Hyperbola.

Time of exposure to produce a biological effect is dependent upon several factors, among them are the passage of the substance through the "shell" of the organism (unless the substance effects the outer "shell" itself, such as the gills), the peculiarity of the substance itself, circulation time from point of entry to site of action, time for action at the site, and buildup of effective internal concentration. Another time consideration is that biological time is a logarithmic phenomena. Long-term studies have shown that this general rule of nature holds true for water pollutants acting on aquatic life.

<u>$TL_{96}50$.</u> Water pollutant concentration and time of exposure to produce a reaction in test organisms are usually reported as lethal concentration LC; lethal dose, LD; toxicity limit, TL; or others such as safe or threshold concentration. Although these values represent concentrations to kill test organisms, some definitions are needed. LC 50 is defined as the concentration of a substance in the surrounding media that is necessary to kill 50 percent of the test organisms. Similarly, LC 75 is the concentration to kill 75 percent of the organisms. LD 50 is the dose necessary to kill 50 percent of the organisms. The difference between LC 50 and LD 50 is that LD denotes the amount of toxicant in the test animal (dose), not in the media. TL 50 is synonymous with LC 50. TL_m is defined as median toxicity limit and is equivalent to TL 50. These values are usually reported with time of exposure and in this study are denoted as $TL_{96}50$, which means the concentration that is lethal to 50 percent of the test organisms in 96 hours (4 days).

<u>Synergism</u>. Most polluants and toxicants exhibit a "synergistic" response with elevated temperatures or depressed dissolved oxygen levels. These responses are not synergism per se and are discussed in the following text.

Fish are coldblooded organisms (poikilotherms), which means that body temperature, hence metabolism, enzyme reactions, reaction kinetics, etc., all increase with increasing water temperature since fish have no mechanisms to keep body temperature constant (like homeotherms or warmblooded organisms). Action of a toxicant will increase with increasing temperature for this reason. Therefore, when reported in the literature that a substance is toxic at a certain level, at no given temperature, the assumption must be made that the concentration reported is for the highest ambient temperature plausible to ensure safety when determining safe concentrations.

Many authors note that toxicants are more toxic at depressed dissolved oxygen levels. This can be explained in the following manner. At lower dissolved oxygen concentrations, fish must pass more water through the gills to keep the blood oxygen level up to that necessary for body maintenance and growth. Since the principal path for a toxicant to enter the blood stream of a fish is through the gills, lower dissolved oxygen concentrations enhance the toxicity of given substances, producing a synergistic-like response.

Habitat. An integral part of any fishery is the physical habitat in which fishes and their associated biota live. This part will disucss what comprises a "good" habitat and what future plans have been proposed that will affect the habitat in the future Jordan River.

One of the principal problems with the Jordan River fishery is channelization (habitat alteration).[5] The natural stream channel has been altered greatly over the years, primarily done for flood control. Five consequences of importance to stream habitat resulting from channelization are increased gradient (faster flow velocities), reduced protective area (hiding places), reduction of pools, removal of submerged cover and creation of uniformity of stream flow.[89]

Channelization reduces the pool to riffle ratio, a measure of slow moving, deeper waters to shallow, faster moving waters.[56] Fish thrive in an area where the pool to riffle ratio is 50:50 to 40-60:60-40. Pools have two purposes in the fish environment. The first is to provide a resting and shelter place. The second is to provide a food source. Adequate resting and hiding places are necessary to protect fish from their predators, both human and natural.

It has been determined that ripples are as much as five times as productive in food resources than pools are. However, pools are preferred eating areas and the best ones are those 2-3 feet deep.[57] Food from riffles is washed into pools where the majority of eating takes place. A recent investigation determined that a non-modified Wyoming stream contained six times the trout biomass than was found in a similar channelized section of the same stream.[89]

Edges of pools lined with small pebbles, larger rocks and some riffles, provide spawning places for fish. A major requirement for spawning areas is that eggs be constantly ventilated with fresh, oxygen-carrying water. It has been demonstrated that salmon and trout will not spawn or deposit eggs in a non-ideal site.[26]

Dredging of channels re-suspends settled sediment and brings previously unsuspended sediment into the water flow. Channelization in the Jordan River has taken the curves out of the stream, making all water flow at a uniform rate. Suspended material settles out along the entire length of the stream, covering spawning areas and aquatic invertebrate habitat. In the nonexistent curves, the swifter outer-bank portion of the curve would "wash" itself of this settled sediment which is then deposited on the slower inside bank of the curves or in slower mid-stream sections. Swifter water is usually more agitated which increases reaeration rates, increasing dissolved oxygen levels, sometimes to levels greater than saturation points.

Food resources for freshwater fishes come from the water itself (aquatic) or from lands surrounding the water (terrestrial). The aquatic invertebrates of greatest importance as a food source to fishes are the anelid worms (earth and sludge worms and leeches), mollusks (snails and clams), arthropods (crustaceans, crayfish and sowbugs), and insects.[58] Most fishes are omnivorous at first, feeding on bacteria, diatoms, desmids, and other microscopic plankton. Bluegills and other sunfish remain omnivourous for their entire lives. Trout become, for the most part, insectivorous, while Largemouth Bass become quite cannabilistic.

Aquatic vegetation and microinvertebrate life have much the same water quality and habitat requirements as do fishes. There are sensitive insects, such as mayflies, stoneflies, and caddis flies, which have very narrow tolerance limits of dissolved oxygen and temperature, and there are relatively insensitive species, such as sludge worms, which can withstand nearly 0.0 mg/1 dissolved oxygen and make their burrows in sludge deposits.

The most productive habitat for aquatic vegetation and macroinvertebrates is one in which there is plentiful dissolved oxygen, mild temperature change (slow), water pH of 6.0 to 8.5, and the substrate is of rubble and stones. Another related requirement is that water be free flowing. This serves to ventilate insect gills and replenish the oxygen supply in the water.[57]

To date, two major development schemes have been suggested for the development of the Jordan River recreational and industrial potential that would affect the habitat. They are the development of a parkway on the river through Salt Lake Valley and the development of the upper river consisting of construction of one large or two smaller reservoirs.

Urban Technology Associates has prepared for the Salt Lake County Commissioners a comprehensive plan for the development of a parkway on the lower Jordan River (North from 4800 South).[52] This concept is feasible as an alternative for flood control as well as providing much needed recreation for Salt Lake City and County residents. As identified by the Utah Division of Wildlife Resources,[5] two of the primary problems of the Jordan River fishery are channelization, done for flood control, and siltation. Channelization is itself a major cause of siltation in the Jordan River and also destroys pools in the river, which have been identified as a necessary habitat parameter for the propagation of fishes.

This plan calls for the returning of the river to the natural channel or a reasonable alternative. Flood waters can be handled by this channel and a secondary channel constructed in the flood plain parkway running parallel to the natural channel. The plan also calls for, at least indicates, that a rock and rubble bottom substrate should be placed along the bottom of the channel. This would serve as a home for aquatic insects and plants, necessary constituents for a balanced fish population.

Implementation of the proposed plan is proceeding slowly but a new report details the improvements necessary for the project.[91] State legislative action has slowed progress but initiative by local governmental agencies is keeping the process going.

As mentioned earlier, an integral part of this plan is the construction of desilting basins on all major tributaries and storm drain discharge points. These basins are to be designed such that 60 to 80 percent of the suspended sediment carried in the flows would be deposited onto concrete floors. In addition to removing a water pollution problem that limits fish production, it is estimated that these basins would delete the need for dredging the Jordan River and save Salt Lake County $100,000 per year which is now spent on silt removal by dredging in addition to the $500,000 to $600,00 spent on cleaning the bottoms of the Jordan River and Surplus Canal (1970 dollars). The criterion used in design of these basins is listed in Table 14.

With an effluent concentration of 30 mg/l suspended solids, the reported values in Figure 8 would be greatly reduced. The desilting basin concept is also supported by the Army Corps of Engineers in their feasibility study for water resources development on the lower Jordan River.[92]

To complement the plan developed for the lower Jordan River, a local consultant firm developed a plan for the upper Jordan River (south of 4800 South).[61] The aspects of importance in this report are the idea of two medium sized reservoirs to be constructed at about 9800 South and 12600 South (c.f. Figure 9). This was a concept design report and as such a detailed analysis cannot be accomplished at this time. However, quantitative data was obtained on the settling of suspended solids at various locations on the upper Jordan River. The first estimates of suspended solids removal developed by Hydroscience [15] and the projections developed later in this report are based on that data.

In addition to the concept of two reservoirs, a one reservoir concept was investigated. This one large reservoir is essentially the combination of the two smaller reservoirs. Therefore, the results obtained for the effluent and standing waters of the two smaller reservoirs will be assumed to be the same as that would be present if there were just one large reservoir.

TABLE 14

CRITERION USED IN DESIGN OF DESILTING BASINS[59]

Parameter	Criteria
Flow-through Velocity	1 fps
Bed Load	200 tons/mi^2/yr[59]
Percent Load	95 percent load in 60 days
Storage	30 days
Drain Load	30.1 mg/l[60]
Depth	10 feet

The concept of reservoirs on the Joran River is not entirely a local concern. The Bureau of Reclamation has proposed a reservoir at 9800 South (Lampton Reservoir) that is essentially the one dam concept.[62] This reservoir would be constructed as part of the Bonneville Unit of the Central Utah Project (CUP). The Environmental Impact Statement for the reservoir did not contain much useful information since the reservoir and dam are still in the preliminary design phase.

Species Specific Safe Constituent Levels

In the past, investigators have used $TL_{96}50$ (or $LC_{96}50$) as the base concentration when determining safe concentrations. The safe concentrations being a percentage of the $TL_{96}50$.[17]

Since no generalization as to the sensitivity of test animals can be made and lab tests are likely to underestimate toxicity, safety factors must be applied to any result.[93] Therefore, in this study and in agreement with Ref. (17) and (93), general safe concentration on a species by species basis is taken to be 5 percent of the average $TL_{96}50$ or 5 percent of the middle of the range of reported values. The middle of the range was computed by weighting the various values and then adjusting to represent four day (96 hour) results. Ranges of species specific toxic concentrations of chlorine, un-ionized ammonia, and detergent are presented in Table 15. Safe species specific concentrations of temperature, dissolved oxygen, chlorine, un-ionized ammonia, and detergent are presented in Table 2.

The pollutants and concentrations that are recommended by EPA to ensure a varied aquatic community are presented in Table 16.[17] These concentrations are considered to be safe concentrations. As can be seen, the values reported by the EPA are somewhat lower than those of this study but as discussed above, these values are determined by the most sensitive species and are not determined on a species to species basis.

Temperature. The temperature range in the Joran River, 7°C to 25°C, will not be growth limiting on any of the warmwater species investigated. The upper end of this range will, however, be only marginally acceptable for growth of coldwater species. Elevated plume temperatures from outfalls such as sewage treatment plant effluents and cooling tower blowdown will be higher than the receiving water and will impose constraints on fish life. However, fish being highly mobile will avoid areas where temperatures are elevated above ambient temperatures. Therefore, these temperature trouble spots will cause only localized problems to the fishery.

Temperatures necessary for reproduction of trout species, are lower than Joran River temperatures (except for brown trout which are mid-winter spawners) and will inhibit spawning even if suitable habitat could be found. Reproduction temperatures for rough fish species will be attained in the Jordan River and will not impose reproduction constraints. However, suitable habitat must also be present for reproduction. Unless some sort of habitat alteration (for the

TABLE 15

TOXIC RANGES OF CHLORINE, UN-IONIZED AMMONIA AND DETERGENT FOR FRESHWATER FISHES

Species[a]	Pollutant: Chlorine (Cl_2) Range[b] (mg/l)	Chlorine (Cl_2) $TL_{96}50$ (mg/l)	Un-ionized Ammonia (NH_3-N) Range[b] (mg/l)	Un-ionized Ammonia (NH_3-N) $TL_{96}50$ (mg/l)	Detergent Range[b] (mg/l)	Detergent $TL_{96}50$ (mg/l)
WARMWATER						
Bluegill	0.1-0.4	---[c]	1.0-2.0	3.4	1.5[c] 15.0[c]	4.0[e][f] 17.6
Largemouth Bass	0.2-0.3	1.0	---[d]	---[d]	--- [d]	---[d]
Channel Catfish	0.1-0.2	---[c]	2.0-4.0	---[c]	--- [d]	---[d]
Perch	---[d]	---[d]	2.9-3.5	---[c]	--- [d]	---[d]
Yellow Perch	0.2-1.0	0.2	---[d]	---[d]	--- [d]	---[d]
COLDWATER						
Brook Trout	0.05-0.4	0.14	0.4-3.6	---[c]	5.0[g]	---[c]
Brown Trout	0.02-0.2	0.12	0.3-4.0	---[c]	---[d]	---[d]
Rainbow Trout	0.03-0.3	0.02	0.1-1.5	---[c]	---[d]	---[d]

a. For fish species investigated in this report.
b. Range is determined as the high and low concentrations reported in the literature that produce few or no casualities of test organisms per time.
c. No $TL_{96}50$ concentration found in literature search
d. No toxicity data found in the literature
e. LAS.
f. ABS.
g. DBSO

TABLE 16. CRITERION FOR FRESHWATER AQUATIC LIFE[17]

Pollutant	Concentration	Remarks
Ammonia	0.02 mg/1	As un-ionized NH_3, dependent on temperature and pH.
Chlorine	0.002 mg/1	For salmoide fish, total residual chlorine.
	0.010 mg/1	For other freshwater aquatic life.
Dissolved Oxygen	5.0 mg/1	Minimum for "good" fish population.
pH	6.5 - 9.0	
Temperature	---	This value is species specific. The method for determination is not reported here.

better) is undertaken, reproduction will probably not take place for any game species and perhaps for rough species even with acceptable temperatures.

Dissolved Oxygen. Dissolved oxygen requirements as determined in this study compare favorably with the general guidelines set forth by the EPA[17] and others. A minimum concentration of 5.0 mg/l as recommended by the EPA is a little lower than the minimum specified by Utah State Water Quality Standards[20] and as determined in this study, except for the yellow perch. The general guideline of a minimum of 5.5 mg/l dissolved oxygen (DO) for warmwater species and 6.0 mg/l DO for coldwater species more closely approaches the species specific safe concentrations as determined in this study. Since aquatic invertebrates and plant life are closely related to a fishery, dissolved oxygen should not fall below 5.0 mg/l to ensure adequate DO for their survival. A minimum of 6.0 mg/l DO would ensure that all species investigated would have an ample supply of dissolved oxygen for growth and reproduction.

Chlorine. As has been shown, chlorine (Cl_2) is toxic at very low concentrations and safe concentrations for all species fall below 0.02 mg/l. The Utah Wastewater Disposal Regulations[20] recommend that a total chlorine residual of 1.0 mg/l be maintained in sewage treatment plant effluents. This value is greater than 100 times the safe in-stream concentration for most species.

Aquatic invertebrates and plant life are also affected by extremely low levels of chlorine and should be expected to be absent from areas of sewage treatment plant outfalls.

Future chlorine levels in the Jordan River will be greatly affected by the method of treating sewage in Salt Lake Valley. To achieve low chlorine residuals of 0.017 mg/l to 0.008 mg/l from an effluent chlorinated to 1.0 mg/l TRC, dechlorination is indicated, either chemical or physical.

Ammonia. As has been discussed earlier, the un-ionized fraction of total ammonia is the toxic portion. Temperature and pH are factors governing the ionized un-ionized ammonia ratio in fresh waters. Total ammonia concentrations corresponding to species specific toxic un-ionized concentrations of 0.04 mg/l to 0.17 mg/l at Jordan River temperature ($7^{o}C$ to $25^{o}C$) and pH (7.5 to 8.0) are in the range of 0.7 mg/l to 37 mg/l and are shown in Table 1. Also shown in Table 1 is the total NH_3 concentration corresponding to a general safe un-ionized concentration of 0.02 mg/l (1.13 mg/l NH_3 summer; 4.33 mg/l NH_3 winter).

Detergent. Toxicities of detergents are dependent upon type of detergent. The more stable (less readily biodegraded) ABS is toxic at about four times the toxic concentration of the less stable LAS. Safe concentrations for detergents appear to be in the range of 0.2 mg/l to 0.8 mg/l as MBAS.

Suspended Solids. Suspended solids are not harmful to fishes at concentrations of 30 mg/l and less. Up to concentrations of 90 mg/l SS, sublethal effects (stress) are apparent. Limited or outrageous data make other conclusions irrelevant.

Others. Pesticides, herbicides, organic compounds and heavy metals were not investigated in this study even though they are extremely toxic at very low concentrations.

Projected Constituent Levels

Temperature

Future temperatures of the Jordan River for all alternatives are expected to remain close to what the historical temperatures are. Possible exceptions are near the discharges from proposed reservoirs (cooler than the historical) and near the outfalls from the sewage treatment plants (warmer than the historical), but this difference is negligible.

Temperature projections are ambiguous and are expected to fluctuate widely, primarily dependent upon the season. Temperatures of the proposed reservoir are expected to be near the Jordan River temperature in the epilimnion but somewhat cooler in the hypolimnion.[15] The expected temperature difference has not been documented for the reservoir and can only be estimated.

Summer temperatures would be lowered somewhat by the provision of more shading from bank vegetation and trees. In addition to shading, bank cover would help to stabilize the bank itself and prevent erosion, a contributor to suspended solids concentrations.

Dissolved Oxygen

Dissolved oxygen projections for the three alternatives investigated show Alternatives II and III as the alternatives with the least deficit below the recommended level of 5.5 mg/l to 6.0 mg/l for winter conditions. All alternatives project concentration below the recommendations for summer conditions. As can be seen in Figures 7, 8 and 24 through 27 the concentration of dissolved oxygen is dependent upon the waste load to the river including NH_3 loads. Nitrogen removal/reduction can increase the dissolved oxygen concentration by as much as 0.5 mg/l in addition to lowering the toxicity of ammonia itself.

Chlorine

Chlorine concentrations in the Jordan River are expected to result for the most part from chlorinated sewage treatment plant effluents. Lack of data made chlorine projections first estimates and indicates the need for more work on this topic, principally in the area of chlorine decay coefficients. Chlorine concentrations were projected using an effluent concentrations of 1.0 mg/l, 0.4 mg/l and 0.04 mg/l and decay coefficients of 0.0/day, 1.0/day, and 5.0/day. The resultant concentrations ranged from 0.001 mg/l to 3.13 mg/l for the minimum and maximum instream concentrations. These lower values are expected to disappear from the system but at a slow rate.

Ammonia

Projections for ammonia were based on effluent concentrations of 20 mg/l, 10 mg/l and 5 mg/l total ammonia reflecting the concept of nitrification by extended aeration. Projected concentrations for the first case resulted in maximum instream concentrations of approximately 6.4 mg/l NH_3-N and concentrations that result in un-ionized concentration of less than 0.02 mg/l for the latter case for the critical summer projection regime. These projections were made using a distributed source of ammonia and a decay coefficient of 0.15/day. It should be noted that removal/reduction of ammonia increased projected instream dissolved oxygen concentrations by about 0.5 mg/l.

Detergent

Effluent detergent concentrations are expected to be in the neighborhood of 0.39 mg/l as MBAS. These concentrations will be diluted to produce instream concentrations of 0.2 mg/l MBAS and lower. It is expected that this detergent will disappear from the system in less than two river miles but again this statement is based on limited data and is a first estimate.

Suspended Solids

Projection of suspended solids concentrations in the Jordan River was quite ambiguous in that future development of the Jordan River and treatment of urban runoff will affect suspended solids concentrations more than will the sewage treatment alternative chosen. For this reason, future concentrations in the river cannot be accurately projected. Nevertheless, it is estimated that with desilting basins constructed on the major tributaries and storm drains along the Jordan River, instream suspended solids concentrations will be much less than 100 mg/l SS, except after storm events when SS concentrations may rise to approximately 350 mg/l.

APPENDIX A

STATE DIVISION OF WILDLIFE RESOURCES

CLASSIFICATION SYSTEM

This section includes an abridged edition of the classification system used by the Utah State Division of Wildlife Resources/Division of Fish and Game to classify the fishery of all the surface waters in the State. The classification system has been modified to exclude reservoirs and lakes. The following is a short discussion of the procedures used in classifying streams followed by the classification worksheet and instructions. Not included, but a part of the classification process, is a stream survey sheet which is filled in by the investigator at the time of the survey in the field. It should be noted that many of the values reported are determined by judgment decision and measurements made by the investigator with respect to general guidelines. Note also that in this report, the classification system begins at number 8. Numbers 1 through 7 are stream designation information and are not included here.

General

Some of the judgment decisions that must be made by the investigator are discussed below.

8. Esthetics:

Whenever a value is placed on esthetics, there are obviously many who find this value in error. The stream esthetics are considered adequate in rating the relative esthetic value of a stream by the experienced eye.

9. Availability:

This section is also subject to judgment decisions by the investigator, however, not to the extent of the previous section. Availability can be measured by quantifiable parameters such as distance from access road or amount of posted land along the stream.

10. Productivity:

The necessary information for this section is obtained from observation and quantitative electro-fishing projects.

16, 17:

These sections have been omitted as they pertain to lakes and reservoirs.

Procedures

The stream to be classified is first divided into sections which are of such nature to be described as homogeneous throughout. (In the case of the Jordan River, five sections were considered adequate). A 0.1 mile section (528 feet) is then chosen as being representative of the total section by the experienced investigator. Transects across the stream are then made to obtain average values such as bottom type, bottom fauna, bank covering and shade, etc. This data (collected in the field) is then converted to a numerical value in the office to obtain a stream classification.

Sections 12 to 24 of the classification sheet are for management procedures.

The following is an abridged edition of the classification system used by the State.

8. Esthetics (Streams):

The following is criteria to keep in mind while classifying streams for esthetics:

A. Natural beauty of the stream.
B. Natural beauty of the area around the stream.
C. Cleanliness and clearness of the area and stream.
D. Consider the wilderness characteristics.
E. Extensive human developments may downgrade a stream one grade.

Esthetics Rating - (5 to 1):

5. A stream of outstanding natural beauty, usually of a unique type and possessing wilderness characteristics; stream usually clean and clear; climatic characteristics that add to the pleasure of fishing.
4. A stream comparable to number 5, except that it often lacks wilderness characteristics; presence of human developments such as roads, farms, or commercial establishments usually comprise the chief difference between 5 and 4. This type of stream usually has high use by tourists. In some cases, the limiting considerations might be climatic or biological. Excessive rainfall, extreme cold, or insect pests might be so bothersome as to limit esthetic values.
3. A stream of considerable natural beauty, but of a more common type than listed under 5 or 4; clean and usually clear flowing through attractive agricultural lands or rough lands with picturesque scenery. This type of stream often is favored by tourists.
2. An area with fair scenic or esthetic qualities. This type of stream is fairly common and has some attraction for non-resident tourists. The water is clean, the scenery is appealing, and the land is not abused. The area, however, lacks what are usually considered unusual or outstanding scenic qualities.

1. A stream with low esthetic qualities; water is often turbid. The surrounding country has only medium scenic appeal and is of common occurrence. A lack of stream side cover is apparent. Mud banks are common, and stream flows may become low enough to expose extensive expanses of mud flats and sand bars. Noxious domestic and industrial wastes may occur. With this type of stream, the primary esthetic appeal usually lies in the fact that, although it may not be attractive, it does offer local people an opportunity to get outdoors near some water.

9. Availability (Streams)

The following are criteria to keep in mind while classifying streams for availability:

A. Access is satisfactory for modern car (in this case, the stream should not be too accessible or inaccessible).

B. Amount of posting and effect it has.

C. Is the stream floatable.

D. Amount of bank cover (trees, brush, etc.)

E. Access by trails or jeep.

Availability Rating - (5 to 1):

5. Accessibility to suitable points on streams is satisfactory for modern cars - (not excessive such as a highway very close or along side of the stream). Access in terms of posting and availability to fisherman use primarily unrestricted. Camping lodging is available within a reasonable distance - stream floatable.

4. Vehicular access relatively good (highway may be close or along side of stream at times); posting not

extensive, stream bank cover not unduly restrictive to fisherman utilization; stream not floatable.

3. Accessible road or trail is fit or appropriate for jeep, horseback, or foot. Posting is not considered an important restrictive problem.
2. Accessibility is often difficult or posting is so extensive as to seriously restrict fisherman access.
1. Accessibility is inadequate as natural or man-made restrictions cause fisherman utilization to be almost impossible.

10. Productivity (Streams):

The following are criteria to keep in mind which classify streams for productivity:

A. Supports high population of game fish (waters where catchables are planted in order to maintain a good fisheries should be rated down).
B. Condition of fish.
C. Amount of natural propagation.
D. Physical characteristics:
   1. Percent of bottom covered at low flow.
   2. Average width at low water.
   3. Volume.
   4. Velocity.
   5. Pool to riffle ratio - (50-50 being best).
   6. Turbidity:
      (a) does not affect the productivity
      (b) some effect on the productivity
      (c) great amount of effect on the productivity.
E. Length of growing season - consider it as good, fair, or poor.
F. Amount of cover - overhang of banks; snags; shade from vegetation along stream; boulders; depth of pools, etc.

G. Temperatures - This should be taken at a time when it might be serious or harmful to the fishery - warm or cold in excess.

H. Bottom type.

I. Bottom fauna (nonburrowing).

J. Stream bank condition.

Productivity Rating - (5 to 1):

5. Supports high fish population in good condition of one or more species of the better coldwater game fish. Natural propagation maintains the fish population, but some hatchery stocking may be required or has been at one time.
4. Supports a moderate fish population of one or more game fish species. Waters are moderate in size, however, productivity is high.
3. Waters are small, however, productivity is low, and artificial propagation is required to maintain fishing success (fry or fingerling).
2. Water is small. There is a short growing season, shallow water, artificial propagation. Catchables are required to maintain the fisheries.
1. Supports no game fish - Waters can be large or small but are of such a nature that successful long-term fisheries cannot be carried out by either natural or artificial means.

11. Classification:

To arrive at this figure, multiply the value given to Aesthetics by 1, to Availability by 2, and to Productivity by 4. Add them together and the appropriate class is defined by the following ranges:

1. 31-35
2. 25-30
3. 18-24

4. 11-17
5. 7-10

Note: The following is for management purposes.

12. Total Miles or Acres:

<u>Streams</u>

Total number of miles to the nearest tenth within this section.

13. Minimum Acres or Flows:

<u>Streams</u>

The lowest flow reading during the year (CGS).

14. Conservation Pool at Present.

15. Minimum Habitat Required:

Streams - Enter the minimum flow required to maintain a fishery. (The lowest minimum instantaneous flow acceptable; below a physical impeding or diversion on a stream, should be the average historical minimum flow of the stream).

18. Streams - Enter the miles of stream which apply to each category:

1. Forest Service
2. Bureau of Land Management
3. National Park
4. Fish and Wildlife
5. State and Local
6. Fish and Game
7. Bureau of Reclamation
8. Private

19. Access - All Waters:

Enter access by percentage in each category.

1. Public access closed.

2. Public access with fees (exclude boat license and launching fees for now).
3. Public access open.

20-21. Total Annual Fisherman Days per Acre/Mile:

The following figures are based on estimations - so keep in mind that you are dealing with present economic factors, present hatchery facilities, esthetic values of our waters, and other concepts, some of which are intangible.

20. Present:

Enter the estimated or known fisherman days per acre or mile.

21. Factor:

Enter the estimated multiplication factor. This factor, times the present fisherman days, would be an estimate of the fishing pressure this water could support based upon individual opinions of maximum, "optimum" pressures for Utah. This factor can be expressed in tenths, using the line as a decimal point. The largest value which can be expressed is (9.9). Use (1.0) as the present factor if the present pressure is the maximum you feel this water can sustain.

22. Management Procedures:

One or more might be used in getting this information. Place an X in the appropriate column(s) of 1 through 7. For number 8, use one or more species.

1. Increased or decreased stocking
2. Natural reproduction
3. Increased public access
4. Pollution abatement
5. Habitat improvement
6. Population manipulation

7. Additional information needed
8. Management for species

23. Fishery at Present:

Enter the code for the principal species present from the following code:

1. Rainbow
2. Cutthroat
3. Brown
4. Brook
5. Lake Trout
6. Salmon
7. Channel Cat
8. Black Bullhead
9. Yellow Bullhead
10. Golden Trout
11. Cisco
12. Mt. Whitefish
13. Grayling
14. Carp
15. Utah Chub
16. Bonytail
17. Leatherside
18. Redside Shiner
19. Squawfish
20. Least Chub
21. Speckled Dace
22. Longnose Dace
23. Fathead
24. Virgin River Spinedace
25. Woundfin
26. Utah Sucker
27. Flannelmoutn
28. Mt. Sucker
29. Bluehead
30. Green
31. Humpback
32. Plains Killifish
33. Rainwater Killifish
34. Mosquitofish
35. White Bass
36. Largemouth Bass
37. Smallmouth Bass
38. Green Sunfish
39. Bluegill
40. Black Crappie
41. Yellow Perch
42. Walleye
43. Sculpin
44. White Crappie
45. Bear Lake Whitefish
46. Bonneville Whitefish
47. Sacramento Perch
48. Striped Bass
49.
50.

24. Present Stocking Program:

Enter species and size code as set up

Species

1. Rainbow
2. Cutthroat
3. Brown Trout
4. Brook Trout
5. Lake Trout
6. Kokanee
7. Other

Size

1. Fry - (up to 2")
2. Fingerling - (2" to 4")
3. Advanced fingerling - (4" to 7")
4. Catchable

WORK SHEET FOR STREAMS

Name of Water:____

Date:____________________ Investigator:____________________

8. ESTHETICS

A. Natural beauty of the stream:

Excellent_____ Good_____ Fair_____ Poor_____

B. Natural beauty of the area around the stream:

Excellent_____ Good_____ Fair_____ Poor_____

C. Cleanliness and clearness of the area:

Excellent_____ Good_____ Fair_____ Poor_____

D. Wilderness characteristics:

Excellent_____ Good_____ Fair_____ Poor_____

E. Human developments:

None_____ Moderate_____ Excessive_____

9. AVAILABILITY

A. Access is satisfactory for modern car:

Good_____ Fair_____ Poor_____ Excessive_____

B. Amount of posting:

None_____ Some_____ Extensive_____ Closed_____

C. Is the stream floatable

Yes_____ No_____

D. Amount of bank cover - (how it affects fishing):

None_____ Some_____ Excessive_____

E. Trail developments or jeep roads:

None_____ Adequate_____ Inadequate_____

10. PRODUCTIVITY

A. Population of game fish:

Excellent____ Good____ Fair____ Poor____ Excessive____

B. Condition of fish:

Excellent____ Good____ Fair____ Poor____

C. Natural propagation:

Excellent____ Good____ Fair____ Poor____ Excessive____

D. Physical characteristics:

1. Amount in percent of bottom covered at low flow:

   Excellent____ Good____ Fair____ Poor____

2. Average width in feet (at minimum flow):

   ____ Actual   ____ Estimate

3. Volume - Is volume excessive or inadequate at any time during the year (limits the fishery)

   Adequate____ Inadequate____ Excessive____

4. Velocity - Is the velocity excessive or inadequate for prolonged periods of the year

   Adequate____ Inadequate____ Excessive____

5. Pool to riffle ratio:

   Excellent____ (40-60)   Good____ (25-39 or 61-75)   Fair____ (1-24 or 76-100)   Poor____ (no pools present)

6. Turbidity:

   does not effect productivity____ some effect on productivity____

   great amount of effect on productivity____

E. Length of growing season:

Excellent____ (200-365)   Good____ (150-200)   Fair____ (100-150)   Poor____ (50-100)

F. Amount of bank cover and shade (overhang of banks, etc.):

Excellent_____ (75-100%) Good_____ (50-75%) Fair_____ (25-50%) Poor_____ (0-25%)

G. Do temperatures restrict fish growth or survival

Suitable_____ Too high_____ Time_____ Too low_____ Time_____

H. Bottom type (gravel, rubble, and boulders):

Excellent_____ (75-100%) Good_____ (50-75%) Fair_____ (25-50%) Poor_____ (0-25%)

I. Bottom fauna:

Excellent_____ (Abundant) Good_____ (Common) Fair_____ (Occasional) Poor_____ (Rare)

J. Watershed:

Excellent_____	Good_____	Fair_____	Poor_____
(Heavy vegetative cover of all types; 75-100% bank stabilized)	(Trees, shrub or grass cover; 50-75% bank stabilized)	(Gullies present; shrub or grass coverage; 25-50% bank stabilized)	(Gullies present; no soil cover; 0-25% bank stabilized)

K. Aquatic vegetation:

Types - ____

____

Excellent_____	Good_____	Fair_____	Poor_____
(Abundant rooted)	(Common rooted or algae)	(Occasionally rooted or algae)	(Rare rooted or algae)

11. CLASSIFICATION FOR STREAMS

Esthetics	1 x _____	=
Availability	2 x _____	=
Productivity	4 x _____	=
Total:		_______

APPENDIX B

TABULATION OF RESULTS FROM LITERATURE SEARCH

TABLE 17

TEMPERATURE LIMITS FOR WARMWATER SPECIES

Temperature (°C)	Deaths Type Exposure	Acclimation Temperature (°C)	Reference	Remarks
Bluegill *(Lepomis machochirus)*				
30.7	*	15	22	*Thermal death point
31.5	*	20	23	*Thermal death point
33.8	*	30	23	*Thermal death point
33.8	TL 50*	--	35	*Upper limit-hatch of fry
21.9	TL 50*	--	35	*Lower limit-hatch of fry
3.2*	$TL_{96}50$	12.1	35	*Lower limit-juvenile
27.5	$TL_{96}50$	12.1	35	*Upper limit-juvenile
15.3	$TL_{96}50$	15.3	35	*Lower limit-juvenile
33.7	$TL_{96}50$	15.3	35	*Upper limit-juvenile
3	TL 50*	15	25	*Lower limit-juvenile, no exposure time
31	TL 40*	15	25	*Upper limit-juvenile, no exposure time
11	TL 50*	30	25	*Lower limit-juvenile, no exposure time
34	TL 50*	30	25	*Upper limit-juvenile, no exposure time
25	*	--	17	*Optimum spawning temp
34	*	--	17	*Max temp-successful incubation,hatching
32	*	--	55	*Max weekly avg temp-growth
25	*	--	55	*Max weekly avg temp-spawning
35	*	--	55	*Max temp for survival-short term exposure
34	*	--	55	*Max temp for survival-short term exposure-embryo

TABLE 17 (cont'd)

Temperature (°C)	Deaths Type Exposure	Acclimation Temperature (°C)	Reference	Remarks
Channel Catfish *(Ictalurus punctatus)*				
0	TL 50*	15	25	*No exposure time
6	TL 50*	25	25	*No exposure time
30	TL 50*	15	25	*No exposure time
34	TL 50*	25	25	*No exposure time
24.9-29.5	*	--	24	*Highest growth rate-optimum range
31.8	*	15	22	*Thermal death point
27	*	--	17	*Optimum spawning temp
29	*	--	17	*Max temp-successful incubation, hatching
32	*	--	55	*Max weekly avg temp-growth
27	*	--	55	*Max weekly avg temp-spawning
35	*	--	55	*Max temp for survival-short term exposure
29	*	--	55	*Max temp for survival-short term exposure-embryo
Largemouth Bass *(Micopterus salmoides)*				
32.5	*	20	22	*Thermal death point
36.4	*	30	22	*Thermal death point
34.5	*	25	23	*Thermal death point
21	*	--	17	*Optimum Spawning temp
27	*	--	17	*Max temp-successful incubation, hatching

TABLE 17 (cont'd)

Temperature (°C)	Deaths Type Exposure	Acclimation Temperature (°C)	Reference	Remarks
32	*	--	55	*Max weekly avg temp-growth
21	*	--	55	*Max weekly avg temp-spawning
34	*	--	55	*Max temp for survival-short term exposure
27	*	--	55	*Max temp for survival-short term exposure-embryo
Perch *(Perca fluviatilis)*				
23-25	*	--	22	*Thermal death point
25	*	10	23	*Thermal death point
27.7	*	15	23	*Thermal death point
29.7	*	25	23	*Thermal death point
Yellow Perch *(Perca flavescens)*				
34	TL 100*	--	65	*No exposure time
28	*	--	65	*Optimal growth rates
27.7	*	15	22	*Thermal death point
12	*	--	17	*Optimum spawning temp
20	*	--	17	*Max temp-successful incubation, hatching
29	*	--	55	*Max weekly avg temp-growth
12	*	--	55	*Max weekly avg temp-spawning
20	*	--	55	*Max temp for survival-short term exposure-embryo

TABLE 18

TEMPERATURE LIMITS FOR COLDWATER SPECIES

Temperature (°C)	Deaths Type Exposure	Acclimation Temperature (°C)	Reference	Remarks
Brook Trout	*(Salvelinus fontinalis)*			
3	TL 50*	3	25	*No exposure time
20	TL 50*	20	20	*No exposure time
25	TL 50*	25	25	*No exposure time
28	*	--	26	*Lethal limit
7-17	*	--	26	*Optimum
23.7	*	55	23	*Thermal death point
24.4	*	10	23	*Thermal death point
25	* q	15	23	*Thermal death point
25.3	*	20	23	*Thermal death point
25.3	*	25	23	*Thermal death point
9	*	--	17	*Optimum spawning temp
13	*	--	17	*Max temp-successful incubation, hatching
19	*	--	55	*Max weekly avg temp-growth
9	*	--	55	*Max weekly avg temp-spawning
24	*	--	55	*Max temp for survival-short term exposure
13	*	--	55	*Max temp for survival-short term exposure-embryo
Brown Trout	*(Salmo trutta)*			
12-18	*	--	25	*Temp preference

TABLE 18 (cont'd)

Temperature (°C)	Deaths Type Exposure	Acclimation Temperature (°C)	Reference	Remarks
26	*	26	22	*Thermal death point
22.5	*	5-6	22	*Thermal death point-fry
23.0	*	20	22	*Thermal death point-fry
25.9	*	--	22	*Thermal death point-yearling
29	*	--	22	*Thermal death point-yearling
17	*	--	55	*Max weekly avg temp-growth
8	*	--	55	*Max weekly avg temp-spawning
24	*	--	55	*Max temp for survival -short term exposure
15	*	--	55	*Max temp for survival -short term exposure-embyo
Rainbow Trout *(Salmo gairdneri)*				
28	*		23	*Thermal death point
34.5	*	25-26	22	*Thermal death point
9	*	--	17	*Optimum spawning temp
13	*	--	17	*Max temp-successful incubation, hatching
19	*	--	55	*Max weekly avg temp-growth
9	*	--	55	*Max weekly avg temp-spawning
24	*	--	55	*Max temp for survival-short term exposure
13	*	--	55	*Max temp for survival-short term exposure-embryo

TABLE 19

DISSOLVED OXYGEN REQUIREMENTS OF WARMWATER SPECIES

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Bluegill *(Lepomis machrochirus)*				
0.2-0.4	*	0-4	22	*Field observation
0.6	*	0-4	22	*Field observation
0.6-1.1	TL 100*	24-30	31	*No exposure time
0.5-1.0	0*	24-30	31	*Fish allowed surface access
0.9	TL 50*	30	31	*Fish allowed surface access
0.5	LC 100*	20	66	*No exposure time
0.8-1.2	0*	25-35	29	*Est avg tolerance limits
0.7-0.9	0*	25-35	29	*Est avg 24-hr tolerance limit
3.1	TL_{24}100	15	30	
0.8	TL_{48}100	≤4	30	
<1.0	Most*	15-16	67	*No exposure time-high CO_2 conc
Channel Catfish *(Ictalurus punctatus)*				
<1.0	*	--	24	*Lethal level, no exposure time
<3.0	*	--	24	*Distress level, no exposure time
1.0-1.1	*	25-35	29	*Est tolerance limit for normal fish
2.0	*	30	29	*Est tolerance limit for fat fish
0.8-0.9	*	25-35	29	*Est avg 24-hr tolerance limit

TABLE 19 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Largemouth Bass	*(Micopterus salmoides)*			
2.3	*	0-4	22	*Field observation
2.3-4.8	*	0-4	22	*Field observation
0.9-1.4	*	25-35	29	*Est avg tolerance limits
0.8-1.2	*	25	29	*Est 24-hr tolerance limits
3.1*	TL_{24}100	15	30	*Live cage-summer
2.3*	TL_{48}100	4	30	*Live cage-winter
1.0	TL 100*	12-16	67	*No exposure time-high CO_2 conc
Perch	*(Perca fluviatilis)*			
0.4	*	15	68	*Thershold conc
1.4	*	25	68	*Threshold conc
1.1-1.3	*	16	22	*Mim conc-survival
7.0	*	20	22	*Activity restricted
0.5-1.2	TL_{168}50	10-20	69	
0.7-1.9	TL 100*	11-24	70	*No exposure time-fingerling
0.4-0.9	TL 100*	11-23	73	*No exposure time-yearling
0.2-0.14	TL 100*	0-20	71	*No exposure time
0.2-0.16	First*	0	71	*No exposure time

TABLE 19 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Yellow Perch	*(Perca flavescens)*			
0.3-0.4	*	0-4	22	*Field observation
1.5-4.8	*	0-4	22	*Field observation
2.25	*	20-26	22	*Min conc for existence
0.37-0.88	*	15.5	22	*No exposure time-high CO_2 conc
2.0	TL 100*	19-24	43	*No exposure time
0.5-0.8	TL 50*	12-21	32	*No exposure time
3.1	TL_{24} 100*	15	30	*Live cage-summer
1.5	TL_{48} 100*	4	30	*Live cage-winter
0.9-1.1	TL 50	18-27	72	*No exposure time

TABLE 20

DISSOLVED OXYGEN REQUIREMENTS OF COLDWATER SPECIES

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Brook Trout	*(Salvelinuw fontinalis)*			
2.0	*	10	23	*Min conc for survival or TL 50-not specified
2.2	*	15	23	*Min conc for survival or TL 50-not specified
2.5 2.5	*	20	23	*Min conc for survival or TL 50-not specified
1.521.52	*	3.5	23	*Min conc for survival or TL 50-not specified
2.4 2.4	*	23	23	*Min conc for survival or TL 50-not specified
2.5	*	19-20	23	*Min conc for survival or TL 50-not specified
1.35-2.35	*	15.6	23*	*Min conc for survival or TL 50-not specified
2.0	TL 100*	17-20	43	*No exposure time-high CO_2 conc
2.0-3.4	First*	12-21	32	*No exposure time
1.6-2.6	TL 50*	12-21	32	*No exposure time
1.2-1.7	Last*	12-21	32	*No exposure time
2.5	TL_{24} 0	12-23	73	
1.9	TL_{24} 100	12-23	73	
1.0-1.8	TL_{24} 50	9	74	
2.3	TL_{84} 50	21-23	75	*No exposure time
Brown Trout	*(Salmo trutta)*			
1.6-2.8	First*	9-21	32	*No exposure time
1.5-2.5	TL 50	9-21	32	*No exposure time

TABLE 20 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
1.3-2.3	TL 100*	9-21	32	*No exposure time
1.1-3.3	First*	0	76	*No exposure time
0.3-0.6*	$TL_{120}0$	7	34	*Min conc tolerated by all newly hatched
1.2*	$TL_{48}0$	5	34	*Min conc tolerated by all 40-day fry
3.2*	TL 50*	22-24	75	*No exposure time
1.6	$TL_{72}0$*	9	34	*80-day fry
1.8	$TL_{48}0$*	16	34	*180-day fry
1.13	*	6.4	22	*Min conc for existence
1.16	*	9.5-10	22	*Min conc for existence
2.13	*	18	22	*Min conc for existence
2.8	*	24	22	*Min conc for existence
1.8-1.6	*	9.4	22	*Min conc for existence
1.64-2.48	*	17.2	22	*Min conc for existence
2.9	*	--	22	*Min conc for existence
Rainbow Trout	*(Salmo gairdneri)*			
2.4-3.7	*	16	22	*Min conc for existence
2.5	*	19-20	22	*Min conc for existence
0.83-1.42	*	11.1	22	*Min conc for existence
1.05-2.06	*	18.5	22	*Min conc for existence
1.3-1.6	$TL_{24}50$	13-20	77	

TABLE 20 (cont'd)

Concentration (mg/1)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
2.6-2.7	TL_{24} 50	13-20	77	
1.3-2.3	First*	11-22	32	*No exposure time
1.1-1.8	TL 50*	11-22	32	*No exposure time
0.8-1.4	TL 100*	11-22	32	*No exposure time
2.5	TL 50*	22-24	75	*No exposure time
2.9	TL_{84} 0	10-20	69	
2.4-3.1	TL_{188} 50	16-20	69	
1.6-1.7	TL_{24} 50-70	16-20	66	
1.5-1.6	TL_{18-24} 10	11-13	78	
1.4	TL_{18-24} 100	11-13	78	
0.8-1.2	First*	17	76	*No exposure time

TABLE 21

CHLORINE TOXICITY LEVELS FOR WARMWATER SPECIES

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Bluegill	*(Lepomis machrochirus)*			
0.10-0.20	*	--	35	*No mortalities-no exposure time
0.4	*	--	36	*Kill adult warmwater fish
0.2	*	--	36	*Kill fry warmwater fish
0.2	*	--	36	*Kill sunfish
0.4	*	--	36	*Kill sunfish-chloramine
0.2	*	--	37	*No kill with 2 hr/day blowdown from cooling tower
0.40-0.55	$LC_{96}50$	6-32	87	
0.20	*	6-32	87	*Stress
0.30	*	6-32	87	*Threshold
0.52	$LD_{72}50$	6	87	
0.52	$LD_{20}50$	32	87	
0.555	$LC_{96}50$	12	84	
0.44*	$LC_{96}50$	15-32	86	*Intermittent exposure
0.43-0.47*	$LC_{96}50$	6-32	87	*Intermittent exposure
Channel Catfish	*(Ictalurus punctatus)*			
0.1-0.2	*	--	24	*Toxic
0.156	$LC_{96}50$	12	84	

TABLE 21 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Largemouth Bass	*(Micopterus salmoides)*			
0.15-0.56	TL 0-TL 55*	--	35	*Cannot obtain meaningful TL from these values
0.574	$TL_1 50$	17	38	
0.494	$TL_{12} 50$	17	38	
0.345	$TL_{24} 50$	17	38	
0.310	$TL_{48} 50$	17	38	
0.300	$TL_{72} 50$	17	38	
0.295	$TL_{96} 50$	17	38	
0.272	$TL_{120} 50$	17	38	
0.261	$TL_{144} 50$	17	38	
0.261	$TL_{168} 50$	17	38	
0.09-0.30	$TL_{96} 50$	--	17	
Yellow Perch	*(Perca flavescens)*			
0.850	$TL_1 50$	17	38	
0.365	$TL_{12} 50$	17	38	
0.245	$TL_{24} 50$	17	38	
0.205	$TL_{48} 50$	17	38	
0.205	$TL_{72} 50$	17	38	
0.205	$TL_{96} 50$	17	38	

TABLE 21 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
0.205	$TL_{120}50$	17	38	
0.205	$TL_{144}50$	17	38	
0.205	$TL_{168}50$	17	38	
0.558	$LC_{96}50$	12	84	
0.7	$LC_{0.5}50$	30	83	
8.0	$LC_{0.5}50$	10	83	

TABLE 22

CHLORINE TOXICITY LEVELS FOR COLDWATER SPECIES

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Brook Trout	*(Salvelinus fontinalis)*			
0.4	*	--	22	*No exposure time-trout
0.05-0.06	*	--	22	*No percent deaths reported in 48 hrs-trout fry
0.08	*	--	22	*No percent deaths reported in 168 hrs-trout
0.05*	$LC_{48}57$	--	79	*Pink salmon
0.08*	$LC_{48}17$	--	79	*Silver salmon
0.25*	$LC_{48}20$	--	79	*Pink salmon
0.38*	$LC_{48}26$	--	79	*Silver salmon
0.3	*	--	36	*Kill trout fry instantaneously
0.06	*	--	36	*No percent deaths reported in 48 hrs-trout fry
0.4	*	--	40	*Kill trout-chloramine
0.99	$LC_{0.5}50$	10	83	
0.94	$LC_{0.5}50$	15	83	
Brown Trout	*(Salmo trutta)*			
0.06	*	--	25	*Incipient toxic level-fry
0.14-0.17	$ILC_{48}50$*	--	35	*Intermittent LC
0.18-0.19	$ILC_{48}50$*	--	27	*Intermittent LC
0.02-0.05	$ILC_{96}50$*	--	27	*Intermittent LC

TABLE 22 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
0.17-0.19	$ILC_{96}50$	--	27	*Intermittent LC
0.01	$TL_{43.5}50$	--	80	
Rainbow Trout	*(Salmo gairdneri)*			
0.03	*	--	25	*Incipient toxic level-chloramine
0.2	*	--	22	*Threshold
0.08	$TL_{168}50$	--	36	
0.08	*	--	39	*Lethal
0.004	*	--	39	*Safe
0.023	$TL_{96}50$	--	81	*Live cages
0.3	*	--	40	*Kill-2 hr
0.25	*	--	40	*Kill-4 to 5 hr
0.2-0.3	*	--	40	*Somewhat toxic
0.172	$LC_{96}50$	12	84	

TABLE 23

AMMONIA TOXICITY LEVELS FOR WARMWATER SPECIES

Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Bluegill *(Lepomis machrochirus)*				
<1.5	*	--	58	*Warmwater fishery limit
6.0	$LC_{48}50$	--	41	
7.4	$LC_{48}50$	--	41	
3.4	$TL_{96}50$	--	46	
Channel Catfish *(Ictalurus punctatus)*				
2-4	*	--	24	*Toxic limit if pH > 7.0
Perch *(Perca fluviatilis)*				
12.0	LC 100*	--	41	*No exposure time-probably total NH_3
0.29	$LC_{96}50$	--	82	
0.35	$LC_{60-120}50$	*	42	*Summer temp

TABLE 24

AMMONIA TOXICITY LEVELS FOR COLDWATER SPECIES

Concentration (mg/1)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Brook Trout	*(Salvelinus fontinalis)*			
0 0.5	*	--	24	*Salmonides-toxicity
0.25-0.33	LC 50*	--	41	*No expsoure timep-trout spawning
2.5	LC_{24}100	--	41	
3.6	LC_{10}50	--	41	
0.4	LC 60*	--	41	*Prolonged exposure-fry threshold
Brown Trout	*(Salmo trutta)*			
0.33	LC_{10}60*	--	41	*Fry
4.0	LC 100*	--	41	*No exposure time-trout
5.0	*	--	41	*Critical level for fingerling silver salmon
Rainbow Trout	*(Salmo gairdneri)*			
12 12.0	*	--	22	*Threshold
100	*	--	22	*Threshold
0.4	LC 50*	--	41	*No exposure time
1.5	LC 50*	--	41	*No exposure time
0.4	LC_{24}50*			

TABLE 24 (cont'd)

Concentration (mg/l)	Deaths Type Exposure	Temperature (^{o}C)	Reference	Remarks
0.4	$LC_{24}50$	--	41	
0.5	LC 50*	--	41	*No exposure time
0.4-0.58	$LC_{24}50$	--	41	
0.39	$LC_{24}50$	--	41	
0.16	$LC_{24}50$	--	41	
0.18	$LC_{48}50$	--	41	
0.09	$LC_{48}5$	--	41	
0.55	$LC_{44}5$	--	41	
0.005	*	--	41	*Gill hyperplasia-1008 hr
0.5	$LC_{24}50$	--	42	
0.49	$LC_{24}50$	--	32	
0.7	$LC_{24}50$	--	42	
0.47	$LC_{24}50$	--	42	
0.3	$LC_{24}50$*	--	42	*Fry
0.2	$TL_{96}50$*	--	42	*Fry

TABLE 25

DETERGENT TOXICITY LEVELS OF FISH

Detergent Type[a]	Concentration (mg/l)	Deaths Type Exposure	Temperature (°C)	Reference	Remarks
Trout					
DBSO	5.0	*	--	25	*Gills covered-sublethal effects
Bluegill	*(Lepomis machrochirus)*				
ABS	15.5-18.3	$TL_{360}50$	--	25	
LAS	2.2*	$TL_{24}50$	--	47	*DO 7.5 mg/l
LAS	2.2*	$TL_{48}50$	--	47	*DO 7.5 mg/l
LAS	2.1*	$TL_{24}50$	--	47	*DO 7.2 mg/l
LAS	2.1*	$TL_{48}50$	--	47	*DO 7.2 mg/l
LAS	2.0*	$TL_{24}50$	--	47	*DO 4.7 mg/l
LAS	1.9*	$TL_{48}50$	--	47	*DO 4.7 mg/l
LAS	0.5*	$TL_{24}50$	--	47	*DO 2.8 mg/l
LAS	0.5*	$TL_{48}50$	--	47	*DO 2.8 mg/l
LAS	0.4*	$TL_{24}50$	--	47	*DO 2.0 mg/l
LAS	0.4*	$TL_{48}50$	--	47	*DO 2.0 mg/l
ABS	17.4	$TL_{96}50$	--	23	
ABS	19.7	$TL_{24}50$	--	45	
ABS	18.1	$TL_{96}50$	--	45	
ABS	17.3	$TL_{30}50$	--	45	
ABS	17.4	$TL_{24}50$	--	23	

TABLE 25 (cont'd)

Detergernt Type[a]	Concentration (mg/l)	Deaths Type Exposure	Temperature (^{o}C)	References	Remarks
ABS	8.2	$TL_{96}50$	--	44	
ABS	8.2	$TL_{96}50$	--	23	
ABS	17.44	$TL_{96}50$	--	46	
LAS	4.0	$TL_{96}50$	--	23	
LAS*	0.72	$LC_{96}50$	20.8	85	*0% degraded
LAS*	0.89	$LC_{96}50$	20.5	85	*36.7% degraded
LAS*	1.16	$LC_{96}50$	20.6	85	*53.3% degraded
LAS*	1.64	$LC_{96}50$	21.0	85	*76.0% degraded
LAS	1.94	*	--	85	*Acute toxicity @ 96% degraded

[a]DBSO = sodium decylbenzene sulfonate
ABS = alkylate benzene sulfonate
LAS = linear alkylate sulfonate ("biodegradable")

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