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PROJECT COMPLETION REPORT

OWRT PROJECT NO. A-051-ARIZ

WATER QUALITY TRANSFORMATIONS AND GROUNDWATER RECHARGE OF SEWAGE EFFLUENT RELEASES IN AN EPHEMERAL STREAM CHANNEL

Agreement No. 14-31-0001-5003

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ABSTRACT

Bio-physicochemical measurements were made on treated sewage effluent releases at established locations within the channel of an ephemeral stream, the Santa Cruz River of Southern Arizona. Water samples were taken in chronological sequence as the effluent moved downstream, to trace changes in quality parameters during low and high hydrograph stages. Results indicate that dissolved oxygen (DO) concentrations at low effluent flows were higher than DO concentrations at high effluent flows; while, conversely, biochemical oxygen demand (BOD) concentrations at low effluent flows were generally lower than BOD concentrations at high effluent flows. Biochemical oxygen demand concentrations are affected by waste loadings, flow conditions, phytoplankton growth and nitrification. Mean river deoxygenation rates (k_r) in sewage flows after six river miles from the Tucson Sewage Treatment Plant were always negative or increasing, indicative of nitrification, algal growth, and concentration of organic constituents through seepage losses.

WATER QUALITY TRANSFORMATIONS AND GROUNDWATER RECHARGE OF SEWAGE EFFLUENT RELEASES IN AN EPHEMERAL STREAM CHANNEL

INTRODUCTION

When an oxygen-demanding waste is introduced into a stream, it is biochemically oxidized. Reoxygenation occurs by the addition of oxygen molecules from plant photosynthesis and the atmosphere to the stream water. The minimum dissolved oxygen (DO) concentration varies according to the relative rates of the deoxygenation and reoxygenation processes, the quantity of the wasteload, and the dilution of the waste. This minimum DO point is called the critical point.

There are seven interrelated factors affecting the bio-physicochemical conditions in low and high sewage flows in the Santa Cruz River (Sebenik, 1975b):

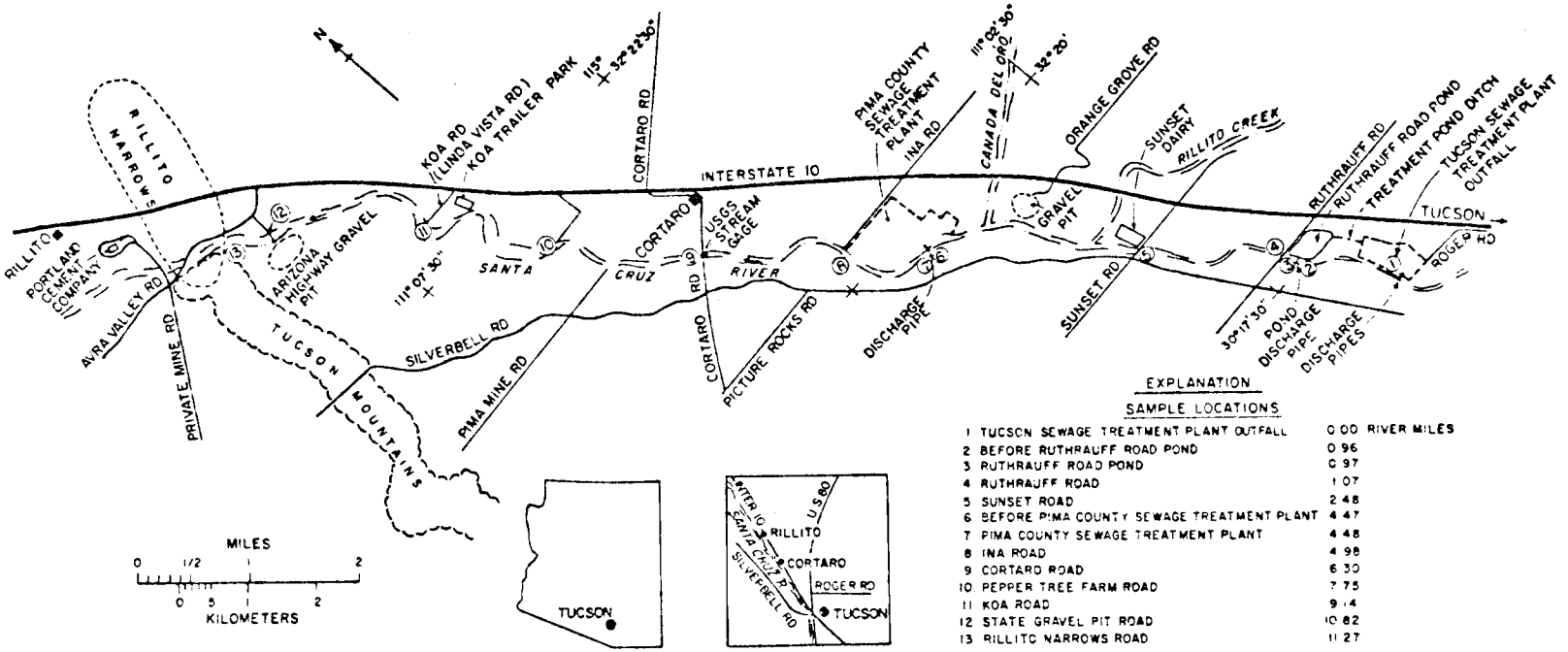
1. initial DO and biochemical oxygen demand (BOD) concentrations.
2. sludge deposits and high benthal demand between Tucson Sewage Treatment Plant and Ruthrauff Road.
3. DO and BOD concentrations, eutrophic nutrients, discharge quantities, and algal populations at the Ruthrauff Road Pond and at Pima County Sewage Treatment Plant.
4. algal growth and microbial metabolism downstream.
5. ammonification and nitrification reaction rates.
6. deoxygenation and reaeration reaction rates.

The overall objective of this project was to examine the biochemical transformations occurring within an ephemeral stream channel (the Santa Cruz River of Southern Arizona) during continuous bycyclical sewage effluent releases from the City of Tucson Treatment Plant. Specific objectives were: (1) to characterize spatial and temporal changes in the biochemical oxygen demand (BOD) and dissolved oxygen (DO) composition of sewage effluent downstream, and (2) to evaluate various factors affecting chemical, biological, and physical conditions in sewage effluent during different flow conditions.

The basic experimental approach consisted of obtaining effluent samples from the river during high and low flow periods at each of 13 stations downstream from the Tucson Sewage Treatment Plant. The samples were analyzed for BOD, DO, temperature, and pH.

PROJECT DESCRIPTION

The project area (Figure 1) lies within the floodplain of the Santa Cruz River, an ephemeral stream, located in Southern Arizona, near Tucson, and extends from the Tucson Sewage Treatment Plant (TSTP) to a bedrock constriction known as the "Rillito Narrows," eleven miles downstream. The relative locations of the 13 sampling points are also shown on Figure 1. A stream survey was



EXPLANATION

SAMPLE LOCATIONS

1	TUCSON SEWAGE TREATMENT PLANT OUTFALL	0 00 RIVER MILES
2	BEFORE RUTHRAUFF ROAD POND	0 96
3	RUTHRAUFF ROAD POND	0 97
4	RUTHRAUFF ROAD	1 07
5	SUNSET ROAD	2 48
6	BEFORE PIMA COUNTY SEWAGE TREATMENT PLANT	4 47
7	PIMA COUNTY SEWAGE TREATMENT PLANT	4 48
8	INA ROAD	4 98
9	CORTARO ROAD	6 30
10	PEPPER TREE FARM ROAD	7 75
11	KOA ROAD	9 14
12	STATE GRAVEL PIT ROAD	10 82
13	RILLITO NARROWS ROAD	11 27

Figure 1. Location Map of Project Area.

made in 1974 by Sebenik (1975) to determine the exact cross-section, water depth, water surface width and wetted area of various representative stream sections.

Natural discharge occurs in the Santa Cruz River only in response to direct precipitation on the watershed. Rates of streamflow resulting from short, intense thunderstorms in the summer generally vary greatly and the duration of flow is no more than one or two days. These runoff events cause considerable erosion and deposition at various stream sections, producing changes in stream geometry. Streamflow resulting from winter precipitation produced by frontal storms may last for several days and may produce considerable recharge to the basin.

The Tucson Sewage Treatment Plant (TSTP) has five main transportation points: (1) plants 1 and 2, measured by a three-foot Parshall flume bypass into a drop inlet which connects to a 3-foot diameter concrete pipe extending to the Santa Cruz River; (2) plant 3, measured by a 3-foot Parshall flume bypassed into a drop inlet which connects to a 3-foot diameter concrete pipe extending to the Santa Cruz River; (3) Ruthrauff Pond Canal, which takes high peak sewage flows from both measured points to Ruthrauff Road holding pond which is approximately 0.25 miles from TSTP; (4) sludge pipe from anaerobic digesters to the Ruthrauff Pond Canal which bypasses the measured control sections; and (5) Ruthrauff Road holding pond, containing about 380 acre-feet of sewage effluent, has a concrete drainpipe and a concrete spillway which may also release sewage effluent to the Santa Cruz River.

During the study period, February 1, 1975 to May 30, 1975, both Parshall flumes were measuring sewage flows to the river. Every day between February 1, 1975, and April 8, 1975, a given portion of the sewage flow was diverted down the Ruthrauff Pond ditch, routed through Ruthrauff Road Pond, which is approximately one river mile downstream, and then discharged back into the remaining sewage flows. Approximately one-half of the total effluent flow was routed through the Ruthrauff Road Pond, cuasing a dampening effect on normal sinusoidal flow patterns from TSTP. After April 8, 1975, no discharges were diverted. In order to measure diverted quantities in the canal, a stilling well, with automatic stage recorder, was installed adjacent to the canal near the inlet to Ruthrauff Pond. A rating curve was prepared in 1974 for the particular trapezoidal section of the canal. With this measurement and standard reservoir routing calculations through the Ruthrauff Road Pond, all quantities of sewage effluent diverted into the river could be determined.

The Pima County Sewage Treatment Plant (PCSTP) is a series of oxidation ponds totaling ten acres near Ina Road, about 12 miles northwest of Tucson, or approximately 5 miles downstream from TSTP. The lagoon site is located on the floodplain of the nearby Santa Cruz River. A one-foot diameter outlet pipe, protruding from the streambank, constantly discharges about 3.0 cfs of effluent. This additional effluent discharge was also tested during the sampling period.

EXPERIMENTAL PROCEDURES

Preliminary Flow Data

Discharge values from TSTP for the study period were collected. Effluent flows at Cortaro Road (see Figure 1), 6.30 river miles downstream from TSTP, and at Rillito Narrows Road near Avra Valley Road, 11.27 river miles downstream from TSTP, were gaged to establish effluent hydrograph conditions. Supplemental flow measurements were also made at intermediate locations. Sewage effluent hydrographs from these locations were used with a modified kinematic wave model developed by Sebenik (1975a) to estimate flow travel times for a particular discharge rate from TSTP. From these travel times, a given mass of effluent with a known, original composition, could be sampled at downstream locations. There are two reasons for accurate tracing of the given incremental flow: (1) the diurnal sinusoidal fluctuation of effluent sewage flows out of TSTP is reflected in a daily advance and recession of the wetted area of effluent in the Santa Cruz River Channel, and (2) the biochemical and physicochemical properties of the effluent change significantly as sewage effluent proceeds downstream. Effluent flow records from the TSTP and the resulting kinematic model flow data were tabulated to delineate peculiar flow characteristics.

Discharges from TSTP during the period from February to April 8, 1975, were nearly uniform. Apparently, routing of some of the flow through the Ruthrauff Pond caused a slight damping effect of the normal sinusoidal fluctuations. Discharges from PCSTP were higher than previously observed. In addition, overall channel infiltration rates were reduced from 0.50 inches per hour observed previously by Sebenik (1975a) to 0.35 inches per hour due to lack of channel cleaning floods and increased siltation produced by gravel cleaning operations downstream. The overall effect of these conditions caused low flows to proceed farther downstream with slightly larger volumes.

Water Quality Sampling

The water quality sampling schedule was as follows: (1) ten sampling periods in 1975 (February 8-9, February 15-16, February 22-23, March 1-2, March 15-16, March 29-30, April 5-6, May 3-4, May 10-11, May 17-18); (2) two sampling times, low and high effluent flows, within each sampling period to reflect the characteristic points of the discharge hydrograph; and (3) thirteen sampling locations, as shown in Figure 1, including three discharge points. These locations/times were selected to monitor the biochemical transformations in a flow parcel of sewage effluent as it proceeded downstream.

Low flow disappeared just before Rillito Narrows Road and, therefore, no water quality samples were taken at this location. During the two-day sampling periods the low flow sampling occurred only during the first day while high flow peak sampling occurred on the first day and the early morning hours of the second day.

A vertically integrated grab sample was collected at each of the thirteen established stations. These samples were obtained in one-gallon sample bottles and then transferred, after field chemical analysis, to one-liter bottles.

Care was taken to prevent bottom sediments from entering the sample bottle, especially at Ruthrauff Road where large accumulations of algae and microbial deposits occurred. During high flow peaks, higher velocities (1 to 2 feet per second) caused a moving stratified sandy sediment layer to occur. Extra care was taken in sampling during high peak flows. All samples were placed in an ice-packed thermal chest to further inhibit biochemical changes. At selected intervals during the sampling period, which lasted approximately twenty hours, all one-liter sample bottles from the ice chest were then transferred to a refrigerator. A standard biochemical analysis was made on each effluent sample taken as described later.

Chemical Analysis

Three properties were analyzed in the field for each sample: (1) temperature (^{o}C), (2) pH, and (3) dissolved oxygen content (mg/l).

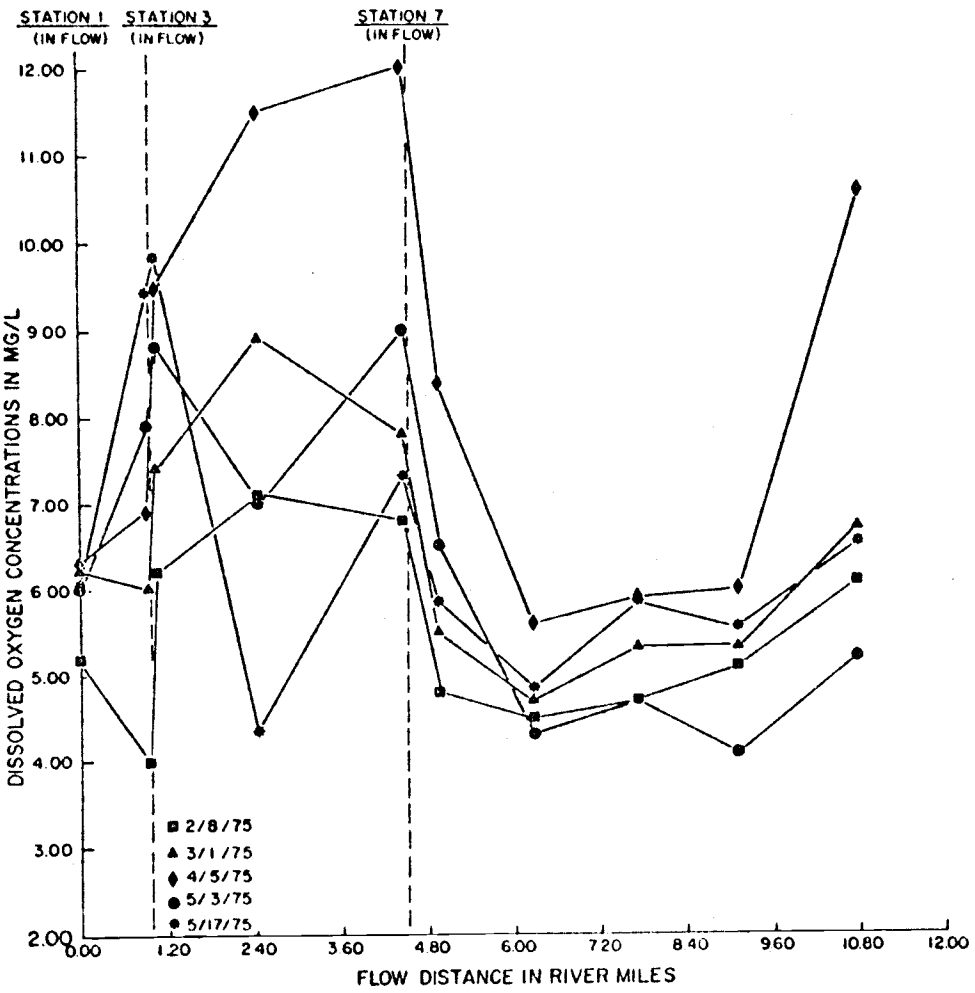
Analyses of the sewage effluent samples were conducted as described in Standard Methods for Examination of Water and Wastewater (1971). The initial dissolved oxygen content was determined for both settled and non-settled sewage samples. The settled sewage samples were placed in an Imhoff glass cone for one hour and then samples were carefully pipetted out. The amount of settled solids (ml) was noted. Analyses of duplicate samples were completed within a four-hour period after being collected. Duplicate sewage samples with appropriate water dilutions were placed in standard BOD bottles and refrigerated at 20^{o} C. Five days later, final dissolved oxygen content of each sample bottle was determined and biochemical oxygen demand was calculated.

RESULTS AND DISCUSSION

Variability of Dissolved Oxygen Relationships by Flow Conditions

Observed DO levels at low sewage flows, increased in the five-mile river section downstream from the Tucson Sewage Plant outfall (see Figure 2). Over the sampling period, the DO levels in sewage at Station 1 averaged 6.3 mg/l, compared with an average DO concentration of 9.2 mg/l at Station 6. This increase in DO is attributed to: (1) normal reaeration, (2) low initial BOD concentration at two discharge points -- Station 1 and Station 3 -- and (3) photosynthesis action by phytoplankton. Some variability in DO levels in the first mile of sewage flows between Station 1 and Station 2 was noted. During the period from February 1 to April 8, 1975, approximately one-half of the total effluent flow was routed through Station 3, where algal concentrations were added to the sewage, and then discharged into the remaining sewage flows. Such phytoplankton-laden discharges from Station 3 prevented any significant oxygen sagging between Station 3 and Station 7. In fact, DO concentrations generally increased as sewage flowed downstream, as represented by mean DO concentration in Table 2. Super-saturated oxygen conditions occurred at both Station 5 and at Station 6 during the spring sample periods.

After April 8, 1975, a significant DO sagging was observed at Sunset Road (Station 5), as shown in Figure 2. In contrast, the mean DO levels at low flows at Station 4 after April 8, were much higher than mean DO levels



,Figure 2. Representative Dissolved Oxygen Concentrations at Low Effluent Flows.

Table 2. Mean Dissolved Oxygen Concentrations at Low Effluent Flows Before and After April 8, 1975.

Station	Flow Distance in River Miles	Mean DO Concentrations at Low Flow (mg/l)	
		Before April 8	After April 8
1	0.00	6.3	6.4
4	1.07	7.9	9.4
5	2.48	8.9	6.0
6	4.47	9.2	9.2

at Station 5 (see Table 2). The difference in dissolved oxygen levels between Ruthrauff Road (Station 4) and Sunset Road (Station 5) during this period ranged from 1.88 to 5.55 mg/l of DO with an average of 4.5 mg/l. The temporal changes in DO levels for low flows at Station 4 and at Station 5, before and after April 8, 1975, reflect the amount of wasteload and phytoplankton population contributed by Station 3 to the sewage flows.

Discharges from Pima County Sewage Treatment Plant (Station 7) into low effluent flows during the entire sampling period also caused decreasing oxygen levels for certain downstream stations. Discharges from Station 7 had a large BOD load (approximately 80 mg/l), which caused a critical oxygen deficit usually at Cortaro Road (Station 9), 1.80 river miles downstream from Station 7. Mean dissolved oxygen levels at Station 6 were 9.2 mg/l compared with 5.5 mg/l at Station 9. The difference in dissolved oxygen levels between Station 6 and Station 9 ranged from 2.5 to 6.6 mg/l with an average oxygen sag of 3.9 mg/l. After Station 9, DO levels in low sewage flows increased due to reaeration and photosynthetic activity. In summary, low flow DO levels were greatly affected by discharges from BOD loading points of Station 3 and Station 7.

Seasonal trends were observed in DO levels in low sewage flows. With approaching spring, sunlight hours increase and air temperatures become higher, resulting in an increased photosynthetic activity. This increased algal metabolism can be observed on Figure 2 by the increasing DO concentrations on all sample days between February 1 through April 8. After April 8, when very little effluent was discharged from Station 3 the critical oxygen deficits at Station 5 were progressively lowered inasmuch as the bacterial utilization of DO was greater than the production of DO by photosynthesis. The critical oxygen deficits steadily decreased at Station 9 as spring progressed, since phytoplankton population from Station 7 were always being added to sewage flows.

Dissolved oxygen concentrations at high effluent flows are shown in Figure 3. Dissolved oxygen concentrations throughout the sample period average 6.4 mg/l at Station 1, 8.1 mg/l at Station 4 and 7.0 mg/l at Station 6. Dissolved oxygen differences in the four-mile river stretch between Station 4 and Station 6 ranged from 0.4 to 2.9 mg/l, averaging 1.1 mg/l of oxygen deficit. Some variability in DO levels in the first mile of sewage flows was noted between Station 1 and Station 2. In contrast to DO concentrations at low flows before April 8, 1975, the mean levels at high flows between Station 4 and Station 6 generally decreased at successive downstream locations. As shown in Table 3 a significant oxygen deficit occured at Sunset Road (Station 5) after April 8, 1975.

Table 3. Mean Dissolved Oxygen Concentrations at High Effluent Flows Before and After April 8, 1975.

Station	Flow Distance in River Miles	Mean DO Concentrations at High Flows (mg/l)	
		Before April 8	After April 8
1	0.00	6.2	6.9
4	1.07	7.8	8.6
5	2.48	7.3	5.8
6	4.47	7.0	6.9

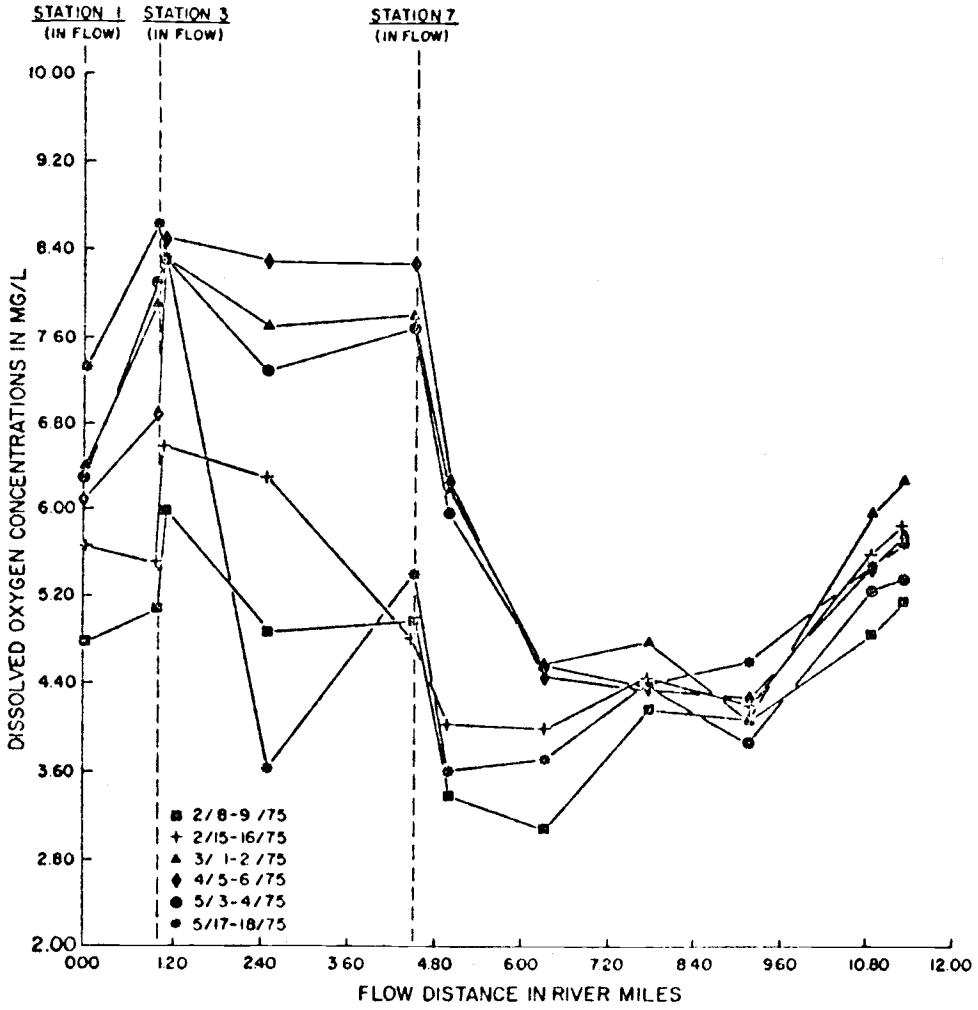


Figure 3. Representative Dissolved Oxygen Concentrations at High Effluent Flows.

The difference in DO concentration trends for different flow conditions between Station 1 and Station 6 can be related to (1) the quantity and quality of sewage released from both discharge points, and (2) the flow velocities in the channel. At the larger velocities, increase scour of sludge and benthal deposits were noted. This uptake of organic deposits by high sewage flows probably causes increased oxygen utilization and the lowering of dissolved oxygen levels. The DO concentrations at high flow rates in this river stretch were further affected by the amount of phytoplankton-laden sewage flows routed through Station 3 during the period from February to April, 1975. Other possible factors affecting DO concentration differences between flow conditions are the following: (1) reaeration rate variabilities, and (2) microbial metabolic differences caused by flow and meteorological conditions.

Phytoplankton-laden discharges and high organic waste loading were also continuously released into high sewage flows from Station 7, causing a decrease in oxygen levels for certain successive downstream stations. The addition of a high waste load into the sewage flows decreases the DO concentration rapidly at the point of introduction. However, this initial shock is mitigated by the algal population within the waste load, which increases DO concentration further downstream. Therefore, discharges from Station 7 into the channel should be considered both an asset and a liability on the actual DO concentrations. For example, high BOD loading and low initial DO levels in Station 7 discharges caused a critical oxygen deficit at Cortaro Road (Station 9). Thus mean DO concentrations at Station 6 were 6.8 mg/l compared with DO concentrations of 4.9 mg/l at Station 9. After Station 9, DO concentrations in high sewage flows generally increased due to reaeration and photosynthetic activity.

Seasonal variation of DO concentration at high flows are somewhat similar to DO levels at low flows. The DO concentration curves on all sample days from February through April, 1975, show a trend in higher DO levels as summer approaches. In May, 1975, with no discharges from the Station 3, the critical oxygen deficit at Sunset Road (Station 5) also steadily increased through May as sunlight hours and air temperatures increased.

Variability of Biochemical Oxygen Demand by Flow Conditions

Biochemical oxygen demand in sewage flows is directly affected by BOD load, discharge quantities, deoxygenation and reaeration rates, eutrophic nutrients, phytoplankton growth and metabolism, and nitrification. An additional effect on BOD values is the concentration of organic constituents in the residual flow as seepage loss into the streambed progresses.

As shown in Figure 4, BOD values in low sewage flows varied greatly in the five-mile river stretch between Station 1 and Station 6, depending upon the initial BOD discharges at both Tucson Sewage Treatment Plant outfall (Station 1) and Ruthrauff Road Pond (Station 3). During periods from February through April 8, 1975, when a portion of the sewage flow was routed through Ruthrauff Pond (Station 3), relatively high initial BOD concentrations (above 15 mg/l) in Station 1 discharges produced a general trend in the oxidation

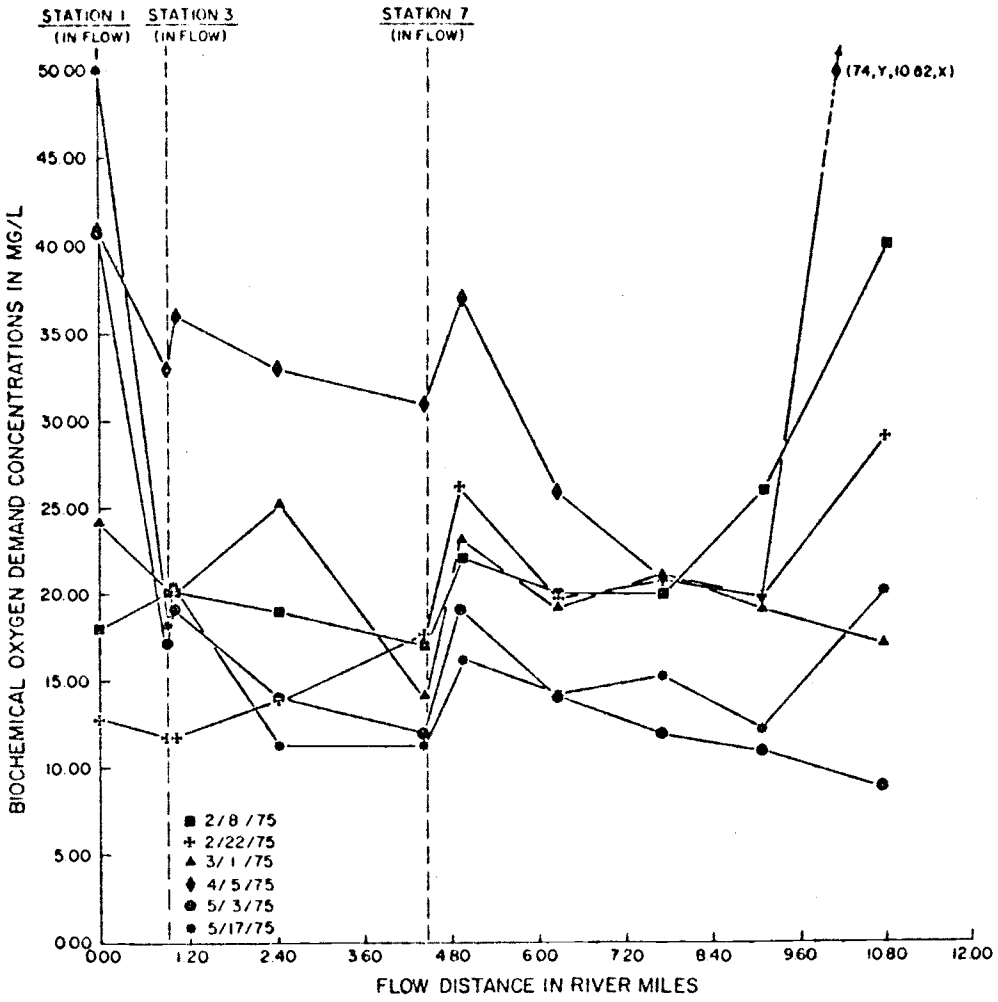


Figure 4. Representative Biochemical Oxygen Demand Concentrations at Low Effluent Flows.

of organic matter as sewage flowed downstream. Increases in BOD loading seemed to be directly related to increases in the rate of self-purification. On February 22, 1975, low initial BOD values at both discharge points of Station 1 and Station 3 produced increasing BOD values as effluent flowed downstream. Inasmuch as Sebenik, Cluff and DeCook (1972), Sebenik (1975a), and Wilson (1974) found no nitrification occurring with this river stretch, it is postulated that photosynthetic growth of phytoplankton caused the increase in BOD. It should be noted that errors in BOD analysis due to algal populations was limited by using a large percentage of dilution water to sewage sample.

Mean values of BOD concentrations before and after April 8, 1975 (Table 4), show that discharges from Station 3 affected the self-purification process by promoting phytoplankton growth. For example, before April 8, 1975, mean BOD concentrations in the downstream direction are very consistent; however, after April 8, 1975, the oxidation of organic matter proceeds normally, causing a decline in BOD concentrations. Therefore, the lack of phytoplankton additions from Station 3 into the sewage flows promoted a normal decay with BOD concentration differences between Station 4 and Station 6 ranging from 7 mg/l to 9 mg/l with average difference of 8 mg/l.

With a large BOD load addition (approximately 80 mg/l) to the sewage flows at Station 7, the BOD in low sewage flows at Ina Road (Station 8), 0.5 river miles downstream from Station 7, have greater BOD values compared with Station 6. Increases in BOD values between the two sample points ranged from 5 to 19 mg/l, averaging 8 mg/l. Biochemical oxygen demand decayed normally after Station 8 until Pepper Tree Farm Road (Station 10), or DOA Road (Station 11), where the BOD increased. These BOD increases are attributed to phytoplankton growth, nitrification and the increased concentration of organic matter through seepage losses.

Biochemical oxygen demand values at high sewage flows varied greatly during sampling periods (Figure 5). The five-mile river stretch between the Station 1 and Station 6 showed no consistent and uniform trends in BOD values as sewage flowed downstream. However, before April 8, 1975, the mean BOD concentrations increased as sewage flowed downstream (Table 5), indicating that phytoplankton growth is important. Sebenik *et al.* (1972) and Sebenik (1975a) found that little nitrification occurred in this river stretch at high flows. After April 8, 1975, mean BOD concentration remained almost constant.

Contrary to BOD concentrations at low flows, BOD discharges from Station 7 during high effluent flows did not always increase the BOD level in the sewage effluent flowing downstream. BOD levels in high sewage flows immediately after Station 7 can be related to the BOD load from Station 7, and the flow quantities of each stream segment. Thus a dilution equation with flows (Q) and chemical concentrations (C) of BOD values was established as follows:

$$(Q_{\text{Sta. 6}} \cdot C_{\text{Sta. 6}}) + (Q_{\text{Sta. 7}} \cdot C_{\text{Sta. 7}}) - (Q_{\text{seepage}} \cdot C_{\text{settled}})$$

$$= Q_{\text{Sta. 8}} \cdot C_{\text{Sta. 8}}$$

Table 4. Mean Biochemical Oxygen Demand Concentrations at Low Effluent Flows Before and After April 8, 1975.

Station	Flow Distance in River Miles	Mean BOD Concentrations at Low Flows (mg/l)	
		Before April 8	After April 8
1	0.00	25	41
4	1.07	25	19
5	2.48	25	11
6	4.47	21	10

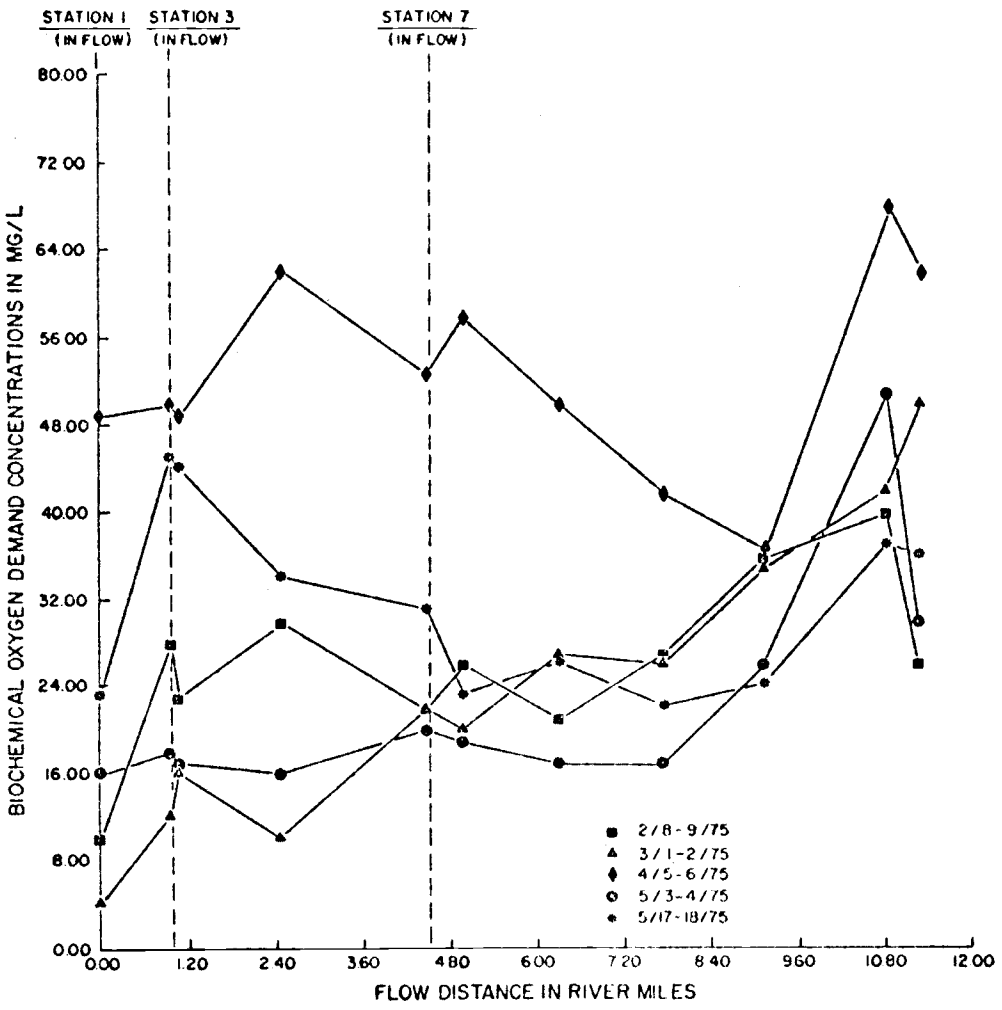


Figure 5. Representative Biochemical Oxygen Demand Concentrations at High Effluent Flows.

Table 5. Mean Biochemical Oxygen Demand Concentrations at High Effluent Flows Before and After April 8, 1975.

Station	Flow Distance in River Miles	Mean BOD Concentrations at High Flows (mg/l)	
		Before April 8	After April 8
1	0.00	15	23
4	1.07	23	30
5	2.48	25	30
6	4.47	28	28

Comparing the calculated BOD concentrations with measured BOD concentrations at Ina Road (Station 8), no significant difference was found. For example, the calculated BOD values at Station 8 averaged 32 mg/l compared to actually measured BOD values of 30 mg/l. Therefore, the mass flux equation can be used to explain the variability in BOD values at high sewage flows for the Ina Road location (Station 8).

After Station 8, and during the cool months of February and March, the BOD values generally increased. It is assumed that phytoplankton growth and associated BOD addition overpowered the decay of organic matter. Sebenik et al. (1972) and Sebenik (1975a) found only small amounts of nitrification occurring in this river stretch during the winter months at high flows. However, during the months of May and June, BOD values decreased rapidly as sewage flow proceeded between Station 7 and Station 10 or Station 11. BOD values increased after Station 11. It is postulated that these fluctuations in BOD measurements are the result of complicated interactions of nitrification, deoxygenation, reaeration, phytoplankton growth and metabolism, and concentration of organic constituents through seepage losses.

Relationships Between Dissolved Oxygen and Biochemical Oxygen Demand by Flow Conditions

Relationships between measured dissolved oxygen and biochemical oxygen demand at low and high flows are shown in Figures 6 and 7. At low flows, overall DO curves are nearly always higher than DO curves at high flows; BOD curves at low flows are nearly always lower than the BOD curves at high flows. In other words, there is an inverse relationship between DO concentrations and BOD loading at low and high sewage flows. This observation was substantiated by statistical analyses (Sebenik, 1975b).

River Deoxygenation Rates (k_r) at Low and High Effluent Flows

Deoxygenation rates (k_r) in natural river flows result from the removal of BOD through oxidation and sedimentation of suspended organics (Eckenfelder, 1970). Velz (1970) stated that the nitrification phase is an important factor when biologically treated effluents are discharged into small streams. He also stated that photosynthesis of algae or phytoplankton make stream analysis complicated especially on sunny days. Therefore, river deoxygenation rates in sewage effluent flows may differ markedly from those in natural water systems.

River deoxygenation rates (k_r) were calculated by Sebenik (1975) using the two-point method, described by the equation: $k_r = 1/(T_b - T_a) \log L_a/L_b$, where the effluent flow progresses from location a to location b, T is the time of sampling each point, and L is the ultimate BOD at each point (Nemerow, 1974). Sebenik (1975) replaced ultimate BOD values with five-day BOD values. This technique produced very unusual and interesting deoxygenation results for measured BOD values in sewage flows. For example, mean river deoxygenation rates (k_r) at low flows between Tucson Sewage Treatment Plant outfall (Station 1) and Cortaro Road (Station 9) were found to be positive values, indicating normal oxidation of organic matter. However, after

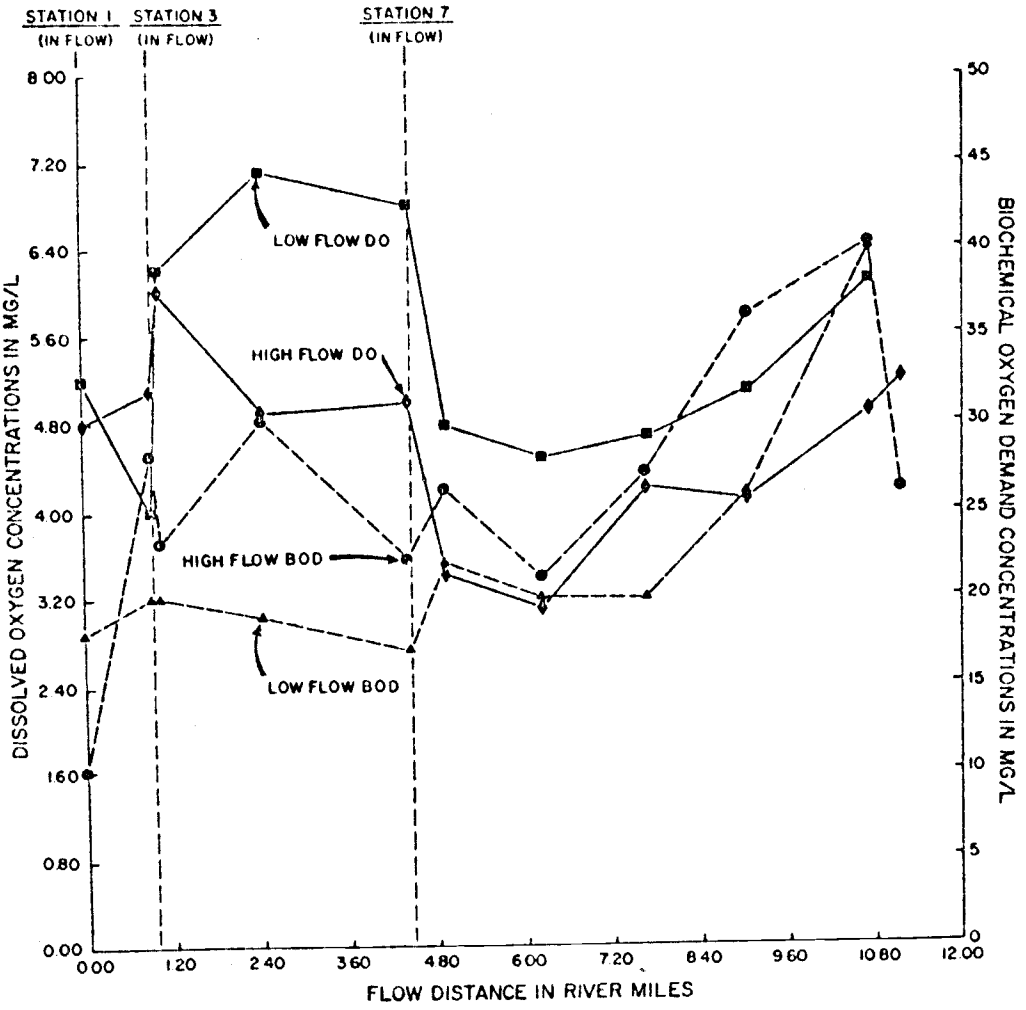


Figure 6. Dissolved Oxygen and Biochemical Oxygen Demand Concentrations at Low and High Effluent Flows, February 8-9, 1975.

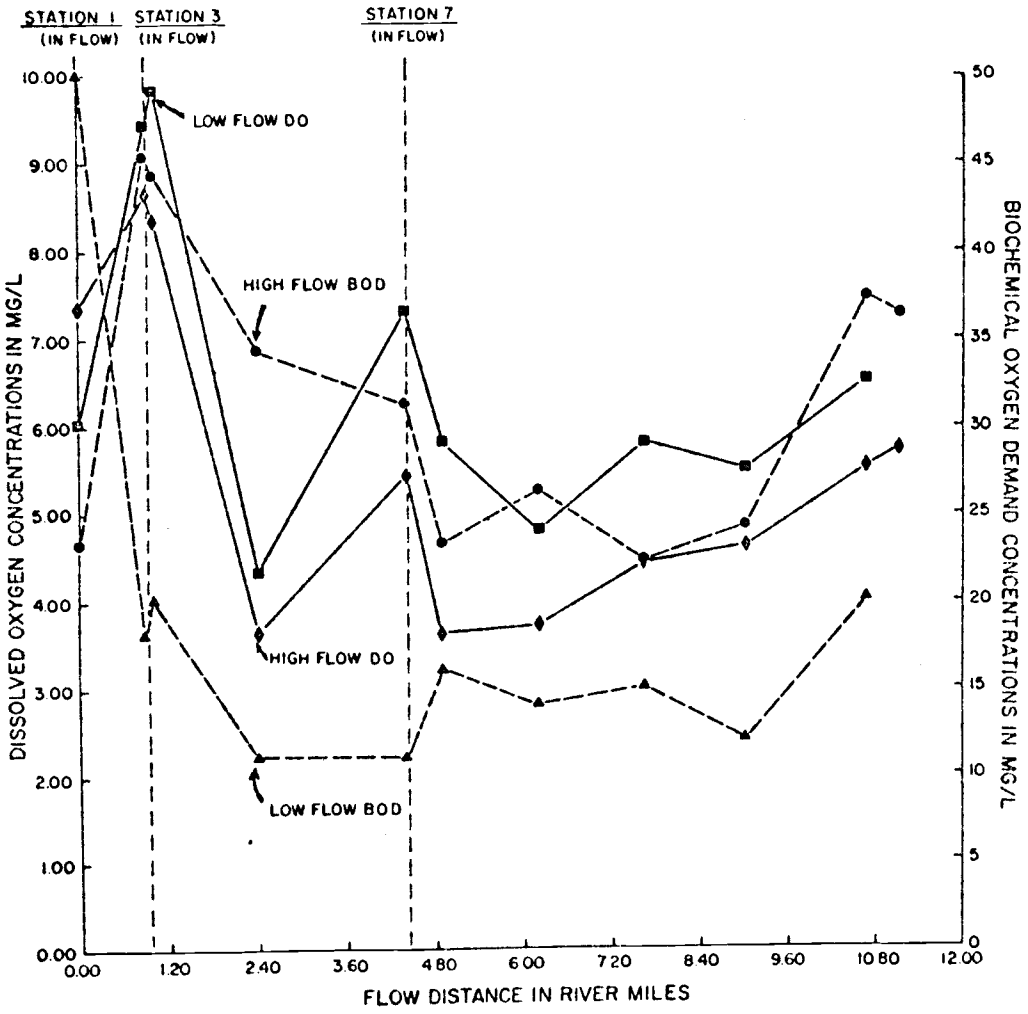


Figure 7. Dissolved Oxygen and Biochemical Oxygen Demand Concentrations at Low and High Effluent Flows, May 17-18, 1975.

Station 9, mean river deoxygenation rates (k_r) were negative values, indicating that oxygen demands were increased in the river system by nitrification, algal growth, and concentration of organic matter through seepage loss. Mean river deoxygenation rates at high flows were generally negative values.

Relationships of Variables

A Pearson correlation analysis between the bio-physicochemical variables at low and high flows was determined by Sebenik (1975b). Certain bio-physicochemical variable combinations were found to have significant correlations at a majority of stations during the sampling period. These variables include following: low flow pH (log $1/[H^+]$) concentration with high flow pH, low flow temperature with high flow pH, and low flow dissolved oxygen with high flow dissolved oxygen. Variable combinations of temperature, dissolved oxygen concentration and biochemical oxygen demand values at both flow conditions were not significantly correlated at numerous locations. Therefore, other factors, such as nitrate concentrations and phytoplankton growth, have some effect on the observations.

CONCLUSIONS

1. Dissolved oxygen levels at low and high effluent flows are greatly affected by discharges from the Ruthrauff Road Pond (Station 3) and Pima County Sewage Treatment Plant (Station 7) which contain phytoplankton populations, eutrophic nutrients and an additional organic load.

2. Dissolved oxygen levels at high effluent flows are lowered by the scour of sludge and benthal deposits.

3. Dissolved oxygen concentrations at low effluent flows are nearly always higher than dissolved oxygen concentrations at high flows; while conversely, biochemical oxygen demand levels at low effluent flows nearly always lower than the biochemical oxygen demand levels at high effluent flows.

4. Biochemical oxygen demand in sewage flows are affected by waste loading, flow conditions, phytoplankton growth and nitrification.

5. Mean river deoxygenation rates (k_r) after Cortaro Road at both low and high effluent flows are negative or increasing, apparently because of nitrification, algal growth, and concentration of organic constituents through the seepage loss of water into the streambed.

6. Variable combinations of temperature, dissolved oxygen concentration and biochemical oxygen demand, at both high and low flows, were not significantly correlated for numerous stations.

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