Publication No. 84-e33

WA-34-1020

IMPACT OF THE PULLMAN SEWAGE TREATMENT PLANT ON THE SOUTH FORK OF THE PALOUSE RIVER

by

CE 515 Students

Steve Juul
John Rohde
Elizabeth Clark
Md. Akram Hossain
Brenda Becker

December, 1984

TABLE OF CONTENTS

APPENDIX

LIST OF ILLUSTRATIONS

INTRODUCTION

Before one can consider the question of where the zone of recovery is on the South Fork of the Palouse River (SFPR) below the Pullman Sewage Treatment Plant (STP), it is necessary to examine the origin and uses of the river's water before it reaches the city of Pullman, WA (Fig. 1). Originating on Moscow Mountain, Idaho, the SFPR flows in a westerly direction through forested areas overlying Cretaceous granitic rocks. Farther along its course, it traverses Tertiary basalts, receiving input from numerous small tributaries draining the low rolling hills characterized by Palouse Loess (Bond, 1978). In the south-east section of Pullman, it merges with Paradise Creek.

Similar in many regards to the South Fork of the Palouse, the headwaters of Paradise Creek are also found on Moscow Mountain and likewise has a substrate composed of sand, silt, gravel, and basalt. Additionally, Paradise Creek serves as the carrier water for sewage effluent from the Moscow, Idaho, wastewater treatment plant eight miles upstream. Although not quantified, its volume can provide the major amount of flow during some parts of the year when the South Fork is running low.

While passing through Pullman, the SFPR receives additional volume from several sources. These include the Missouri Flats Creek, Dry Fork Creek, and storm water runoff from city streets and drains. Along this segment, it is classified as a Class B stream by the Washington State Department of Ecology (1978). The water course then progresses past the Pullman Sewage Treatment Plant, where it becomes the recipient of more domestic waste water effluent, continues through agriculturally developed land, and finally combines with the Palouse River at Colfax, WA.

SAMPLING SITES

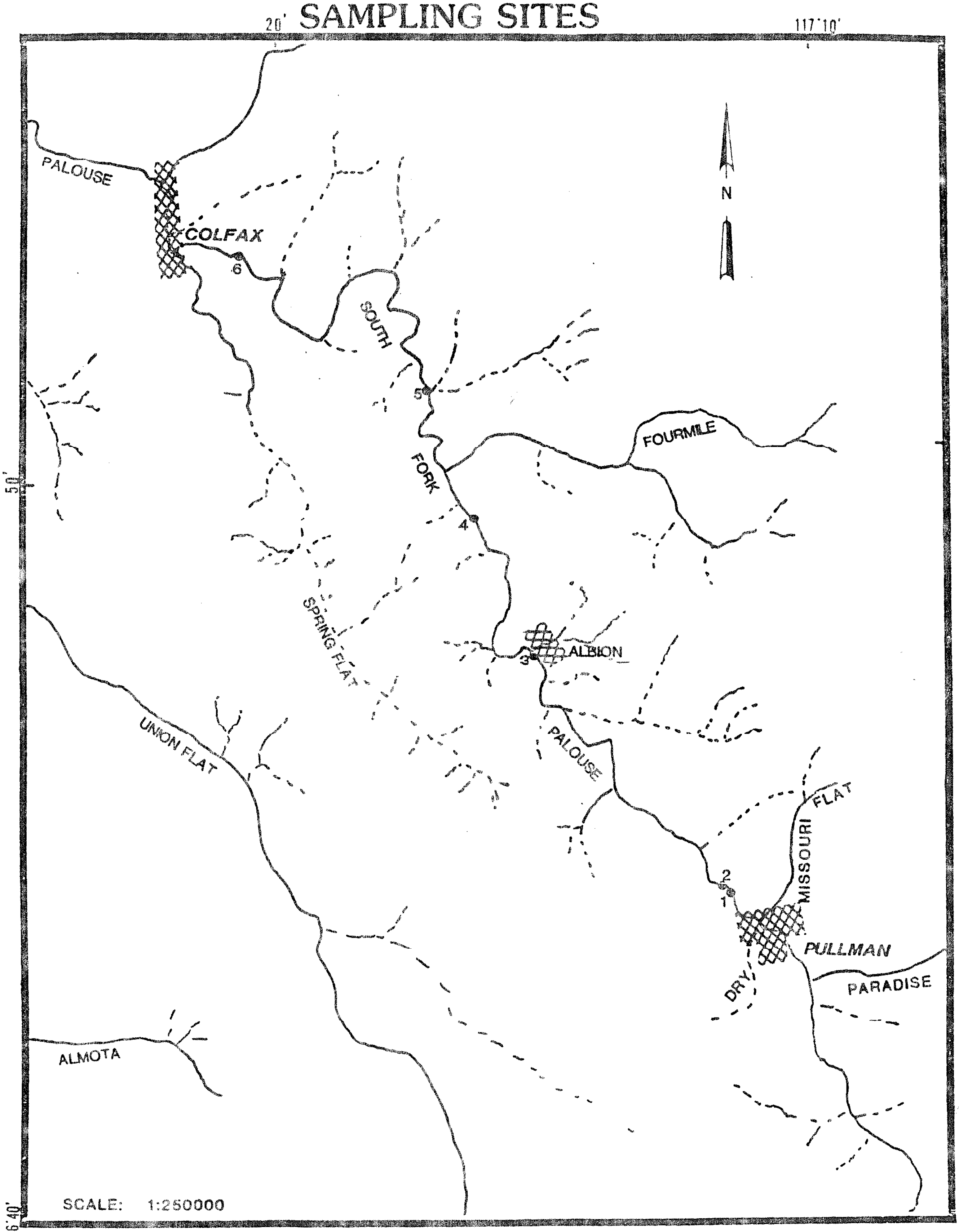

Fig. 1

The Pullman Sewage Treatment Plant was constructed in 1949, modernized in 1964 to incorporate an activated sludge process, and is now in the final stages of another renovation project. The purpose of this is to improve effluent quality and avoid raw wastewater bypassing which has previously occurred during high loading rates (see Appendix A for completion dates of each phase).

In the past, many studies have been conducted to ascertain the chemical, physical, and biological effects of this discharge on the river (Farrell, 1982; Julin, 1984; Larsen, 1984). Thus, it is the purpose of this project to determine what, if any, effect the new facilities in operation at the STP have had on the biological, physical, and chemical parameters of downstream water quality to date.

SITE DESCRIPTION

An initial sampling trip was conducted on September 23, 1984 to establish sampling and gaging locations below the STP as well as an upstream reference station. Consequently, six sites (Fig. 1) were selected using the following criteria:

1. results of previous studies,
2. physical similarity between sites,
3. temperature and dissolved oxygen results, and
4. accessability.

The sampling sites were:

Station 1: Upstream from the STP at river mile 21.95
Station 2: At river mile 21.7, just east of the bridge
Station 3: River mile 16.0, immediately west of the bridge in Albion

Station 4: River mile 11.7, approximately 75 yards south of the bridge on the road out of Albion towards Parvin

Station 5: River mile 9.4, under the bridge at Parvin

Station 6: River mile 2.3, 200 yards upstream from a privately owned bridge located about one mile east of Colfax.

METHODS

Sampling was conducted on October 7, 14, 21, and 28, 1984 between 0830 and 1200 hours. On each of these four sampling dates, water samples were collected for the evaluation of dissolved oxygen (DO), conductivity, pH, temperature, biochemical oxygen demand (BOD), and fecal coliforms. All samples were collected in clean non-porous polyethylene bottles at 1/3 to 1/2 depth at midstream below riffle areas to assure complete mixing. Additionally, stream gaging was performed on each of the above dates and macroinvertebrates collected once on October 7. All analyses were performed as described in Standard Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1980) unless otherwise noted in the following individual descriptions.

Stream flow.--Gaging was accomplished by use of a Marsh McBirney Model 201 magnetic flow meter in a straight reach with a relatively uniform bottom profile (Corbett et al., 1945).

pH.--An Orion Ionanalyzer, Model 407A was used to determine pH in the field. The meter was allowed to warm up and recalibrated using VWR Scientific Inc. green buffer solution, pH 7, at each location (Barnes, 1964).

DO and temperature.--Both were measured in the field with a calibrated Yellow Springs Instrument Co. (YSI) Model 57 Oxygen meter. DO was measured in mg/l and temperature in degrees Centigrade (C).

Conductivity.--Conductivity was determined with a calibrated YSI Model 33 S-C-T meter in umhos/cm.

BOD.--Five-day, BOD's were carried out at 20 degrees C on samples from each site within 24 hours of collection. The DO measurements for BOD were performed using the Azide Modification to the Winkler Method.

Coliforms.--Prior to sampling, 0.1 ml 10% sodium thiosulfate per 125 ml was added to all containers to suppress chlorine effects. Fecal coliforms were analyzed in the lab using the Membrane Filter Technique delineated in Microbial Methods for Monitoring the Environment (EPA, 1978). *Escheri~~s~~chea* $\overset{c}{\text{C}}$*oli* (*E*. *Coli*) were also enumerated via Membrane filtration and all colonies subsequently verified as prescribed by Dufour et al. (1981). Filtering was initiated immediately upon return to the laboratory. Rosalic acid was absent from the M-FC Agar plates used for the first two analysis, but was incorporated in the third set.

Macroinvertebrates.--Benthic macroinvertebrates were qualitatively sampled once by use of a kick screen. Organisms were separated from the screen in the field as much as possible, but in cases where substrate algae, macrophytes and detritus were dislodged and captured on the screen, all material was returned to the lab for further separation. Samples were preserved in 37% formaldyhyde. The Cairns Sequential Comparison Index (SCI) was used to compute a diversity index (DI) and the specimens keyed to their respective Orders (Cairns et al., 1968).

RESULTS

Streamflow.--On each sampling date, streamflow increases by 20-42% immediately downstream from the STP (Fig. 2), and continues to increase at subsequent stations. The only exception is a noticeable decrease on 10/7 between Site 2 and the station in Albion.

pH.--pH declines between Sites 1 and 2, and gradually increases through Site 6 on all sampling days, except for a slight decrease between Sites 5 and 6 on 10/28 (Fig. 3). The pH recovered to pre-STP levels by Site 6 on 10/21 and by Site 3 on 10/7 and 10/21. On 10/14 it never returned to the reference station level.

Dissolved oxygen.--Due to the lack of expertise with the DO meter, readings taken on 10/7 were considered unreliable and omitted. On the following three sampling dates, DO exhibits a dramatic decrease from site 1 to Site 2 where critical deficits occur (Fig. 4). Downstream, DO gradually increases, approaching saturation by station 6 (Fig. 5).

Temperature.--Figure 6 illustrates streamflow temperature increase on all sampling dates between Site 1 and 2 and a decline towards Site 3. Past that point, results are not consistent. On 10/7 it rises and reaches a maximum at Site 6, whereas on the three latter sampling occasions it either levels off, declines or increases. In no instance did the temperature drop below that recorded at the reference site for that given date.

Specific Conductance.--Conductivity increases by 25-75 umhos/cm between the first two stations and then decreases by Site 3 on each occasion (Fig. 7). On 10/21 it continued to decrease at the remaining sites, yet followed an opposite trend on 10/28. On 10/14 it increased between Site 3 and 5, and then declined to almost the same value at Site 6

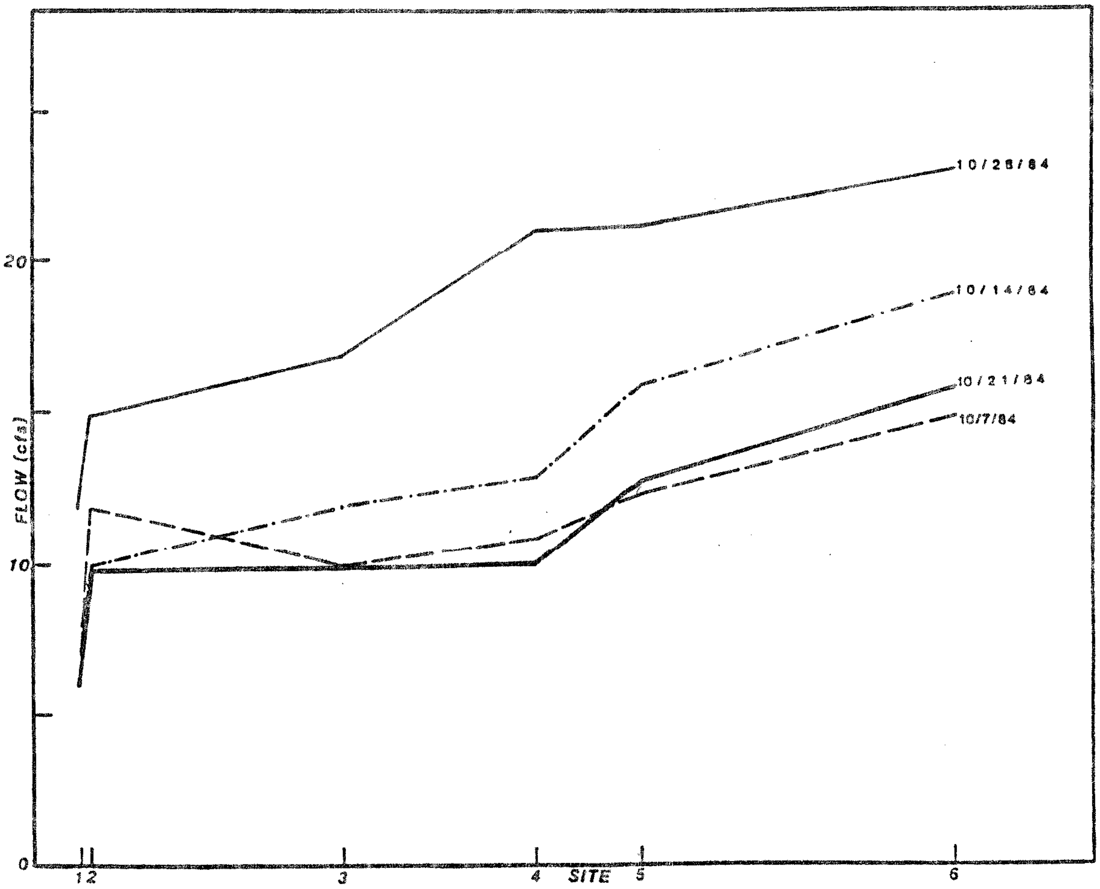

Fig. 2.--Streamflow

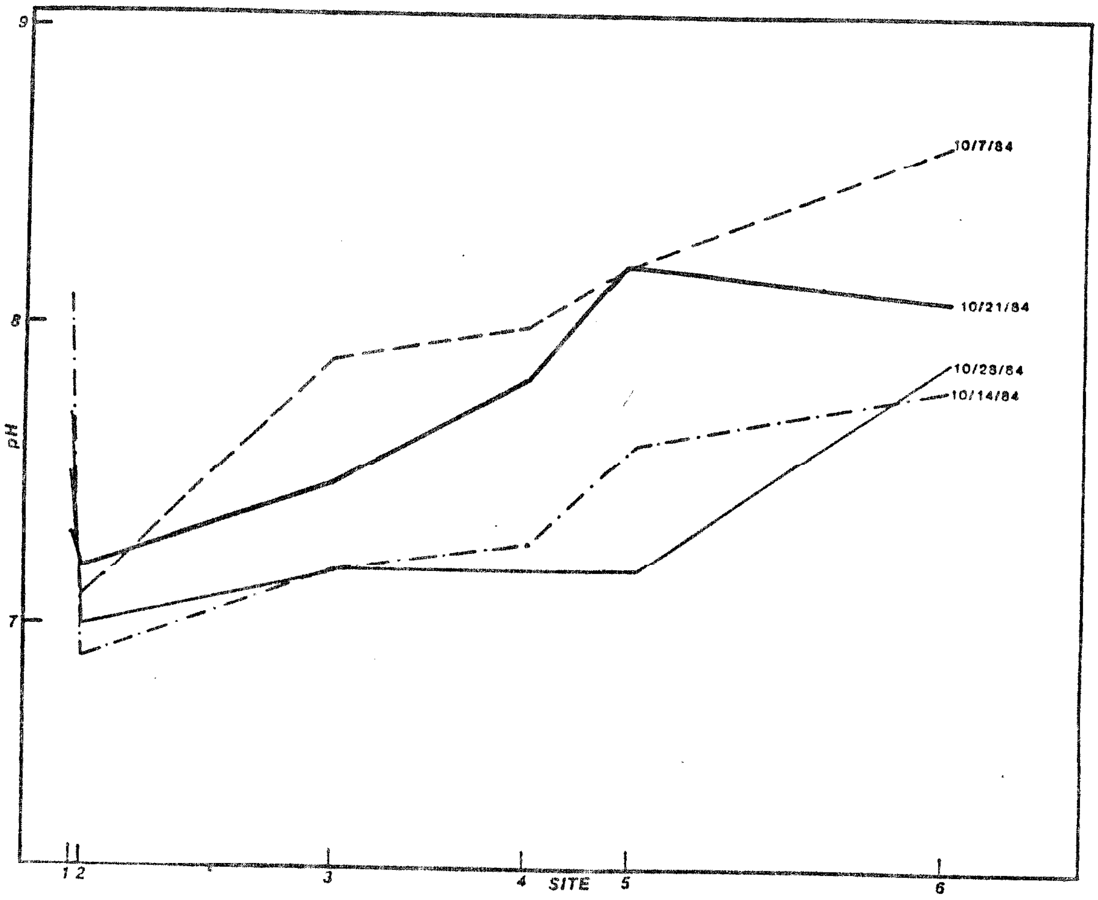

Fig. 3.--pH

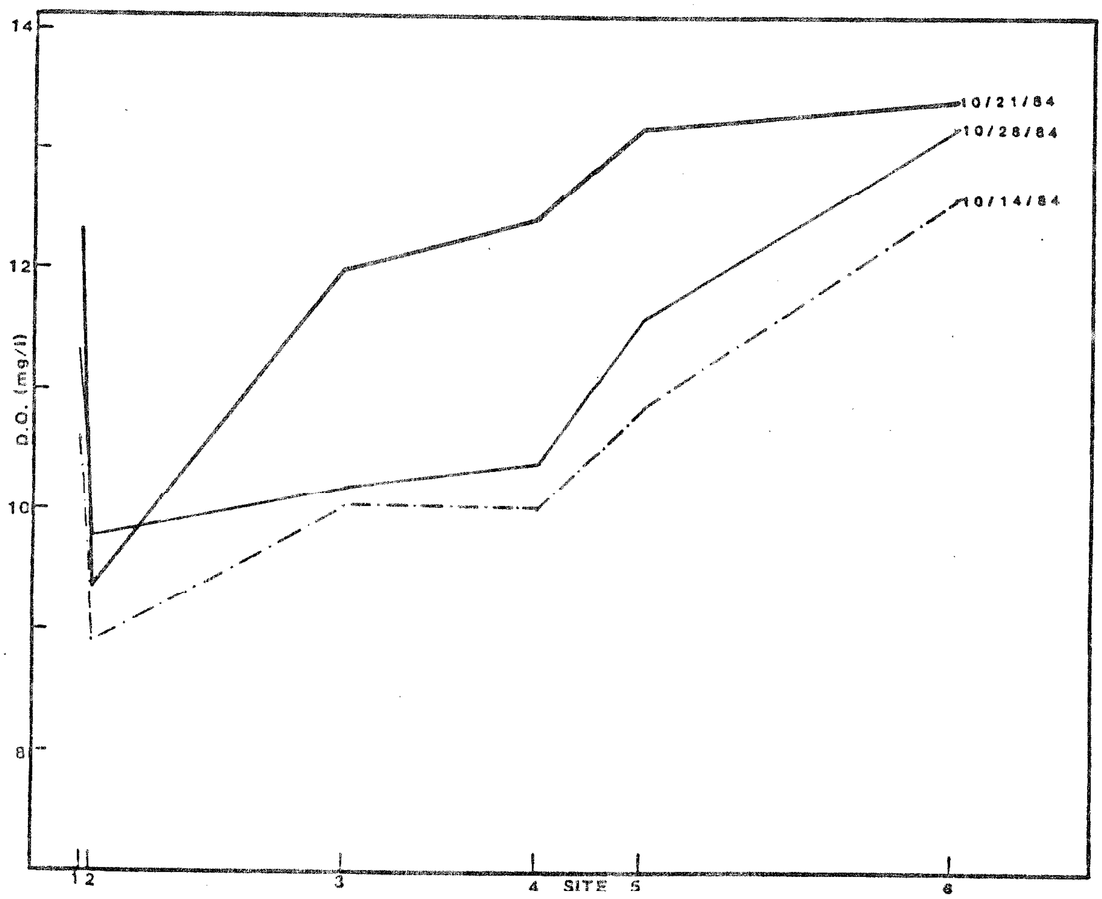

Fig. 4.--Dissolved Oxygen

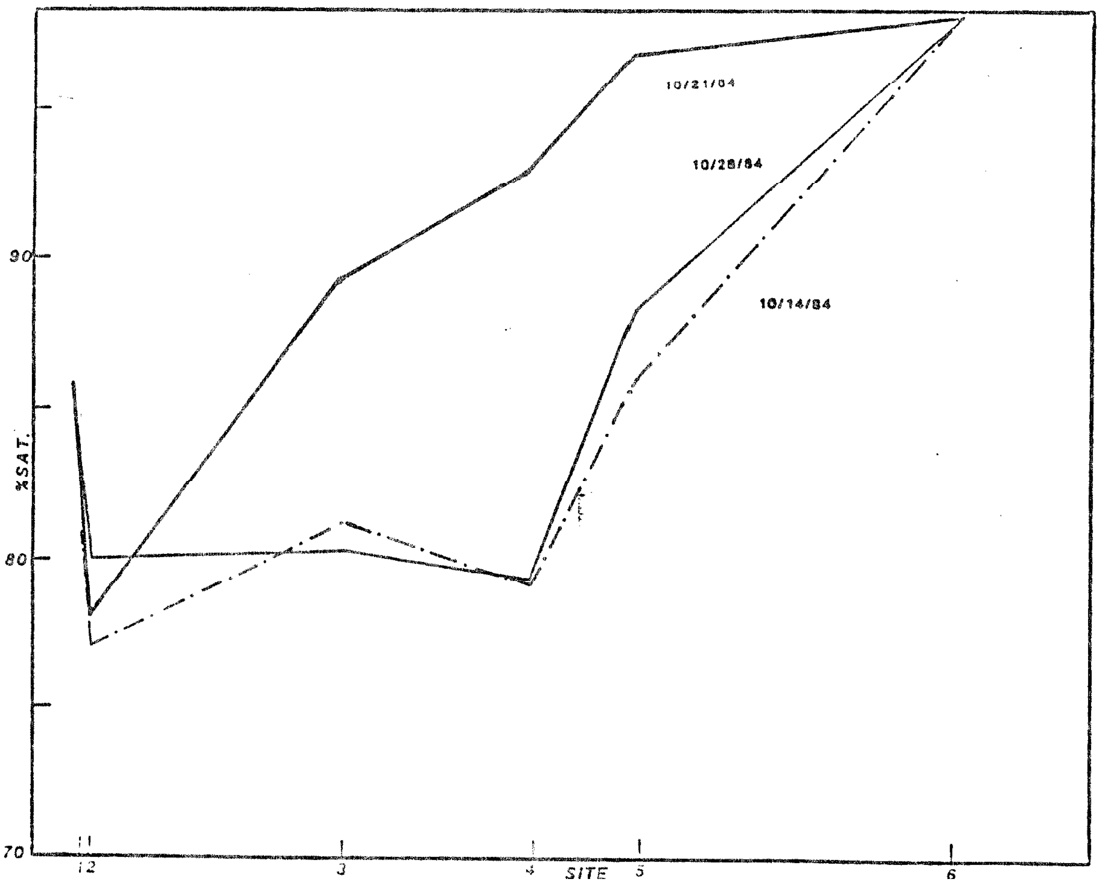

Fig. 5.--Percent Oxygen Saturation

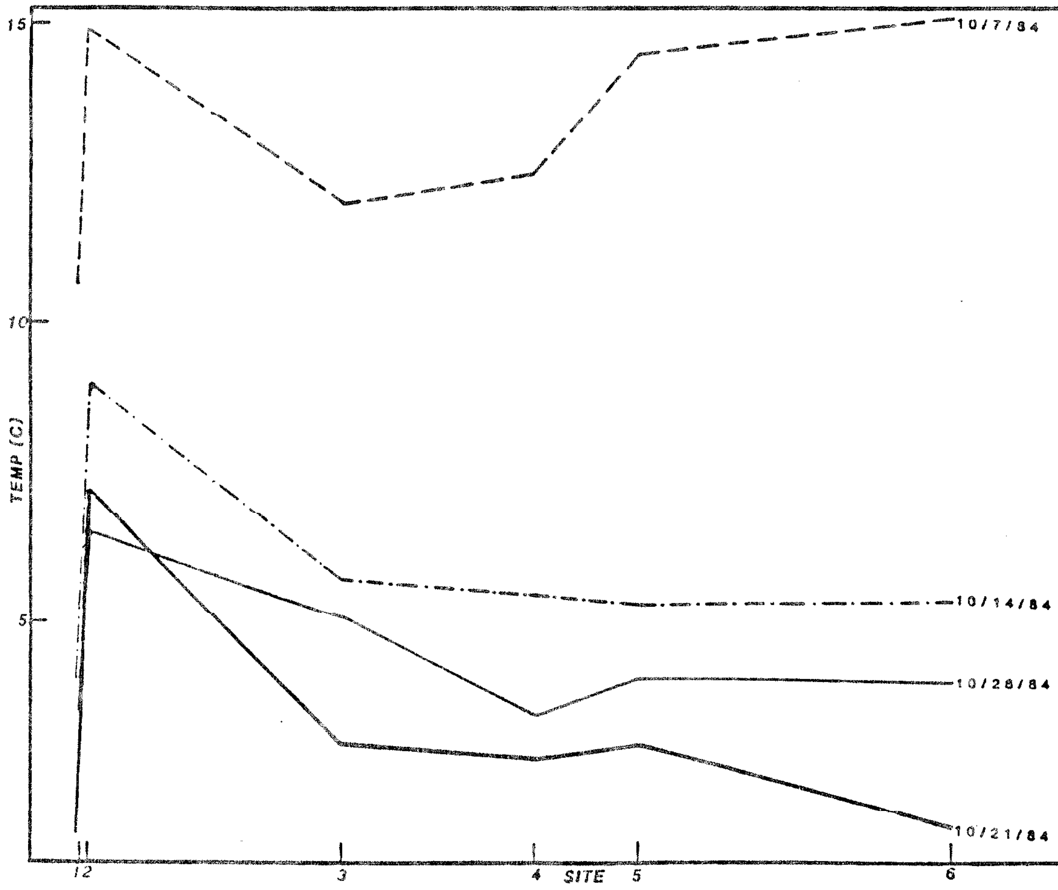

Fig. 6.--Temperature

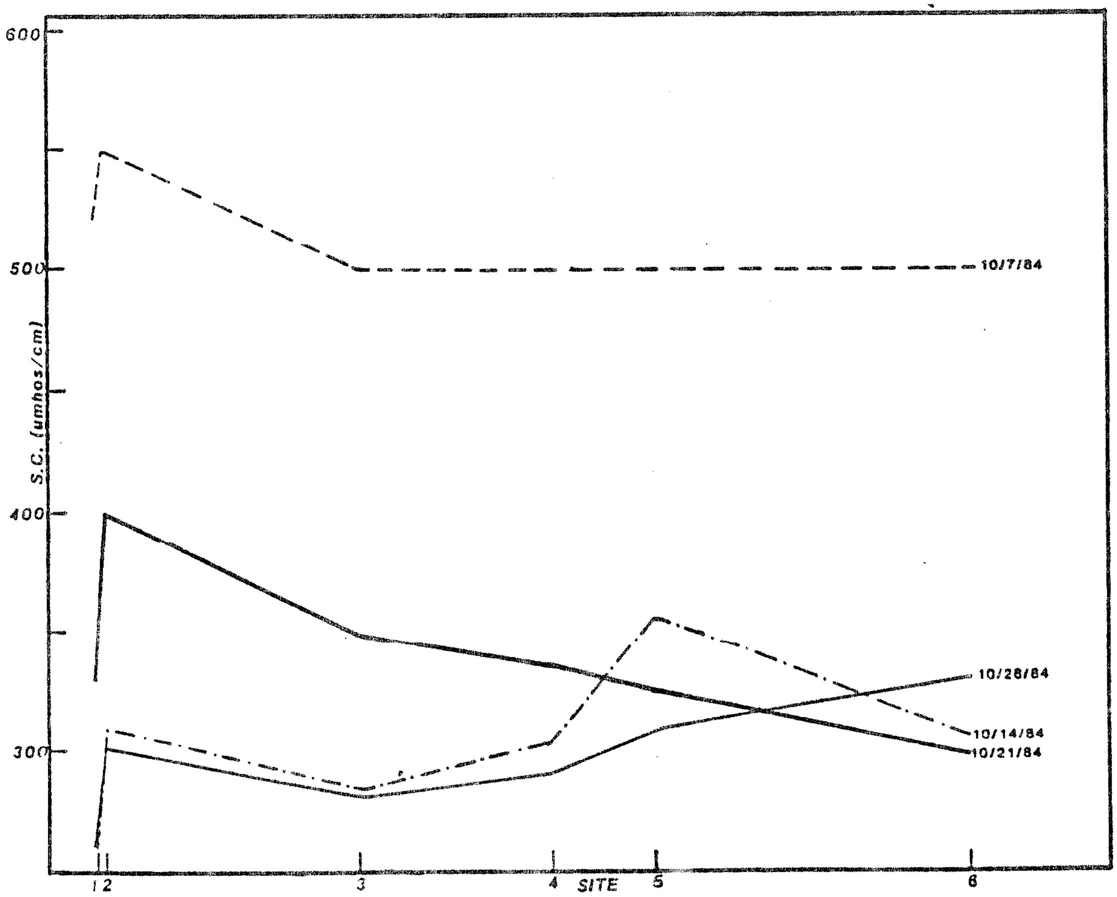

Fig. 7.--Specific Conductance

as was registered on 10/21. Conductivity on 10/7 was substantially higher than on the other sampling dates and remained the same following station 3.

Biochemical oxygen demand.--As seen in Figure 8, BOD follows a trend antithetical to that of DO. First there is a sharp increase from Site 1 to Site 2, followed by a continual downstream decline. The only exception is on 10/7, where a slight increase occurs between the last two sites.

Coliforms.--As depicted in Fig. 9, Fecal Coliform results were inconsistent from one sampling date to the next. Results from the first analysis demonstrated an increase in colony forming units (CFU) from Site 1 to Site 2, followed by a general decline. Subsequent analyses, however, indicated a reduction in CFU's between Site 1 and Site 2, a slight resurgence at Albion and then a decline-rise-decline scenario. *E. Coli*, Figure 10, also varied drastically on the two occasions when filtrations were [illegible] the sampling trip of 10/14, the number of *E. Coli* greatly increase at Site 2 and then gradually decrease until a plateau is achieved between Sites 5 and 6. On October 21, *E. Coli* were again analyzed, but with different results. Site 1 was found to have approximately the same number of organisms as in the previous sample, but rather than increase at station 2, it decreased.

Benthic Macroinvertebrates.--As seen in Figure 11, the computed diversity index decreases at the first site after the sewage treatment plant and continues to do so until a minimum is observed at Albion. At successive locations, the trend is for the DI to increase, except for a slight decrease at the last site. Appendix B provides the relative composition of the invertebrate Orders along the stretch of stream investigated. Characteristically, it changes from those classified as moderately

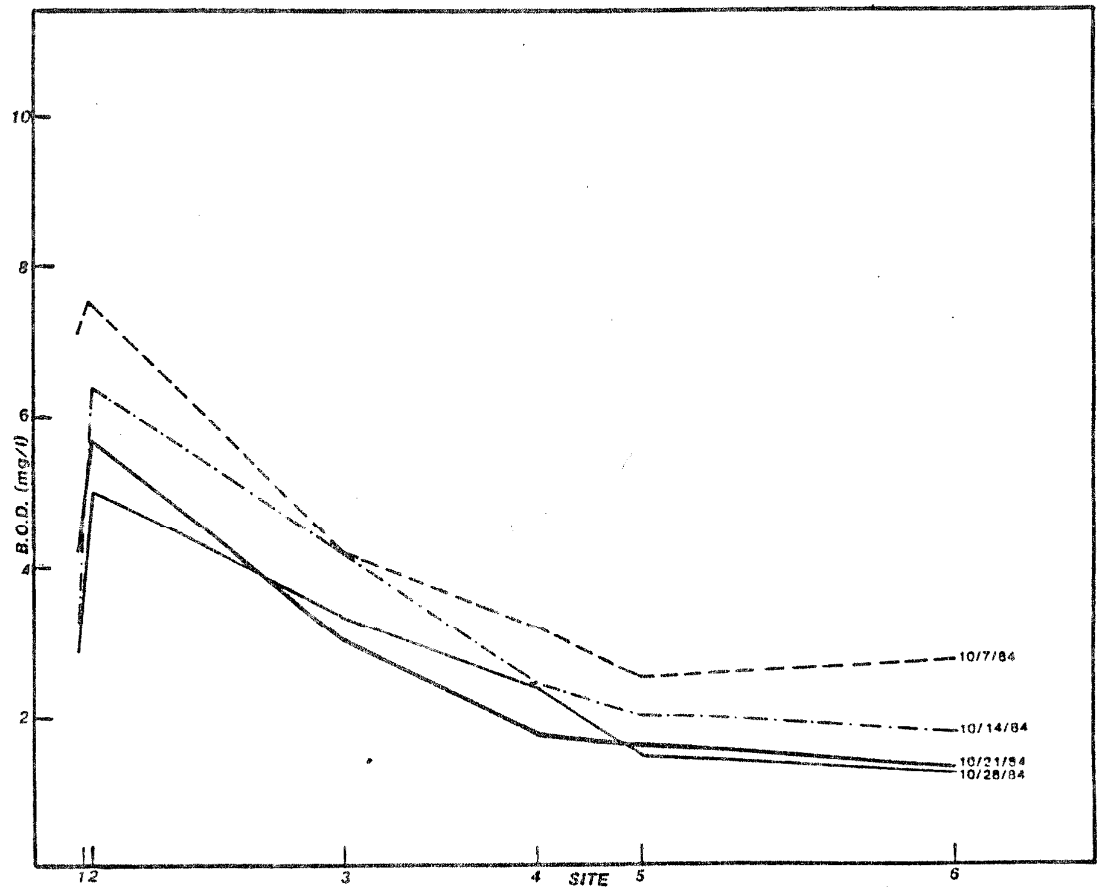

Fig. 8.--Biochemical Oxygen Demand

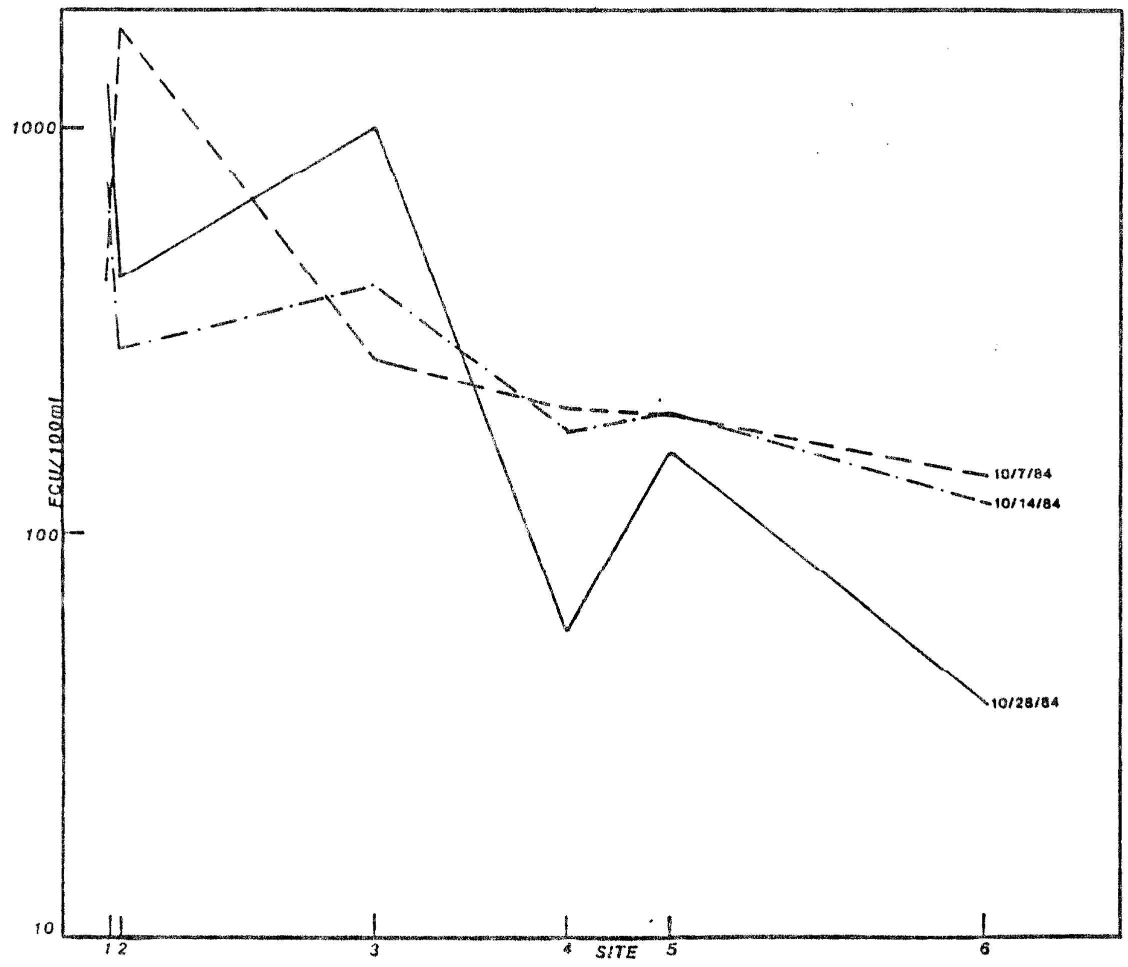

Fig. 9.--Fecal Coliforms

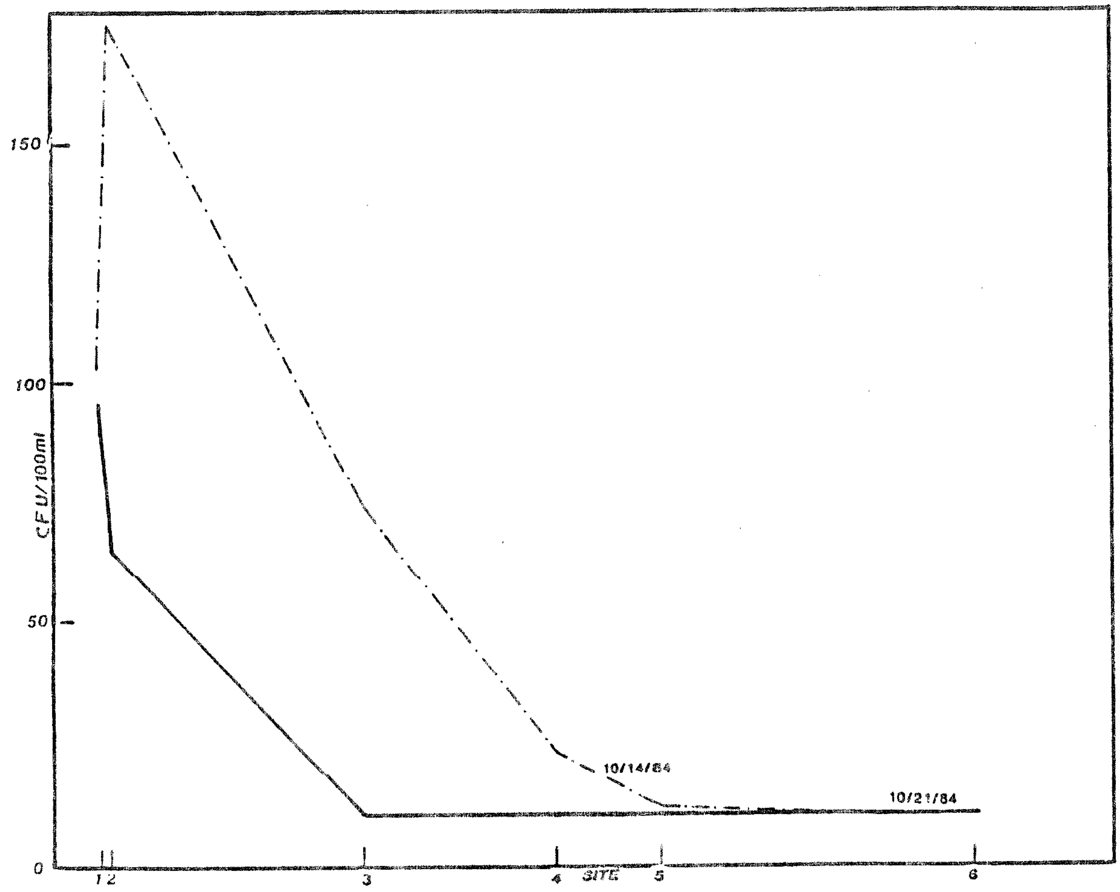

Fig. 10.--*Escherichia Coli*

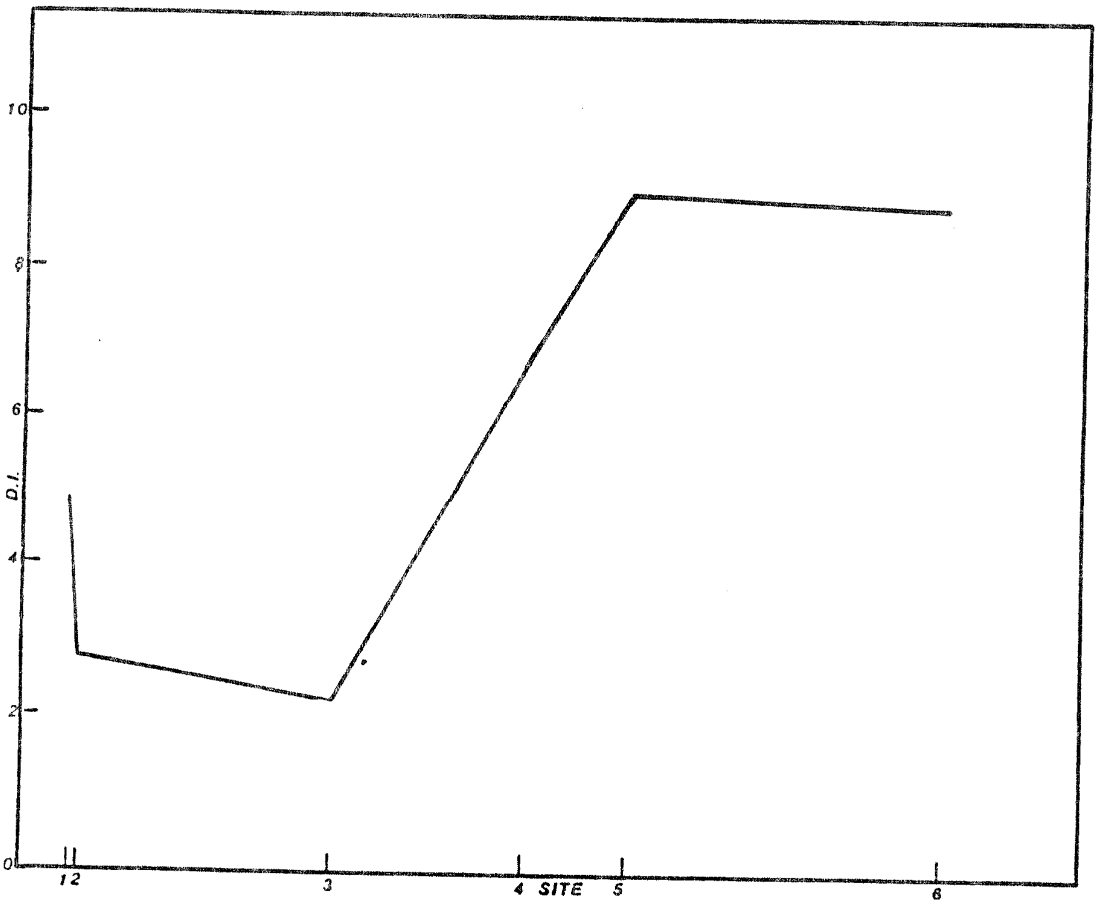

Fig. 11.--Diversity Index

pollution tolerant at the control site, to more tolerant individuals below the STP and then gradually shifts to encompass a greater ratio of pollution intolerant Orders.

DISCUSSION

By definition, the zone of recovery is that area where water quality, as established by the aforementioned methods, is equal to or better than that found prior to the Pullman STP. On this basis, an upstream location was chosen such that our sampling would reflect "before and after" water quality. As previously mentioned though, and illustrated by the data provided, the stream ecosystem is already in a perturbed condition prior to the control station. Thus, what we will define as "recovery" is relative to those conditions and not to the "pristine" state found closer to the river's point of origin.

The lotic environment is a dynamic ecosystem dependent not just on one parameter, but rather on the synergistic relationship between all factors; biological, physical, and chemical. These relationships will be emphasized as much as possible throughout this discussion.

As indicated in Fig. 2, treatment plant effluent does have a marked effect on stream flow. This augmentation was greatest on the sampling dates when the lowest flow measurements were taken at the control site. Additionally, this corresponded to the time when precipitation had not occurred the previous week, indicating that the greatest influence of wastewater effluent occurs at the time of base flow. Additivity of flow could not be established. Currently, effluent flow is not gaged at the treatment plant, but rather estimated on the basis of last year's data.

The pH in a given aquatic system is an indication of the acid-base conditions and is a function of the carbonate, bicarbonate, and hydroxide content, and temperature (Sawyer and McCarty, 1978). The drop in pH between Sites 1 and 2 can be attributed to the STP effluent which ranged for pH 6.6 to 6.8, whereas the upstream measurements ranged from 7.4 to 8.1. Interestingly, the higher the pH before the treatment plant, the lower it is afterwards, and no explanation for this phenomena can be provided at this time. As the effluent progresses downstream, dilution and chemical conversion of the constituents which contribute to low pH occurs, thereby mitigating its impact. Carbon dioxide, which can react with water and lower the pH, is expelled from the stream by agitation, increasing the bicarbonate and carbonate concentration, thereby increasing pH (Best 1977).

The rise in temperature after the STP is again directly related to the discharged effluent. As seen in Appendix C, effluent temperature ranges from 9 to 19 degrees warmer than stream water at the control site. Subsequently, the stream temperature equilibrates with ambient air temperature and progressively returns to upstream levels. On 10/7, an apparent discrepancy occurs, but can again be attributed to air temperature. On that day, the air temperature was 26 degrees C, whereas on the other three dates it was approximately 8 degrees C. Thus the higher air temperature that day, combined with the low flow, produced the general rise in stream temperature observed.

Temperature is also important via its influence on other parameters. The elevated temperature provided by the treated sewage increases the rate of chemical reactions, the potential uptake of pollutants by the biota and may act as a selective agent for some invertebrates and macrophytes (Hynes, 1960). Additionally, it affects the water oxygen saturation which will be discussed later.

Specific conductance is the inverse of resistance to electrical flow (Sawyer and McCarty, 1978), with pure water having low conductivity, and increasing with the contribution of charged ions. The influx of these entities at the point of discharge are due to both the ions inherent in treated waste and the carrier water which originates in deep aquifers. Conductivity subsequently declines with dilution and biological utilization of anions and cations. The generally high conductivity measurements recorded on 10/7 are due to the low flow conditions and the high proportion originating from the Moscow, Idaho, ground water supply. Such water sources are typically more mineralized than surface water due to its long residence time in the bedrock and soil of the area (Hem, 1959). Subsequent fluctuations, particularly the increase seen between Sites 4 and 5 on two occasions can also be attributed to the delayed discharge of subsurface flow from the previous weeks rainfall (McMeeken, 1976).

Dissolved oxygen and biochemical oxygen demand are intrinsically related in aerobic lotic ecosystems. DO is necessary to maintain aerobic conditions in surface waters and is considered a primary indicator of the suitability of an aquatic ecosystem to support life (Krenkel and Nopotny, 1980); whereas, BOD measures the oxygen required by bacteria to oxidize organic materials present in the water body. Ideally, DO concentrations should approach the saturation point indicated by Henry's Law (Sawyer and McCarty, 1978), but is frequently less, even in "unpolluted" settings, due to the oxygen consumption of autochthonous organic matter. Thus, it is not surprising that a classical oxygen sag curve occurs along the analyzed portion of the stream. Principally, this results from the increased bacterial decomposition of effluent organic matter. It is worth noting that the lowest value of saturation at Site 2 is always higher than the value expected for a zone of decomposition; suggesting that the plant effluent poses only a moderate stress to the river. Since percentage oxygen saturation is inversely related to temperature (Fig. 5), this effect could potentially become a critical factor during summer low flow and increased water temperature.

Progressing downstream, turbulence aerating the water, commensurates with the decline and stabilization of organic material as the stream undergoes self purification (Metcalf and Eddy, 1978). When stabilization is complete, the oxygen content returns to the level at which it can exist under the prevailing temperature and pressure. The increase in BOD between station 5 and 6 on 10/7 is due either to the addition of organic material from a source other than treatment plant effluent or experimental error.

A second factor, previously mentioned, which influences DO is temperature. As temperature increases, the oxygen content of water decreases (Wetzel, 1983) implying the increased effluent temperature physically limits oxygen saturation.

Recovery in terms of DO and BOD share common features. At Site 3 there is always evidence of marked DO recovery, and by Site 5, it exceeds that of the reference station. This is because dissolved and suspended impurities present in the water influence the DO content at that particular temperature and pressure. It is interesting to note from Figure 8, that the lowest BOD values are between 1 and 2 mg/l, which is the lower limit usually obtainable due to the unavoidable presence of decaying vegetation and erosion.

Data obtained on the coliforms are erratic, perhaps to a great enough degree that it is unreliable. On 10/7 and 10/28 FC decreased at Station 2 which is consistent with the low effluent number reported by the treatment plant personnel (Appendix C) and the probability that residual chlorine would further reduce the stream bacterial population. On 10/7, however, we noted a substantial increase in FC/100 ml at Site 2 which is not consistent with what was in the effluent in that time period. One reason for this discrepancy, and others, is the fact that there was considerable fungus growth on the agar plates, even after the addition of Rosalic acid, thus making counting difficult and somewhat subjective. The increase in FC's on 10/14 and 10/28 at Sites 3 and 5 may again be due to runoff from recent storm events which washed excrement from the streets and stock yards at Albion and Parvin.

On 10/14 both E. Coli and FC were analyzed but the results did not parallel each other as they should have. At Site 1, the number of FC CFU is seven times greater than the number of EC CFU's. This is not extraordinary because Fecal Coliforms are more plentiful in waste than E. Coli (Davis et al., 1980). At Site 2, however, the number of FC decreases to an estimated 286/100 ml, while the EC increase to an estimated 175/100 ml. As previously mentioned, the FC colonies were quite difficult to count, whereas the EC were very distinct and a more reliable indicator.

The use of biological parameters, such as benthic macroinvertebrates, as an adjunct to chemical and physical factors has been documented by several researchers (Wilham and Dooris, 1968; Mason, 1981). Since they are reasonably sedentary and have comparatively long lives, the species composition and diversity of a site can effectively be used to assess the long term habitat conditions, whereas chemical and physical indicators only relate the condition at the time of sampling.

One method of measuring the stress on an aquatic environment is to determine the diversity index on the invertebrates sampled. Maximum diversity is considered to occur in environments characterized by a large number of species, with no species constituting the majority of the community. Conversely, when the ecosystem becomes stressed, those species sensitive to that particular stress are eliminated and the vacant niche inhabited by more tolerant organisms; thereby reducing diversity.

Several diversity indexes are available, but many require taxonomic expertise to identify individual organisms to the species level. For this reason, Cairns SCI method was employed since it is not dependent on entomological knowledge and the results are still beneficial (Cairns et al., 1968). Field experience has shown that "healthy" streams have DI values greater than 12.0, whereas polluted habitats have DI values of 8.0 or less; no lower limit is provided (Cairns and Dickson, 1971).

Despite the wide use of diversity indices, caution must be exercised when interpreting the results. Hughes (1978) found that the sampling method, area sampled, time of year, and level of identification all influenced the DI, while Murphy (1978) determined that seasonal variations in the index were greater than differences between sites along a river. Thus to aid our analysis, the collected specimens were keyed to determine the presence or absence of pollution tolerant and intolerant organisms.

At station 1, the DI indicates a moderately polluted condition and is confirmed by the predominance of moderately tolerant snails, followed by the more pollution tolerant Diptera (Hart and Fuller, 1974). In view of the physical and chemical parameters for this site, this is reasonable.

Water entering the SFPR via Missouri Flats Creek, Dry Fork Creek, and runoff from Pullman (including the Palouse Producers Chemical Plant just upstream) probably restricts habitation by pollution intolerant Orders, such as the Ephemeroptera and Plecoptera, by limiting oxygen saturation and increasing the suspended solids. Although we did not test for pollutants such as heavy metals, insecticides and pesticides, it is possible that runoff carries such inhibitory material.

The organisms at station 2 reflect deterioration of water and habitat quality. The Diptera, primarily Chironomids and mosquito larvae, comprise greater than 76% of the benthic population. To understand the reason for this, one can again look at the physical parameters. Conductivity, as previously described, reaches a maximum at this point and is indicative of the increased suspended matter discharged by the sewage treatment plant. The net effect of this is to fill in the inter-rock spaces on the stream bottom, reducing overall habitat diversity. Additionally, increased abrasion provided by more particulate matter acts as an abrasive on the gills of some species (Hynes, 1960). Dissolved oxygen is also depressed at this location and prevents habitation by those organisms requiring higher oxygen saturation (i.e., Ephemeroptera and Plecoptera). The increased temperature may also serve as a selective agent, but any definitive conclusions could only be drawn by sampling at various times of the year, since it might serve a beneficial role in the winter time by keeping the ecosystem artificially warm.

The results from station 3 indicate the lowest diversity of any site sampled and is predominated by organisms such as clams and flatworms which are typical of moderately polluted waters (Welch, 1980). The reason for this may be twofold. First, this site is located next to a bridge in

Albion, and potentially receives roadway debris, such as sand and gravel, from passing vehicles and may well serve as a play area of children due to easy access. Furthermore, this area had a large quantity (relative to the other sites) of algae and macrophytes growing on the substrate. Although we tried to sample similar ecosystem types at each station, the vegetative growth would certainly act as a selective agent and influence the species composition.

Site 4 shows the first sign of recovery, and in fact has greater diversity and a smaller proportion of pollution tolerant Orders than the control site. Niches previously occupied by Diptera, clams, and flatworms are now filled by more moderately tolerant species. Notably, the Odonata (moderately tolerant) predominate, with Coleoptera and Decoptera making their first appearance. One reason this area is not "more recovered" than it is, could be due to cattle. Although not observed entering the stream, their excrement and hoof prints were abundant on the stream banks.

At the next sampling station, the biota indicates better conditions. Odonata are still dominant, but the Tricoptera immediately follow. The first evidence of Ephemeroptera at this location point to the increased dissolved oxygen content and less sediment occupying the rocky bottom which they prefer.

Finally, at the last stream segment, Tricoptera are ascendant and the Ephemeroptera more prevalent than at previous sites. Plecoptera, considered to be the most pollution sensitive Order is also present, albeit in a small percentage. Diptera are, of course, still evident as they will be in most aquatic environments, and one should keep in mind that although an organism is classified as pollution tolerant, that does not exclude it from inhabiting non-polluted waters. In fact, different species within the same order will exhibit varying tolerances and preferences, pointing to the importance of species identification (Oladimeji and Wade, 1984). The diversity does, however, decrease by 1.8% from the previous location, but can easily be attributed to random sampling and error in determining the DI.

CONCLUSION

An important question with regard to the management of stream water quality, is where the zone of recovery commences following waste input. To accomplish this task, it is necessary to consider biological, physical, and chemical factors; aiming, ultimately, to understand their interactions and how they relate to the environment under study.

On the basis of the data collected for this particular investigation, it was found that the sewage effluent discharged from the Pullman STP impacts all of the parameters considered to some degree. Those providing the most consistent, and thus reliable information for defining recovery were found to be DO, BOD, and the macroinvertebrates. BOD and the benthic population both indicate recovery is almost complete by Site 4 whereas DO does so by Site 5. On two occasions, BOD had recovered to pre-treatment plant levels by Site 3. Thus, in any future work, it may be a good idea to include a sampling station prior to Albion to exclude any influence the town may have on the river.

It must be stressed that the sampling regime of this study only encompassed one month and thus only represents conditions during that time period. The results, however, are consistent with a study conducted in the fall of 1982 (Cook, 1982; Farrel, 1982), which established recovery between

Albion and Parvin. An investigation completed last year during November indicated recovery between Parvin and Colfax (Julian, 1984; Larsen, 1984). Therefore, no significant improvement of water quality has been observed with the new plant facilities' operation.

A final note, future studies would be instructive on two counts. First, if conducted during the same time of year, the data collected could be used to evaluate the effectiveness of the treatment plant modifications once they become fully operational. Noticeable improvement should be detectable after one hydrologic cycle since high flow will remove much of the contaminated sediment that serves both as a source of deleterious substances and restricts habitation of many benthos considered characteristic of stable unpolluted ecosystems. Secondly, similar studies should be carried out at various times of the year to determine seasonal variations in the recovery zone.

LITERATURE CITED

American Public Health Association, American Water Works Association and Water Pollution Control Federation, 1980. Standard Methods for the Examination of Water and Waste Water, 15 edition, Washington, D.C.

Barnes, I., 1964. Field Measurements of Alkalinity and pH, USGS Water Supply Paper 1535-H.

Benoit, R.J., 1971. Self Purification in Natural Waters, In: Water and Water Pollution Handbook Vol. 1, Leonard L. Ciaccid (ed), Marcel Dekker, Inc., New York, pp. 223-261.

Bond, J.G., 1978. Geologic Map of Idaho, Idaho Bureau of Mines and Geology.

Cairns, J. and K. L. Dickson, 1971. A Simplified Method for the Biological Assessment of the Effects of Waste Discharges on Aquatic Bottom-dwelling Organisms, J. Water Control Fed., 43:755-772.

Cairns. J., Albaughl, D.W. and Busey, F. and M.D. Chancy, 1968. The [illegible]mparison Index--A Simplified Method for Non-biologists to Estimate Relative Differences in Biological Diversity in Stream Pollution Studies, J. Water Pollut. Control Fed., 40:1607-1613.

Collins, M.R. and G.T. Higgins, 1973. Stream Temperatures in Washington State, Atlas HA-385, Washington State Dept. Water Resources.

Corbett, D.M. et al., 1945. Stream Gaging Procedures. U.S.G.S. Water Supply Paper 888.

Cook, T., 1982. An Analysis of Water Quality on the South Fork of the Palouse River below the Pullman Sewage Treatment Plant, Pullman, Wa., W.S.U., WA, 31p.

Davis, Dulbecco, Eisen and Ginsberg, 1980. Microbiology, Harper and Row Inc., New York.

Dufour, A.P., E.R. Stickland, and V.J. Cabelli, 1981. Membrane Filter Method for Enumerating Escherichia coli, Journal of Applied Environmental Microbiology, 41:1152-1158.

Environmental Protection Agency, 1978. Microbial Methods for Monitoring the Environment, EPA-600/8-78-017.

Farrel, D.J., 1982. The Zone of Recovery: An Analysis of the Assimilative Capacity of the South Fork, Palouse River, W.S.U., Pullman, WA, 20p.

Hart, C.W. and S.L.H. Fuller, 1974. Pollution Ecology of Freshwater Invertebrates, Academic Press, New York, 389p.

Hem, H.D., 1970. "Study and Interpretation of the Chemical Characteristics of Natural Water," U.S. Geological Survey Water Supply Paper 1473.

Hooper, P.R. and D. Webster, 1982. Geology of the Pullman, Moscow West, Coulton and Uniontown 7-1/2 Minute Quadrangles, Washington and Idaho, Geologic Map GM-26, Washington Division of Geology and Earth Resources.

Hughes, B.D., 1978. The Influence of Factors Other Than Pollution on the Value of Shannon's Diversity Index for Benthic Macroinvertebrates in Streams, Water Res., 12:357-364.

Hynes, H.B.N., 1960. The Biology of Polluted Waters, Liverpool University Press, Liverpool, England, 202p.

Julin, S.K., 1984. A Study of the Effect of the Discharge of Sewage Effluent from the Pullman Sewage Treatment Plant into the South Fork of the Palouse River, W.S.U., WA., 16p.

Krenkel, P.A. and V. Nopotny, 1980. Water Quality Management.

Larsen, C.P., 1983. Determination of the Recovery Zone from the Effects of Sewage Effluent Discharged into the South-Fork of the Palouse River by the Pullman Sewage Treatment Plant, W.S.U., Pullman, WA, 30p.

Mason, C.F., 1981. Biology of Freshwater Pollution, Longman Inc., New York, 250p.

McMeekin, M.P., 1976. Study of the Relationships Between Streamflow and Water Quality Parameters for Several Parameters in the State of Washington, Washington State University, Masters Thesis.

Metcalf and Eddy, Inc., 1979. Wastewater Engineering: Treatment, Disposal, Reuse, McGraw Hill Book Co., New York, 917p.

Oladimeji, A. and J.W. Wade, 1984. Effects of Effluents from a Sewage Treatment Plant on the Aquatic Organisms, Water, Air and Soil Pollution, 32:309-316.

Sawyer, C.N. and P.M. McCarty, 1978. Water Resources and Environmental Engineering, McGraw Hill, USA, 532 p.

Welch, E.B. and T. Lindell, 1980. Ecological Effects of Waste Water, Cambridge University Press, New York, 337p.

Wetzel, R.G., 1983. Limnology (2nd edition), Saunders College Publishing, New York, 767p.

Wilham, J.L. and Dooris, T.C., 1968. Biological Parameters for Water Quality Criteria, Bioscience, 18:447-481.

APPENDIX A

STP CONSTRUCTION TIME LINE

APPENDIX A

TIME SCHEDULE FOR THE PULLMAN SEWAGE TREATMENT PLANT MODIFICATIONS

STP Construction Time Line

2/15/84	gravity thickener off line
5/12/84	bio-tower on line
6/05/84	aeration basin on line bio-tower supplying secondary treatment
8/07/84	number 1 aeration basin on line
8/24/84	number 2 aeration basin on line
9/07/84	new secondary clarifier and chlorine contact chamber on line, old secondary clarifier and chlorine contact chamber off line and demolished
10/14/84	gravity thickener on line
10/22/84	old secondary clarifier back in service
10/23/84	dissolved air flotation thickener on line (used to dewater activated sludge)
10/31/84	belt press in service (used to dewater sludge for final disposal)

Changes Still Undergoing Construction

old primary clarifier back on line

new aerobic digester

sulfonation system

APPENDIX B

BENTHIC MACROINVERTEBRATES

APPENDIX B

MACROINVERTEBRATE DATA

Site 1: DI = 4.89 N = 83

36	Snails (Gastropoda)	43.37%
18	Diptera	21.69
8	Leeches (Hirundinea)	9.64
7	Flatworms (Tricladida)	8.43
5	Clams (Polecypoda)	6.02
5	Oligocheata	6.02
4	Odonata	4.82

Site 2: DI = 2.80 N = 97

74	Diptera	76.29%
15	Odonata	15.46
4	Flatworms	4.12
2	Snails	2.06
2	Leeches	2.06

Site 3: DI = 2.36 N = 85

48	Clams	56.47%
14	Leeches	16.47
12	Flatworms	14.12
6	Snails	7.06
5	Diptera	5.88

Site 4: DI = 6.92 N = 58

20	Odonata	34.48%
12	Diptera	20.69
7	Coleoptera	12.07
6	Shrimp (Decopoda)	10.34
5	Flatworms	8.62
4	Clams	6.90
4	Leeches	6.90

Site 5: DI = 9.02 N = 68

21	Odonata	30.88%
11	Tricoptera	16.18
9	Shrimp	13.24
8	Coleoptera	11.76
6	Flatworms	8.82
5	Diptera	7.35
4	Clams	5.88
4	Ephemeroptera	5.88

Site 6: DI = 8.86 N = 131

79	Tricoptera	60.31%
13	Shrimp	9.92
12	Ephemeroptera	9.16
9	Odonata	6.87
7	Coleoptera	5.34
6	Diptera	4.58
4	Plecoptera	3.05
1	Crayfish (Crustecea)	0.76

APPENDIX C

STP EFFLUENT DATA

APPENDIX C

PULLMAN SEWER TREATMENT PLANT EFFLUENT[1]

Date	Estimated Flow (CFS)	Temperature (°C)	pH	BOD (mg/l)	DO (mg/l)	Fecal Coliforms (CFU/100 ml)	
						am	pm
Oct. 4	---	----	---	----	---	10	10
5	3.5	20.8	6.8	16.0	0.8	--	---
6	3.5	20.5	6.7	----	1.3	--	---
7	3.5	20.0	6.7	----	1.6	--	--
8	---	----	---	----	---	10	118
12	4.1	19.9	6.7	----	2.7	150	200
13	4.1	19.4	6.8	18.0	1.5	--	---
14	4.1	18.5	6.6	----	1.5	--	---
16	---	----	---	----	---	10	50
17	3.5	----	---	16.0	---	--	---
19	---	16.5	6.6	----	1.3	--	---
20	3.3	18.1	6.6	----	1.5	10	290
21	3.5	17.9	6.7	17.0	1.8	--	---
24	---	----	---	----	---	10	340
25	---	----	---	19.0	---	--	---
26	3.6	18.7	6.7	----	1.5	--	---
27	3.5	17.1	6.6	----	2.0	00	000
28	3.5	12.5	6.6	----	2.2	10	400
29	---	----	---	15.0	---	--	---

---

[1] All parameters were not sampled on each sampling date.

APPENDIX D

RESEARCH DATA

Site No.	Dissolved Oxygen (ppm) (% Saturation)			Biochemical Oxygen Demand (mg/l)				Flow (CFS)			
	10-14	10-21	10-28	10-7	10-14	10-21	10-28	10-7	10-14	10-21	10-28
1	10.6 (81)	12.2 (86)	11.3 (86)	7.1	4.21	3.34	2.94	7.3	8.0	6.2	12.0
2	8.9 (77)	9.4 (87)	9.8 (80)	7.5	5.75	6.42	5.03	12.2	10.0	10.0	15.5
3	10.0 (81)	12.0 (89)	10.2 (80)	4.2	3.03	4.19	3.28	10.0	12.4	9.6	17.0
4	10.0 (79)	12.4 (93)	10.4 (79)	3.2	1.73	2.38	2.31	10.6	13.0	10.4	21.5
5	10.9 (86)	13.2 (99)	11.6 (89)	2.5	1.61	2.02	1.48	13.0	15.7	12.6	20.6
6	12.6 (99)	13.4 (99)	13.2 (99)	2.7	1.33	1.78	1.20	15.3	19.0	16.5	23.0

Site No.	Temperature (°C)				pH				Specific Conductivity (umhos/cm)			
	10-7	10-14	10-21	10-28	10-7	10-14	10-21	10-28	10-7	10-14	10-21	10-28
1	10.6	4.2	1.5	3.6	7.5	8.1	7.3	7.7	520	260	330	260
2	14.9	9.0	7.2	6.5	7.1	6.9	7.2	7.0	550	310	400	300
3	12.0	5.8	3.0	5.1	7.9	7.2	7.5	7.2	500	285	350	280
4	12.5	5.6	2.8	3.5	8.0	7.3	7.8	7.2	500	310	335	290
5	14.5	5.3	3.0	4.1	8.2	7.6	8.2	7.2	500	360	325	310
6	15.0	5.3	1.6	4.0	8.6	7.8	8.1	7.9	500	310	300	330

Site No.	Fecal Coliforms (CFU/100ml)			*E. coli* (CFU/100ml)	
	10-7	10-14	10-28	10-14	10-21
1	440	720	1300*	105*	95*
2	1829*	286*	450*	175*	65*
3	283	420	1033	75*	10
4	220	187*	60*	25*	10
5	200	200	167	10	10
6	150*	120*	40*	10	10

*Estimated values