Publication No. 84-e01

JOHN SPELLMAN
Governor

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
7272 Cleanwater Lane, LU-11 • Olympia, Washington 98504 • (206) 753-2353

MEMORANDUM
February 29, 1984

To: Roger Ray, Eastern Regional Office

From: GB Gary Bailey and Lynn Singleton JS, Water Quality Investigations Section

Subject: Liberty Lake WTP Receiving Water Study

Introduction

The new Liberty Lake wastewater treatment plant (WTP) began discharging to the Spokane River in August 1982. The Washington State Department of Ecology (WDOE) Eastern Regional Office (ERO) requested a Class II inspection of the WTP and a receiving water survey to determine the operational efficiency and the impact of the discharge on the water quality of the upper Spokane River after one year of operation. This report details the receiving water survey conducted on August 30 and 31, 1983. The concurrent Class II inspection of the treatment plant is reported by Heffner (1984).

Two reports dealing with water quality of the upper Spokane River have recently been released by Gibbons et al. (1984) and Nielsen (1983). The physical and chemical data from Gibbons et al. (1984) for stations near the outfall are compared with our data for a pre- and post-discharge evaluation. The biological data from both reports are reviewed to determine the biological status of the upper river and to determine the biological impact of the discharge during the initial start-up of the treatment plant in September 1982.

Methods

On August 30, 1983 approximately 100 mLs of Rhodamine WT dye were placed in the WTP discharge stream in order to locate the effluent discharge in the river and to determine the dispersion characteristics. After the dye plume had dispersed, measurements and samples were taken immediately below the discharge (river mile [r.m.] 92.3), just above the discharge (r.m. 92.4), and about 0.3 mile below the discharge (r.m. 92.0) (Figure 1). On August 31, another set of measurements and samples were taken at the same locations. Temperature, dissolved oxygen, pH, and specific conductance were measured in the field. Water samples were shipped to the WDOE Olympia laboratory for analysis of COD, fecal coliform (thiosulfate dechlorination), nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen, orthophosphate-phosphorus, total phosphorus, total solids, total nonvolatile solids, total suspended solids, total nonvolatile suspended solids, total hardness, chloride, copper (total and soluble), zinc (total and soluble), nickel (total and soluble), chromium (total and soluble), cadmium (total and soluble), lead (total and soluble), total aluminum, and total silver. Some metal analyses were also conducted at the U.S. Environmental Protection Agency laboratory at Manchester, Washington. The methods of analysis are from U.S. EPA (1979) and are equivalent to methods reported for the pre-discharge study (Gibbons, et al., 1984).

Results

The time of travel from the treatment plant to the river discharge point was 17 minutes 51 seconds at a plant flow of 0.32 MGD (0.5 cfs). The discharge line is about 12 inches in diameter and was not equipped with a diffuser. The dye emerged at a point about 15 feet from the south shore, and the plume traveled slowly along the south shore. The dye was just barely visible about 1/4 mile below the discharge point. The riffle area just below the last point of the visible dye plume was chosen as the downstream sampling station.

The river flow (Post Falls datum) at the time of sampling was 370 cfs (USGS, 1983). A 7-day low flow of 10-year recurrence interval was calculated as 103 cfs for r.m. 93.9 (URS Company, 1978), but the Washington Water Power Company has recently agreed to a 300 cfs minimum release at Post Falls (Bailey and Saltes, 1982). The Spokane River between Post Falls (r.m. 102.0) and Harvard Road (r.m. 92.7) may lose water to the aquifer so that a 300 cfs flow at Post Falls equates to an approximate 200 cfs flow at Harvard Road (Kennedy, Michael A., Consulting Engineers, 1981). The effluent dilution ratios based on 103 cfs and 200 cfs are 1:200 and 1:500, respectively.

Immediately below the discharge site, there was a slight but consistent drop in pH and an increase in specific conductance. Both parameters had returned to background levels at the downstream station (Table 1).

Dissolved oxygen was saturated (90 to 105 percent) and above the Class A standard (8 mg/L) at all three stations on both days. Diurnal variation is apparent in dissolved oxygen, temperature, and pH, with higher values for the afternoon measurements than for measurements made the following morning.

Table 1. Water quality data for the Spokane River near the Liberty Lake WTP outfall. River flows and effluent flow at times of sampling were 370 cfs and .5 cfs (.32 MGD), respectively.

Parameter	August 30, 1983			August 31, 1983			
	Above Outfall	At Outfall	0.3 mile Below Outfall	Above Outfall	Effluent 24-hour Composite	At Outfall	0.3 mile Below Outfall
Time	∿1600	∿1600	∿1600	0830	--	0845	0900
Temperature (°C)	23.0	23.4	23.4	20.9	--	20.9	20.9
D.O. (mg/L)	9.0(103)[1]	9.0(105)	8.9(103)	8.2(91)	--	8.1(90)	8.2(91)
pH (S.U.)	8.0	7.8	8.0	7.0	6.6	6.9	7.0
Sp. Cond. (μmhos/cm)	47	57	48	48	420	53	48
COD (mg/L)	4	4	4	4	19	4	4
Fecal Coliform (col/100 mL)	<1	3 est	1 est	5 est	11	12 est	1 est
NO_3-N (mg/L)	<0.01	0.10	0.04	<0.01	17	0.34	0.07
NO_2-N (mg/L)	<0.01	<0.01	<0.01	<0.01	0.10	<0.01	<0.01
NH_3-N (mg/L)	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01
O-PO_4-P (mg/L)	<0.01	0.04	0.02	0.01	6.7	0.12	0.03
Total Phos. P (mg/L)	0.02	0.04	0.03	0.02	6.7	0.12	0.04
Total Solids (mg/L)	40	34	33	27	320	29	27
TNVS (mg/L)	26	30	26	8	220	11	10
TSS (mg/L)	<1	2	2	7	8	3	3
TNVSS (mg/L)	<1	<1	<1	<1	<1	<1	<1
Total Hardness (mg/L)	23	23	27	27	--	27	15
Chloride (mg/L)	2.1	2.1	2.1	2.1	39	2.1	1.4
Copper (μg/L) - total	<1	10	<10	1	40	/6/	<10
soluble	<1	10	<10	--	20	--	<10
Zinc (μg/L) - total	42	44	/51/	/70/	90	/65/	/66/
soluble	42	40	41	--	85	--	60
Nickel (μg/L) - total	<50	<50	<50	<50	<50	<50	<50
soluble	<50	<50	<50	--	<50	--	<50
Chromium (μg/L) - total	<10	<10	<10	<10	<10	<10	<10
soluble	<10	<10	<10	--	<10	--	<10
Cadmium (μg/L) - total	<2	<2	<2	/0.4/	1	/0.4/	<2
soluble	<2	<2	<2	--	0.8	--	<2
Lead (μg/L) - total	<50	<50	<50	<50	2	<50	<50
soluble	<50	<50	<50	--	<1	--	<50
Aluminum (μg/L) - total	<500	<500	<500	<500	<500	--	<500
Silver (μg/L) - total	<0.1	<0.1	<0.1	<0.1	<0.1	--	<0.1

[1]( ) = dissolved oxygen percent saturation.

est = estimated

/ / = exceeded acute or chronic water quality criteria.

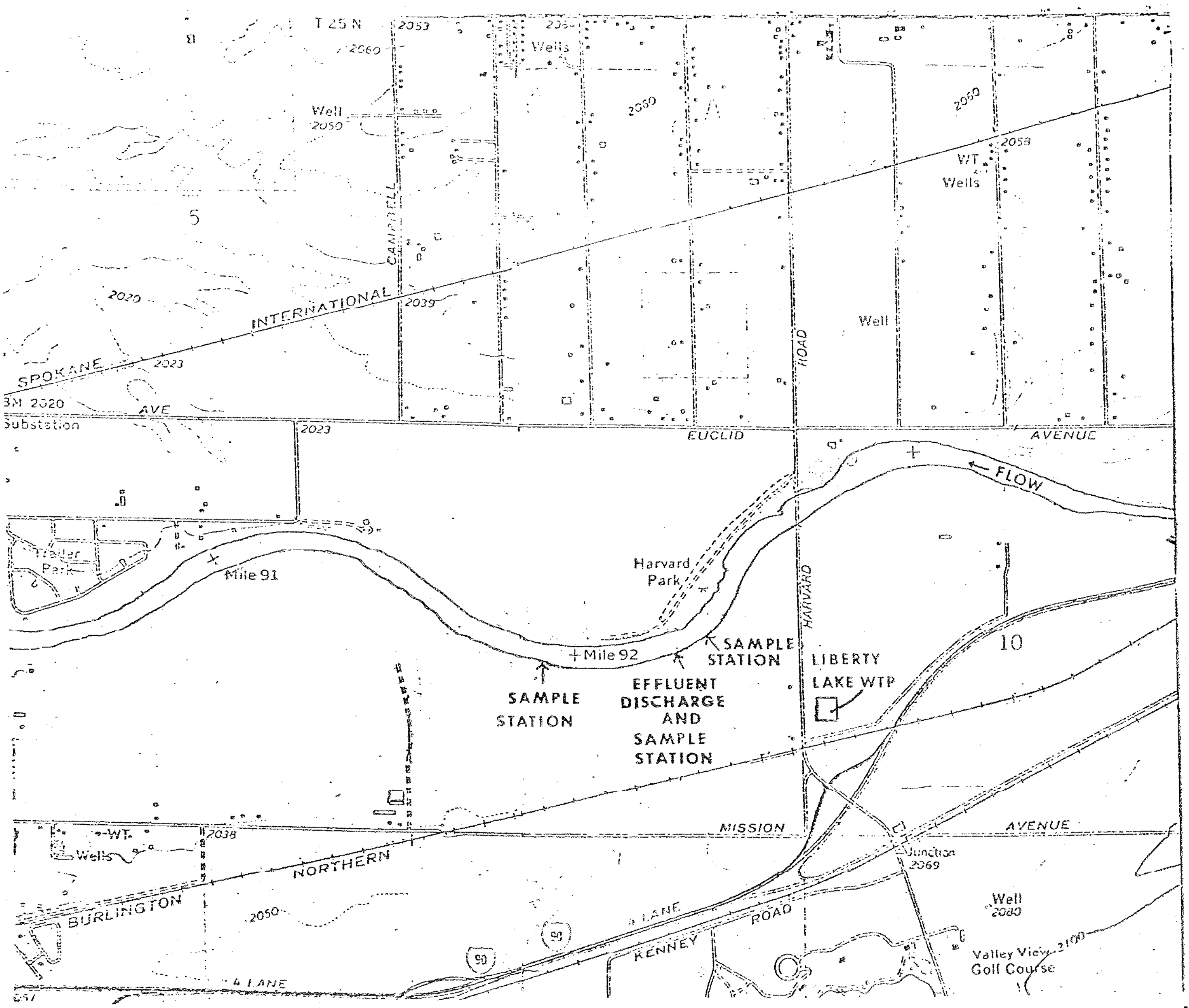

Figure 1. Liberty Lake WTP receiving water survey area, August 30-31, 1983.

Fecal coliform counts were low (less than 1 to approximately 5) for all stations on both days and within Class A standards.

Most metal concentrations were below detectable limits, but copper, zinc, and cadmium exceeded the 24-hour average criteria at one or more stations. Copper concentrations increased from 1 or less than 1 µg/L at the upstream station to 6 to 10 µg/L at the discharge site (Table 1). The 24-hour average criterion for copper is 5.6 µg/L (U.S. EPA, 1980c). Copper concentrations at the downstream station were less than 10 µg/L. Zinc concentrations at all stations exceeded the 24-hour average criterion of 47 µg/L (U.S. EPA, 1980a) on August 31, but there was no apparent increase in zinc attributable to the effluent discharge. Cadmium concentrations at the upstream station and the discharge site were 0.4 µg/L on August 31. The downstream concentration measured by a less sensitive analysis was less than 2 µg/L. The 24-hour average criterion for cadmium is .006 µg/L at 25 mg/L hardness (U.S. EPA, b).

The loadings to the Spokane River are given in Table 2. The percent of total river load assumes that upstream load plus WTP equals the total downstream load.

The water quality data collected during this survey are generally similar to data collected by Gibbons et al. (1984) during 1980 and 1981 at comparable locations and time of year (Table 3). The obvious exceptions are the higher concentrations of NO_3-N and O-PO_4-P at the station below the Liberty Lake effluent discharge; however, it also appears that our downstream data do not represent fully mixed conditions. At an effluent flow of .32 MGD (.5 cfs), an effluent NO_3-N concentration of 17 mg/L (Heffner, 1984) and a river flow of 370 cfs (USGS, 1983), our downstream nitrate concentration indicates 33 to 58 percent mixing at the sampling site. A critical problem of phosphorus enrichment exists in the Long Lake reservoir and the Spokane River has been identified as a major source of phosphorus (Soltero, et al. 1983). The phosphorus discharged to the river by the Liberty Lake WTP has been included in the phosphorus allocation strategy presented by Singleton (1981) and in current contract studies. In accordance with the current phosphorus allocation, the Liberty Lake WTP permit specifies phosphorus removal when effluent flows reach .89 MGD.

Based on these physical and chemical data, it appears that the impact of the effluent discharge is minimal except for increased nutrient concentrations. In the summary statement of a two-year study of the upper Spokane River, Gibbons et al. (1984) also concluded that, "In general, the physical and chemical properties of the upper Spokane River are indicative of good water quality conditions."

Because of the lack of biological data in our study, we examined the work of Gibbons, et al. (1984) and Nielsen (1983) to judge the biological impact of the effluent. In the Recommendations section of their report, Gibbons, et al. (1984) concluded that, "the aquatic communities

Table 2. Loading to the upper Spokane River from the Liberty Lake WTP at 0.32 MGD effluent flow and 370 cfs river flow.

Parameter		Loading (lbs/day)	Effluent Load as Percent of Total River Load
BOD_5		7.5	--
COD		50.7	.6
Inorganic N		45.7	70-100
Soluble P		17.9	47
Total P		17.9	31
Total Solids		853	1
Total Suspended Solids		21.3	.3
Copper	- total	.11	5.2
	soluble	.05	--
Zinc	- total	.24	.2
	soluble	.23	--
Cadmium	- total	.003	.4
	soluble	.002	--

Table 3. A comparison of water quality parameters before (1980, 1981) and after (1983) discharge of the Liberty Lake WTP effluent. Data for 1980 and 1981 are from Gibbons, et al., 1983.

Parameter	August 26, 1980		September 3, 1981		August 1983[1]	
	Above[2]	Below[3]	Above[2]	Below[3]	Above[2]	Below[3]
Temperature (°C)	18.5	18.5	19.0	18.5	22	22
Dissolved Oxygen (mg/L)	8.4	7.8	8.7	8.4	8.6	8.6
pH (Standard Units)	7.0	6.8	7.2	7.2	7.5	7.5
Specific Conductance (μmhos/cm)	56	57	60	62	48	48
Total Phosphate P (mg/L)	0.015	0.017	0.028	0.034	0.02	0.04
Orthophosphate P (mg/L)	0.005	0.006	0.005	0.006	0.01	0.03
NO_3-N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.01	0.06
NH_3-N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (μg/L) - total	106	111	65	60	56	59
Fecal Coliform (col/100 mL)	4 est.	4 est	15	43	3 est	1 est
Total Suspended Solids (mg/L)	0.3	1.8	1.0	1.5	4	3
Copper (μg/L) - total	<1	<1	<1	<1	<1	<10

[1]Values are means for August 30 and 31, 1983.

[2]Above = Harvard I station (r.m. 93.1).

[3]Below = Harvard II station (r.m. 92.2).

in the upper Spokane River are indicative of a meso-eutrophic condition" and that "this region is approaching its maximum absorptive capacity for nutrients." Nielsen (1983) also observed that, "the upper Spokane River was in an early stage of eutrophication according to the biological indicators...before the addition of secondarily treated municipal effluent at Harvard Road" and that the effluent caused an acceleration of eutrophication.

The term "eutrophication" or "nutrient enrichment" as used in lake and reservoir managment has a relatively precise criterion in relating nutrient loading to algal production and subsequent impairment of beneficial uses (Rast and Lee, 1978). The absence of criteria for relating loss of beneficial uses to nutrient enrichment in flowing systems was discussed briefly by Johnson (1980). In the absence of specific nutrient loading criteria, the enrichment of a flowing system must be based on biological indicators such as phytoplankton, benthic invertebrates, and periphytic algae. Because both Gibbons et al. (1983) and Nielsen (1983) had assessed the upper Spokane River to be in a meso-eutrophic to eutrophic condition based on biological parameters, a review of their data, analyses, and criteria was conducted. The raw data from the two reports are not included here, but our computations and analyses from their data are shown in Appendix A. The three main biological components examined by Gibbons et al. (1984) in the two-year study before Liberty Lake WTP effluent discharge began were: phytoplankton (algae in the water column); macroinvertebrates; and periphyton (attached algae). Nielsen (1983) examined periphyton growth above and below the Liberty Lake WTP discharge immediately before and after the discharge began (September 1982).

Phytoplankton

Gibbons, et al. (1984) stated: "There is a rich phytoplankton community in the upper Spokane River that is dominated by diatoms. The densities observed during the study suggest that the potential for nuisance populations of algae could develop if the flow and/or the velocity of the river was greatly reduced. Such a reduction in velocity of the river would create a lentic environment that would be much more conducive to phytoplankton production than the present lotic environment (Appendix 1)." "Large populations of diatoms, expecially *Asterionella formosa*, are supported throughout the year, and on occasion the nuisance algae (blue-greens) achieve bloom proportions in the summer period, especially at the lower river stations Plantes Ferry to Hangman Creek (Table C-1, Appendix C)." Our examination of the data presented by Gibbons et al. (1984) indicates that the planktonic algae in the Spokane River probably originate as washout from Lake Coeur d'Alene and are kept in suspension downriver by turbulent high flows. The highest plankton counts occur in the period of February to June during high flows and the lowest counts occur in August during low flows. The dominant algae is *Asterionella formosa* which is a true planktonic algae (characteristic of lake and pond algae) (Hynes, 1970), and there is no indication that algae numbers increase downriver.

Their data also show that *Aphanizomenon*, a blue-green algae, was counted in significant numbers on June 5, 1981 and September 3, 1981. On June 5, the counts among stations ranged from 209 to 3238 cells per mL, but not in any upstream-to-downstream pattern. On September 3, the counts increased from 35 cells per mL at the upper station (Harvard II) to 20,067 cells per mL at the last downriver station (near Hangman Creek). This increasing count with river travel does indicate a population growth in the river. *Aphanizomenon flos-aquae* is a common nuisance algae and forms surface scums in eutrophic lakes. Whether it would form a nuisance scum in the turbulent Spokane River is uncertain. The duration of the high *Aphanizomenon* numbers is unknown, but the counts of this algae on August 25 and November 3, 1981 were negligible.

Macroinvertebrates

Gibbons, *et al.* (1984) stated: "The diversity values...range from 0.00 to 2.84 with a mean of 1.54. Wilhm (1970) reviewed studies of diversity values from polluted and unpolluted streams and found diversity values of 0.00 to 1.60 in polluted streams and 2.60 to 4.61 in unpolluted streams. On this basis, the diversity values from the Spokane River would indicate a somewhat polluted or stressed environment. The stress probably is due to the high zinc concentrations present in the river. The lack of variety of species and absence of stoneflies that are present in the upper drainage regions may be due to a lack of variety of food (Hynes, 1970) rather than metal-induced stress on the organisms. Many stoneflies, mayflies, and chironomids are resistant to zinc (Jones, 1958; Hynes, 1960."

"The lack of stoneflies and the low diversity could have been related to the high zinc concentration and its effect on the food chain in the river; however, the downstream effects of Lake Coeur d'Alene may also have an influence."

Our interpretation of the preceeding statements by Gibbons is that the cause of the low biological diversity in the upper Spokane River is uncertain, but is probably not due to nutrient enrichment. Other workers have compared macroinvertebrate communities above and below reservoirs (Spence and Hynes, 1971; Ward and Stanford, 1979) and found that the rivers below reservoirs have communities with the same characteristics as the upper Spokane River. Specifically, they found a reduced diversity, fewer stonefly and mayfly species, and an increase in *Hydropsychidae* (caddisfly) and *Similium* (blackfly) below reservoirs.

Periphyton

Periphytic algae were analyzed by enumeration, chlorophyll a, and biomass (ash-free dry weight) at ten stations over a two-year period on the Spokane River (Gibbons, et al., 1984). The data were analyzed for differences among the two growth substrates used and it was found that rock substrate had higher chlorophyll a and ash-free dry weight than glass substrate. No comparisons among stations were made, perhaps because of the large number of samples that were vandalized and no relationships were developed for equating the periphyton results to the nutrient concentrations in the river.

Nielsen (1983) conducted a periphyton study near the Liberty Lake WTP discharge site at the time the WTP began the initial discharge (September 1982). One of his stations below the discharge (r.m. 92.0) corresponded with our sampling station below the discharge. He assessed the impact of the effluent discharge on the periphyton of the Spokane River by placing rock tiles above and below the discharge. The station above the discharge (r.m. 92.8) had two samplers with 12 tiles each. The first station .3 mile below the discharge (r.m. 92.0) had three samplers and the next downstream station (r.m. 91.9) had one sampler. Periphyton was sampled every three days (to a maximum of 18 days) and analyzed for cell counts, generic identification, ash-free dry weight, and chlorophyll a. Nielsen had three 12- to 18-day periods of growth; two periods before discharge began (July 25 to August 12; August 15 to August 24) and one period after discharge (September 1 to September 18).

Nielsen concluded that the Spokane River at the discharge site was in an early stage of eutrophication before the introduction of effluent. The criteria he used for this observation were: (1) periphton cell counts of 10,000 cells/mm^2 or more (Butcher, 1946; Butcher, 1945); and (2) an observation attributed to Hynes (1970) that desmids are the primary flora of oligotrophic waters and are replaced by other types of algae as the waters become enriched.

Butcher's criteria were developed from examination of organically polluted waters and are not specific for nutrient enrichment. In addition, an examination of the periphyton data presented by Gibbons et al. (1984) for the pre-discharge period shows that although the counts did occasionally exceed 10,000 and sometimes 100,000 cells/mm^2, the mean (log transformed) cell count for rock substrate during summer and fall was 2,861 cells/mm^2.

Nielsen (1983) observed desmids infrequently in the Spokane River, but after careful examination of Hynes (1970), for confirmation of the desmid association with oligotrophic flowing waters, it appears that Nielsen (1983) misinterpreted Hynes or gave an incorrect citation. Desmids are typically found in soft, still waters often rich in humic acids (Hynes, 1970; Hutchinson, 1967; Prescott, 1962; Smith; 1950). Only one rare genus of desmid is listed by Smith (1950) as being periphytic (found on substrate in flowing waters).

Nielsen (1983) also concluded that "With the introduction of secondarily treated sewage plant effluent there occurred increases in the rate of accrual and total accumulation of chlorophyll a and periphyton cell counts; faster periphyton colonization rates, especially Lyngbya spp.; and higher frequency of occurrence of algae such as Synedra rumpens, Gleotrichia, and Nitzschia that indicated the occurrence of an acceleration of the eutrophication of the upper Spokane River due to the effluent introduction."

Comparisons of periphyton growth for different sample periods are valuable ecological information, but do little to assess the effect of the discharge because of the difficulty in eliminating effects of factors such as declining temperature and day length during the three discrete sample periods. The best comparison to determine the effect of the discharge is a comparison of stations above and below the discharge for the same period of time. This above-and-below comparison is only valid when other factors such as water depth, sun exposure, and velocities are similar. Nielsen (1983) conducted an analysis of variance comparing stations among and within periods by sampling day and according to his Table G-2 (reproduced in Appendix A), there were some sampling days within the post-discharge period when the means for the above and below stations were significantly different. There are two basic problems with the analysis as presented. The first is the occurrence of some significant growth differences in the periods "Before 1" and "Before 2" prior to the start of effluent discharge (Table G-2). Nielsen (1983) attributes these differences to variations in day-to-day flows which occurred in the study periods before effluent discharge began. Flow in the study period after effluent discharge was relatively constant over the sample period. Nielsen doesn't explain why daily flow variations caused station differences.

The other conceptual problem in the analysis of variance is that if 50 percent of the days shows a sigificant station (above and below) difference (as for chlorophyll a), it means that on 50 percent of the days there was no difference. Nielsen recognized these conceptual problems and proceeded from his analyses of variance to a comparison (non-statistical) of the number of significant days before and after effluent introduction.

We performed T-tests and analyses of variance on Nielsen's data. For both tests, each data point was divided by days of incubation and log transformed. The T-test assumes each data point is a random observation and compares means for above and below the discharge. The T-tests indicated a significant difference (P = .1) among stations for algae cell counts and chlorophyll a, but no difference for ash-free dry weight.

The analysis of variance, a more exact statistical test, differed from Nielsen's analysis by treating each data point (growth parameter divided by days of growth) as an independent observation. This eliminates one level of complexity in a nested design and is more specific for testing station differences over the period of observation. Our analysis of variance indicated no significant difference (P = .1) among stations for cell counts, chlorophyll a, or ash-free dry weight (Appendix A).

We also used Nielsen's data to compare the rates of accrual of cell counts, ash-free dry weight, and chlorophyll a between upstream and downstream stations. There was no apparent difference in rate of accrual for any parameter (Appendix A).

The significance of the appearance of blue-green algae Lyngbya spp. on day 3 on the downstream plates as compared to day 6 or day 9 on the upstream plates is uncertain because by day 15 or day 18 the Lyngbya sp. counts are insignificant at both stations.

The environmental factors affecting the occurrence of specific algae are generally not well defined with respect to nutrients (Lowe, 1974). Nielsen (1983) points to the higher frequency of occurrence of specific algae such as Synedra rumpens, Gleotrichia sp., and Nitzschia sp. as indicators of nutrient enrichment, but his data indicate the frequency of occurrence of only Synedra rumpens was substantially (greater than 20 percent) different when comparing stations above and below the discharge. Nielsen (1983) cites a study by Patrick (1966) who observed an increase in Synedra rumpens when phosphorus concentrations increased from 0.83 to 5.0 mg/l. Williams and Soltero (1978), however, observed a decrease in the frequency of occurrence of Synedra rumpens below the City of Spokane WTP discharge.

The results of the data collected and analyzed by Nielsen were interpreted as being representative of the whole river, but our data indicate that Nielsen's downstream stations were probably in the effluent mixing zone so that even if significant effects had been observed, the results would only be applicable to the dilution zone.

There is no doubt that nutrient/organic enrichment may cause heavy periphytic growth that is aesthetically displeasing. The heavy filamentous Cladophora sp. growth in the middle Snake River (Bailey,

1974) is a good example of this; however, it appears that there are currently no published criteria to enable us to predict the nutrient loading and other conditions which cause that heavy algal growth. We observed no heavy periphytic growth around the Liberty Lake outfall site during our sampling.

Conclusions

The physical and chemical parameters of the upper Spokane River indicate good water quality with the exception of high metal concentrations.

The effluent from the Liberty Lake WTP caused some increases in phosphorus and nitrogen concentrations 0.3 mile below the discharge and within the discharge plume at 370 cfs river flow.

The biological data in the report by Gibbons, et al. (1984) for the predischarge period does not substantiate significant nutrient enrichment in the upper Spokane River.

Contrary to his conclusions, the periphyton data and analyses reported by Nielsen (1983) do not indicate the Liberty Lake WTP discharge caused a significant increase in periphytic algae growth in the dilution zone during the initial operation of the WTP.

Monitoring Recommendations

There are two potential problems with nutrient loading in the upper Spokane River. Below the discharge, the nutrients may cause heavy blanket-type or long filamentous (Cladophora) algae growth. Although this growth may not be biologically damaging in the immediate area, it is aesthetically displeasing, and the accumulation of sloughed algae may cause measurable BOD in pools downstream. The nutrients may also cause heavy algae or weed growth in the Upriver Reservoir. Neither of these problems is easily predicted and may not occur concurrently. Therefore, it is recommended that some monitoring of stream quality be conducted as effluent flows increase.

Future monitoring may be conducted when effluent flows reach 0.6 MGD (.9 cfs) and 0.8 MGD (1.2 cfs). The 0.6 MGD is an approximate doubling of the current discharge, but the change in magnitude of the dilution ratio is small. The 0.8 MGD value is slightly less than 0.89 MGD, the flow at which phosphorus removal is required in the discharge permit.

The monitoring work should be conducted in August, the month of lowest flows and maximum temperatures.

The monitoring should be one- or two-day surveys. The stations and parameters should include those reported here. An additional water quality station at the Barker Road bridge (r.m. 90.4) would represent a complete mix of the effluent. A visual comparison of periphytic algae should be made above and below the effluent discharge, including the first riffle area past the discharge. Samples of periphyton for quantification and identification may be collected if a difference is visually noted above and below the effluent. In addition, some visual observation and/or planktonic algae counts should be made at Upriver Reservoir.

The critical points at which some action would be taken include:

1. Observation of heavy periphytic algae growth below the WTP discharge.

   The current discharge with a diffuser does not appear to meet the guidelines for effluent dilution (WDOE, 1978), but the effluent does not appear to be causing a problem at present flows. Heavy periphytic growth occurring in the dilution zone at greater effluent flow combined with the nutrient data would provide information on the threshold for excessive nutrient loading in the upper river. The periphytic growth in the dilution zone would be aesthetically unappealing, but would probably not cause any biological upset. Installation of a diffuser would be required when the growth is observed.

2. Blue-green algae blooms or heavy weed growth in Upriver Reservoir.

   If high primary production is observed, then the phosphorus loading from the Liberty Lake WTP should be evaluated to perhaps initiate phosphorus removal before the effluent flows reach 0.89 MGD.

If either condition 1 or 2 is observed, an additional, thorough analysis should be undertaken or contracted to develop the nutrient assimilative capacity for the upper river.

A predictive model for flowing waters may be used as an alternative to the strategy presented above if one becomes available in the interim.

GB:LRS:cp

cc: John Bernhardt
Files

References

Bailey, G.C., 1974. Aquatic vegetation. In Bayha, K. and Koski, C. (eds.). Anatomy of a River. A report of the Hell's Canyon controlled flow task force. Pacific Northwest River Basins Commission, Vancouver, WA. 203 pp.

Bailey, G.C. and J. Saltes, 1982. Fishery assessment of the upper Spokane River. Project completion report to Wash. St. Dept. Ecol. 111 pp.

Butcher, R.W., 1946. Studies in the ecology of rivers. VI. The algal growth in certain highly calcareous streams. J. Ecol. 33: 268-283 p.

Butcher, R.W., 1947. Studies in the ecology of rivers. VII. The algae of organically enriched waters. J. Ecol. 35: 186-191 p.

Gibbons, H.L., Jr., W.H. Funk, R.M. Duffner, T.S. Nielsen, and T. Notestine, 1984. Baseline study to determine the water quality and the primary and secondary producers of the Spokane River, Phase I. Project completion report to Wash. St. Dept. Ecol., State of Washington Water Research Center, Rpt. No. 57, 238 pp.

Heffner, M., 1983. Class II inspection report of the Liberty Lake WTP. In prep.

Hutchinson, G.E., 1967. A Treatise on Limnology Vol. II. John Wiley & Sons, N.Y. 1115 pp.

Hynes, H.B.N., 1970. The Ecology of Running Waters. Univ. of Toronto Press. 555 pp.

Johnson, A., 1980. Notes on nutrient criteria for algal bloom thresholds. WDOE tech. memo.

Kennedy, Michael A. Consulting Engineers, 1981. Additions to the Liberty Lake Wastewater Treatment Facilities - Water Quality Impact Assessment. 62 pp.

Lowe, R.L., 1974. Environmental requirements and pollution tolerance of freshwater diatoms. EPA-670/4-74-005. 334 pp.

Nielsen, T.S., 1983. Comparison of periphyton growth before and after the introduction of secondarily treated sewage plant effluent. M.S. Thesis, Dept. Civil & Env. Engr., Wash. St. Univ., Pullman WA. 73 pp.

Patrick, R., 1966. The effect of varying amounts and ratios of nitrogen and phosphate on algae blooms. Proc. 21st Indust. Waste Conf., Purdue Univ. Engng. Exter. Service: 41-51 p.

Prescott, G.W., 1962. Algae of the western Great Lakes area, with an illustrated key to the genera of desmids and freshwater diatoms. Wm. C. Brown Co., Dubuque, Iowa. 977 pp.

Rast, W. and G.F. Lee, 1978. Summary analysis of the North American (U.S. portion) OECD Eutrophication Project: Nutrient Loading - Lake Response Relationship and Trophic State Indices. U.S. EPA, ERL. Corvallis, OR. EPA-600/3-78-008.

Singleton, L.R., 1981. Spokane River wasteload allocation study - supplemental report for phosphorus allocation. Wash. St. Dept. Ecol., Rept. No. 81-15.

Smith, G.M., 1950. The fresh-water algae of the United States. McGraw-Hill, Inc., N.Y. 719 pp.

Soltero, R.A., D.G. Nichols, and M.R. Cather, 1983. The effect of seasonal alum addition (chemical phosphorus removal) by the City of Spokane's advanced wastewater treatment plant on the water quality of Long Lake, Washington, 1982. Project Completion Report to the City of Spokane. 119 pp.

Spence, J.A. and H.B.N. Hynes, 1971. Differences in benthos upstream and downstream of an impoundment. Journ. Fish. Res. Board Can. 28: 45-46 p.

URS Company, 1978. Wastewater facilities plan for the Newman Lake Area. Spokane, WA. Cited in Kennedy, Michael A. 1981. ob. cit.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. EPA, 1980a. Ambient water quality criteria for zinc. EPA-440/5-80-079.

U.S. EPA, 1980b. Ambient water quality criteria for cadmium. EPA-400/5-80-025.

U.S. EPA, 1980c. Ambient water quality criteria for copper. EPA-440/5-80-038.

U.S.G.S., 1983. Personal communication of provisional Post Falls flow data -- Spokane office.

Ward, J.V. and J.A. Stanford, 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams. In Ward, J.V. and J.A. Stanford (eds.), 1979. The Ecology of Regulated Streams. Plenum Press, N.Y. 398 pp.

WDOE (State of Washington Department of Ecology), 1978. Criteria for Sewage Works Design. Report DOE 78-5. 357 pp.

Wilhm, J.L., 1970. Range of diversity index in benthic macroinvertebrates. Jour. Water Poll. Control Fed. 42: R221-R224.

Williams, P.H. and R.A. Soltero, 1978. Response of the Spokane River diatom community to primary sewage effluent. Northwest Sci. 52: 186-194 p.

APPENDIX A

Analysis of Periphyton Data from Nielsen (1983)

NOTE: This table, reproduced from Nielsen (1983), summarizes several analysis of variance tests.

Table G-2—P Values of the F Test Comparing Stations in a Period

	Before 1	Before 2	After	Before 1	Before 2	After
	Ash-Free Dry Weight			Blue-Green Algae		
Day						
3	.171	.463	.719	.465	.465	.0006*
6	.527	.202	.204	.859	.737	.749
9	.214	.017*	.105	.541	.084	.788
12	.782	.012*	.075	.735	.779	.365
15	.277	#	.368	.032*	#	.011*
18	.605	#	.737	.708	#	.329
	Chlorophyll a			Diatoms		
Day						
3	.857	.672	.522	.053	.038*	.721
6	.528	.945	.365	.560	.206	.365
9	.069	.172	.008*	.512	.423	.003*
12	.895	.008*	.003*	.829	.512	.329
15	.410	#	.010*	.495	#	.000*
18	.517	#	.136	.262	#	.068
	Green Algae			Total Cell Counts		
Day						
3	.289	.006*	.682	.081	.280	.592
6	.005*	.538	.164	.409	.587	.621
9	.717	.127	.000*	.581	.050*	.010*
12	#	.903	.037*	.742	.846	.322
15	.873	#	.002*	.058	#	.006*
18	.721	#	.201	.692	#	.155

* Indicates Significant Difference
# No Data

I. T-tests - Spokane River periphyton data

A. Ash-free dry weight

Location	n	df	$\overline{Y}$	$\Sigma(Y_i-\overline{Y})^2$
Above	12	11	1.265	1.7479
Below	18	17	1.380	1.669
		28		3.4169

$$S^2 = \frac{3.4169}{28} = .1220$$

$$S_d^2 = .1220\ (\frac{1}{12} + \frac{1}{18}) = .0169$$

$$t = (\frac{\overline{Y}_2 - \overline{Y}_1}{S_d}) = \frac{.115}{.13} = .88$$

$t_{.1,28} = 1.313$

Failed to reject H_0: $\overline{Y}_1 = \overline{Y}_2$

Log ($\mu g/cm^2$/day ash-free dry weight)

Above	Below
1.30	1.72
1.11	1.50
1.14	1.39
1.23	1.15
1.65	1.72
1.60	1.68
1.33	1.26
1.04	1.18
.28	.83
1.09	.91
1.74	1.88
1.67	1.56
$\overline{Y}_1$ = 1.265	1.30
	1.26
S^2 = .1589	.92
	1.25
S = .3986	1.73
	1.60
	$\overline{Y}_2$ = 1.380
	S^2 = .09817
	S = .3133

B. Chlorophyll *a*

Location	n	df	$\bar{Y}$	$\Sigma(Y_i-\bar{Y})^2$
Above	12	11	1.712	1.8661
Below	18	17	1.828	2.4176
		28		4.2837

$$S^2 = \frac{4.2837}{28} = .1530$$

$$S_d^2 = .1530\left(\frac{1}{12} + \frac{1}{18}\right) = .02125$$

$$t = \left(\frac{\bar{Y}_2 - \bar{Y}_1}{S_d}\right) = \frac{.107}{.1458} = .734$$

$$t_{.1,28} = 1.313$$

Failed to reject H_o: $\bar{Y}_1 = \bar{Y}_2$

Log (nannogr/cm^2/day)

Above	Below
2.678	1.456
1.722	2.689
1.828	2.144
1.598	1.809
1.193	1.715
1.046	1.667
1.826	1.757
1.583	2.034
2.045	1.681
1.879	1.847
1.551	1.965
1.703	.901
$\bar{Y}_1$ = 1.721	2.228
S = .412	2.180
S^2 = .170	1.817
	1.796
	1.789
	1.422
	$\bar{Y}_2$ = 1.828
	S = .3771
	S^2 = .1422

C. Total cell counts

Location	n	df	$\overline{Y}$	$\Sigma(Y_i-\overline{Y})^2$
Above	12	11	1.752	3.1977
Below	18	17	2.192	8.0053
		28		11.203

$$s^2 = \frac{11.203}{28} = .400$$

$$s_d^2 = .400\left(\frac{1}{12} + \frac{1}{18}\right) = .0556$$

$$s_d = .2357$$

$$t = \frac{2.192 - 1.752}{.2357} = 1.87$$

$$t_{.1,28} = 1.313$$

Reject $H_o: \overline{Y}_1 = \overline{Y}_2$

Log (cells/mm^2/day)

	Above	Below
	1.753	3.124
	1.954	3.147
	2.163	2.471
	1.835	1.903
	1.222	2.334
	.522	1.626
	1.954	2.156
	1.740	2.494
	2.702	2.378
	1.753	2.592
	2.062	2.632
	1.368	.891
$\overline{Y}_1 =$	1.752	2.423
$s =$	.5391	2.007
$s^2 =$	.2907	2.233
		2.349
		2.358
		3.46
	$\overline{Y}_2 =$	2.192
	$s =$	.686
	$s^2 =$	.4709

II. Analysis of variance - Spokane River periphyton

A. Periphyton algae counts for period after effluent discharge. Tabled values are log (cell count ÷ days incubation). Cell count data from Nielsen (1983).

	Upstream		Downstream		
	A	B	D	E	G
	1.753	1.954	3.124	2.156	2.423
	1.954	1.740	3.147	2.494	2.007
	2.163	2.702	2.471	2.378	2.233
	1.835	1.753	1.903	2.592	2.349
	1.221	2.062	2.334	2.632	2.358
	.523	1.368	1.626	.891	.347
Σ =	9.449	11.579	14.605	13.143	11.717
	Σ = 21.028		Σ = 39.465		

1. Grand total - 60.493

2. Sum of squared observations = 134.572

3. Sum of squared subgroup totals = $\frac{9.449^2}{6} + \frac{11.579^2}{6} \ldots = 124.448$

4. Sum of squared group totals = 123.375

5. Grand total squared and divided by total sample size = 121.980

6. SS total = 134.572 - 121.980 = 12.592

7. SS groups = 123.375 - 121.980 = 1.395

8. SS subgroup = 124.448 - 123.375 = 1.073

9. SS within = 134.572 - 124.448 = 10.124

Anova Table

Source of Variation	df	SS	MS	F_s	$F_{.1(1,3)}$
Among groups (stations)	1	1.395	1.395	∿3.9	5.54
Samplers within stations	3	1.073	.358	.884	
Samples within samplers	25	10.124	.405		
Total	29	12.592			

No significant difference among stations $.25 < P(F_s = 3.9) < .1$

B. Chlorophyll a as (ng/cm^2/day) log

	Upstream		Downstream		
	A	B	D	E	G
	2.678	1.826	1.456	1.757	2.228
	1.722	1.584	2.689	2.033	2.18
	1.828	2.045	2.144	1.681	1.817
	1.598	1.879	1.809	1.847	1.796
	1.193	1.551	1.715	1.965	1.789
	1.046	1.703	1.667	.901	1.422
Σ =	10.065	10.588	11.480	10.184	11.232

1. Grand total = 53.549
2. Sum of squared observations = 99.948
3. Sum of squared subgroup totals = 95.845
4. Sum of squared group totals = 95.665
5. Grand total squared and divided by total sample size = 95.583
6. SS total = 4.365
7. SS groups = .082
8. SS subgroup = .18
9. SS within = 4.103

Anova Table

Source of Variation	df	SS	MS	F_s	$F_{.1(1,3)}$
Among groups (stations)	1	.082	.082	≈1.37	5.54
Samplers within stations	3	.18	.060	.366	
Samples within samplers	25	4.103	.164		

No significant difference among stations $.5 < P(F_s = 1.37) < .25$

C. Ash-free dry weight log ($\mu g/cm^2/day$)

Upstream		Downstream		
A	B	D	E	G
1.297	1.334	1.722	1.255	1.297
1.112	1.042	1.505	1.179	1.257
1.141	.286	1.394	.826	.923
1.229	1.092	1.154	.915	1.249
1.650	1.745	1.725	1.879	1.732
1.597	1.675	1.685	1.558	1.598
Σ = 8.026	7.174	9.185	7.612	8.056

1. Grand total = 40.053

2. Sum of squared observations = 56.985

3. Sum of squared subgroup totals = 53.848

4. Sum of squared group totals = 53.568

5. Grand total squared and divided by total sample size = 53.475

6. SS total = 56.985 - 53.475 = 3.51

7. SS groups = 53.568 - 53.475 = .093

8. SS subgroup = 53.848 - 53.568 = .28

9. SS within = 56.985 - 53.848 = 3.137

Anova Table

Source of Variation	df	SS	MS	F_s	$F_{.1(1,3)}$
Among groups (stations)	1	.093	.093	≃1.0	5.54
Samplers within stations	3	.28	.093	.74	
Samples within samplers	25	3.137	.125		

No significant difference among stations $.5 < P(F_s = 1.0) < .25$

III. Rate of accrual of Spokane River periphyton

Cell counts (cells/mm^2/day)

	Above	Below
0 - 3 days	73	579
3 - 6 days	-1	25
6 - 9 days	252	-370
$\bar{X}$ =	108	78

Chlorophyll a (μg/cm^2/day)

	Above	Below
0 - 3 days	.272	.085
3 - 6 days	-.226	.164
6 - 9 days	.044	-.165
$\bar{X}$ =	.03	.03

Ash-free dry weight (μg/cm^2/day)

	Above	Below
0 - 3 days	21	30
3 - 6 days	-9	-8
6 - 9 days	-4	-8
$\bar{X}$ =	3	5