Memorandum

TO: Bruce Willey, HDR, Inc.

DATE: **October 8, 2001**

PROJECT: SPOCFP

FROM: Joseph Helfand
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SUBJECT: **DRAFT** Modeling of Dissolved Oxygen in the Spokane River in Response to Effluent from the Proposed Spokane County WWTP

SUMMARY

Limno-Tech, Inc. performed dissolved oxygen water quality modeling using the QUAL2E program to model summer and winter scenarios for a proposed Spokane County WWTP for the design year 2025. A range of effluent concentrations (called Low, Medium, High and Highest, reflecting their impact on dissolved oxygen concentrations) was run for each season.

The model was applied solely to predict the incremental impact of the proposed WWTP on Spokane River dissolved oxygen concentrations. Predictions of absolute dissolved oxygen concentrations requires assumptions regarding the performance of other discharges that can not be defined at this time.

The proposed discharge is expected to have minimal (no more than 0.1 mg/L) effect on wintertime dissolved oxygen concentrations at any location under Low or Medium impact scenarios, and the effect could be as much as 0.22 mg/L under the Highest scenario. Summertime dissolved oxygen concentrations should decrease no more than 0.13 mg/L under Low or Medium impact scenarios, and up to 0.29 mg/L under the Highest scenario.

INTRODUCTION

Spokane County proposes to build a new Waste Water Treatment Plant (WWTP) in the City of Spokane with a design horizon of the year 2025. Among the review requirements of the Washington State Department of Ecology (Ecology) is an assessment of the impact of the plant effluent on dissolved oxygen (DO) levels in the receiving water, the Spokane River. In support of this assessment, Limno-Tech, Inc. (LTI) conducted water quality modeling using the QUAL2E computer program (Brown and Barnwell, 1987), which performs steady-state one-dimensional modeling. The modeling is based on existing QUAL2E modeling developed by Ecology (Pelletier, 1994; Pelletier, 1997) with appropriate adjustments to inputs for the range of design conditions for both summer and winter seasons.

MODEL INPUT ASSUMPTIONS

Designation of Scenarios

In assessing the effluent impacts, it was desired to examine a range of values for each of several effluent parameters, in each of two seasons (summer and winter). In order to have a reasonable number of scenarios to examine, these ranges were grouped according to their expected impact on water quality. A total of 8 scenarios were designated as "Low", "Medium", "High", and "Highest" impact for Summer (May 1 – October 31) and for Winter (November 1 – April 30). A baseline run was done for each season, with the treatment plant removed, to allow the incremental impact of the WWTP to be defined for each scenario.

Model Reaches

The Pelletier model contained four reaches: the 2.8 mile reach from Inland Empire Paper Company to Upriver Dam, the 2.2 mile reach from Upriver to Greene Street, the 3.8 mile reach from Greene Street to Monroe Dam (City Dam), and the 1.4 mile reach below Monroe Dam to the USGS gage location. This model discards the reach above the Upriver Dam and retains the next three reaches. The WWTP discharge is assumed to be at River Mile 78.5, just above Greene Street. Reach hydraulics functions and inflows/outflows remain as in the Pelletier model.

Upstream Flow

Ecology requires that the assessments be done using seasonal 7Q20 upstream flows when the analysis covers separate summer and winter periods. The 7Q20 flow is defined as the discharge at the 20-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days. For seasonal 7Q20s the 7 consecutive day periods are limited to the season of interest.

The 7Q20 flows used for this study are the same as were used for the Pelletier modeling; 623 cfs for summer and 1077 cfs for winter (both at the Spokane Gage). Allowing for inflows and outflows between the gage and the discharge location, the design river flows are calculated to be 593 cfs for summer and 1047 cfs for winter.

Ambient Temperatures

State guidance (Ecology, 2001) recommends using the 90^{th} percentiles of the available data. Spokane River temperature data were compiled from STORET and from data collected at Greene Street. Calculated 90^{th} percentiles were 7.6 ^{o}C for winter and 17.75 ^{o}C for summer, equating to 45.7 ^{o}F for winter and 64.0 ^{o}F for summer.

In-Stream Kinetics

First order decay rates at 20 ^{o}C were assumed to be 0.5/day for ammonia, as in the Pelletier model, and 0.23/day for BOD. The QUAL2E default value was selected for BOD decay, as the Pelletier model used a BOD decay rate defined specifically for the Inland Empire Paper discharge. Temperature correction "theta" factors were 1.08 for ammonia decay and 1.047 for BOD decay. Effective in-stream decay rates for ammonia and BOD were thus, respectively, 0.19/day and 0.13/day in winter and 0.42/day and 0.21/day in summer. The BOD_u/BOD_5 ratio was 1.46.

Effluent Flow and Concentrations

The design flow for 2025, 11.9 MGD (18.4 cfs), was used for all scenarios. Concentration ranges were 2-6 mg/L DO in summer and winter, 5-20 mg/L BOD_5 in summer and 20-30 mg/L in winter, and 1-4 mg/L ammonia nitrogen in summer and 4-20 mg/L in winter.

Summary of Model Inputs

Eight scenarios were used, as described in Table 1. Table 2 summarizes some of the model inputs. Kinetic parameters are as described above, and the upstream DO concentration was assumed to be 90 percent of the temperature-based saturation concentration.

Table 1. Model Scenarios

Scenario	Season	Expected Impact on DO
1	Summer	Low
2	Summer	Medium
3	Summer	High
4	Summer	Highest
5	Winter	Low
6	Winter	Medium
7	Winter	High
8	Winter	Highest

Table 2. Selected Model Inputs

Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Model Input								
Effluent Flow, cfs	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
7Q20 Flow at Gage/Discharge, cfs	623/ 593	623/ 593	623/ 593	623/ 593	1077/ 1047	1077/ 1047	1077/ 1047	1077/ 1047
River Temp., F.	64.0	64.0	64.0	64.0	45.7	45.7	45.7	45.7
Effluent DO, mg/L	6	6	4	2	6	6	4	2
Effluent BOD_5, mg/L	5	10	15	20	20	20	25	30
Effluent NH_3-N, mg/L	1	2	3	4	4	8	14	20

RESULTS

Scenario Outputs

The QUAL2E model was run for each of the eight scenarios described above to simulate conditions with and without the proposed discharge. The primary output parameter of interest is the incremental dissolved oxygen deficit, i.e. the difference in dissolved oxygen between the proposed discharge and no discharge simulations.

Winter

The winter scenarios feature a higher 7Q20 flow and low ammonia and BOD decay rates. Therefore, impacts for each scenario were lower than for the corresponding summer scenario. In particular, the Low and Medium winter scenarios showed minimal impacts of no more than 0.1 mg/L. The initial impact from entry of the low-DO concentration effluent into the river ranged from 0.06 to 0.13 mg/L across the four scenarios. BOD and ammonia decay then cause a steady increase in the impact down to Monroe Dam. Above the dam, impacts ranged from 0.09 to 0.22 mg/L across the four scenarios.

Summer

The summer scenarios have a lower 7Q20 flow and higher ammonia and BOD decay rates. Therefore, impacts for each scenario were higher than for the corresponding winter

scenario. The Low and Medium summer scenarios showed impacts of up to 0.13 mg/L. The initial impact from entry of the low-DO concentration effluent into the river ranged from 0.07 to 0.19 mg/L across the four scenarios. Above the Monroe Dam, impacts ranged from 0.08 to 0.29 mg/L.

Summary

Results for both critical locations for each scenario are summarized in Table 3. A plot of DO-decrease vs. river mile downstream of Upriver Dam is shown in Figure 1 for Scenario 2 (Summer-Medium Impact). Figure 2 shows a similar plot for Scenario 6 (Winter-Medium Impact).

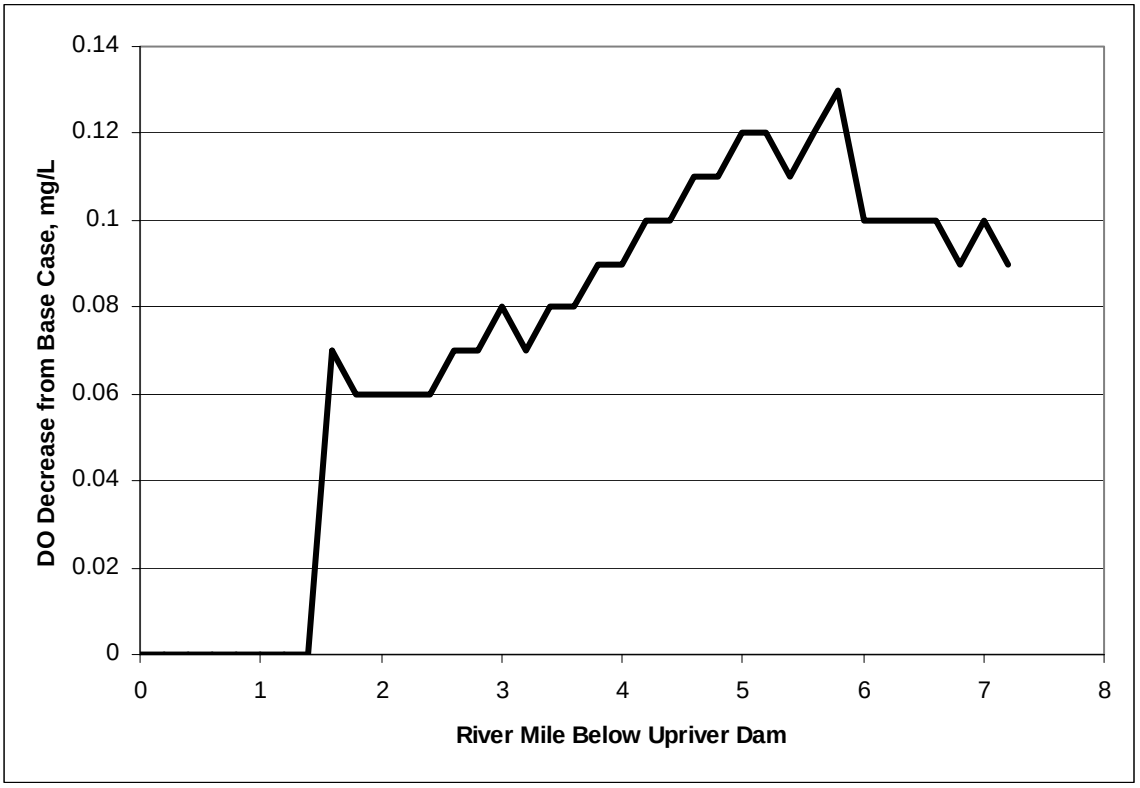

Figure 1. Scenario 2, Incremental Dissolved Oxygen Decrease vs. River Mile

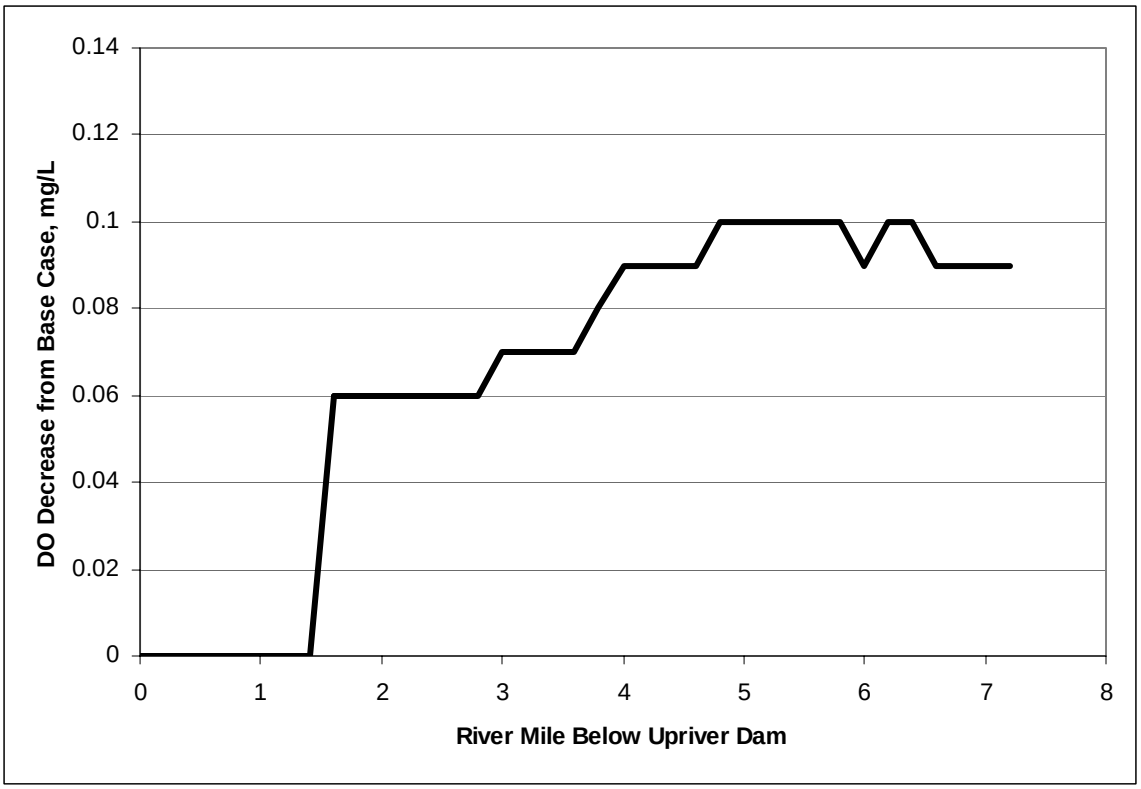

Figure 2. Scenario 6, Incremental Dissolved Oxygen Decrease vs. River Mile

Table 3. Scenario Results at Critical Points

Scenario	Initial DO Decrease, mg/L	DO Decrease at Monroe Dam, mg/L
1	0.07	0.08
2	0.07	0.13
3	0.13	0.21
4	0.19	0.29
5	0.06	0.09
6	0.06	0.10
7	0.09	0.16
8	0.13	0.22

CONCLUSIONS

- Winter-season DO levels in the Spokane River will only be impacted up to 0.1 mg/L under the Medium scenario.

- Summer-season DO levels in the Spokane River will only be impacted up to 0.13 mg/L under the Medium scenario.

- There are two critical points in the river for decreased DO: 1) at the discharge location and, 2) just above Monroe Dam. The primary source of the deficit at the first location is low DO in the effluent. The primary source of the deficit at the second location is BOD and ammonia in the effluent.

REFERENCES

Brown, L. C. and Barnwell, T. O. "The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual", EPA/600/3-87/007, May, 1987.

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