Hudson River PCBs Superfund Site

Phase 1 Final Design Report

Attachment G - Assessment of Flow Necessary in the East Channel of the Hudson River at Rogers Island to Meet Water Quality Standards

Prepared for:

General Electric Company

Albany, NY

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Quantitative Environmental Analysis, LLC

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SECTION 1
BACKGROUND

To facilitate dredging in the East Channel at Rogers Island, river flow may be diverted to the West Channel, creating a near-stagnant condition in the East Channel. The Washington County SD#2 Waste Water Treatment Plant (WWTP) discharges to the East Channel and the organic matter in its discharge consumes oxygen as it degrades in the river. A certain minimum water flow must be maintained in the East Channel to ensure that the dissolved oxygen (DO) in the channel is maintained above the New York State (NYS) standard of 5 milligrams per liter (mg/L) and ammonia is maintained below the temperature and pH dependent NYS standard (NYSCRR Title 6, Chapter 10, Part 703). A conservative limit of 1.4 mg NH_3/L (1.2 mg-N/L) was assumed, as described is Section 4.5. Approximately 0.3 to 0.6 cubic meter per second (m^3/s) of flow is provided by Bond Creek, which enters the East Channel just upstream of the WWTP. A simple DO modeling analysis was conducted to estimate the additional flow needed to meet the DO standard, while a simple mass balance was conducted to determine the additional flow needed to meet the ammonia standard. The additional flow would be provided by allowing flow to enter the East Channel at the diversion structure constructed at the northern end of the channel.

SECTION 2
APPROACH FOR DO MODELING

2.1 EQUATIONS

The conventional one-dimensional DO deficit model was applied to the East Channel from the WWTP to the confluence of the East and West Channels at the southern end of Rogers Island. This model computes DO deficit (D; the difference between DO saturation, c_s, and DO concentration, c) as follows:

$$D = \left\{ \frac{K_d L_0}{K_a - K_d} \left(e^{-K_d \frac{x}{u}} - e^{-K_a \frac{x}{u}} \right) + \frac{S}{K_a h} \left(1 - e^{-K_a \frac{x}{u}} \right) + D_0 e^{-K_a \frac{x}{u}} \right. \qquad (2\text{-}1)$$

in which:

D	=	DO deficit x meters downstream of the WWTP (mg/L)
K_d	=	BOD decay rate (d^{-1})
K_a	=	reaeration rate (d^{-1})
L_0	=	initial BOD in the river (mg/L)
S	=	SOD (g/m^2-d)
h	=	water depth (m)
D_0	=	initial DO deficit (mg/L)
x	=	distance downstream of the WWTP (m)
u	=	river velocity (m/d)

The initial biological oxygen demand (BOD) in the river is calculated from the BOD load discharged by the WWTP and the flow in the river:

$$L_0 = \frac{W}{Q} \qquad (2\text{-}2)$$

in which:

W = BOD load from the WWTP (g/d)

Q = river flow (m^3/d)

The reaeration rate is calculated by the O'Connor-Dobbins equation:

$$K_a = \frac{K_L}{h} \tag{2-3}$$

where:

$$K_L = \sqrt{\frac{D_L u}{h}} \tag{2-4}$$

and:

D_L = diffusivity of oxygen in water (1.8×10^{-4} m^2/d @ 20^oC)

K_L = mass transfer coefficient for oxygen at the air-water interface (m/d)

The minimum value of K_L at low velocity is about 0.6 to 1 meter per day (m/d) (Thomann and Mueller, 1987). If the value calculated using Equation 2-3 is less than 0.6 m/d, then 0.6 m/d was used in the model.

2.2 BOD LOAD FROM THE WWTP

The data for the Washington County SD#2 WWTP (National Pollutant Discharge Elimination System [NPDES] Permit #NY0183695) extracted from the United States Environmental Protection Agency's (EPA's) Envirofacts website are shown in Table G-1, below. Values were averaged based on the report for monitoring the effluent gross value.

Table G-1. Washington County SD#2 WWTP Effluent Data (NPDES ID# NY0183695)

Limits	BOD (lbs/d)	BOD (mg/L)	TSS (lbs/d)	TSS (mg/L)	FLOW (MGD)
Average Limit	626	30	626	30	2.5
Maximum Limit	938	45	938	45	-

12/1/2003 - 9/30/2005	BOD (lbs/d)	BOD (mg/L)	TSS (lbs/d)	TSS (mg/L)	FLOW (MGD)
Mean	323	16.5	175	9.2	2.3
Maximum	1758	82	796	34.9	-

May - Nov. (2004 & 2005)	BOD (lbs/d)	BOD (mg/L)	TSS (lbs/d)	TSS (mg/L)	FLOW (MGD)
Mean	290.4	16	140.2	7.7	2.3
Maximum	698	31.3	447	15.1	-

Notes: For the parameters above, mean values are mean 30-day averages for the time period given and maximum values are maximum 7-day averages over the time period given. BOD was tested with a 5-day incubation period at 20^{o}C without nitrification inhibition.

Acronyms:
lbs/d = pounds per day
MGD = million gallons per day
^{o}C = degrees Celsius

The maximum BOD load for the May to November period (698 lbs/d) was used in the model along with a flow of 2.3 MGD. To account for the difference between ultimate BOD and the 5-day BOD on which the load is based, the BOD load was multiplied by two.

2.3 BOD DECAY RATE (KD)

The decay rate of BOD discharged by a secondary WWTP typically is on the order of 0.1/d. A reasonably conservative value that would maximize oxygen demand in the river of 0.15/d was used in the modeling. BOD loss due to settling was not considered; a conservative assumption that also maximizes oxygen demand in the river.

2.4 SEDIMENT OXYGEN DEMAND

The sediment oxygen demand (SOD) in a river like the Upper Hudson that does not receive large inputs of particulate organic matter from waste discharges is likely to be in the range of 0.2 to 1 g/m^2-d (reference). DO measurements at Rogers Island and Thompson Island Dam conducted by GE as part of the Baseline Monitoring Program (BMP) indicate that the river remains at or near DO saturation throughout the year. This finding suggests that the SOD is relatively low. A value of 0.5 g/m^2-d was used in the model as a conservatively high estimate.

2.5 EAST CHANNEL GEOMETRY

The East Channel between the WWTP and the confluence with the West Channel averages about 80 meters (m) wide, 3 m deep, and 750 m long.

2.6 RIVER FLOW, TEMPERATURE, DO SATURATION, AND INITIAL DEFICIT

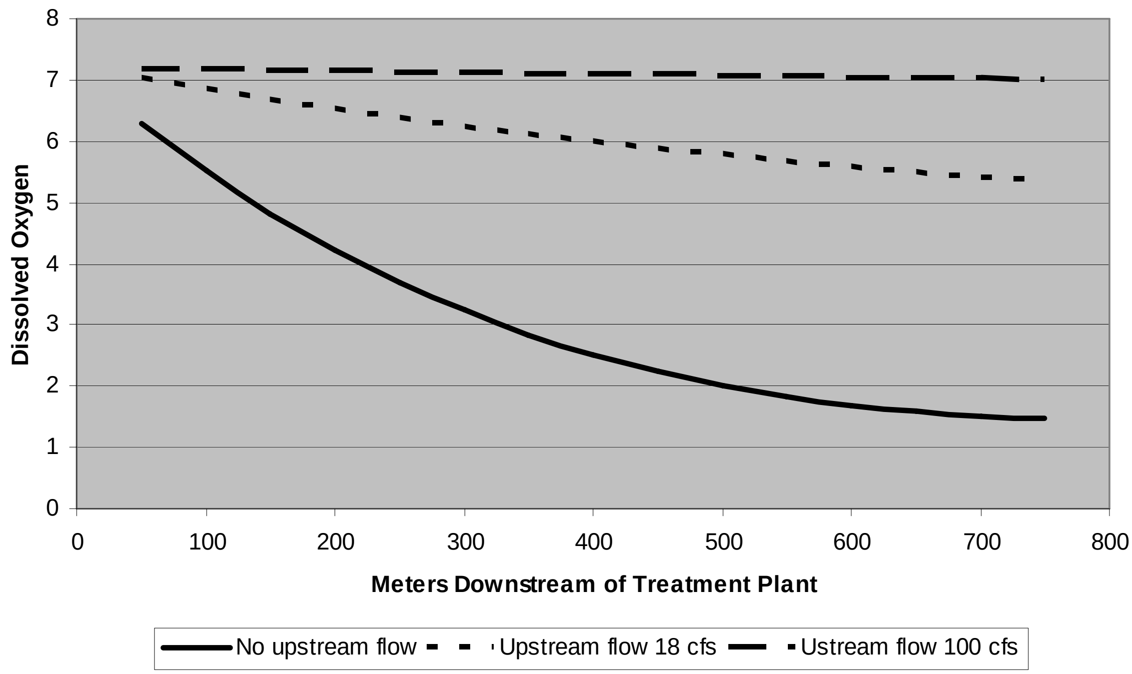
The base flow in the East Channel if the entire flow of the Hudson was diverted to the West Channel was assumed to be 0.4 cubic meter per second (m^3/s) (0.3 m^3/s from Bond Creek and 0.1 m^3/s [2.3 MGD] from the WWTP). The BMP has found that water temperature peaks from late July to early August at about 25 to 26 ^oC. A value of 26^oC was used in the model to specify a DO saturation of 8.1 mg/L.

Under present conditions at Rogers Island, the DO deficit is approximately zero. Under the stagnant conditions that would occur with a complete flow diversion, a deficit would occur upstream of Bond Creek due to the background SOD. At an SOD of 0.5 g/m^2-d and a reaeration mass transfer coefficient of 0.6 m/d, a deficit of about 0.8 mg/L would result. To be conservative, an initial deficit of 1 mg/L was assumed.

SECTION 3
DO MODEL RESULTS

The model indicates that with no flow in the East Channel other than that provided by Bond Creek and the WWTP, the summertime critical DO condition (i.e., maximum temperature condition) will result in DO values below the NYS standard (Figure G-1). To keep the DO above 5 mg/L requires an upstream flow of about 0.5 m^3/s (18 cubic feet per second [cfs]). An upstream flow of about 2.8 m^3/s (100 cfs), which is the basis of design (see Section 5), will keep the DO above 7 mg/L.

Figure G-1. Summer-Critical DO Profile in East Channel Rogers Island



SECTION 4
APPROACH FOR AMMONIA MASS BALANCE

4.1 EQUATION

The ammonia concentration in the East Channel at Rogers Island was computed using the following mass balance equation:

$$(Q_u + Q_e)c_d = Q_u c_u + Q_e c_e \tag{4-1}$$

in which:

Q_u = river flow upstream of the WWTP (m^3/d)

Q_e = flow from the WWTP (m^3/d)

c_d = ammonia concentration in the river downstream of the WWTP (mg-N/L)

c_u = ammonia concentration in the river upstream of the WWTP (mg-N/L)

c_e = ammonia concentration in the WWTP effluent (mg-N/L)

4.2 WWTP EFFLUENT AMMONIA

The data for the Washington County SD#2 WWTP (NPDES Permit #NY0183695) extracted from the EPA's Envirofacts website are shown in Table G-2, below.

Table G-2. NH_3 Concentration at Washington County SD#2 WWTP

Collection Date	Ammonia Concentration (mg-N/L)
31-Aug-05	12
31-May-05	6
28-Feb-05	21
30-Nov-04	19
31-Aug-04	15
31-May-04	28
29-Feb-04	12

The highest value on record of 28 mg-N/L was used in the mass balance calculation, for c_e.

4.3 UPSTREAM RIVER AMMONIA

Ammonia concentration in the river was estimated from Total Kjeldhal Nitrogen (TKN) concentration measured at Rogers Island as part of the BMP. TKN concentrations range from < 0.1 to 1 mg/L, with an average of 0.36 mg/L (assuming half the detection limit for non-detect values). Ammonia typically is a minor fraction of TKN accounting for about 10 to 20% with a maximum of about 50%. For the mass balance calculation, the upstream ammonia concentration (c_u) was assumed to be 0.2 mg/L. For comparison, Lampman et al. (1999) measured ammonia concentrations in the Lower Hudson at Albany of about 0.14 mg/L (10 uM).

4.4 WWTP EFFLUENT FLOW

The permit limit flow of 2.5 MGD (see Table G-1) was used in the mass balance calculation for Q_e.

4.5 NYS AMMONIA STANDARD

The ammonia standard is pH independent below pH 7.75. The pH in the Upper Hudson River ranges between 7 and 8, with an average value of about 7.5, so pH variation was not considered. The standard decreases with increasing temperature. At the maximum river temperature of 26^oC, the standard is 1.4 mg NH_3/L (1.2 mg-N/L). This value is substituted for c_d in Equation 4-1.

SECTION 5
AMMONIA MASS BALANCE RESULTS

Applying Equation 4-1, substituting the ammonia standard for c_d, 0.2 mg/L for c_u, 28 mg/L for c_e, and 0.11 m^3/s (2.5 MGD) for Q_e results in a required upstream flow (Q_u) of 2.7 m^3/s (95 cfs). Assuming that 0.3 m^3/s (10 cfs) is provided by Bond Creek, 2.4 m^3/s (85 cfs) would have to be provided through the diversion at the northern end of the East Channel to ensure that the NYS ammonia standard is not violated. Therefore, the basis of design for the flow through the diversion wall is 2.8 m^3/s (100 cfs). At this flow, the DO is calculated to remain above about 7 mg/L.

SECTION 6
REFERENCES

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