Introduction

The following comments concern a mathematical model for dissolved oxygen concentrations in the Lower Fox River. This particular model was developed by Quirk, Lawler, and Matusky for the State of Wisconsin, Department of Natural Resources. The work was done under Institute general support (Project 2786).

Computer Program

The main program and subroutines given in the text of the report were run on the IBM 360, Model 44 computer. The program did not work and the following errors were found and corrected.

1. All statements containing real and subscript D0 ("dee oh") variable indicated the error, "Multidefined Name." Therefore, the variable D0 was changed to variable DO ("dee zero") in all of the more than 600 statements of the program.

2. The statement "WRITE (OPN, 316)" in the section of Mixing Reach just after statement number 311 had an error. The digit 1 appearing in the third line of this "WRITE" statement in column No. 6 was changed to digit 2.

After making these corrections, the program was run with the input data as listed in the report. The output of the program obtained did not agree with the output results given in the report.

(1) Development of a Computerized Mathematical System Model of the Lower Fox River from Lake Winnebago to Green Bay -- August 1969.
The detailed descriptions of four functions "FKR," "DFT," "FOFQ" and "FK3" used in this report are also given in this report with their corresponding notations of various variables. A summary of notation of the most frequently used variables is also enclosed here.

Model Sensitivity:

According to Q.L.M., the model is most sensitive to following factors:

1. Quantity of waste discharged (WL)
2. Ratio of 5 day to ultimate BOD (K₁)
3. Algal photosynthesis rate (P)
4. Sludge deposit uptake (K₉)

Sensitivity analysis reportedly showed that river flow, temperature and BOD removal rates are of secondary importance. If waste load reductions are made, the model becomes less sensitive to total waste and more sensitive to nitrification, sludge uptake, and initial BOD.

DISCUSSION AND FUTURE PLANS

Much work needs to be done to find the sensitivity of the model to the actual values of parameters which were selected by Q.L.M. This work would involve computer runs and analysis of computed results. It is noteworthy that there are qualitative conclusions in the Q.L.M report, but not a tabulation of actual sensitivities to the many particular parameters which are used. The detailed calculation and interpretation required for such a complex model would take considerable effort, but would result in definite information as to the change in profiles which could be possible with certain changes in
Number of Survey Samples Less Than 2 ppm Dissolved Oxygen

(Lower Values Denote Higher Oxygen Levels)

Flambeau

Lower Fox

Oconto

Wisconsin
A. FUNCTION FKR (XMI, XKD, Q)

"Compute BOD Removal and Deoxygenation Rates"

FKR = \(K_R\) = Unit rate of BOD removal, % per day

XMI = \(X\) = River mile points, miles

XKD = \(K_d\) = Unit rate of deoxygenation, % per day

Q = River flow rate, cubic feet per second

The values of \(K_d\) and \(K_r\) are given as follows as a function of Q and X:

1. \(X \geq 38.63\)
   
   STOP

2. \(38.63 > X \geq 30.80\)  
   (Section Nos. 1-13)
   
   (a) \(Q \geq 4000\)
   
   \(K_r = 0.50\)

   \(K_d = K_r\)

   (b) \(Q < 4000\)

   \(K_r = (0.05/1000) \times Q\)

   \(K_d = K_r\)

3. \(30.80 > X \geq 25.60\)  
   (Section Nos. 14-19)
   
   (a) \(Q \geq 5000\)

   \(K_r = 0.70\)

   \(K_d = K_r\)
7. $X < 0.0$

STOP

B. FUNCTION DFT (D1, XK2T, T, XKDT, XILU, XKRT, F, XKST, RH, XKNTD, WNO, R, P1, AP, T1, DFT1, DFT2, DFT3, DFT4, DFT5, DFTA, DFTB)

"Compute Dissolved Oxygen Deficit"

$DFT = D = \text{Dissolved oxygen deficit at anytime, ppm}$

$D1 = D_0 = \text{Initial dissolved oxygen deficit, ppm}$

$XK2T = K_2 = \text{Atmospheric reaeration rate constant at } T^\circ \text{C}$

$T = t = \text{Time of travel}$

$XKDT = K_d = \text{Deoxygenation rate constant at } T^\circ \text{C}$

$XILU = L_o = \text{Initial ultimate BOD in any reach, ppm}$

$XKRT = K_r = \text{BOD removal rate constant at } T^\circ \text{C}$

$F = f = \text{Percentage of the river bottom in any reach covered by sludge deposits}$

$XKST = K_s = \text{Sludge deposit uptake rate constant at } T^\circ \text{C}$

$RH = R_h = \text{Hydraulic radius, feet}$

$XKNTD = K_n = \text{Nitrification rate constant at } T^\circ \text{C}$

$WNO = N_o = \text{Initial total oxidizable nitrogen in any reach, ppm per day}$

$R = R_a = \text{Unit rate of algal respiration, ppm per day}$

$P1 = P_m = \text{Maximum rate of algal photosynthesis, ppm per day}$

$AP = P = \text{Unit rate of algal photosynthesis, ppm per day}$

$T1 = t' = \text{Clock time}$

$DFT = (DFTB) + (DFT5) = (DFTA) + (DFT5) = (DFT1 + DFT2 + DFT3 + DFT4)$

$+ (DFT5)$
C. FUNCTION FOFQ (Q)

"Compute Constant for De Pere Dam Aeration"

FOFQ = \( f \) = Transfer function

Q = River flow rate, cubic feet per second

1. \( Q \geq 2500 \)
   \( f = 0.30 \)

2. \( 2500 > Q > 1500 \)
   \( f = 3.55 - 0.0013 \times Q \)

3. \( Q \leq 1500 \)
   \( f = 1.50 \)

D. FUNCTION FKN (DO)

"Compute Coefficient of Nitrogenous Oxygen Demand"

FKN = \( R_{N,T} \) = Rate of nitrification, (% of maximum)

DO = Dissolved Oxygen concentration, mg. per litre

1. \( DO > 9.20 \)
   \( R_{N,T} = 100.00 \)

2. \( 9.20 \geq DO > 6.50 \)
   \( R_{N,T} = 89.7778 + 1.1111 \times DO \)

3. \( 6.50 \geq DO > 4.60 \)
   \( R_{N,T} = 73.7368 + 3.57895 \times DO \)

4. \( 4.60 \geq DO > 3.40 \)
   \( R_{N,T} = 60.6833 + 6.41667 \times DO \)

5. \( 3.40 \geq DO > 2.10 \)
   \( R_{N,T} = 48.2385 + 10.0769 \times DO \)

6. \( 2.10 \geq DO > 1.0 \)
Atmospheric Reaeration and Nitrogen Concentrations Relationship

\[ XK2T = K_2 = \text{Atmospheric reaeration coefficient} \]

\[ WN = \text{Nitrogen loadings, lb. per day} \]

\[ WNO = N_o = \text{Nitrogen concentrations, ppm} \]

\[ Q = \text{River flow rate, cubic feet per second} \]

\[ THK2 = \theta = \text{Temperature constant of reaeration coefficient} \]

A. Section Nos. 1-3 (Neenah Channel)

\[ K_2 = 12.96 \left( 0.457 \frac{Q}{W} \right)^{0.5} \theta \]

\[ N_o = \frac{WN}{(0.457) (5.4Q)} \]

B. Section Nos. 4-6 (Menasha Channel)

\[ K_2 = 12.96 \left( 0.543 \frac{Q}{W} \right)^{0.5} \theta \]

\[ N_o = \frac{WN}{(0.543) (5.4Q)} \]

C. Section Nos. 7-45

\[ K_2 = 12.96 \left( \frac{Q}{W} \right)^{0.5} \theta \]

\[ N_o = \frac{WN}{(5.4Q)} \]

Ultimate BOD and Detention Time Relationship

\[ XIBOD = \text{Initial 5-day BOD at Neenah Dam} = 6.0 \text{ ppm} \]

\[ XIL5 = \text{Initial 5-day BOD for each reach} \]

\[ XILU = \text{Ultimate BOD for each reach} \]

\[ T = \text{Detention time of each reach} \]

\[ WL = \text{Waste loadings, lb. BOD}_5 \text{ per day} \]

\[ Q = \text{River Flow Rate} = 1127 \text{ Cubic feet per second} \]

\[ XK1 = K_1 = \text{Ratio of 5-day BOD to the ultimate BOD} \]

\[ V = \text{Volume of section, in million cubic feet} \]

Neenah Channel

\[ XIL5 = XIBOD + \frac{WL}{(0.457) (5.4Q)} \]
OBJECTIVE: To develop computer simulation and systems analysis of pulp and papermaking technology. First objective was the simulation and study of the IPC webformer for use in the process control course.

BUDGET: None

SCHEDULE: None

SUMMARY OF RESULTS AND PLANS FOR FUTURE WORK:

None. This was a limited-budget Institute project, and due to the press of other affairs was never carried beyond its initial stages except for maintaining a literature file on the subject of simulation models in the industry.