OFFICE MEMO

TO: Parviz Nader	**DATE:** 11/19/01
FROM: Ganesh Pandey	**SUBJECT:** **Implementation of DOC Growth Module in DSM2-QUAL**

Background

The Municipal Water Quality Investigations (MWQI) Program of DWR conducted field experiments to determine the changes in DOC (dissolved organic carbon) concentrations due to water contact with peat soil. Based on these experimental findings, Jung (2001) proposed a set of logistic type equations to characterize the increase or "growth" of DOC on flooded Delta islands due to peat soil leaching and microbial decay. Due to concerns about disinfection byproduct formation during drinking water treatment, the Delta Wetlands Water Quality Management Plan restricts the amount of DOC impact at urban diversions resulting from Delta island storage releases. This restriction has created the need to assess impacts at urban diversion due to DOC growth on the flooded islands. This report summarizes the methodology used to implement Jung's proposed logistic equations in DSM2-QUAL.

Logistic Equation

The logistic equation proposed to simulate the concentration of DOC in flooded Delta islands due to initial concentration and growth is expressed as:

$$Y(t) = \frac{A}{1 + Be^{-kt}} \qquad (1)$$

where Y(t) represents the DOC concentration in mg/l at time t, "A" represents the maximum DOC concentration in mg/l, "k" is the growth rate in $days^{-1}$, and "t" is the water storage duration in days. "B" is a dimensionless parameter that is calculated from the initial DOC concentration. The values of "A" and "k" depend on reservoir specific characteristics, such as type and depth of the peat soil, antecedent flooding conditions, temperature, etc.

The magnitude of "B" is calculated by DSM2-QUAL. When t=0, Equation (1) simplifies to C_0 = A / (1+B), where C_0 is the initial DOC concentration of the water diverted to the reservoir. The value of C_0 is dynamically determined in DSM2. Knowing the values of C_0 and "A", the value of "B" can be computed. During the filling period, exchange of mass between peat soil and water body takes place starting with the first parcel of water entering the reservoir. Because the filling process is not instantaneous, the diversion water concentration changes over time. Thus, two aspects of DOC concentration change must be accounted for: (1) growth of DOC due to peat soil interactions and (2) conservative mixing of channel diversion water in the reservoir. The first aspect usually represents a gradual change, whereas the second aspect can potentially be an abrupt change, especially if the diversion water quality is highly variable. In order to model both aspects, "B" is adjusted each time step to account for the changes in DOC due to channel diversions. Once a filling cycle is completed, conservative mixing ends and "B" is held constant. During a draining cycle, "B" is held constant.

Depth Adjustment

All model parameters (A, B, and k) are specified with respect to a given reference depth which is currently set at 2 feet. To adjust DOC growth for varying water depths, Jung (2001) recommends an inverse power law transformation, as shown in Equation (2):

$$y_d = y_2 \left(\frac{2}{d} \right)^{1.01} \qquad (2)$$

where y_d is the adjusted DOC concentration, y_2 is the DOC concentration per Equation (1) with model parameters based on a 2 feet water depth, and d is the actual water depth. During the first phase of model implementation, the water depth dynamically calculated in DSM2 was used to represent "d". However, it was discovered that during the early stages of the filling cycles, very low water depths resulted in unreasonably high DOC adjustments. As a possible remedy, "d" was set equal to the maximum water depth during each filling cycle. Maximum water depth is computed by the model; however, its value is not known until the end of each filling cycle. To work around this problem, a default value of 15 feet is used for "d" during the filling cycle until the actual water depth exceeds the default value. Once the default value is exceeded, the dynamically calculated value is used in Equation (2).

Timing of Filling and Draining

During each filling and draining cycle, it is assumed that the exchange of mass between peat soil and water body takes place immediately after the arrival of the first parcel of water. The value of t in Equation (1) must be initialized at the beginning of each filling cycle. Initiation of a filling cycle is defined by the diversion rate – the filling cycle begins when the diversion rate exceeds a certain default flow rate (currently set at 100 cfs). The DOC growth contribution from Equation (1) is curtailed once the storage depth becomes smaller than a minimum specified depth, currently set at 1.5 feet.

Results Using a Test Case

The DOC growth module was first tested within DSM2 utilizing a Delta Wetlands operations study (Mierzwa, 2001). In this study, Webb Tract and Bacon Island were used as storage reservoirs. In past efforts, the DOC concentration of island releases was predetermined using a "book-end" approach, with 6 mg/l as the lower limit and 30 mg/l as the upper limit. With the new DOC growth module, island release water quality is dynamically computed. Two model scenarios were conducted. In Scenario 1, the return quality was determined using the newly developed DOC module. Table 1 shows the model parameters used in Scenario 1. In Scenario 2, DOC was modeled as a conservative substance with no growth within the reservoirs. Differences between the two scenarios can be attributed to the growth term incorporated in the DOC module.

Table 1- DOC Module Input Parameters for Scenario 1

Storage Reservoir	A (mg/l)	k ($days^{-1}$)	Minimum Depth (ft)

Webb Tract	217	0.0216	1.5
Bacon Island	107	0.0256	1.5

Figure 1 compares the predicted DOC concentrations in the Webb Tract reservoir for the two scenarios for the period covering January 1979 to September 1981. The water exchange is also shown on the same plot. Model results follow the same path in the first filling cycle. Once the filling cycle is completed in March 1979, predicted values quickly diverge, illustrating the growth of DOC. The largest differences occur right before the beginning of the next filling cycle. Model results converge again with the start of a new filling cycle. The convergence and divergence cycles continue throughout the simulation period consistent with the operation schedule for the filling cycle. The peak DOC concentration in Scenario 1 approaches the value of "A", adjusted for depth using Equation (2).

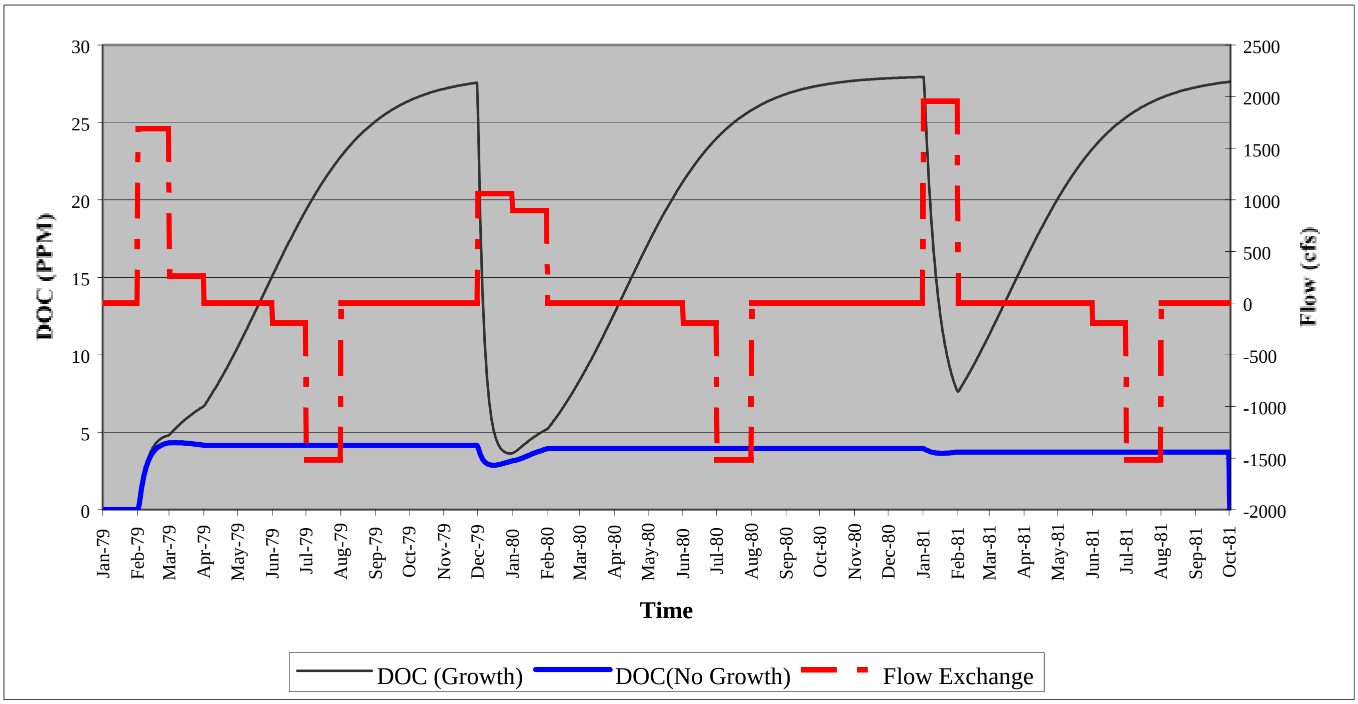

Figure 1: Time series plots of DOC concentrations and flow exchange on Webb Tract. The positive and negative flow values indicate filling and draining cycles, respectively.

Figure 2 shows a similar comparison of the predicted channel DOC values near the Webb Tract reservoir release site. Model results correctly predict that the DOC concentrations during the filling and storage cycles are very similar. The model results then diverge with the start of a draining cycle. The model results then start merging one to two months after the end of the draining cycle.

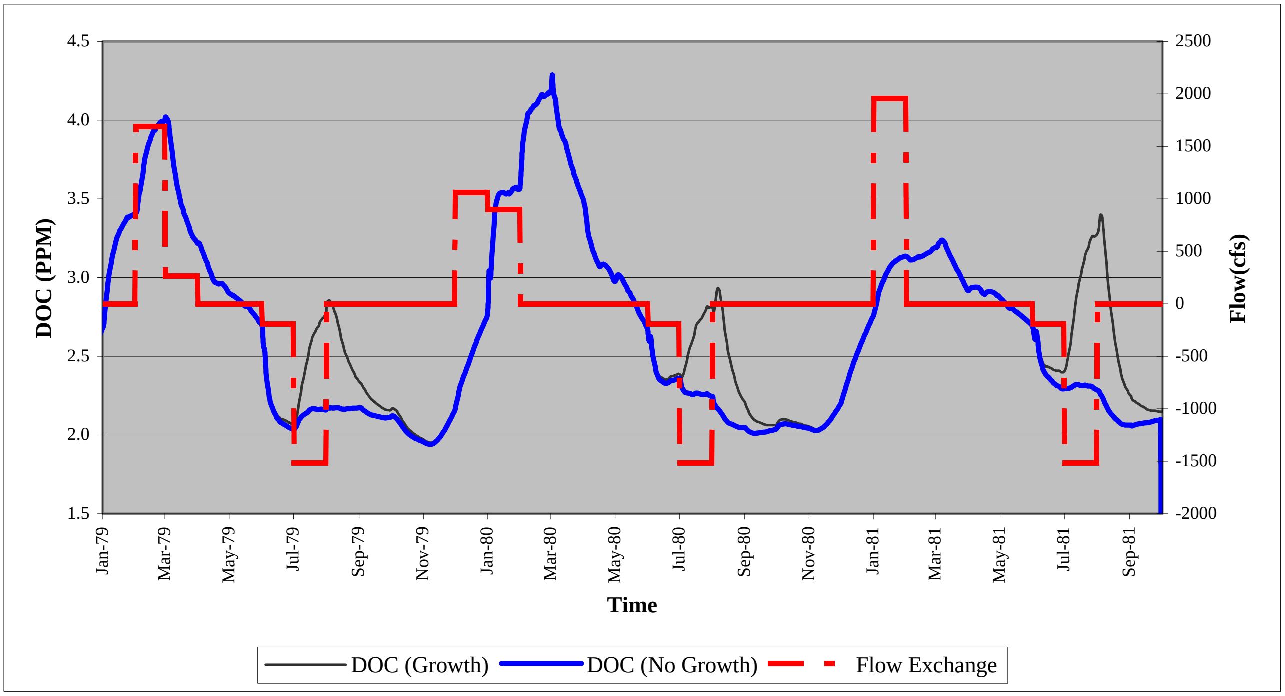

Figure 2: Time series plots of the variations in DOC concentrations at San Joaquin River near Mokelumne River junction and flow exchange at Webb Tract. The positive and negative flow values indicate filling and draining cycles, respectively.

Summary

Marvin Jung proposed a governing logistic equation for the growth of DOC in the storage reservoirs. See Equations (1) and (2). These equations were implemented dynamically into DSM2-QUAL. The algorithm requires three input variables from the user. A test case was carried out assuming two islands as storage reservoirs. The test case showed that the model was behaving as expected, and the DOC growth in the islands were consistent with Marvin Jung's algorithm. The changes in the DOC concentrations in the reservoir and channels appear to be consistent and reasonable.

References

1. Jung, Marvin (2001), "Consultants Report to the Department of Water Resources In-Delta Storage Investigations Program, Executive Summary", MWQI, California Department of Water Resources, Sacramento, CA.
2. Mierzwa, Michael (2001) "Delta Wetlands DSM2 CALSIM Studies", Presentation to In-Delta Storage Water Quality Stakeholder, October 30, Delta Modeling Section, California Department of Water Resources, Sacramento, CA.