Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 9:
Implementation of DOC Growth in DSM2-QUAL

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9 Implementation of DOC Growth in DSM2-QUAL

9.1 Background

The Municipal Water Quality Investigations (MWQI) Program of DWR conducted field experiments to determine the changes in dissolved organic carbon (DOC) concentrations due to water contact with peat soil. Based on the experimental findings, Jung (2001) proposed a set of logistic type equations to characterize the growth of DOC on a flooded Delta island. The proposed set of equations primarily account for the amount of DOC coming out of peat soil due to leaching and microbial decay. The water on a flooded island, which has a higher DOC content due to growth, would be released back into the Delta. Much of this released water would eventually find its way to urban diversion. Due to formation of disinfection byproducts during the drinking water treatment process, the Delta Wetlands Water Quality Management Plan restricts the amount of DOC impact due to in-Delta storage reservoir releases. This has created the need to assess the impact of DOC increases at urban diversion due to increased DOC on the flooded islands. This chapter summarizes the methodology used to implement the logistic equations in the DSM2-QUAL and describes the results used to verify the validity of the implemented algorithm.

9.2 Implementation Detail

9.2.1 Logistic Equation

The logistic equation proposed to simulate the concentration of DOC in the stored water due to initial concentration and growth is expressed as (Jung, 2001):

$$Y(t) = \frac{A}{1 + Be^{-kt}} \qquad \text{[Eqn. 9-1]}$$

in which 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 constants "A" and "k" depend on reservoir specific characteristics, such as type and depth of the peat soil, antecedent flooding conditions, temperature, etc. Thus they are considered as input variables in the formulation. See Jung (2001) for details.

The magnitude of "B" is dictated by the concentration of the incoming water and is internally determined within the DSM2-QUAL. With t=0, Equation (1) leads to C_0=A/(1+B), where C_0 is the initial DOC concentration of the water diverted to the island. The value of C_0 is dynamically determined in DSM2. Knowing the value of C_0 and "A", the value of "B" can be determined. During the filling period, the exchange of mass between peat soil and water body takes place, starting with the first parcel of water entering the reservoir. The filling process is not instantaneous however. This means that the concentration of the diverted water keeps on changing over the filling period. Thus, during the filling of the reservoir, two aspects of DOC concentration changes must be accounted for: (1) the growth of DOC as governed by Equation 9-1, and (2) conservative mixing of water diverted from the channel into the reservoir. The first aspect usually represents a gradual change, whereas the second can potentially be an abrupt change, especially if the quality of the diverted water is highly variable. In order to model both aspects, the constant "B" is adjusted dynamically each time step to account for the changes in DOC due to channel diversions. Once filling has been completed, no more conservative mixing takes place and "B" is held constant. During the draining period, no changes to "B" are necessary.

9.2.2 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 find the other depth of the stored water, the results from Equation 9-1 need to be adjusted for depth. To adjust DOC growth for varying water depths, Jung (2001) recommends an inverse power law transformation, as shown in Equation 9-2:

$$y_d = y_2 \left(\frac{2}{d} \right)^{1.01} \qquad \text{[Eqn. 9-2]}$$

in which y_d is the adjusted DOC concentration, y_2 is the DOC concentration per Equation 9-1 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 dynamically calculated water depth was used to represent "d". However, it was discovered that during the early cycles for the filling, very low water depths could lead to unreasonably high DOC adjustments. As a possible remedy, it was decided to set "d" equal to the maximum water depth during each filling cycle. However, the maximum water depth, which is computed by the model, is not known until the filling cycle has been completed. 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 9-2.

9.2.3 Timing of Filling and Draining

During each cycle of filling and draining, it is assumed that the exchange of mass between peat soil and water takes place immediately after the arrival of the first parcel of water. The value of t in Equation 9-1 must be initialized at the beginning of each filling cycle. To avoid ambiguities, it was decided that a filling cycle was initiated when the rate of inflow exceeds a certain default flow rate (currently set at 100 cfs). It was also decided to stop the growth contribution from Equation 9-1 once the depth becomes smaller than a minimum specified depth, currently set at 1.5 feet.

9.3 Results

The DOC module was first tested with the Delta Wetland Project (Mierzwa, 2001). In this study, Webb Tract and Bacon Island were used as storage reservoirs. In past efforts, the DOC concentration of the water returned to the river was predetermined using a "book-end" (upper and lower limit) approach. With the new DOC module, these values are dynamically determined. The operation schedule was specified as monthly varying. Two model runs were conducted. In the first run, the return quality was determined using the newly developed DOC module. Table 9.1 shows the model parameters used in the first run. In the second run, DOC was modeled as a conservative substance. Any difference between these two runs can be attributed to the growth term incorporated in the DOC module.

Table 9.1: DOC Model Input Parameters.

Island Resevoir	**A (mg/l)**	**k**	**Min. Depth (ft) to trigger a stop in DOC growth**
Webb Tract	217	0.0216	1.5
Bacon Island	107	0.0256	1.5

Figure 9.1 shows a comparison between the predicted DOC concentrations in the Webb Tract for the two runs for the period covering January 1979 to September 1981. The water exchange is also shown on the same plot (with diversions shown as positive flows onto the island and the releases as negative flows leaving the island). 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 in the first run. The largest differences occur right before the beginning of the next filling cycle. Model results appear to converge again with the start of the new filling cycle. The convergence and divergence cycles continue throughout the simulation period consistent with the operation schedule for the filling cycle. The peak expected DOC concentration in the first run approaches the value of "A", adjusted for depth using Equation 9-2.

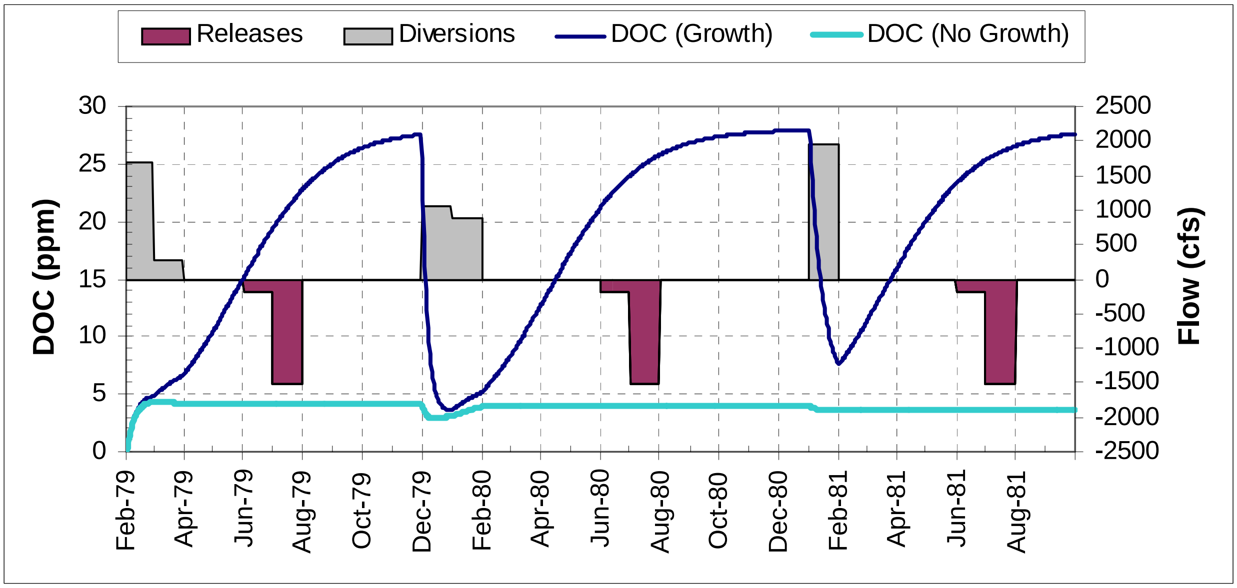

Figure 9.1: Time Series Plots of DOC Concentrations and Flow Exchange at Webb Tract.

Figure 9.2 shows a similar comparison between the two runs for 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.

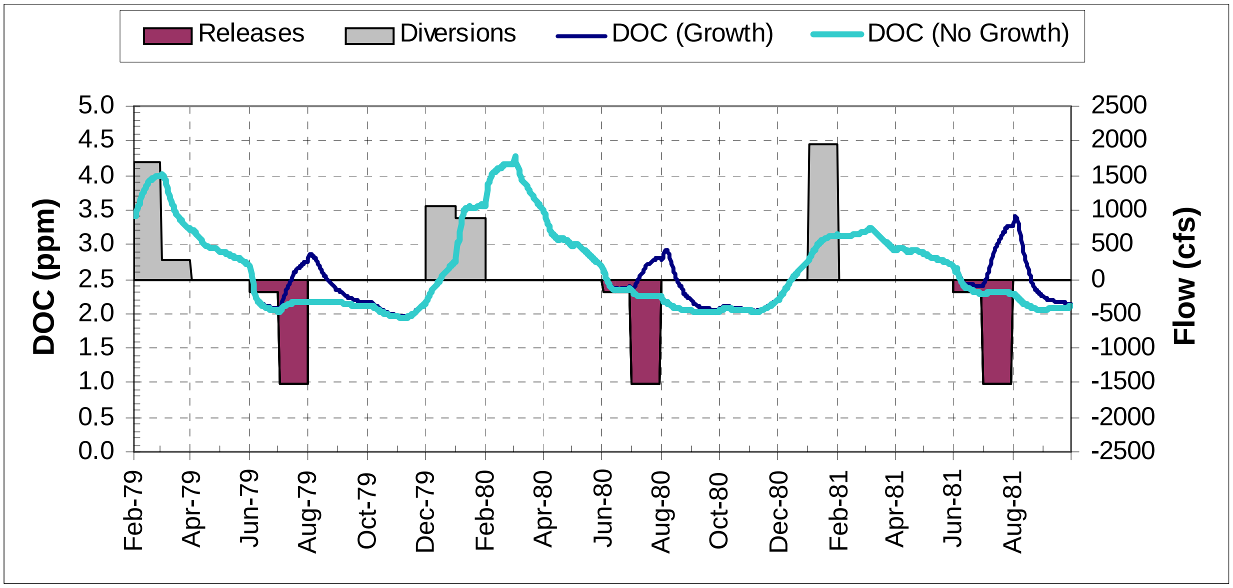

Figure 9.2: Time Series Plots of the Variations in DOC Concentrations at San Joaquin River near Mokelumne River Junction and Flow Exchange at Webb Tract.

9.4 Summary

Marvin Jung proposed a governing logistic equation for the growth of DOC in the storage reservoirs (Equations 9-1 and 9-2). 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.

9.5 References

Jung, Marvin. (2001). "Consultants Report to the Department of Water Resources In-Delta Storage Investigations Program Executive Summary." Municipal Water Quality Investigations, California Department of Water Resources. Sacramento, CA.

Mierzwa, Michael. (2001). "Delta Wetlands DSM2 CALSIM Studies." Presentation to In-Delta Storage Water Quality Stakeholders, October 30. Delta Modeling Section, California Department of Water Resources. Sacramento, CA.