Water | Environment | Scientists | Engineers

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DRAFT MEMORANDUM

FROM: **Amanda Flynn, Dave Dilks,**
Laura Weintraub

PROJECT: **TRUCK**

TO: **Truckee River Nutrient WQS and TMDL Third Parties: T. Svetich (City of Reno); J. Buzzone (Washoe County); D. Bruketta (City of Sparks); R. Penrose (TMWA); R. Pahl (NDEP); J. Heggeness (NDEP); S. Wilson (USEPA)**

CC:

SUBJECT: DRAFT: Truckee River HSPF Model Water Quality Algorithms

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Summary

The *Hydrologic Simulation Program – FORTRAN* (HSPF) version 12.2 is being used to simulate hydraulics and water quality for the Truckee River to support a third-party driven effort to review existing nutrient water quality standards and total maximum daily loads (TMDLs). The Truckee River HSPF (TRHSPF) model simulates a large number of instream water quality constituents including dissolved oxygen (DO), biochemical oxygen demand (BOD), inorganic and organic forms of nitrogen and phosphorus, and two types of benthic algae (non-nitrogen-fixers and nitrogen-fixers).

The purpose of this memorandum is to provide a concise summary of the algorithms describing these water quality constituents in TRHSPF. More information on the TRHSPF model can be found in the 2008, 2009, and 2011 LimnoTech reports (LimnoTech 2008, 2009, 2011). Detailed information on the HSPF algorithms can be found in the model User's Manual (Bicknell et al. 2005).

Algorithms

The information in the following sections provides a brief overview of DO, BOD, nutrient, and benthic algae algorithms.

Dissolved Oxygen

TRHSPF simulates the primary processes that determine the DO concentration in the water column of each defined reach within the model domain (Figure 1). The state variable DOX represents the oxygen dissolved in water that is immediately available to satisfy the oxygen requirements of the system.

DO concentration is modeled as a function of:

- Decay of carbonaceous BOD
- Reaeration
- Nitrification of ammonia and nitrite
- Benthic (sediment) oxygen demand
- Algal photosynthesis and respiration

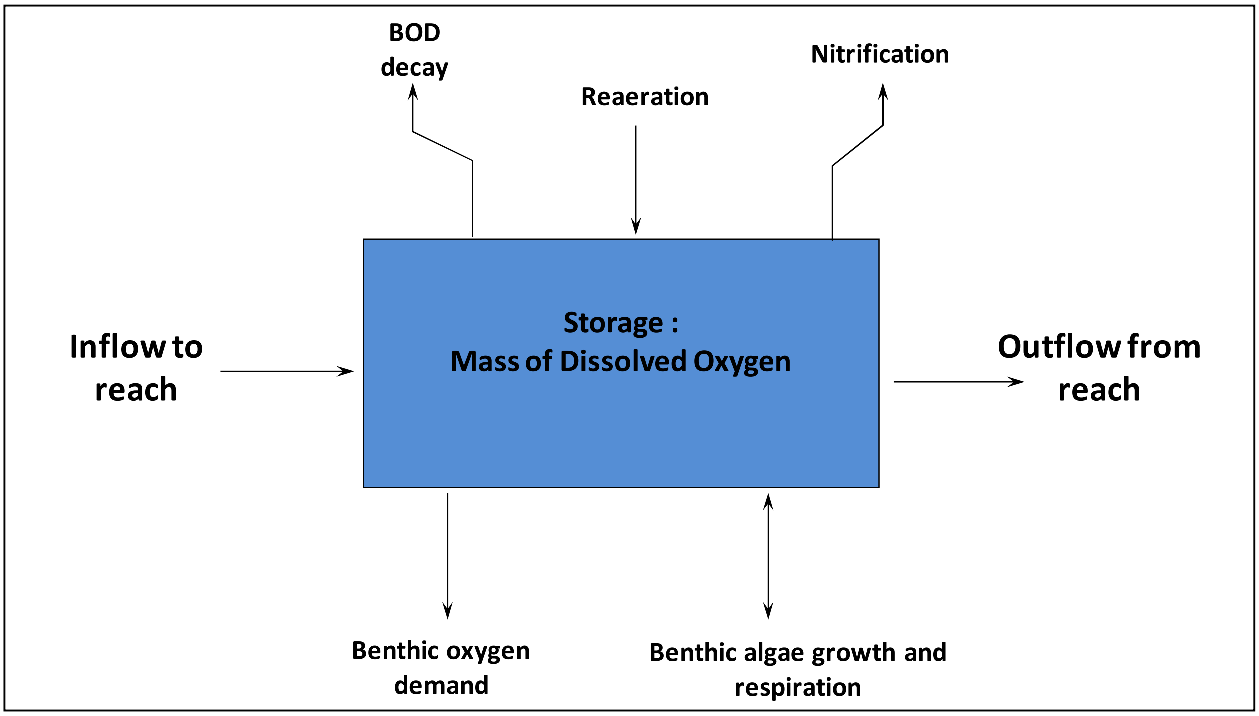

Figure 1. Conceptual model of DO processes represented in TRSHPF.

DO equation and terms:

$$\frac{\delta}{\delta t} DOX = \begin{bmatrix} IDOX + (KOREA * (SATDO * DOX)) - BENOX - BODOX - \\ DODEMD + (\mathrm{CVPB} * \mathrm{CVBO} * \mathrm{GROBAL}) - RODOX \end{bmatrix}$$

$\delta/\delta t$ = change in DO concentration over time
DOX = dissolved oxygen concentration (mg/L)
IDOX = inflow of DO from upstream reach (mg/L per interval)
KOREA = reaeration coefficient
SATDO = saturated concentration of dissolved oxygen (mg/L)
BENOX = amount of oxygen demand exerted by benthal muds (sediment oxygen demand) (mg/m^2/interval)
BODOX = quantity of oxygen required to satisfy BOD decay (mg/L per interval)
DODEMD = loss of dissolved oxygen due to nitrification (mg/L per interval)
CVPB = conversion factor from micromoles phosphorus to mg biomass
CVBO = conversion factor from mg biomass to mg oxygen
GROBAL = net growth (photosynthesis minus respiration) of benthic algae (micromoles phosphorus/L per interval)
RODOX = total outflow of DO to downstream reach (mg/L per interval)

Biochemical Oxygen Demand

The BOD state variable represents the total quantity of oxygen required to satisfy the first-stage (carbonaceous) BOD demand of dead non-refractory organic materials in the water. The primary processes accounted for in the model are shown in Figure 2.

BOD concentration is modeled as a function of:

- BOD decay
- Settling
- Benthic release of BOD
- Algal death

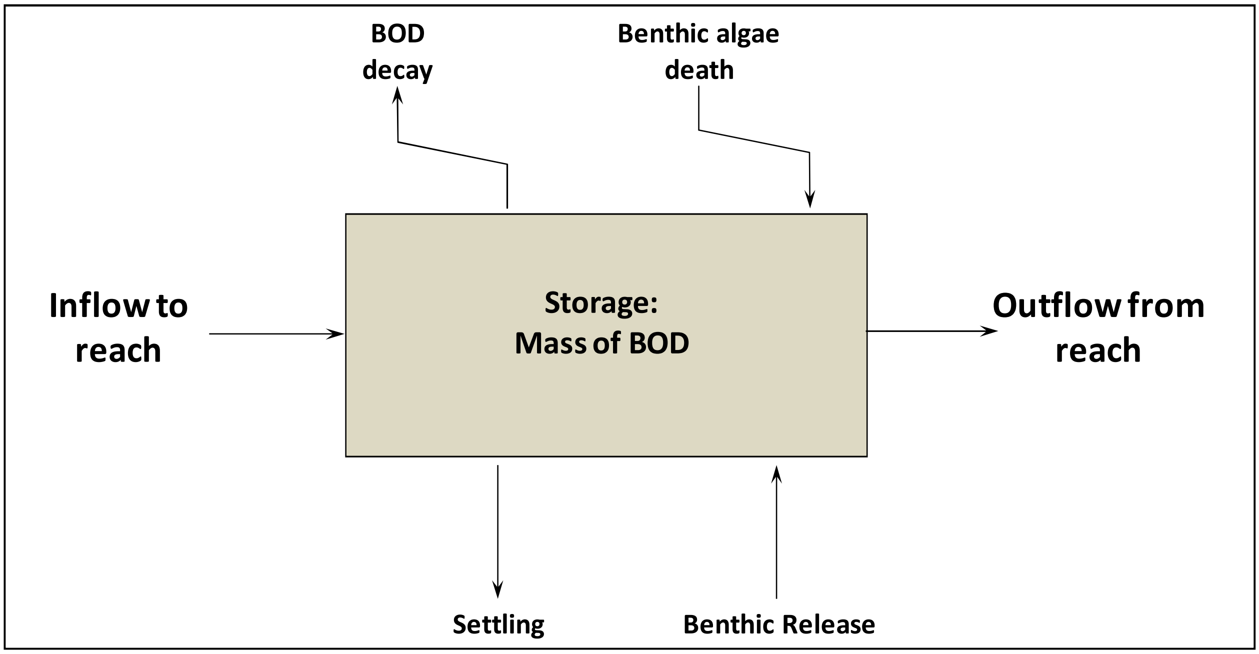

Figure 2. Conceptual model of BOD processes represented in TRSHPF.

BOD equation and terms:

$$\frac{\delta}{\delta t} BOD = \left[IBOD - BODOX - SNKOUT + RELBOD + (DTHBAL * CVNRBO * CVPB) - ROBOD \right]$$

$\delta/\delta t$ = change in BOD concentration over time
BOD = BOD concentration (mg/L)
IBOD = inflow of BOD from upstream reach (mg/L per interval)
BODOX = quantity of oxygen required to satisfy BOD decay (mg/L per interval)
SNKOUT = fraction of BOD material that settles out (reduction of concentration/interval)
RELBOD = BOD released by bottom muds (mg/m^2 per interval)
DTHBAL = benthic algae death (micromoles P/l per interval)
CVNRBO = conversion from mg biomass to equivalent mg oxygen demand (allowing for refractory fraction)
CVPB = conversion from micromoles phosphorus to mg biomass
ROBOD = total outflow of BOD to downstream reach (mg/L per interval)

Nutrients

The model simulates the primary processes that determine the mass balance of nitrogen and phosphorus in natural waters. Nutrients are modeled as a function of:

- Longitudinal advection of dissolved NO_3, NO_2, NH_3, and PO_4
- Benthal release of NH_3 and PO_4
- Ammonia ionization (NH_3/NH_4^+ equilibrium)
- Ammonia vaporization
- Nitrification of NH_3 and NO_2
- Denitrification of NO_3
- Ammonification due to degradation of BOD materials

Figure 3 provides a schematic of the different nutrient pools and species represented and modeled in TRHSPF. The inorganic pool, simulated in the "NUTRX" module or sub-model, is comprised of nutrient species that are readily available for algal growth. The organic pool, simulated in the "PLANK" module, is comprised of two pools, labile and refractory. The labile pool is not readily available for algal growth; however, some portion of the pool may readily break down to an inorganic form that is available for algal growth. The refractory pool is an unavailable form that is not available for algal growth and is transported out of the system with no further transformations or reactions.

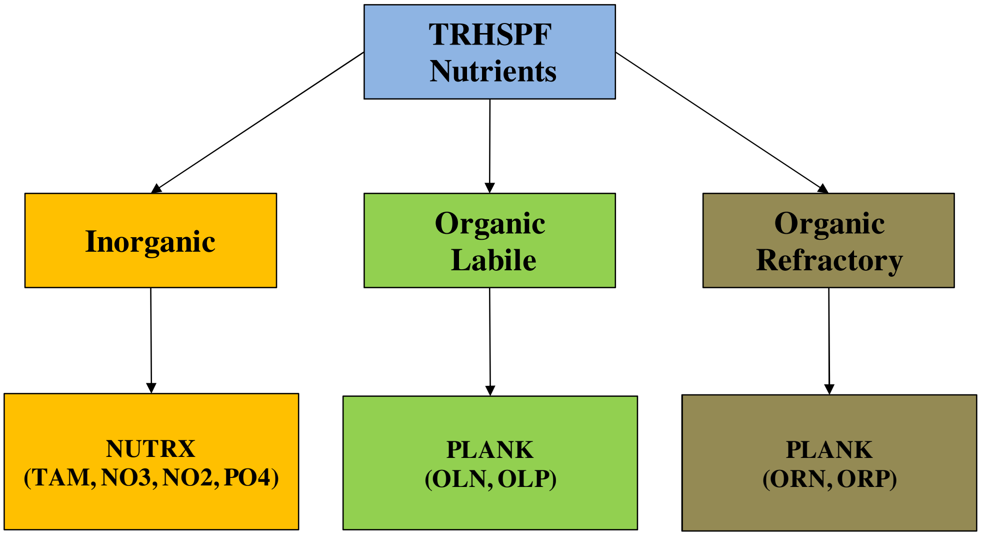

Figure 3. Diagram of the nutrient pools and species accounted for in TRSHPF.

Generalized equations and terms:

$TN = TORN + TAM + NO_3 + NO_2$
$TP = TORP + PO_4$

Where $TORN = OLN + ORN$ and $TORP = OLP + ORP$

TN = total nitrogen (mg N/L)
TORN = total organic nitrogen (labile plus refractory) (mg N/L)
OLN = organic labile nitrogen (mg N/L)
ORN = organic refractory nitrogen (mg N/L)

TAM = total ammonia (mg N/L)
NO3 = nitrate (mg N/L)
NO2 = nitrite (mg N/L)

TP = total phosphorus (mg P/L)
TORP = total organic phosphorus (labile plus refractory) (mg P/L)
OLP = organic labile phosphorus (mg P/L)
ORP = organic refractory phosphorus (mg P/L)
PO4 = ortho-phosphorus (mg P/L)

Benthic Algae

The model simulates two types of algae (non-nitrogen-fixers and nitrogen-fixers) that are attached to rocks or other stable structures. Benthic algal growth, respiration, and death processes influence nutrient, BOD, and DO concentrations. Algae are assumed to grow at an optimal rate dictated by temperature, light, and nutrients. The primary processes accounted for in the model are shown in Figure 4.

Benthic algae biomass is modeled as a function of:

- Growth (dependant on temperature, light, nutrients, and density)
- Respiration
- Death
- Removal (grazing and scouring)

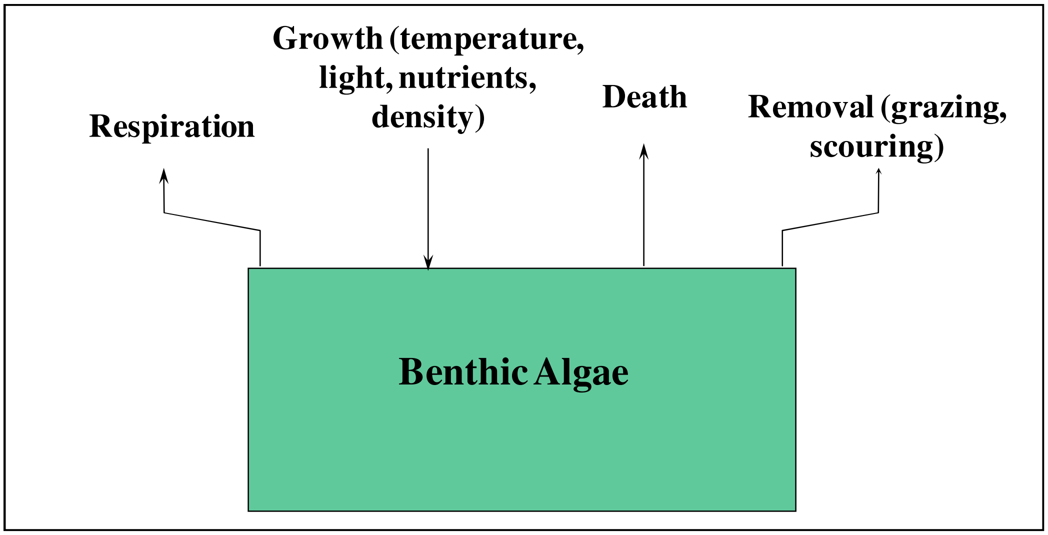

Figure 4. Conceptual model of benthic algae processes represented in TRSHPF.

Benthic algae equation and terms:

$$\frac{\delta}{\delta t} BENALB(x) = \left[GROBA(x) - RESBA(x) - SLOF(x)\right]BENALB(x) - REMBA(x)$$

x = individual algal groups (i.e., non-nitrogen-fixers and nitrogen-fixers)

$\delta/\delta t$ = change in algal biomass over time
BENALB(x) = benthic algal biomass for algal type x (g OM/m^2)
GROBA(x) = production for benthic algal type x (/interval)
RESBA(x) = respiration for benthic algal type x (/interval)
SLOF(x) = biomass removal rate from scouring for each benthic algal type (/interval)
REMBA(x) = removal rate (grazing plus disturbance) for benthic algal type x (g OM/m^2/interval)

References

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