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A Modelling Framework For Simulating River And Stream Water Quality

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ABSTRACT

Model predictions might be used in addition to or instead of monitoring data for two reasons: (1) modeling could be feasible in some situations where monitoring is not, and (2) integrated monitoring and modeling systems could provide better information than monitoring or modeling alone for the same total cost. For example, regression analyses that correlate pollutant concentration with some more easily measurable factor (e.g., streamflow) could be used to extend monitoring data for preliminary listing purposes. Models can also be used in a Bayesian framework to determine preliminary probability distributions of impairment that can help direct monitoring efforts and reduce the quantity of monitoring data needed for making listing decisions at a given level of reliability.

A simple, but useful, modeling approach that may be used in the absence of monitoring data is "dilution calculations." In this approach the rate of pollutant loading from point sources in a

water body is divided by the stream flow distribution to give a set of estimated pollutant concentrations that may be compared to the standard. Simple dilution calculations assume conservative movement of pollutants. Thus, the use of dilution calculations will tend to be conservative and lead to higher than actual concentrations for decaying pollutants. Of course one could include a best estimate of the effects of decay processes in the dilution model.

I.INTRODUCTION

Combined runoff and water quality prediction models link stressors (sources of pollutants and pollution) to responses. Stressors include human activities likely to cause impairment, such as the presence of impervious surfaces in a watershed, cultivation of fields close to the stream, over-irrigation of crops with resulting polluted return flows, the discharge of domestic and industrial effluents into water bodies, installing dams and other channelization works, introduction of non-indigenous taxa, and over-harvesting of fishes. Indirect effects of humans include land cover changes that alter the rates of delivery of water, pollutants, and sediment to water bodies.

Models that relate stressors to responses can be of varying levels of complexity. Sometimes, models are simple qualitative conceptual representations of the relationships among important variables and indicators of those variables, such as the statement "human activities in a watershed affect water quality including the condition of

the river biota." More quantitative models can be used to make predictions about the assimilative capacity of a water body, the movement of a
pollutant from various point and nonpoint sources through a watershed, or the effectiveness of certain best management practices.

II.MODEL SELECTION CRITERIA

Water quality predictive models include both mathematical expressions and expert scientific judgment. They include process-based (mechanistic) models and data-based (statistical) models. The models should link management options to meaningful response variables (e.g., pollutant sources and water quality standard parameters). They should incorporate the entire "chain" from stressors to responses. Process-based models should be consistent with scientific theory. Model prediction uncertainty should be reported. This provides decision-makers with estimates of the risks of options.

Water quality management models should be appropriate to the complexity of the situation and to the available data. Simple water quality problems can be addressed with simple models. Complex water quality problems may or may not require the use of more complex models. Models requiring large amounts of monitoring data should not be used in situations where such data are unavailable. Models should be flexible enough to allow updates and improvements as appropriate based on new research and monitoring data.

Water quality models can also be classified as either pollutant loading models or as pollutant response models. The former predict the pollutant loads to a water body as a function of land use and pollutant discharges; the latter is used to predict pollutant concentrations and other responses in the water body as a function of the pollutant loads.

The basic equation describes the variation of the concentration of a quality constituent C with
the time and space. The basic equation describes the variation of the concentration of a quality constituent C with the time and space. Internal source/sink term, or internal reaction term are also called the transformation processes with the meaning that the substance in concern is being transformed by various physical, chemical, biochemical and biological processes resulting in the change of the quantity of the substance in an elemental water body. This change is either a "loss" or sink term caused by processes such as settling, chemical-biochemical decomposition, uptake by living organisms or a "gain", a source term, such as scouring from the stream bed, product of chemical-biochemical reactions, biological growth, that is the "build-up " of the substance in concern on the expense of other substances present in the system. The actual form of these transformation processes will be presented in relation to concrete model equations such as the BOD-DO models, the models of the oxygen household and the plant nutrient (phosphorus) transformation processes of the lake models.

III.STREAM AND RIVER MODELS

3.1FINDING THE CONCENTRATION OF MATTER IN THE RIVER

Stream and river models: These include inputs:

- Flow of water and pollutant loadings
- Dispersion and advection terms in modeling equations
- Physical, chemical and biological reactions

3.2MODELING EQUATIONS

At any point X, upstream (X<0) or downstream (X>0) which is the distance from the discharge of pollutants, the change in concentration over time is given as:

$\partial C/\partial t = (1/A)\,[\partial(EA(\partial C/\partial X) - UAC)/\partial X] \pm \Sigma\, Sk$ …..**(1)**

where, $\partial C/\partial t$ **=** the change in concentration over time

U= net downward velocity

E= dispersion factor (m^2/sec) depends upon amplitude and frequency of tide and turbulence.

$EA(\partial C/\partial X)-UAC$ = total flux (m/sec)

flux due to dispersion $EA(\partial C/\partial X)$ is assumed to be proportional to concentration gradient over distance

X =direction (upstream X<0 or downstream X>0)

UAC = advective flux due to the movement of water containing the concentration C at velocity rate U across cross sectional area A .

Σ Sk = sources or minus any sinks, Sk. (kg/m^3/sec)

3.3STEADY-STATE SINGLE CONSTITUENT MODELS

(a) Condition of advection and dispersion

Steady state means $\partial C/\partial t = 0$

Assume natural decay of the constituent is the only sink which is defined as kC , where k is the decay rate constant.

Now Equation (1) becomes

$0 = E\,\partial^2 C/\partial X^2 - U\,\partial C/\partial X - kC$ …..… **(2)**

For a constant loading, $W_C(MT^{-1})$ at site X = 0, the concentration C :

$C(X) = (W_C/Qm)\exp[\,(U/2E)(1 + m\,)X]\ ;\ X \le 0$ (upstream) …...................................**(3)**

$(W_C/Qm)\exp[\,(U/2E)(1 - m)X]\ ;\ X \ge 0$ (downstream) .... **(4)**

where, m and Q are assumed as constants

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$m = (1 + (4kE/U^2))^{1/2}$

parameter m is always equal or greater than 1.

Therefore exp <0. Hence either X>0 or X<0, the concentration C(X) will decrease as distance X increases. The maximum concentration C occurs at X = 0 and is W_C /Qm.

C(0) = Wc /Qm

(b) Condition of advection only:

In this, flow of river is not under the influence of tides . Therefore, dispersion is small.

Assuming the dispersion coefficient E is 0, then parameter m =1. Hence when E =0, the maximum concentration at X = 0 is W_C/Q.

$C(0) = W_C/Q$; if E = 0.

Now, $(1-m) = -2kE/U^2$

Equation (3),(4) becomes

C(X) = 0 ; X ≤ 0 ……..…**(5)**

(WC/Q) exp[– kX/U] ; X ≥ 0……...……**(6)**

(c) Condition of dispersion only:

As rivers approach the sea then the turbulence in the water increases. The dispersion coefficient E increases and the net downstream velocity U decreases. The flow Q = AU, and

since the parameter $m = (U^2 + 4kE)^{1/2}/U$,

then as the velocity U approaches 0,

=> the term $Qm = AU(U^2 + 4kE)^{1/2}/U = 2A(kE)^{1/2}$

and exp[UX(1±m)/2E] in equation (3) and (4) approaches $\pm\exp[X(k/E)^{1/2}]$.

Hence for small velocities, Equation (3), (4) becomes:-

$C(X) = (WC/2A(kE)^{1/2})\exp[+X(k/E)^{1/2}]$; X ≤ 0 ……......................................…**(7)**

$(WC/2A(kE)^{1/2})\exp[-X(k/E)^{1/2}]$; X ≥ 0 ……......................................….**(8)**

The above equations are plotted as :-

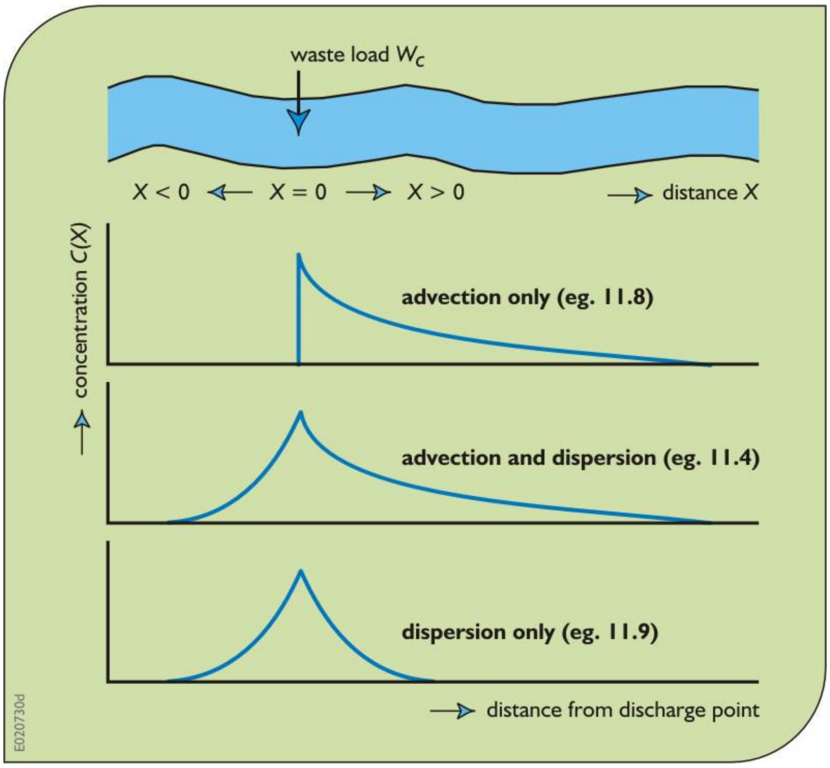

Fig: Showing variation of concentration with respect to distance

IV.CONCLUSION

If accompanied by field data and uncertainty analysis, many existing models can be used to assist those responsible for developing water quality management plans in an adaptive implementation or management framework. Adaptive implementation or management will allow for both model and data improvements over time. Adaptive approaches strive toward achieving water quality standards while relying on monitoring and experimentation to reduce uncertainty. It often is the only way one can proceed given the complexity of the real world compared to the predictive models available and compatible with the data and time available for analyses. The trial and error aspects of adaptive management based on monitoring and imperfect models may not satisfy those who seek more definitive direction from water quality analysts and their predictive models.

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