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Stephen C. Newbold and Juha V. Siikamäki. 2009. Prioritizing conservation activities using reserve site selection methods and population viability analysis. *Ecological Applications* 19:1774–1790.

Appendix A. Derivation of watershed pollution-loading model.

First, we specify the total mass of pollution generated in watershed *i*, M_i [g/yr], as the sum of the products of the area of each land use type in the watershed, $\mathbf{L}_i$ [m^2], and the pollution-generating intensity of each land use type, $\boldsymbol{\omega}$ [g/m^2/yr]: $M_i = \mathbf{L}_i'\boldsymbol{\omega}$. (Note: bold variables represent column vectors.) We assume that not all of the pollution generated in a watershed will be delivered to the river; some will be transformed into inert forms or adsorbed to soils before reaching the river. To determine the net delivery of pollution to a river reach, first let ψ [m/m^2] be the density of higher-order (un-mapped) *streams* in the landscape (as distinguished from the mapped *rivers* where the available GIS data indicate that salmon habitat is found). We assume that the length of a representative stream reach is half the width of a rectangle with the same area as the watershed and length equal to the length of the river flowing through the watershed, i.e., $A_i/(2l_i)$ [m], as shown in Figure 1. The total number of streams in the watershed is the total length of streams in the watershed, ψA_i [m], divided by the length of a representative stream, $A_i/(2l_i)$ [m], which gives $2\psi l_i$ streams. The total mass of pollution generated in the portion of the watershed that drains to a single stream is the total mass of pollution generated in

the entire watershed divided by the number of streams, $M_i/(2\psi l_i)$ [g/yr]. We assume that no pollution decay occurs during overland flow to the streams, so all pollution generated in the watershed is delivered to a stream. Note that this implicitly assumes that land use types are evenly distributed throughout the watershed. Next we assume that pollution is delivered to each stream uniformly, which means that the rate of delivery of pollution to each stream is the total mass of pollution delivered to the stream, $M_i/(2\psi l_i)$, divided by the length of a stream, $A_i/(2l_i)$, which gives $M_i/(\psi A_i)$ [g/m/yr]. Next, we assume that the mass of pollution $m(x)$ carried in the water as it flows in each stream towards the river decays—either through settling on the channel bottom or through bio-chemical transformations to more inert forms—at a constant rate μ [m^{-1}] (where *x* measures the distance along a stream from the top of the watershed to the river's edge). Thus, the rate of change of pollution mass along a stream is $dm/dx = M_i/(\psi A_i) - \mu m$, which can be rewritten as $dm/dx = -\mu\left(m - M_i/(\mu\psi A_i)\right)$. Separating variables gives $dm/\left[m - M_i/(\mu\psi A_i)\right] = -\mu dx$, and integrating both sides gives $\ln\left[m - M_i/(\mu\psi A_i)\right] = -\mu x + C_1$, where C_1 is a constant of integration. This can be solved for *m* to get $m = M_i/(\mu\psi A_i) + \exp(-\mu x + C_1)$. Then, using the boundary condition $m = 0$ at $x = 0$, we get $m(x) = \left[1 - \exp(-\mu x)\right] M_i/(\mu\psi A_i)$. We can then evaluate this expression at $x = A_i/(2l_i)$ to determine the mass of pollution delivered to the river from each stream, which we denote π_i [g/yr]: $\pi_i = \left[1 - \exp\left(-\mu A_i/(2l_i)\right)\right] M_i/(\psi A_i \mu)$. Finally, we treat the delivery of pollution to the river via streams as uniform along the length of the river in the watershed. Since there are $2\psi l_i$ streams delivering π_i [g/yr] of pollution to the river over its length l_i, the delivery rate of pollution per unit distance to the river is $2\psi\pi_i$ [g/m/yr], i.e.,

$m_i = 2\left[1-\exp\left(-\mu A_i/\left(2l_i\right)\right)\right]\mathbf{L}_i\boldsymbol{\omega}/\left(A_i\mu\right)$. This is the equation that appears in the main text of the paper. Note that the density of streams in the watershed ψ does not appear in this final expression for the net pollution load to the river since it does not matter how many streams deliver the pollution to the river. Only the fraction of the total amount of pollution generated in the watershed that reaches the river is relevant, and that is determined only by the decay rate μ and the travel distance $A_i/\left(2l_i\right)$. I.e., in this model the same fraction of the total amount of pollution generated in a watershed is delivered to the river no matter how the total is divided up among streams since all streams are assumed to be of the same length. The key payoff from going through this extended (pseudo-)mechanistic derivation is that the pollution load becomes a function of both the amount of each land use type in the watershed and (an index of) the shape of the watershed, A_i/l_i. This adds an extra bit of spatial realism to a model that would otherwise take little account of the spatial arrangement of land use types within and among watersheds.

Finally, to calculate the pollution concentration at all points along a river reach, we switch to a discrete model, which allows us to account for changes in water flows along each reach in a more straightforward way. Consider a representative small "control volume" containing water in a reach between downstream distance x and $x+\Delta x$, as illustrated in Figure 2. Pollution flows into the control volume with the inflowing river flow and via non-point source runoff from human land uses, as described in the previous paragraph, and pollution flows out of the control volume with the outflowing river flow and through decay/decomposition at a constant rate η [$\left(\Delta x\text{m}\right)^{-1}$] (analogous to the decay rate μ from above). The Q's are water flows [m^3/yr] and the C's are pollution concentrations [g/m^3]. Setting the inflows equal to the outflows, the steady-state concentration at the downstream border of the control volume is

$C_i\left(x+\Delta x\right)=\left[\left(1-\eta/2\right)Q_i\left(x\right)C_i\left(x\right)+m_i\Delta x\right]/\left[\left(1+\eta/2\right)Q_i\left(x+\Delta x\right)\right]$. The average pollution concentration along reach *i*, $\overline{C}_i$, is then calculated by summing the concentrations in all control volumes (cells) along a reach and dividing by the number of cells. This is the final measure of in-stream pollution that is used in Eq. 4 in the main text.

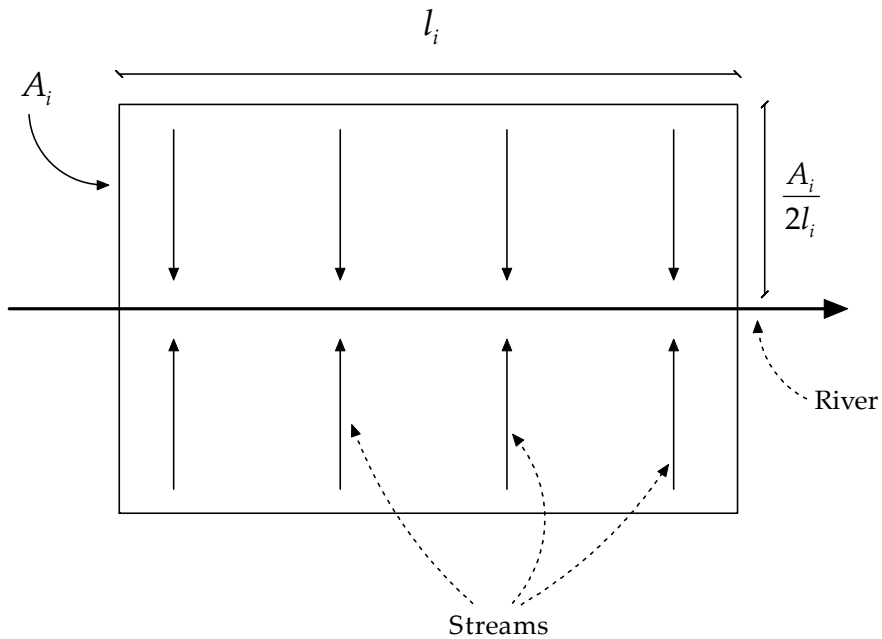

FIG. A1. Stylized representation of a watershed, with (un-mapped) streams draining to a main river reach.

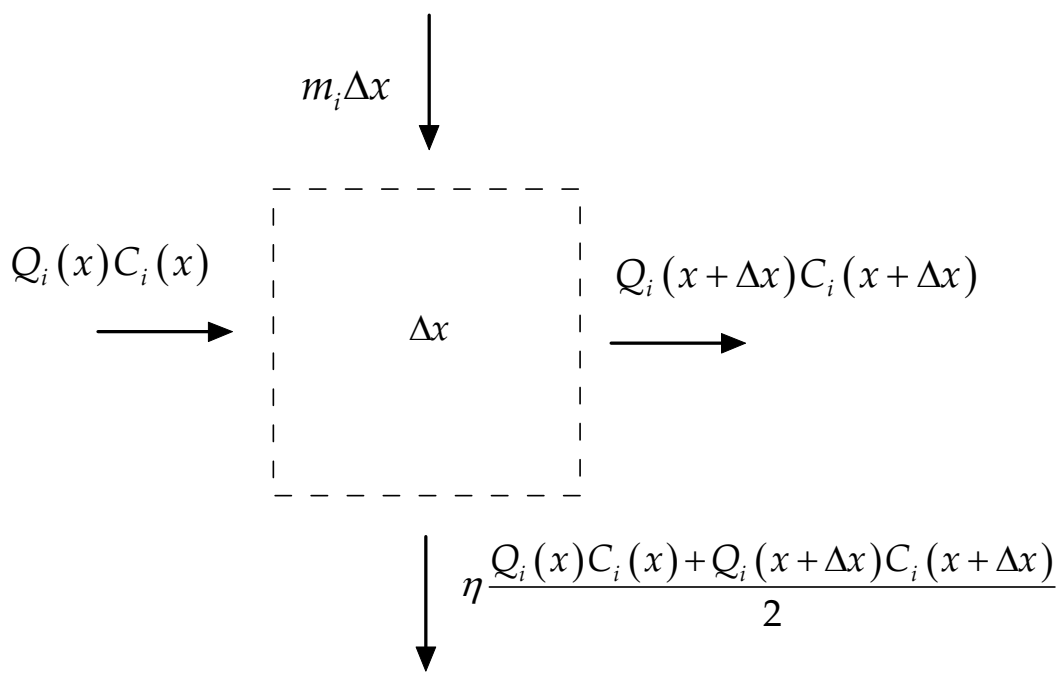

FIG. A2. A representative small "control volume" containing water in a reach between downstream distance x and $x+\Delta x$.