

### Appendix 3. Model Parameterization

The hydrologic and biogeochemical conditions of a watershed can be significantly altered by land cover change. Due to the broad range in projections for population and impervious surfaces in the UMRW, it is essential that these potential ecosystem changes are accurately accounted for and simulated in the PnET-FrAMES linked model. Several parameterizations were made to adequately account for the changes in solute loading, and runoff timing and magnitude due to these land cover projections.

Simulated runoff in PnET-FrAMES is parameterized to account for changes in watershed impervious surfaces. The linked model partitions direct and in-direct runoff from the fraction of total impervious areas ( $f_{imp}$ ) via the fraction of hydrologically connected imperviousness parameter ( $f_{hci}$ ). We assume during the contemporary period that  $f_{hci} = f_{imp}$ , which is consistent with observations of hydrologic connectivity of impervious areas at moderate total imperviousness ( $f_{imp} = 0.2$ ) estimated through hydrologic partitioning at catchment scales in the region (Pellerin et al. 2008). This relationship overestimates the hydrologic connection at low values of total imperviousness (Alley and Veenhuis 1983, Shuster et al. 2005), which we consider consistent with our scales of simulation relative to such studies. In future scenarios, for Small Community Food we alter parameter values to account for low-impact design (LID), while for Backyard we assume no change. For Small Community Food, we assume that LID reduces effective imperviousness progressively into the future. We reduce  $f_{hci}$  each future decade according to  $f_{hci} = \kappa f_{imp}$  with  $\kappa$  decreasing linearly from 1.0 in 2010 to 0.1 in 2060. In conjunction with the reduction in  $f_{hci}$ , available water

capacity (AWC) of lawn areas is increased to accommodate an additional 25 mm of precipitation. This increase accounts for increased storage capacity in lawn areas due to LID improvements.

PnET-FrAMES simulates five natural and anthropogenic sources of chloride through the Non-point Anthropogenic Chloride Loading (NACL) module (Zuidema et al. In Prep) to capture salt impairment of aquatic habitat. Road salt (deicer) loading is the predominate source of chloride in the model domain. The flux of road salt to the system ( $m_{DEI}$ , units) is the product of frozen (winter) precipitation ( $P_w$  [ $mm\ d^{-1}$ ]), fraction of impervious area ( $f_{imp}$ ), fraction of treated impervious area ( $f_{DEI}$ ), cell area ( $A$ ), and rate of road salt loading per mm of snow fall ( $C_{DEI}$  [ $g\ Cl\ mm^{-1}m^2$ ] or [ $g\ Cl\ L^{-1}$ ]). The fraction of treated impervious area ( $f_{DEI}$ ) is an estimate of roads, sidewalks and parking lots that require deicing, set to 0.6 for both scenarios. The road salt loading parameter was estimated to be about 7 [ $g\ Cl\ L^{-1}$ ] in the Merrimack River Watershed (MRW) (Zuidema et al. In Review). The Backyard scenario maintains *status quo* road salt loading ( $C_{DEI} = 7.0$  [ $g\ Cl\ L^{-1}$ ]), whereas the Community scenario includes an abrupt transition to recommended levels, to  $C_{DEI}^{REC} = 2.5$  g Cl L<sup>-1</sup> in 2015 to simulate improved management.

Inorganic nitrogen loading is a function of forest DIN loading, derived from the forest ecosystem model PnET (see below) and anthropogenic N loading from developed and agricultural lands (determined from empirical relationships in FrAMES). Suburban and agricultural DIN loading is parameterized according to logistic functions on the fraction of suburban or agricultural land and runoff depth (Wollheim et al. 2008a).

Patterns of DIN loading with increasing suburban area are as in Wollheim et al. (2008b), with maximum of 1.4 mg L<sup>-1</sup>, and  $x_{mid} = 51.39\%$  suburban development. This function is nonlinear and assumes little response in DIN loading until some threshold of development is crossed, assuming that natural retention processes prevent losses at lower development. We here assume that maximum DIN loading concentration in agricultural land is 3.5 times higher than in suburban land (Price 2014). To simulate improved management in the Community scenario, maximum DIN loading concentrations from agricultural land is assumed to only be 2 times higher than suburban loading, assuming that best practices and organic agriculture called for in the scenario (Thorn et al. this issue) would result in a 40% reduction in agricultural DIN export.

WWTPs are a significant point source of DIN load to the upper Merrimack R. watershed (Stewart et al. In Prep). For the contemporary scenario, influent TN fluxes to WWTPs are estimated based on the population served by each plant (USEPA 2008), and a per capita TN emission rate (20 g TN per person per day, Van Drecht et al. 2009). Daily effluent masses of DIN from WWTPs to the river network were estimated based on TN removal efficiencies for each WWTP treatment technology (Van Drecht et al. 2009), and the proportion of effluent TN that is in DIN form (Dumont et al. 2005). In the Backyard scenario, we assume wastewater for new population is managed via septic systems (consistent with dispersed development) so WWTP DIN effluent remains constant (Stewart et al. Unpublished). In the Small Community Food scenario, we allocate all increased waste N from additional population growth to the nearest downstream existing WWTP, and increase WWTP efficiency to 90% removal of influent TN.