

Holistic Watershed Management for Existing and Future Land Use Development Activities:

Opportunities for Action for Local Decision Makers:

Phase 1 – Modeling and Development of Flow Duration Curves (FDC 1 Project)

**SUPPORT FOR SUTHEAST NEW ENGLAND PROGRAM (SNEP) COMMUNICATIONS STRATEGY AND
TECHNICAL ASSISTANCE**

**Draft Final Report. Appendix F
Factsheets**

September 10, 2021

Prepared for:
U.S. EPA Region 1



Prepared by:



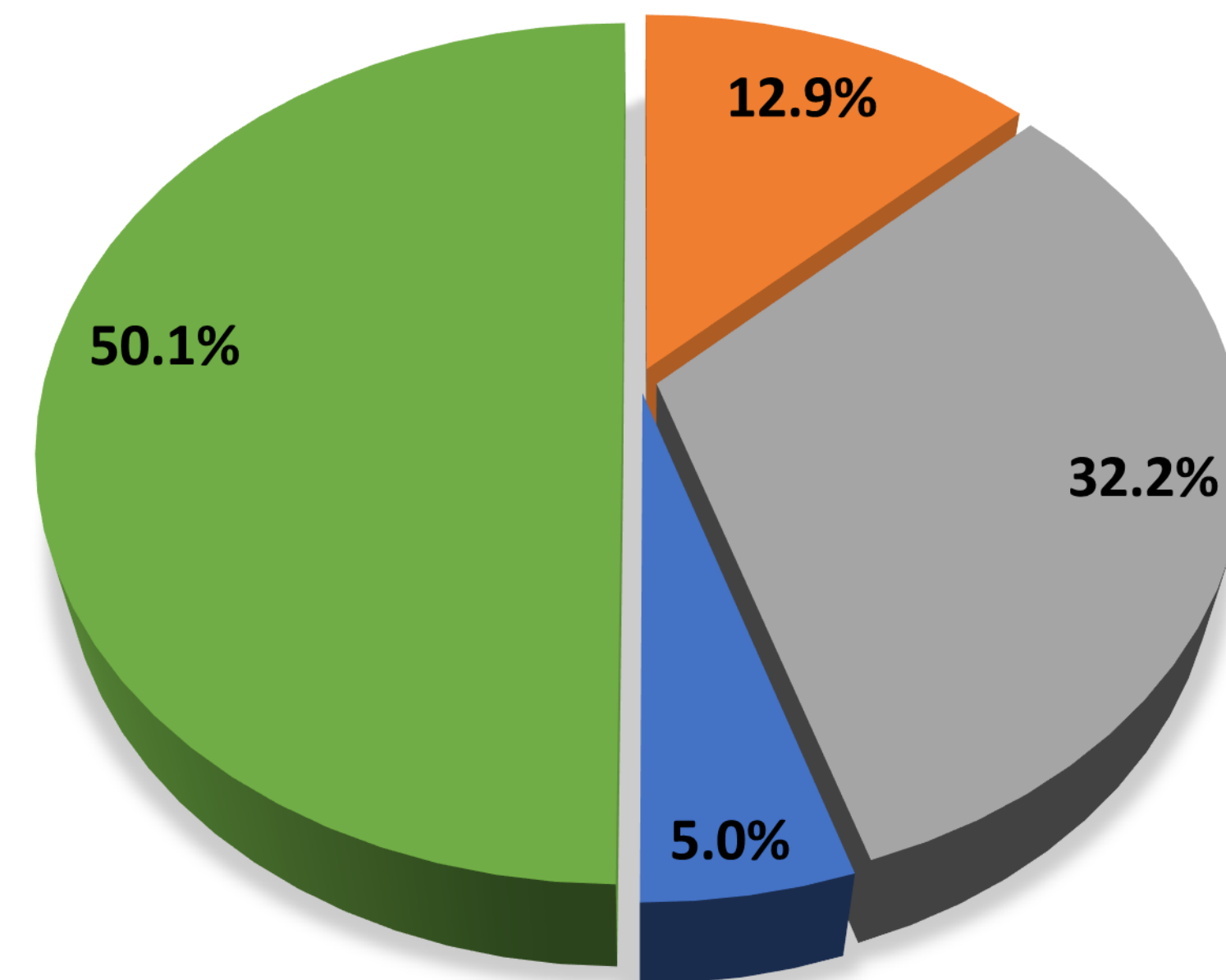
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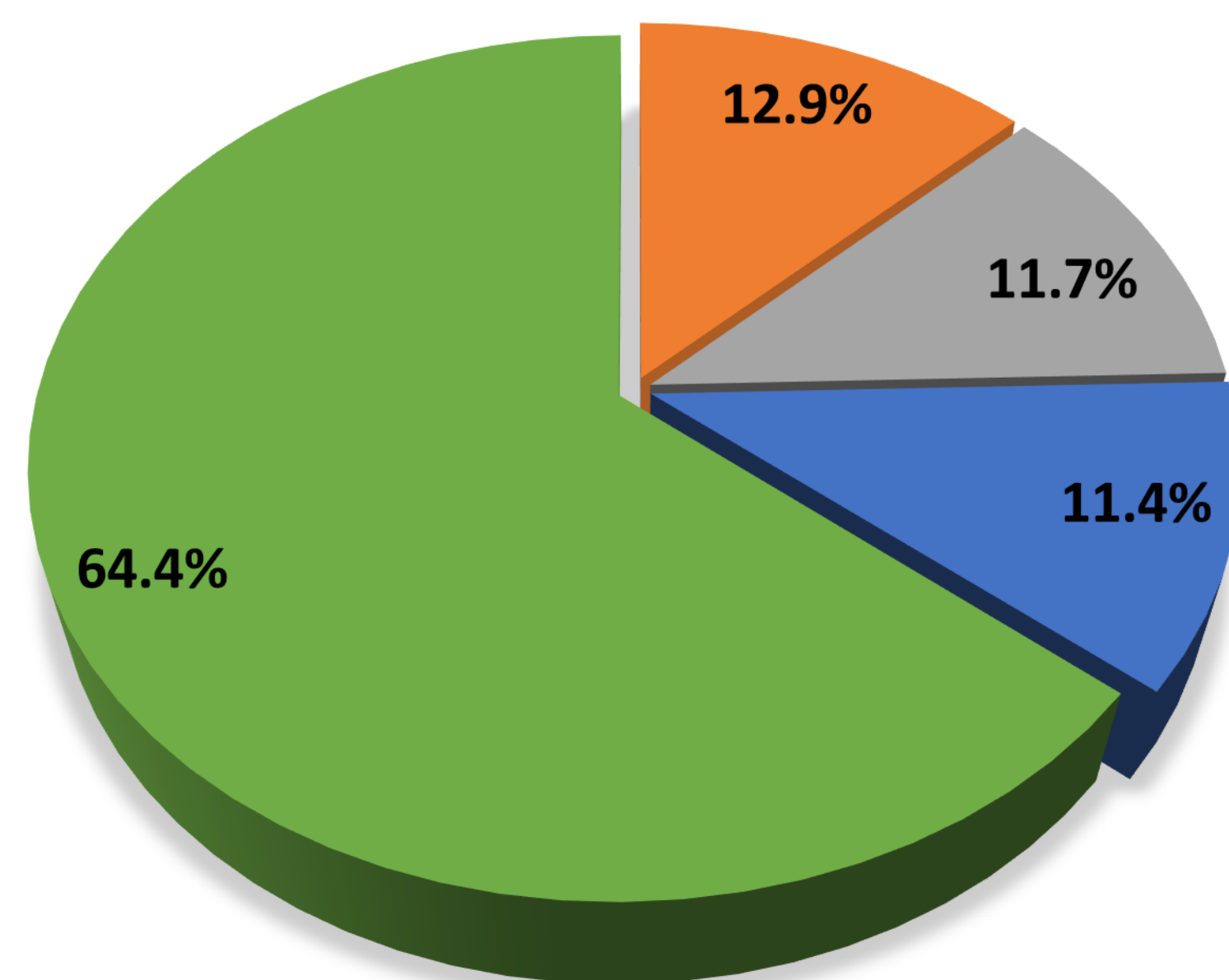
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- Interflow
- Groundwater
- Overland Flow
- Evapotranspiration

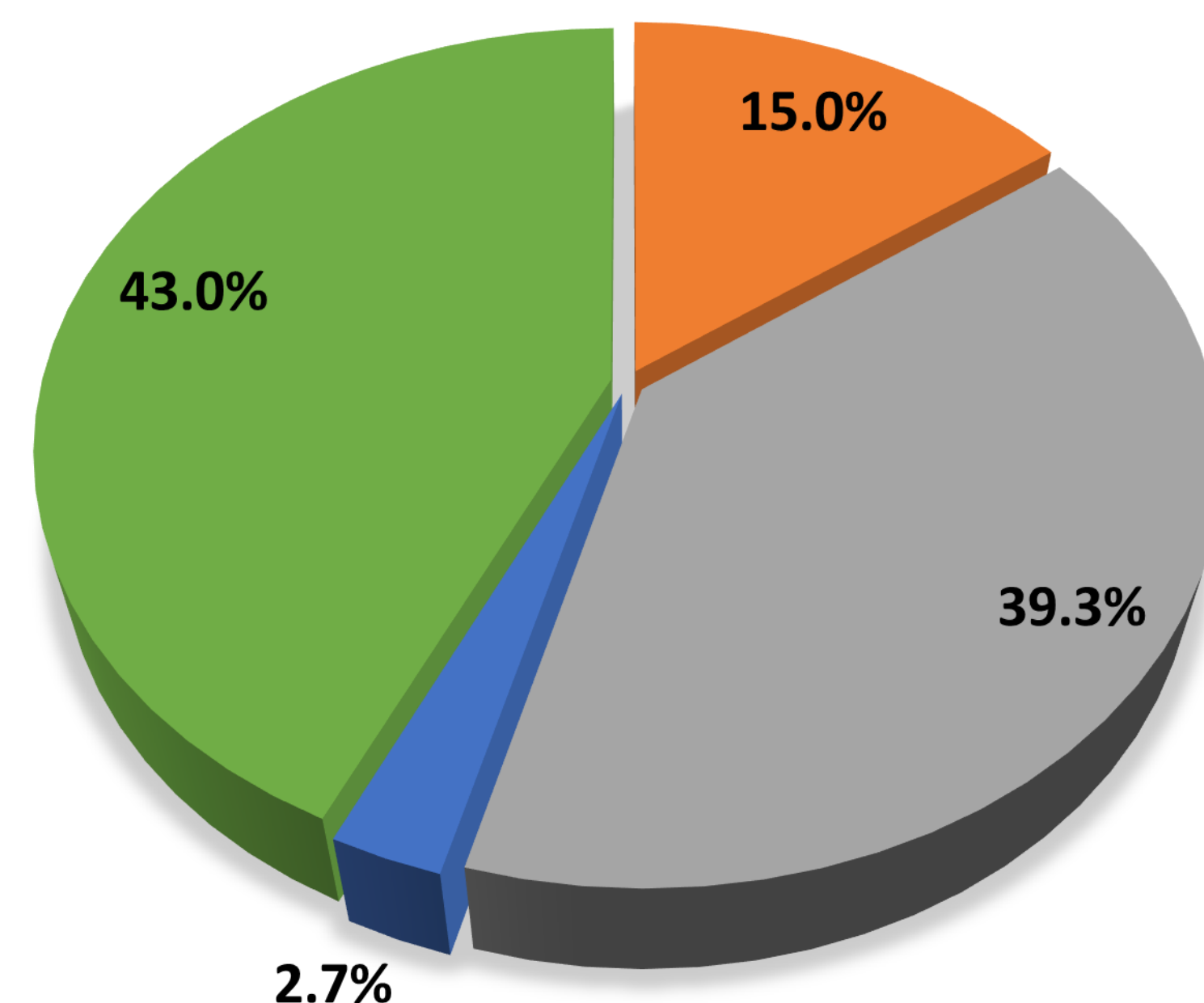
Forest



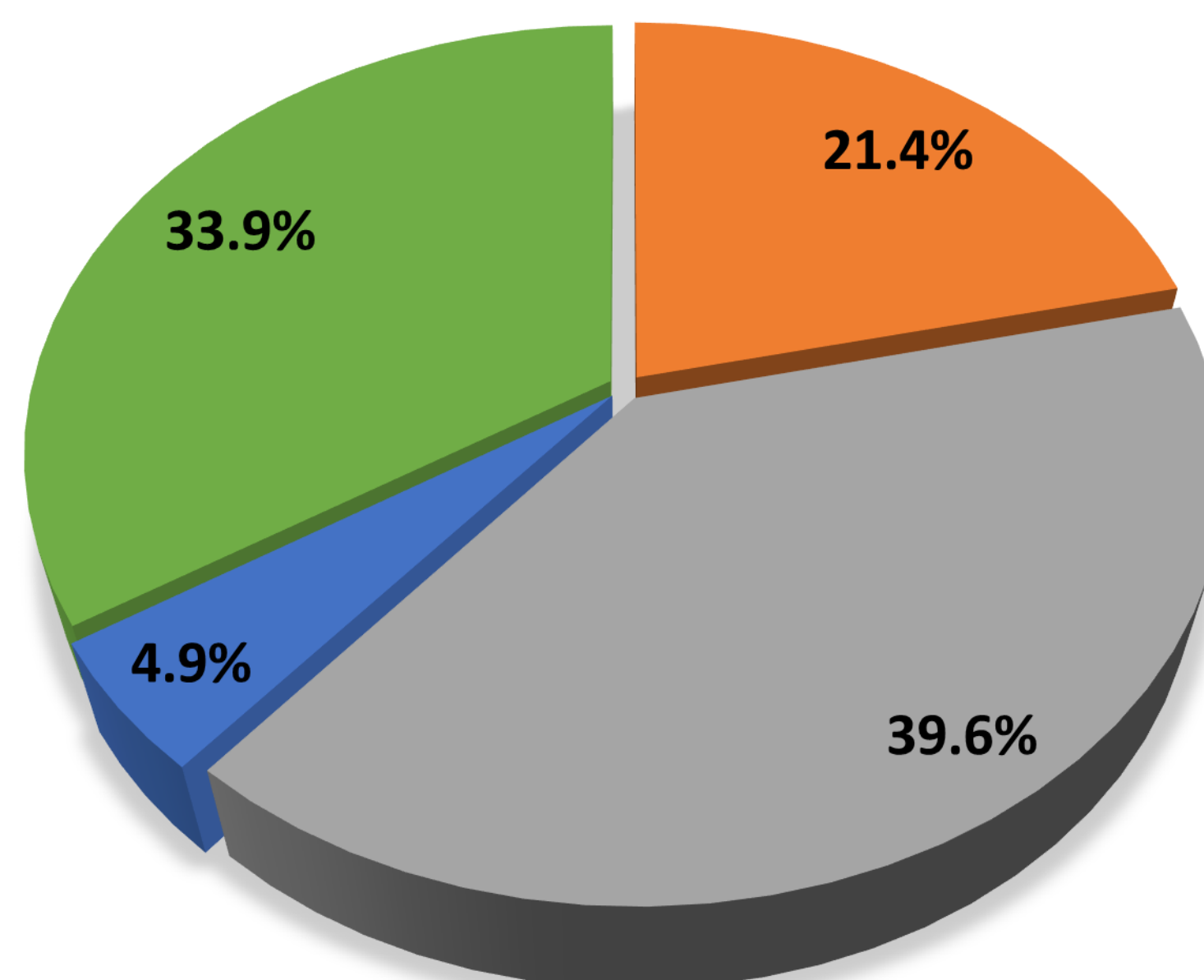
Wetland



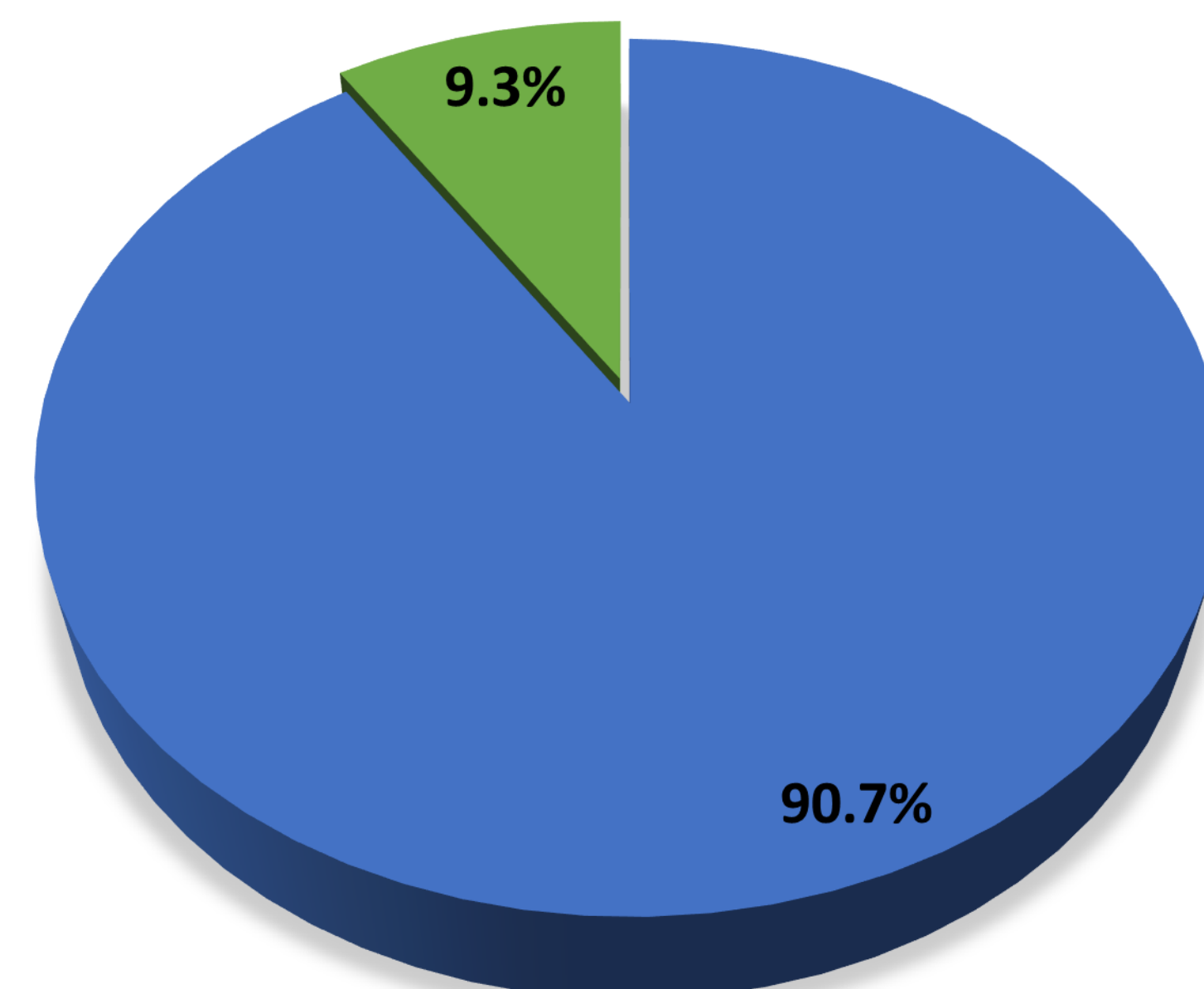
Agriculture



Developed Open Space

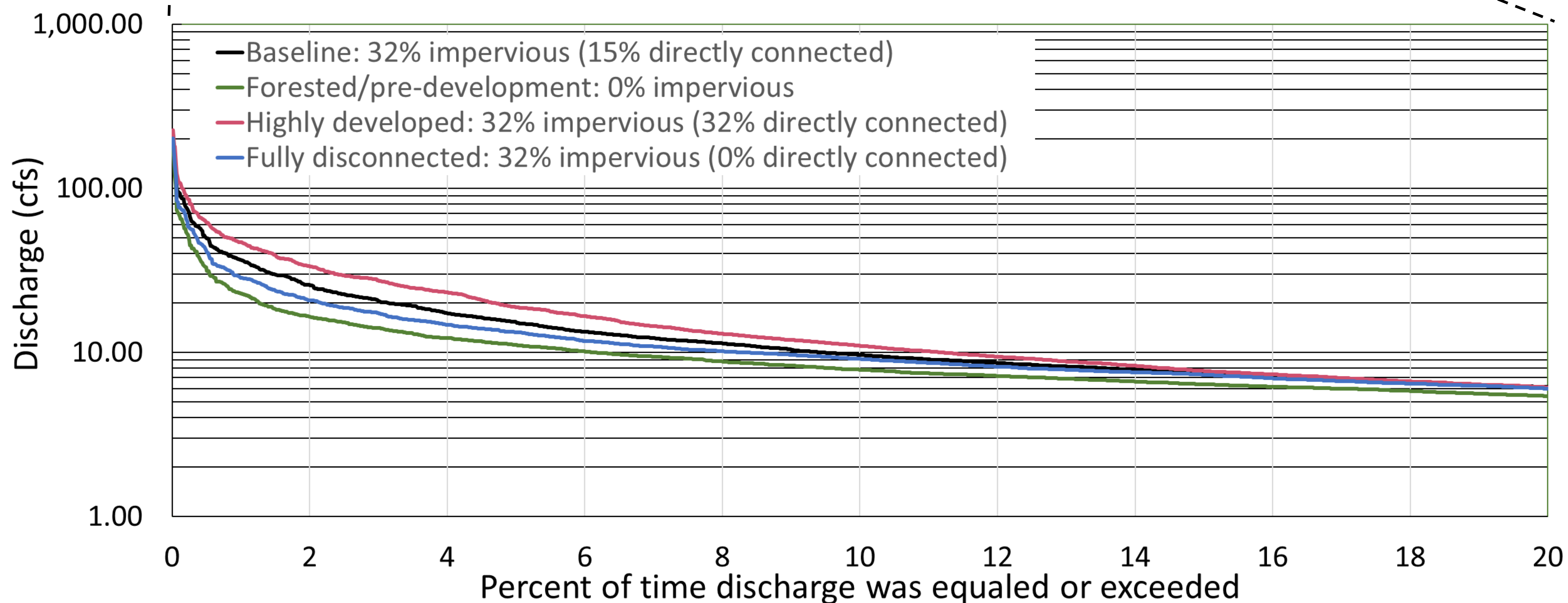
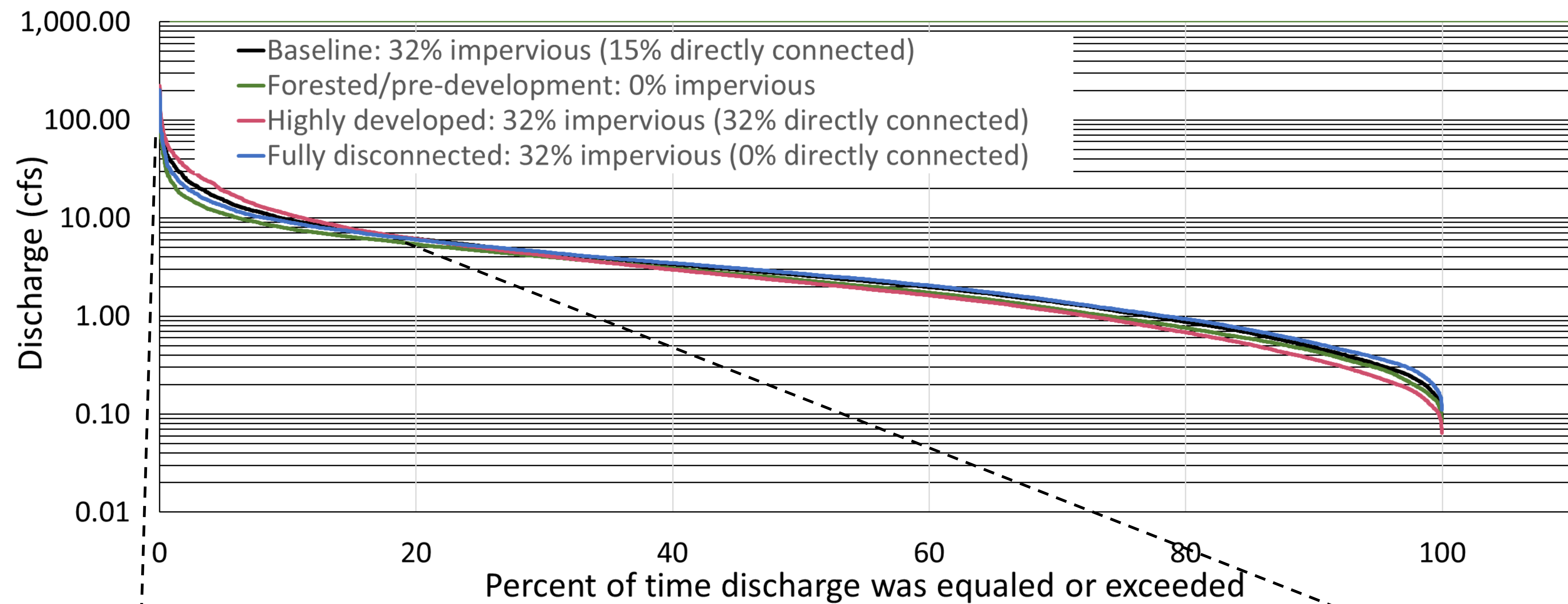


Impervious



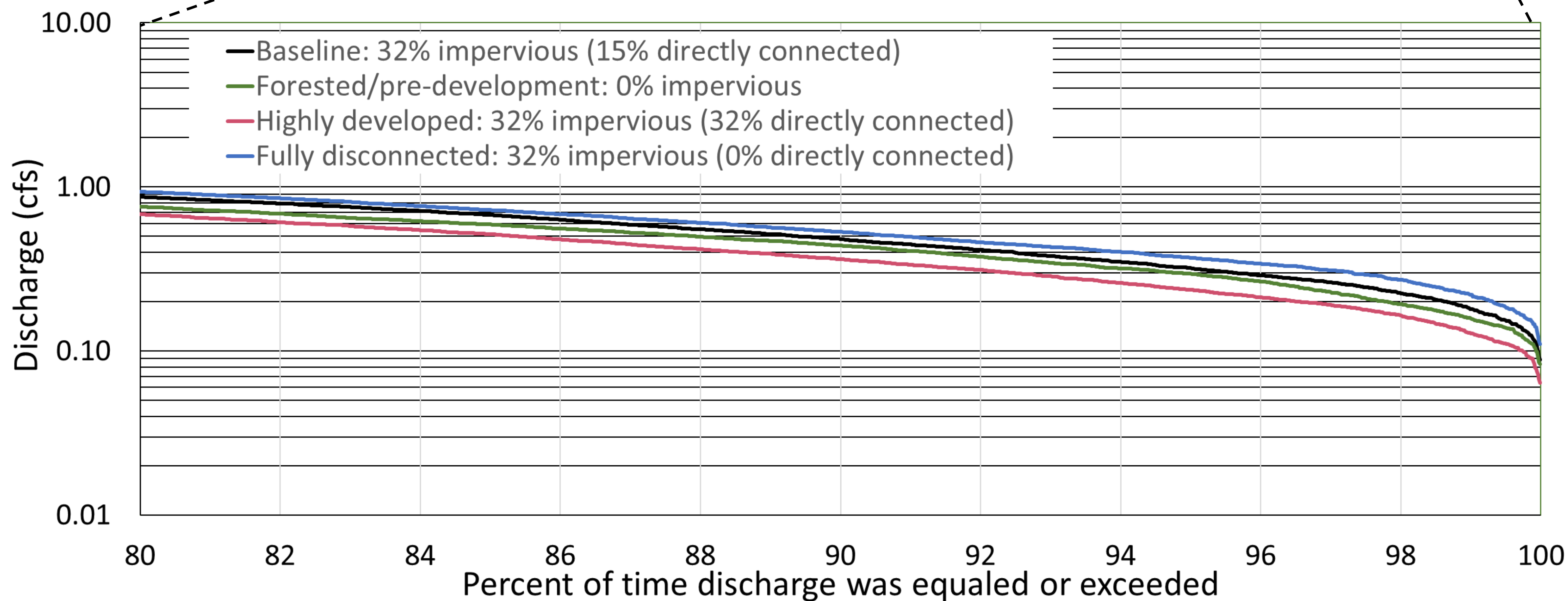
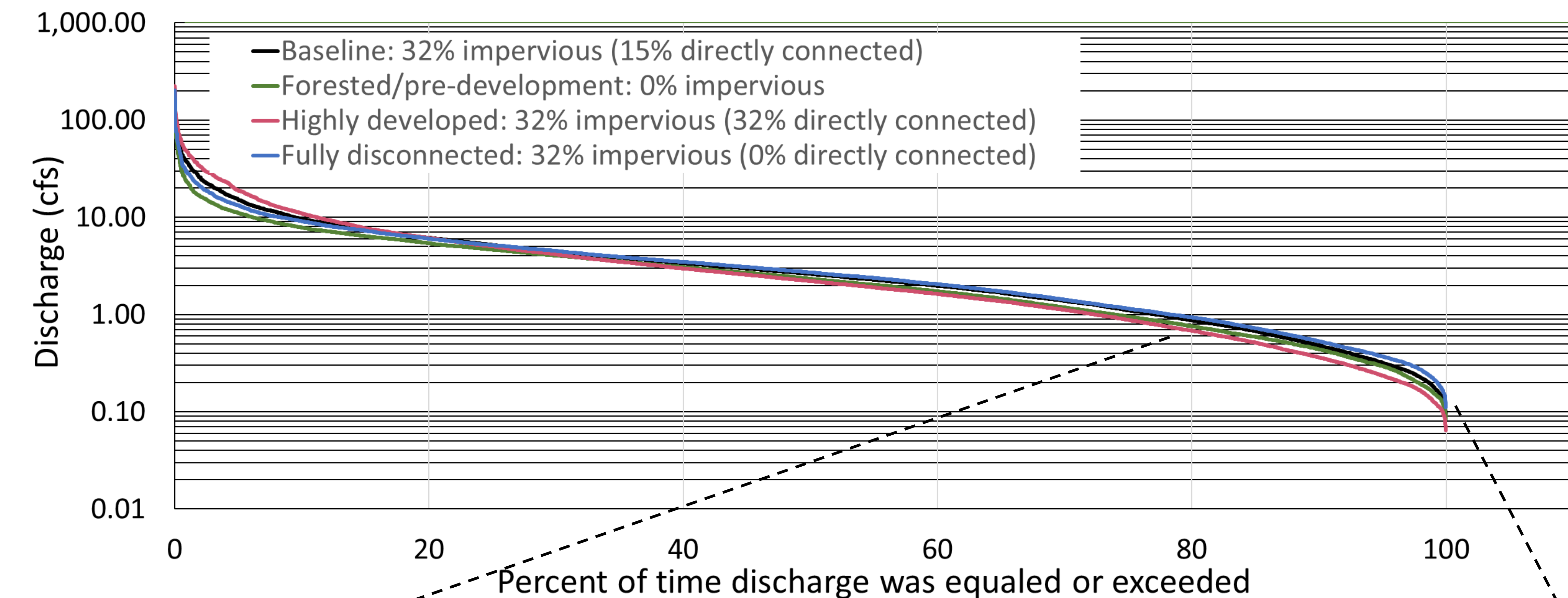
Impact of Land Cover on Water Balance

Land cover change (e.g., converting forest to developed areas) can have major impacts on how water moves through a watershed. Results from a watershed modeling study in Taunton, MA show that for forests and wetlands, most of the rainfall can be expected to be returned to the atmosphere via evapotranspiration (ET). Transitioning to impervious surfaces drastically reduces ET and increases runoff. Land cover change also impacts interflow (shallow subsurface flow) and groundwater recharge. Pervious developed open space appears to have relatively low ET but increased interflow and groundwater recharge compared to other pervious land uses. These results suggest the combined importance of infiltration and ET on stream flows.



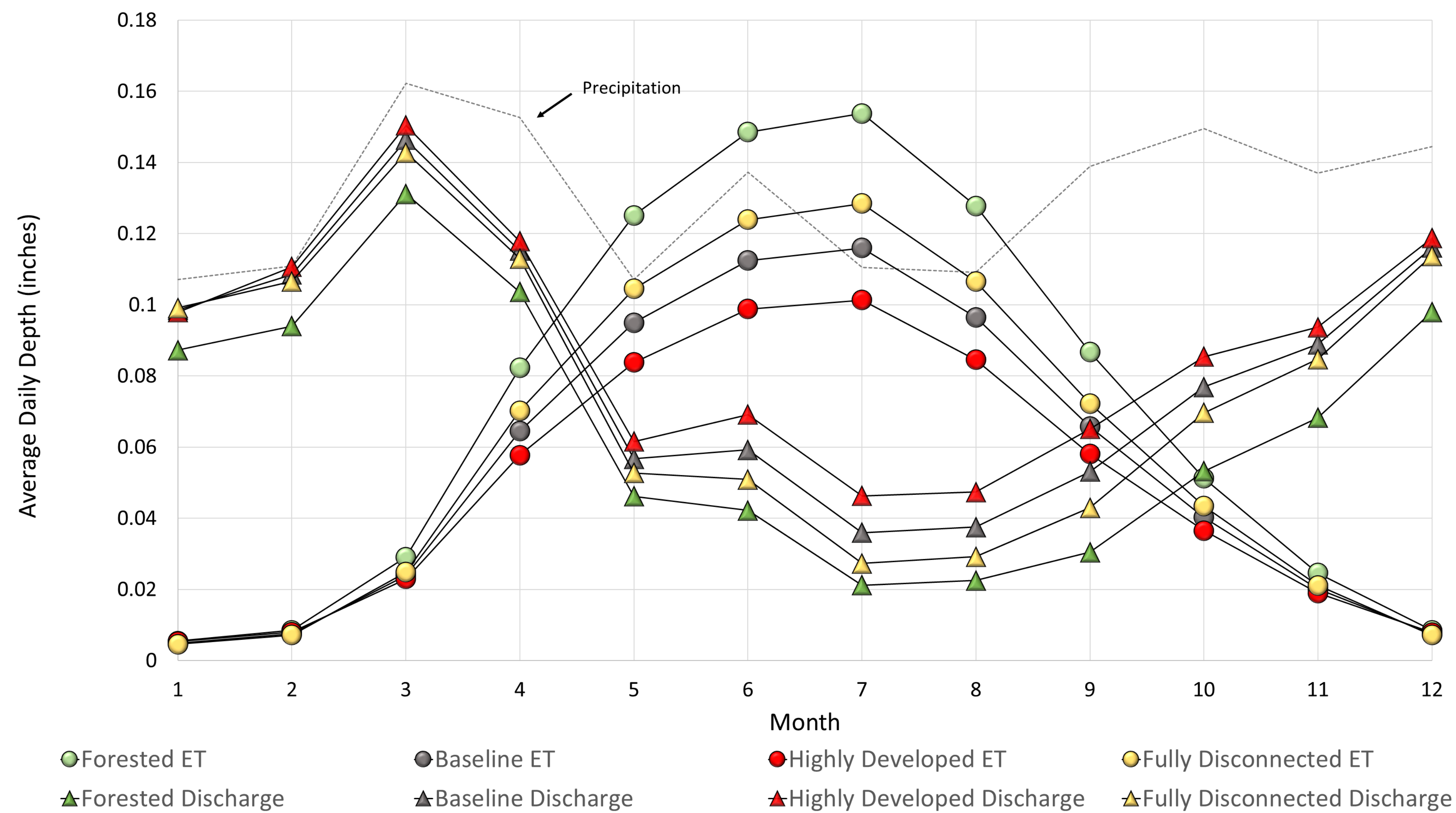
Impact of Land Cover on High Flows

The forested/pre-development condition has lower high-flows compared to all development scenarios. The fully disconnected scenario was closest to the forested condition, although still elevated. The highly developed scenario resulted in the highest high-flows.



Impact of Land Cover on Low Flows

The highly developed scenario had the lowest low-flows. Both the baseline and fully disconnected scenarios had higher low-flows than the forested condition. The fully disconnected scenario produced the highest low-flows.



Relationship between ET and flows

The role of ET on average daily flows is important. The graph to the left shows an inverse relationship between ET and average daily flows during the growing season.



However, while forested conditions may have relatively low average flows during the growing season, the highly developed condition resulted in the most extreme conditions for low flows. The graph on the left shows the highly developed scenario producing the lowest three-day minimum flows while the fully disconnected scenario resulted in the highest.

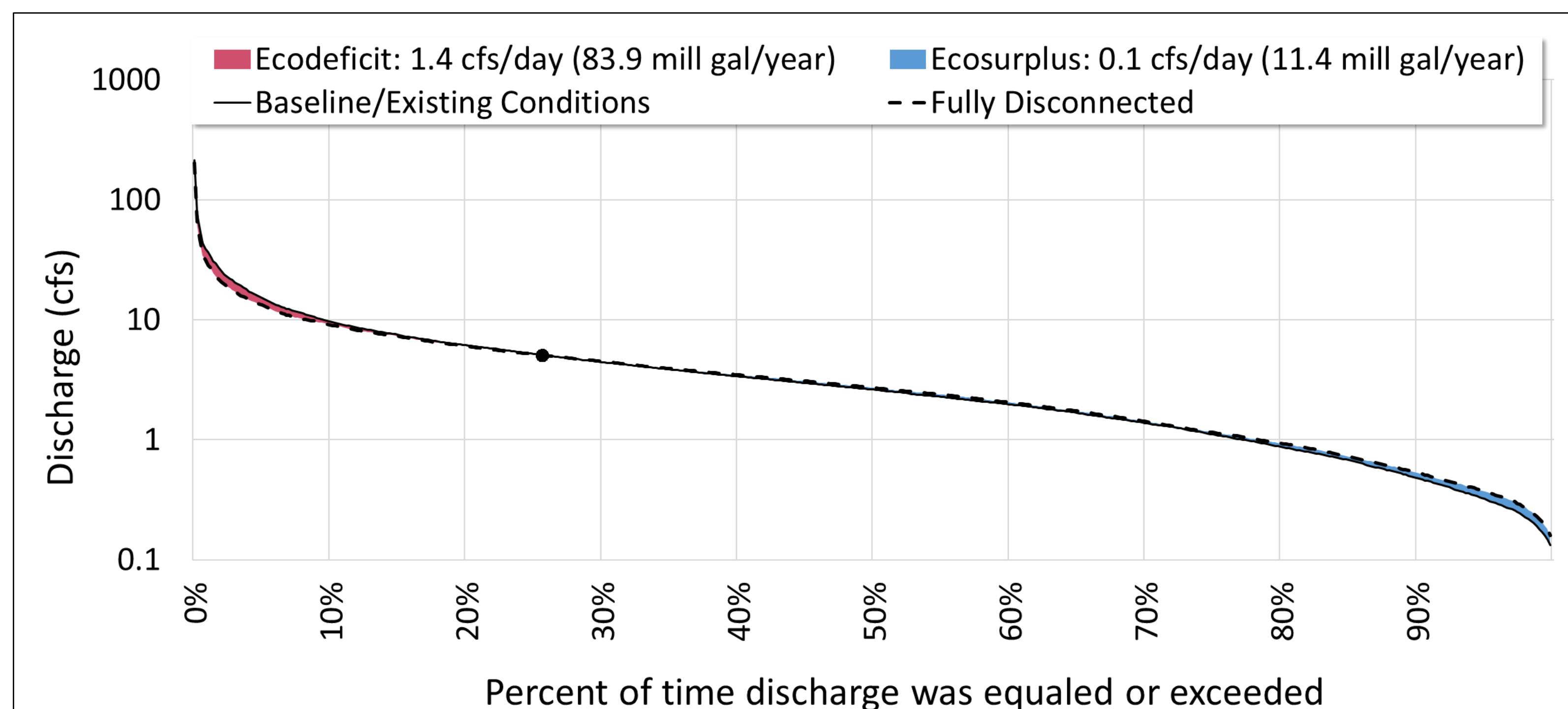
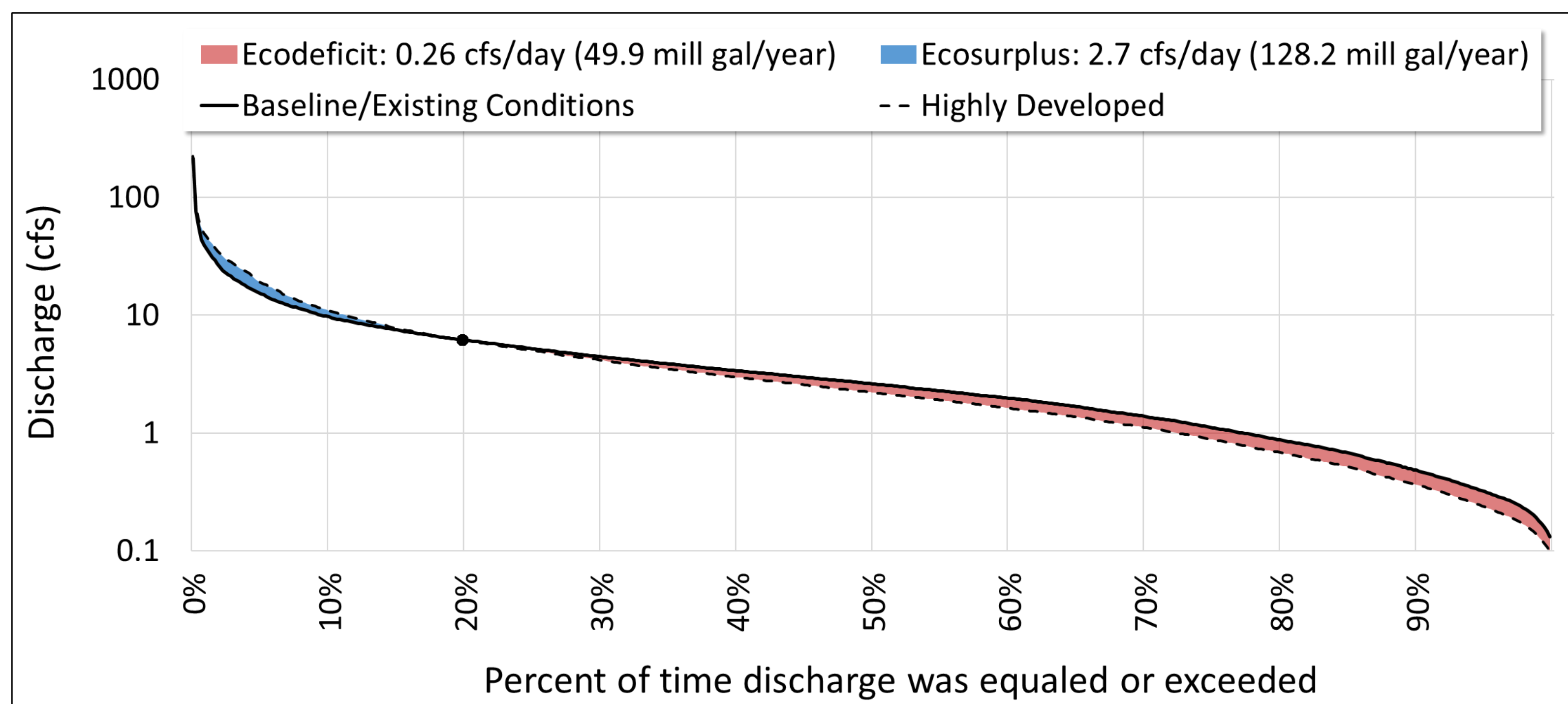
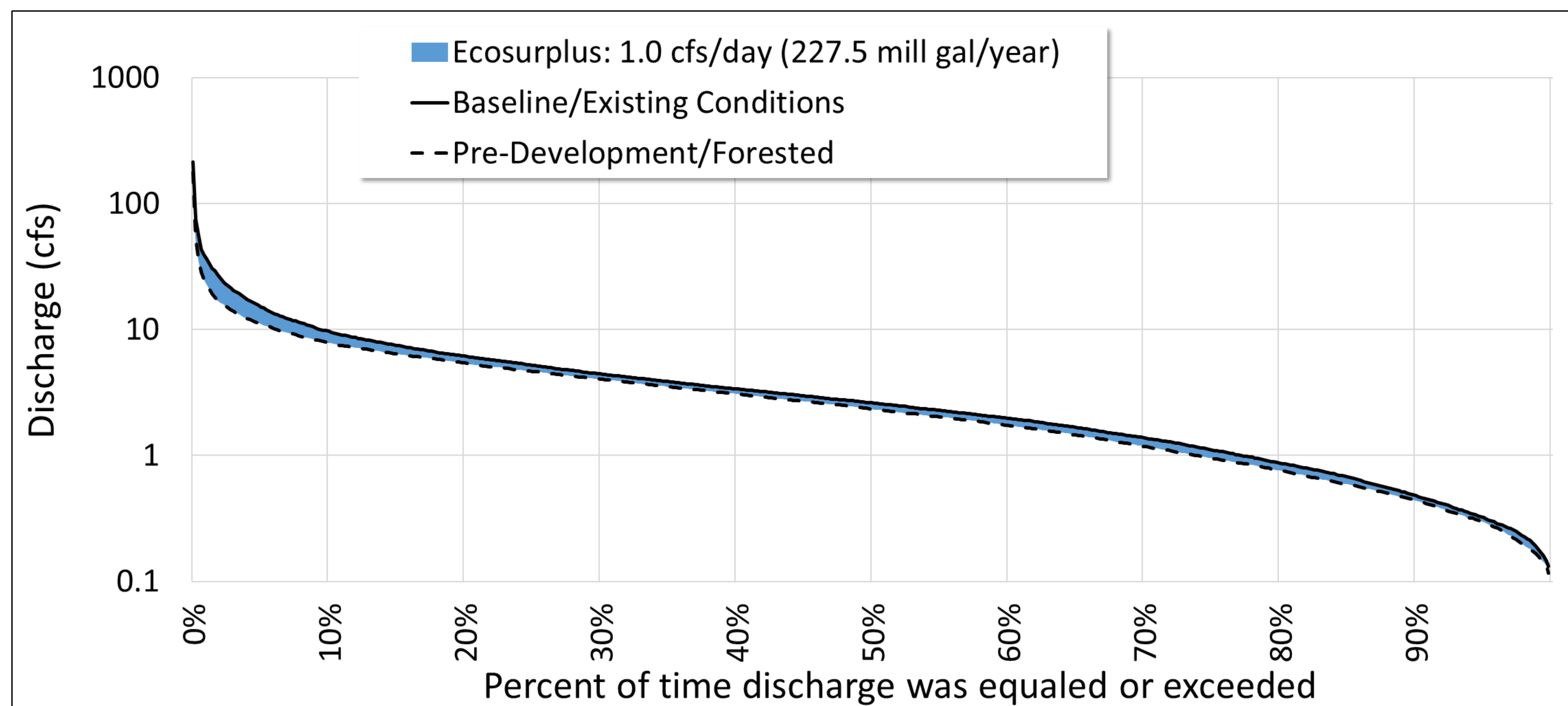
Relationship between land cover and flows

Ecodeficits and ecosurpluses are calculated from flow duration curves (FDCs). They provide information on the overall loss (ecodeficit) or gain (ecosurplus) in a stream over the period of analysis.

The baseline condition for a watershed has 15% of its land as directly connected impervious surfaces, which results in an ecosurplus compared to pre-development conditions. This is sustained across the entire FDC (top graph).

When a highly developed condition (middle graph) is compared to the baseline condition, the highly developed condition results in ecosurpluses at high flows but ecodeficits at low flows. The higher high flows are a result of the increase in directly connected impervious areas, allowing runoff to be quickly conveyed to the stream. The ecodeficit is likely due to reduced opportunities for precipitation to infiltrate into the ground.

Compared to the highly developed condition, the opposite ecosurplus/ecodeficit response is seen when impervious areas are fully disconnected (bottom graph). Ecodeficits exist at high flows because disconnection reduces the amount and speed at which water is conveyed to the stream. Ecosurpluses at low flows may be the result of greater infiltration increasing interflow and groundwater flow.

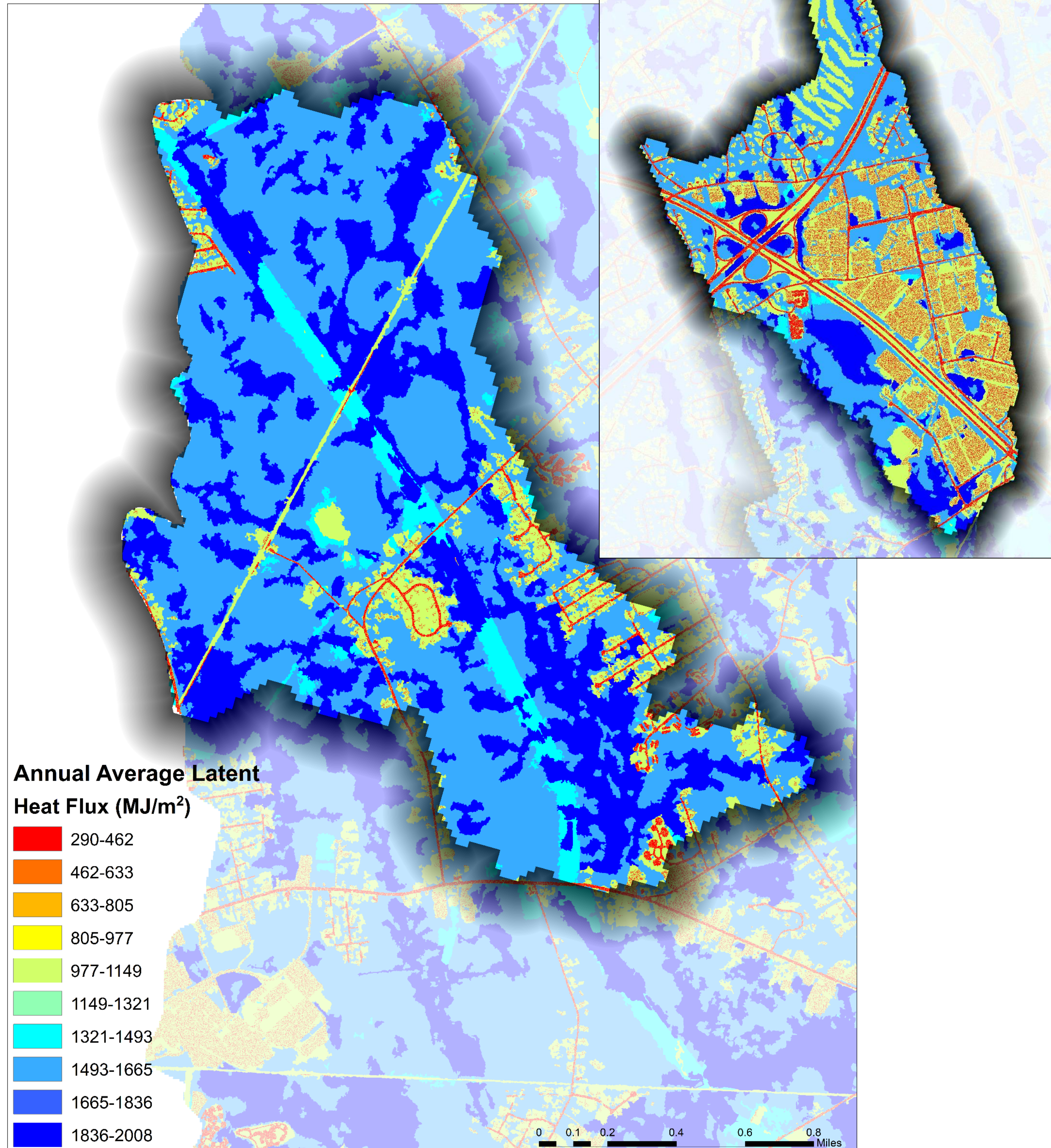


Ecological and human risks associated with changing water tables/base flow. Adapted from Bhaskar et al., 2016

Falling water table/baseflow	Rising water table/baseflow
<i><u>Ecological alteration / risk</u></i>	<i><u>Ecological alteration / risk</u></i>
Increased extreme water temperature	Reduction in extreme water temperature
Increased likelihood of channel drying	Increasing flow permanence and damping of seasonal fluctuations in water depth
Reduced water depth for fish survival and recruitment	Increase in nutrient loads
Reduced water quality due to increased contaminant concentrations	Increase in salinity of surface soil and water
Falling O ₂ levels associated with reduced flow velocity	Reduction in species that rely on riffle habitat for feeding or spawning
Altered in-stream species assemblage structure	Altered in-stream species assemblage structure
Reduced nutrient processing in riparian areas	Increased invasion by competitive non-native species
Reduced un-stream processing associated with reduced groundwater upwelling	Altered in-stream and riparian vegetation
Terrestrialization of the riparian vegetation community	
Reduced health of deep-rooted vegetation across the catchment	
<i><u>Human Risk</u></i>	<i><u>Human Risk</u></i>
Reduced water quality due to increased contaminant concentrations	Flooding of buildings
Reduced access of existing bores to groundwater	Flooding of underground infrastructure
Reduced volume of water for household use and irrigation (where groundwater contributes to water use)	Increasing contamination of ground-ad stream water by septic systems
	Increased leakage of groundwater into wastewater systems leading to wastewater treatment plants treating groundwater

Upper Hodges Brook

Pilot Tributary



Impact of Land Cover on Latent Heat Flux

Comparing the Upper Hodges Brook and Pilot Tributary provides an example of the impact land cover has on heat exchange and temperature. Surfaces such as asphalt and pavement absorb solar radiation and warm the surrounding air and ground. Vegetation, however, uses solar radiation during photosynthesis and evapotranspiration; water is taken up by roots and transferred via plant tissue to leaves, where it evaporates. This results in a cooling effect due to energy (heat) being absorbed by water vapor as it changes from liquid to gas. The cooling impact of land cover can therefore be quantified by the latent heat flux.

The Upper Hodges has more developed area than the Pilot Tributary, resulting in lower values of latent heat flux (yellow to red) and less evaporative cooling. The difference in energy between the Pilot Tributary and Upper Hodges was enough to burn approximately 88,900 Calories!

Impact of Land Cover on Carbon Sequestration

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (CO₂), the most produced greenhouse gas. Carbon is sequestered in vegetation such as grasslands or forests, as well as in soils as organic carbon; this keeps CO₂ out of the atmosphere, where it would contribute to climate change. Activities that involve land conservation or restoration can sequester carbon, while disturbances such as fire and land development can release carbon.

Using the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model, carbon balances were developed for the Upper and Lower Hodges Brook and Pilot Tributary to compare carbon storage for pre- and post-development conditions. While there are simplifications in this model, these results indicate that the ability of these watersheds to store carbon is reduced as the amount of development increases.

Total Carbon (megagrams)	Upper Hodges Brook	Lower Hodges Brook	Pilot Tributary
Predevelopment/Forested Condition	109,290	82,405	99,350
Existing Land Use/Land Cover Condition	45,628	60,065	79,233
Change in Carbon for Existing Condition	-63,662	-22,340	-20,117
Percent Change in Carbon for Existing Condition	-58%	-27%	-20%

Note: 1 megagram = 1.102 US ton