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

Final Report. Appendix E
Factsheets

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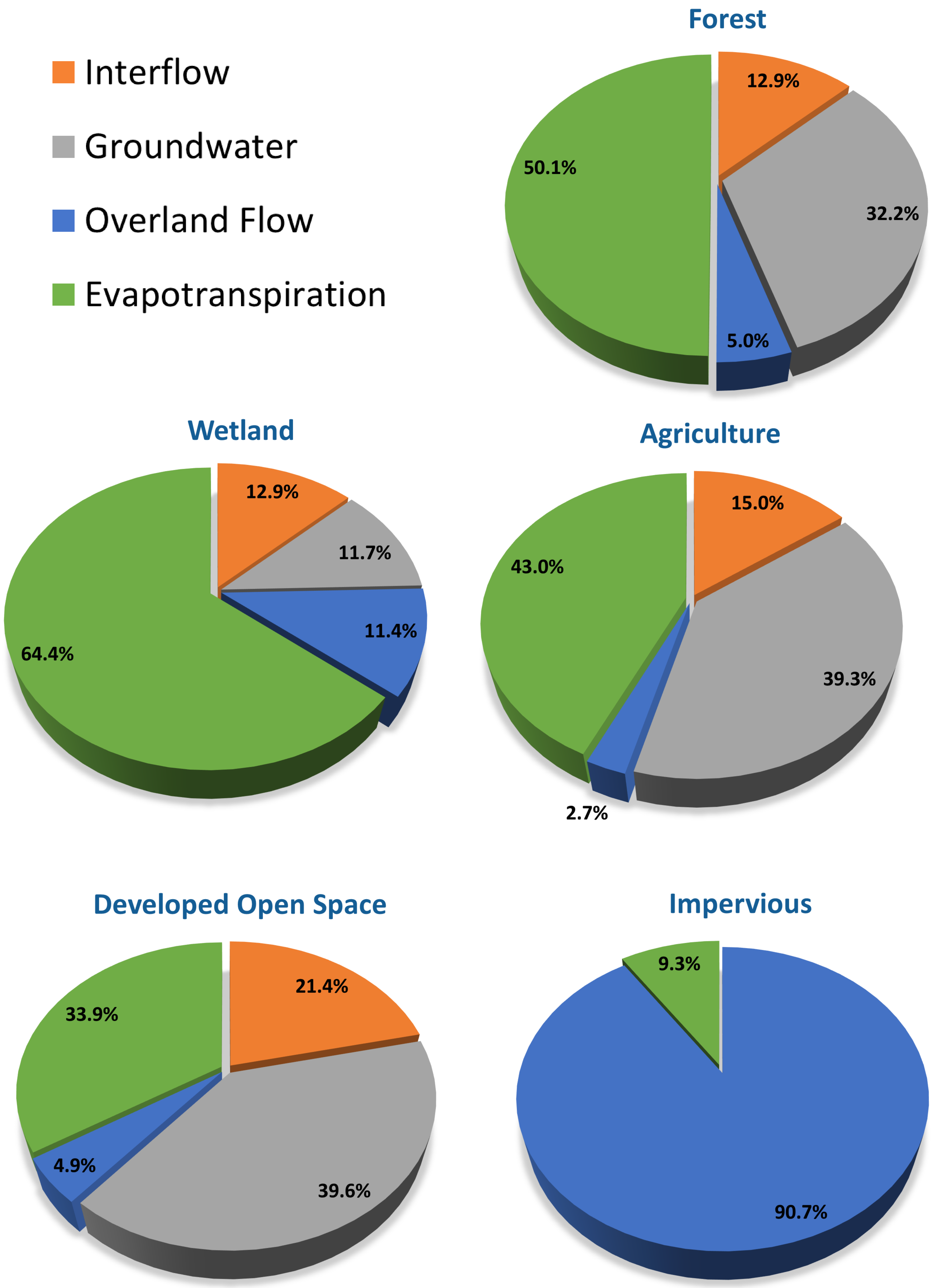
Prepared for:
U.S. EPA Region 1

Prepared by:

PARADIGM ENVIRONMENTAL

GLEC

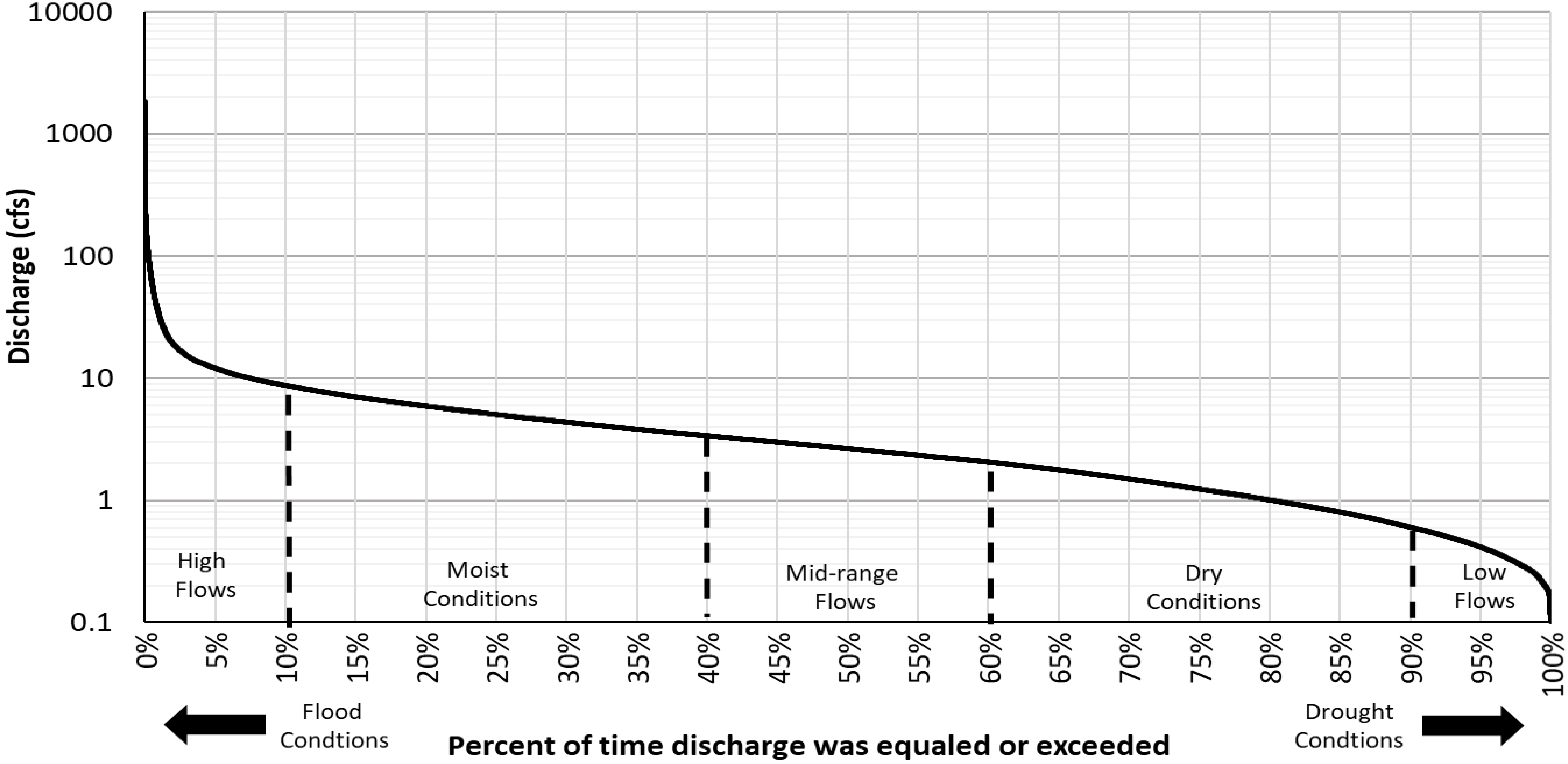
Blanket Purchase Agreement: BPA-68HE0118A0001-0003
Requisition Number: PR-R1-20-00322
Order: 68HE0121F0001



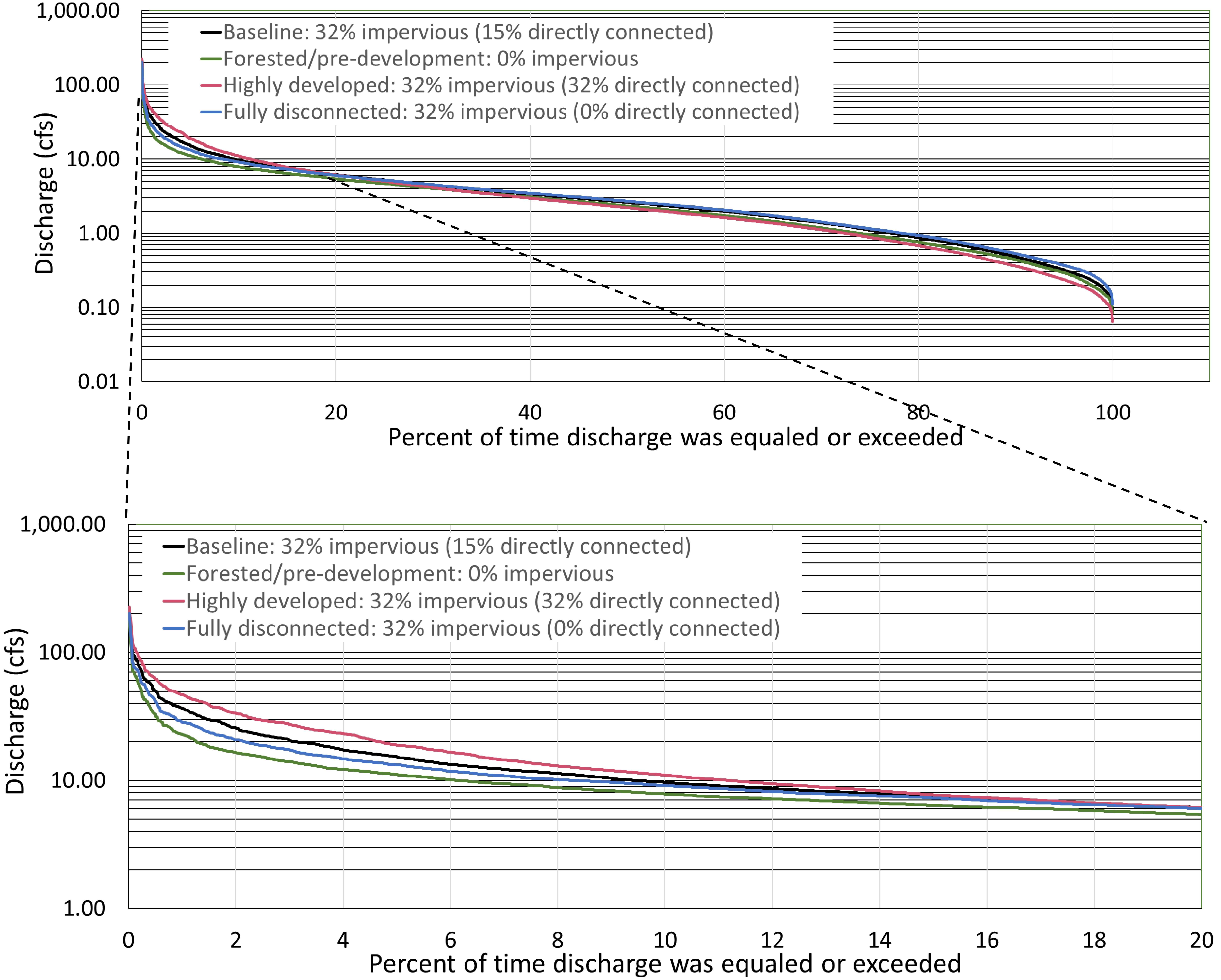
<u>Impact of Land Cover on Water Balance</u>

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.

Example Flow Duration Curve with labeled flow regimes

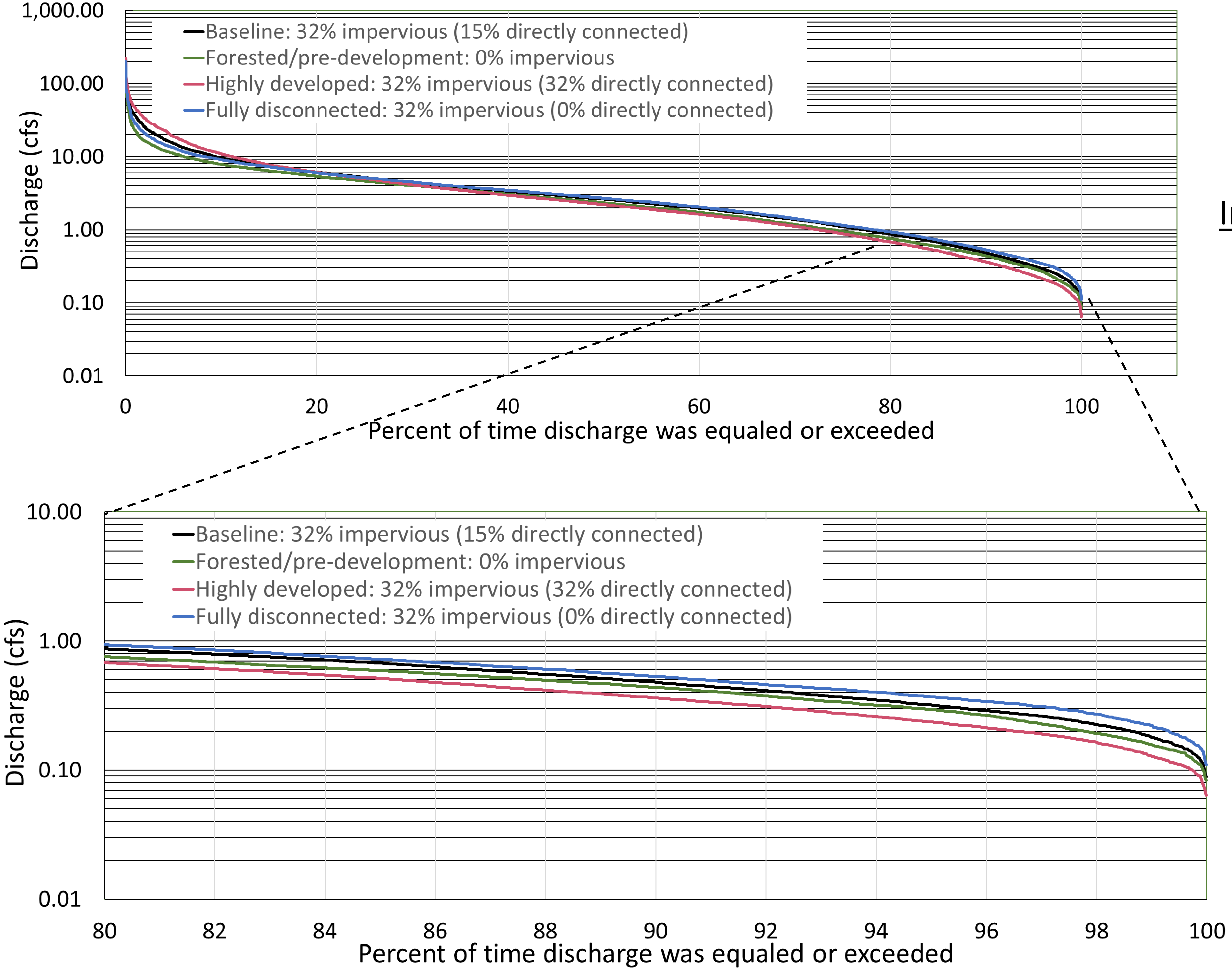


Adapted from EPA 2007. “An Approach for Using Load Duration Curves in the Development of TMDLs”



Impact of Land Cover on High Flows

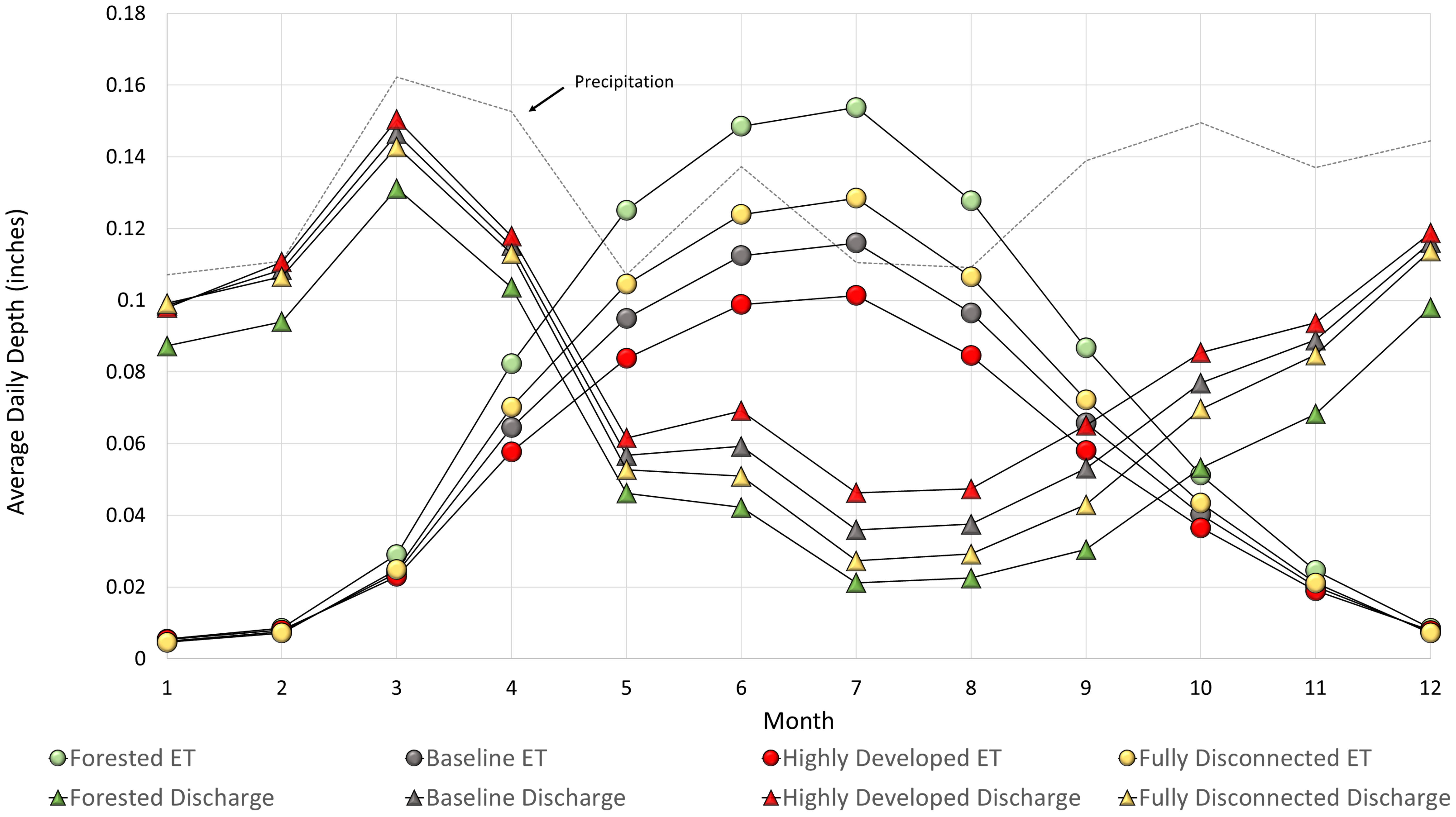
The forested/pre-development condition has lower high-flows compared to all development scenarios. The fully disconnected scenario was closest to the forested condition, although still elevated. The highly developed scenario resulted in the highest high-flows.



Impact of Land Cover on Low Flows

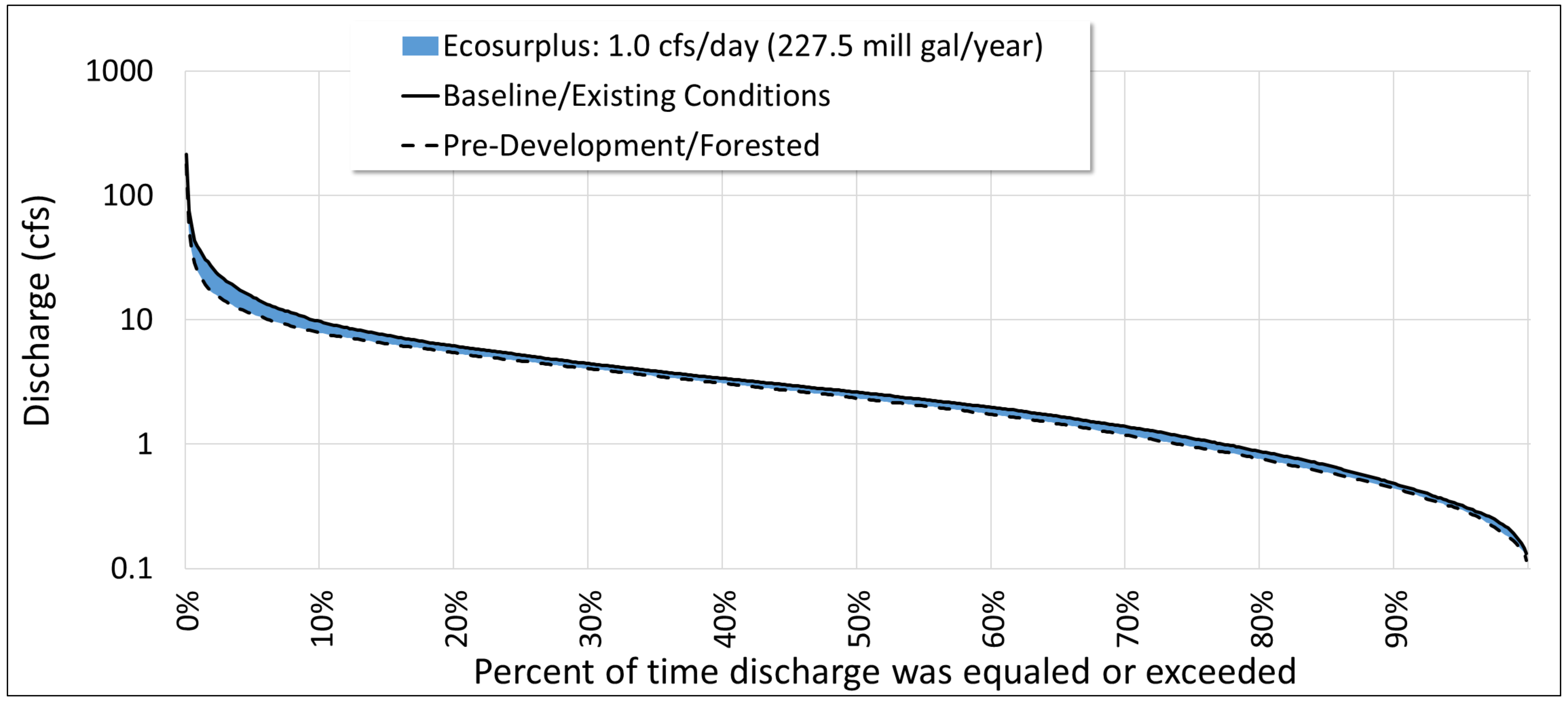
The highly developed scenario had the lowest low-flows. Both the baseline and fully disconnected scenarios had higher low-flows than the forested condition. The fully disconnected scenario produced the highest low-flows.

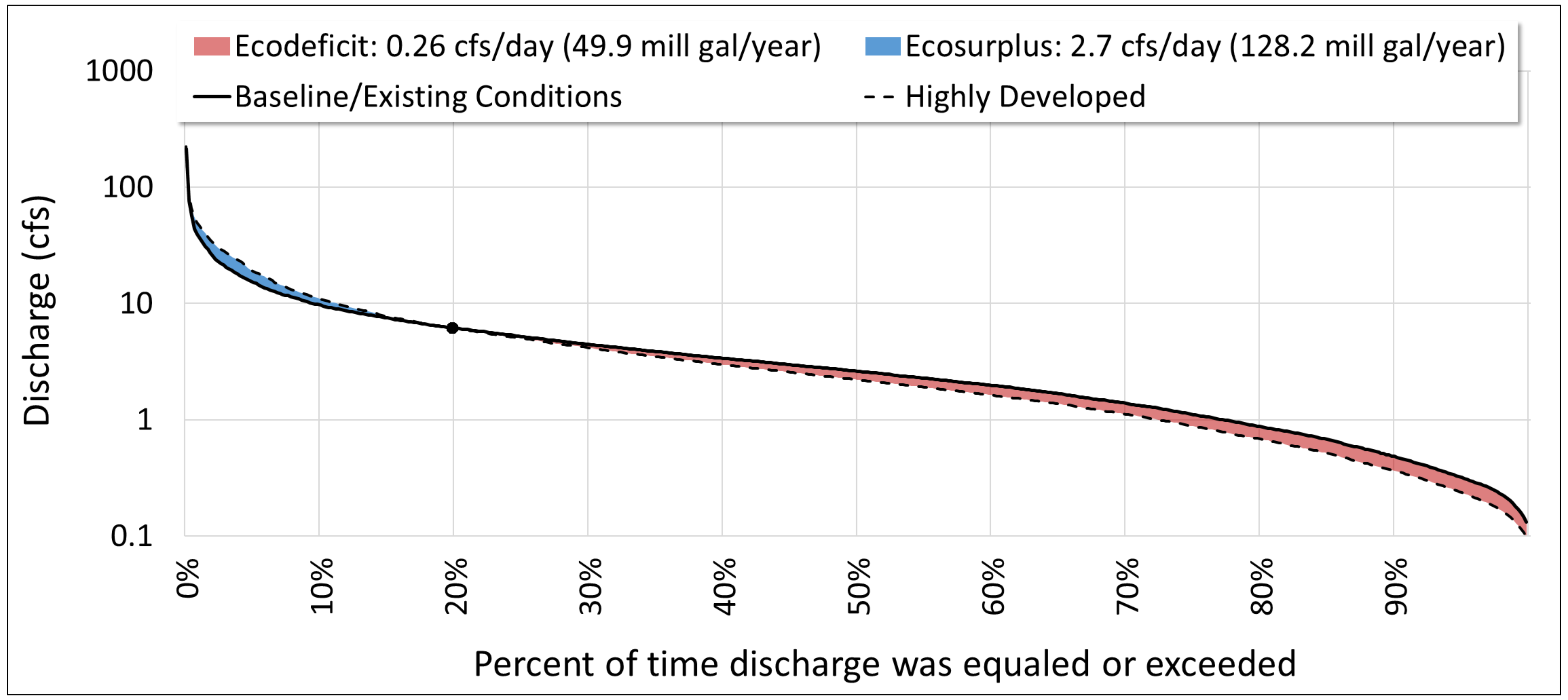
Relationship between ET and flows

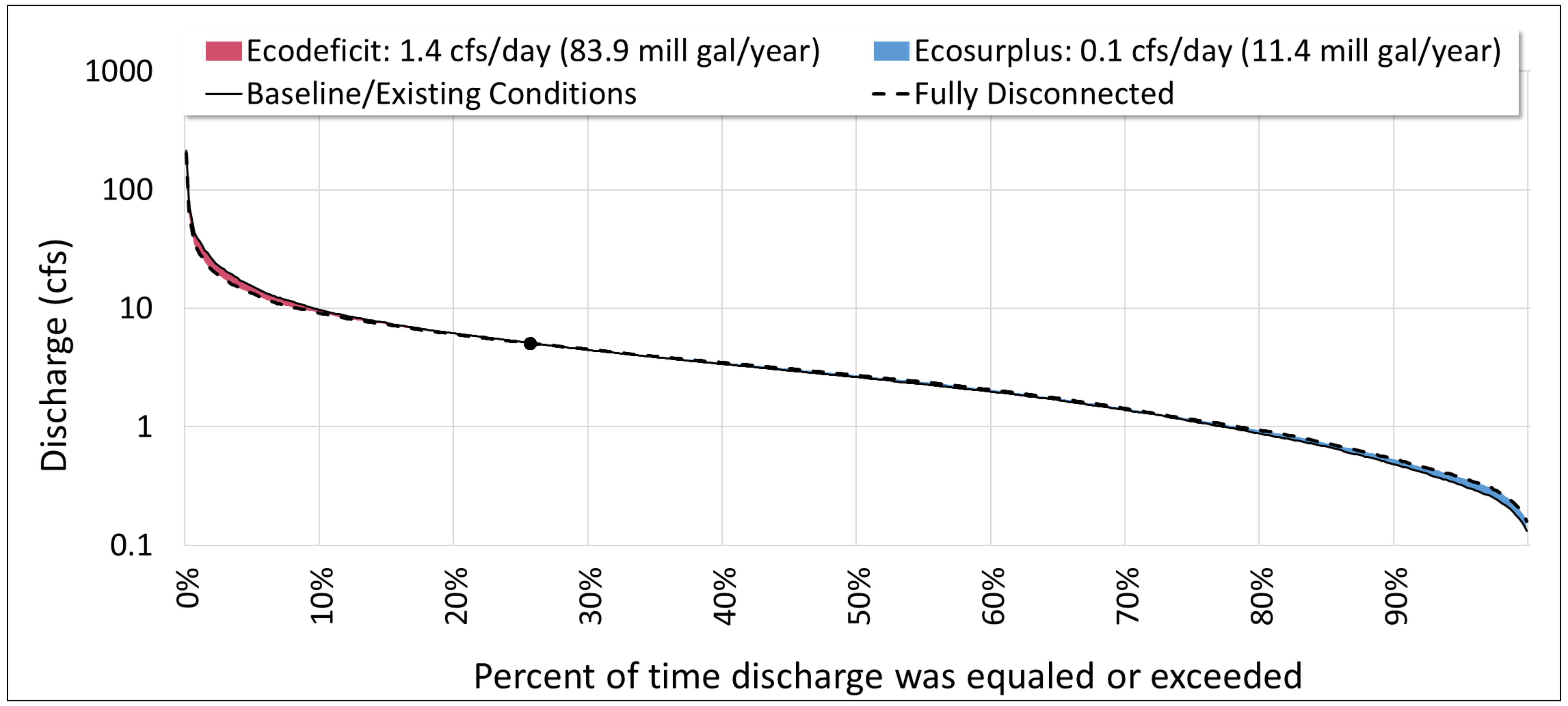


The role of ET on average daily flows is important. The graph to the left shows an inverse relationship between ET and average daily flows during the growing season.

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.







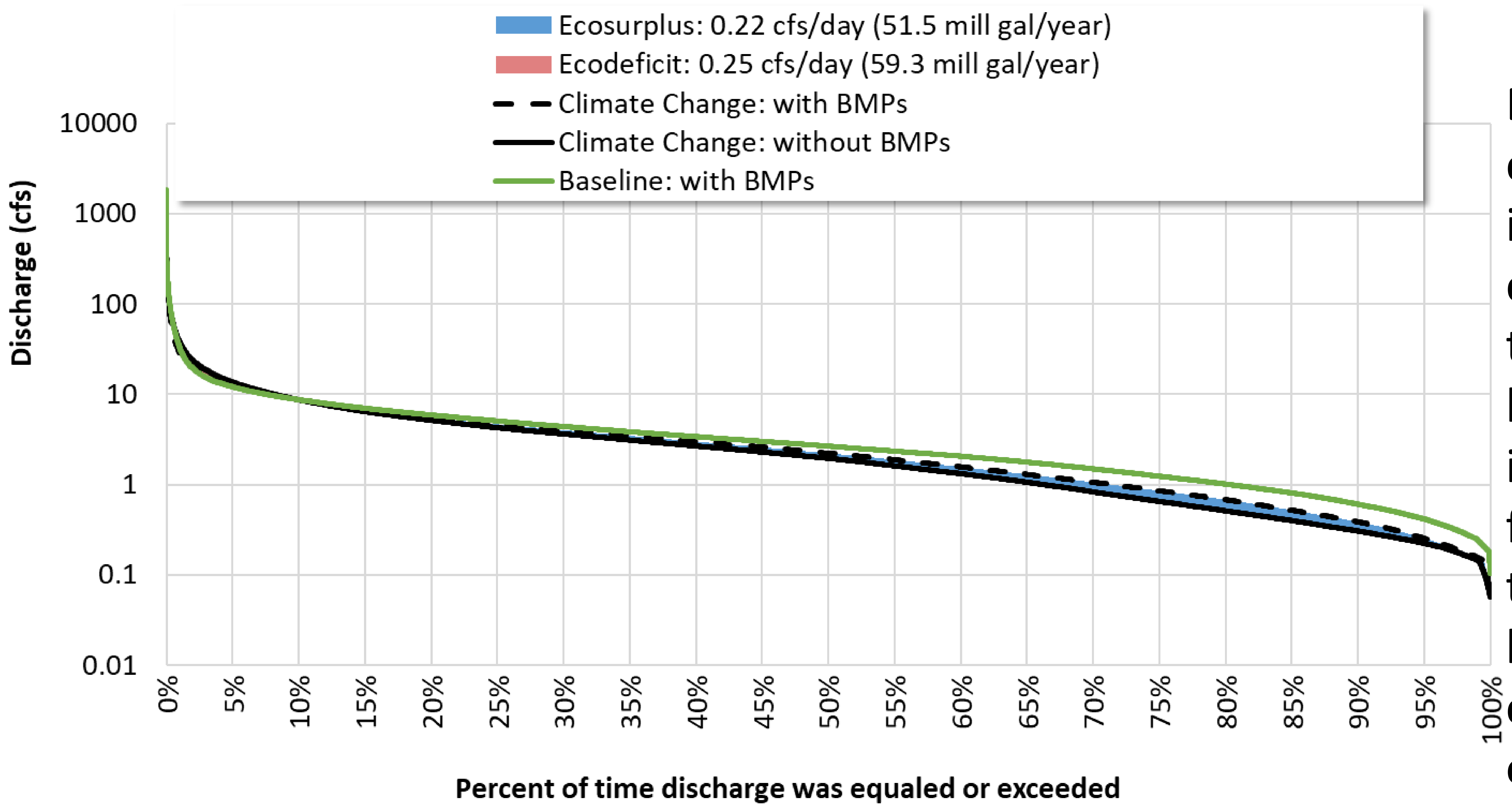
Relationship between land cover and flows

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.

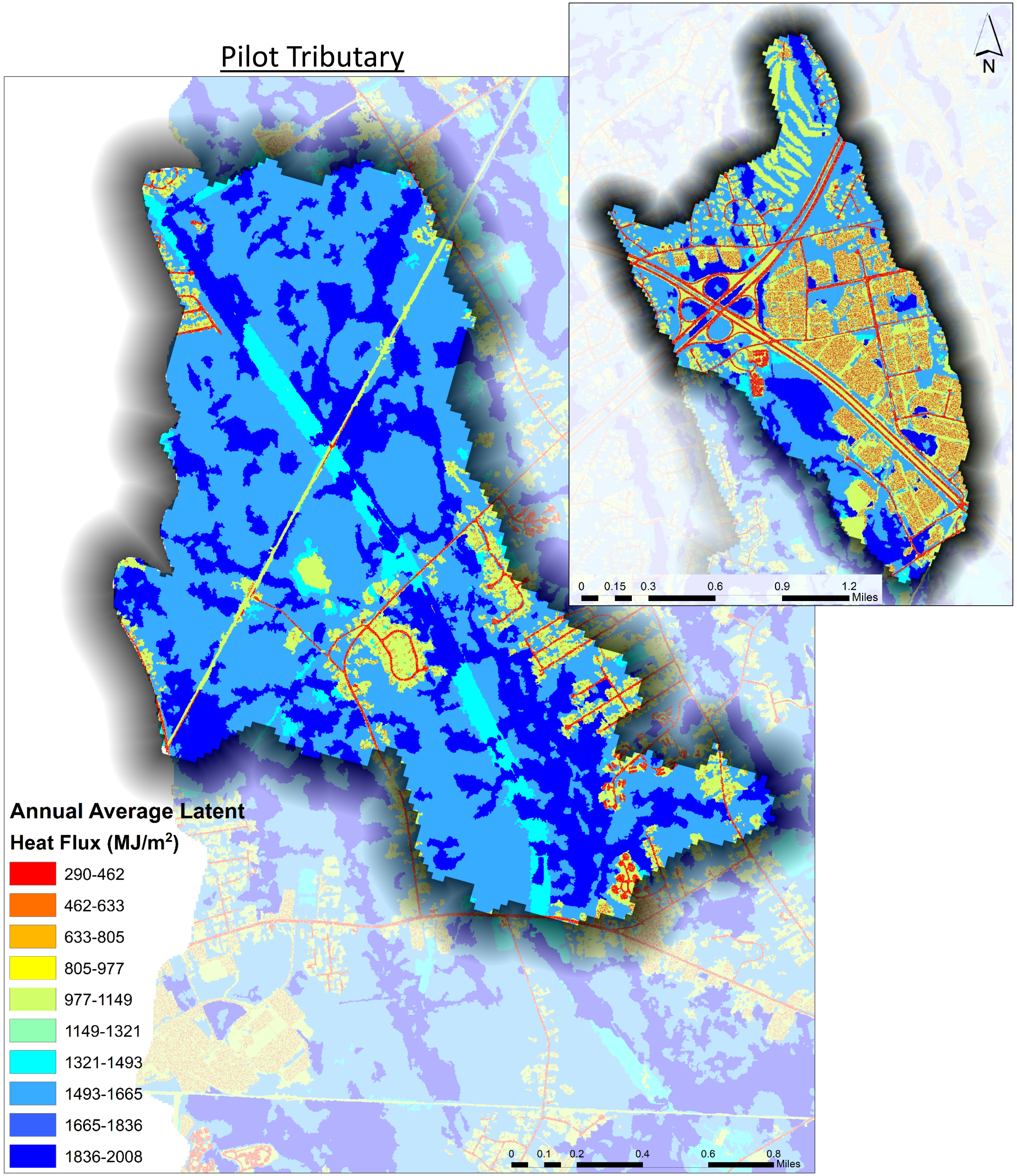


Resiliency to Climate Change

BMP implementation can help mitigate the impacts of climate change. Results from Phase I of EPA's FDC project in the Taunton Watershed in Massachusetts suggest that climate change will result in lower base flows. The graph to the left demonstrates that BMP implementation can limit the reduction in baseflows. Additionally, BMP implementation provides mitigation by reducing higher flows. The ecosurplus (blue area) at the right-hand side of the FDC demonstrates that BMP implementation can help keep baseflows closer to baseline conditions in a changing climate. While not visible, an ecodeficit exists on the left-hand side of the graph, showing that BMPs have also reduced the higher flows associated with climate change.

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
Ecological alteration/risk	*Ecological alteration/risk*
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	
Human Risk	*Human Risk*
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 watersheds 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 watershed has more developed area than the Pilot Tributary watershed, 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 a year!

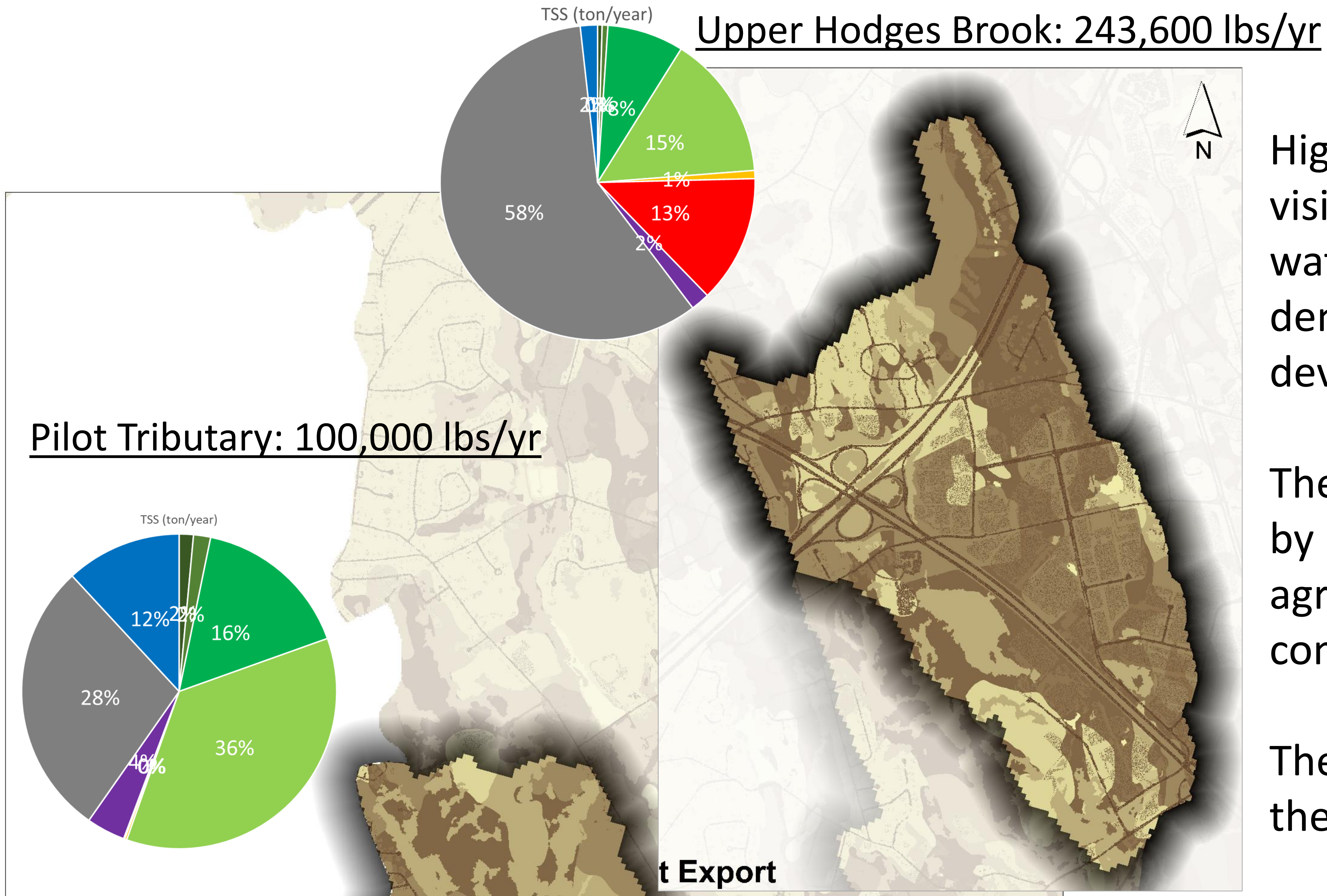
Total Carbon (megagrams)	Upper Hodges Brook	Lower Hodges Brook	Pilot Tributary
Predevelopment/Forested Condition	109,290	82,405	99,350
Existing Land Use/Land Cover Condition	45,628	60,065	79,233
Change in Carbon for Existing Condition	-63,662	-22,340	-20,117
Percent Change in Carbon for Existing Condition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

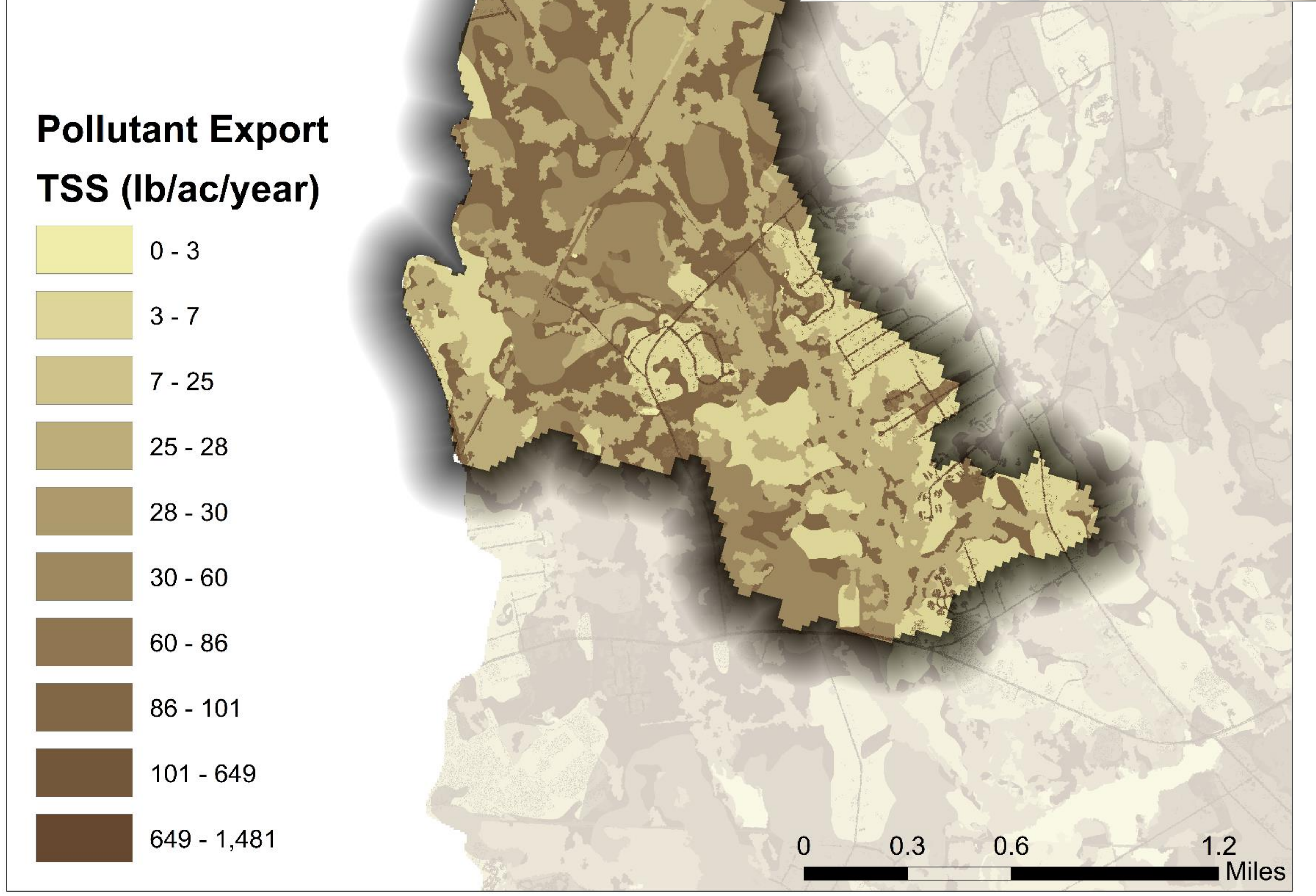
Note: I megagram = 1.102 US ton

Impact of Land Cover on Carbon Sequestration

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (CO_2), 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 CO_2 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.



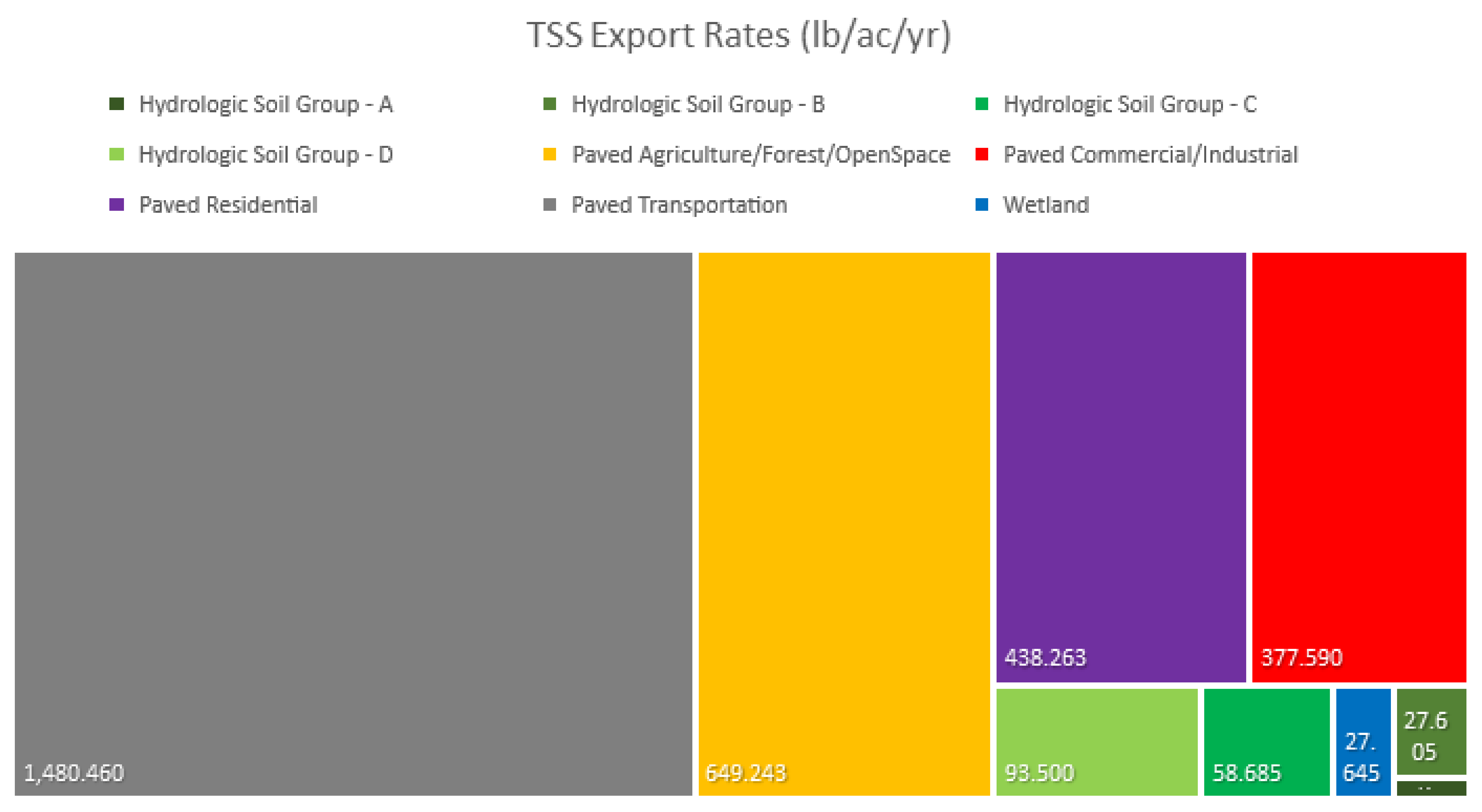


Impact of Land Cover on TSS Export

High TSS export from roadways and developed areas is visible in both the Upper Hodges Brook and Pilot Tributary watersheds. In the Upper Hodges Brook, the greater density of developed area is visible, while in the less developed Pilot, TSS export is lower.

The bar chart below shows that TSS export is dominated by paved areas that include transportation, agriculture/forest/open space, residential, and commercial/industrial land uses.

The pie charts show the total sediment load by source for the pilot tributary and Upper Hodges sub-watersheds.

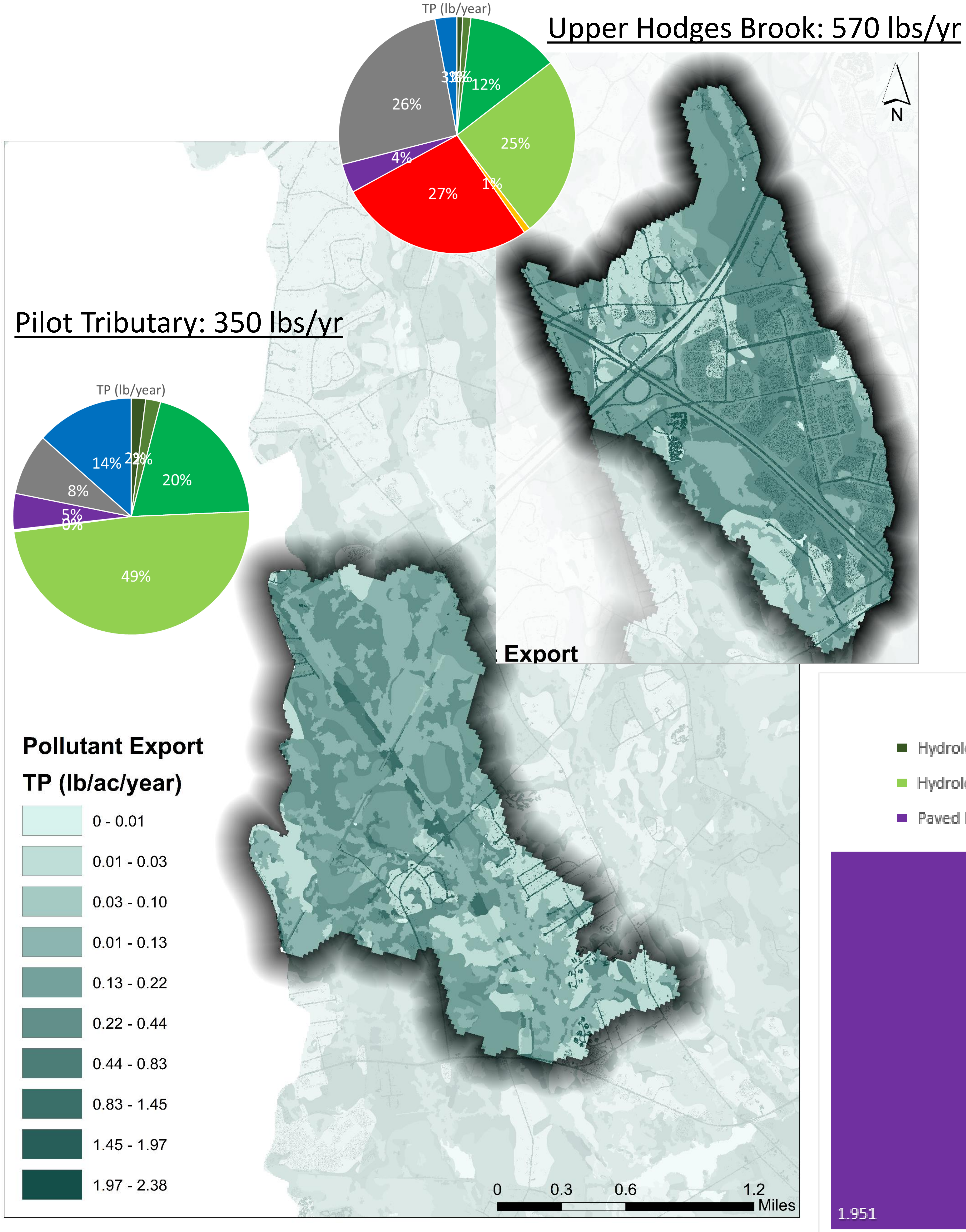


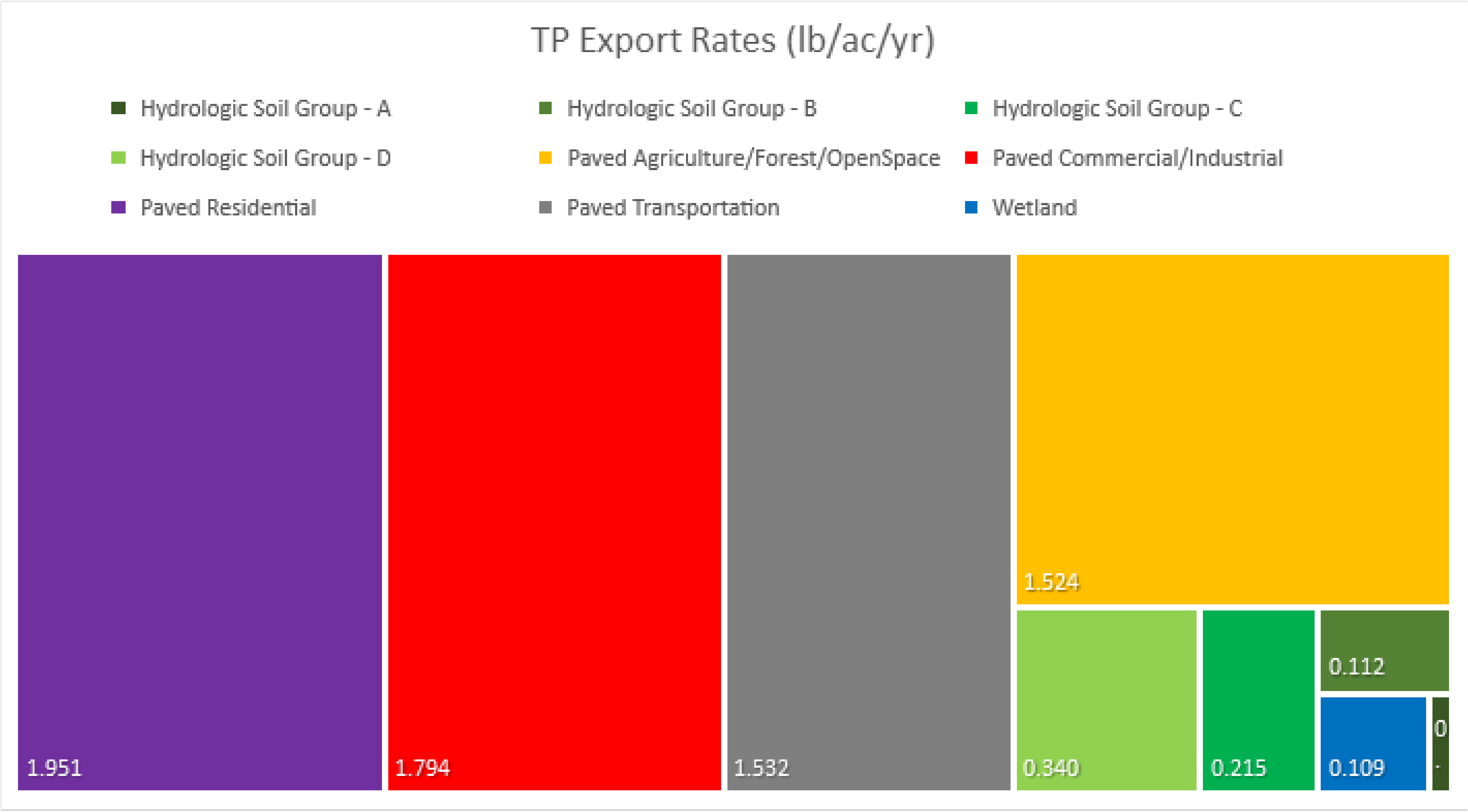
Impact of Land Cover on TP Export

High TP export is visible from roads and urbanized areas.

The bar chart below shows the highest TP yields are from paved areas that include residential, commercial/industrial, transportation, and agricultural/forest/open space land uses.

The pie charts show the TP load by source for the pilot tributary and Upper Hodges sub-watersheds.



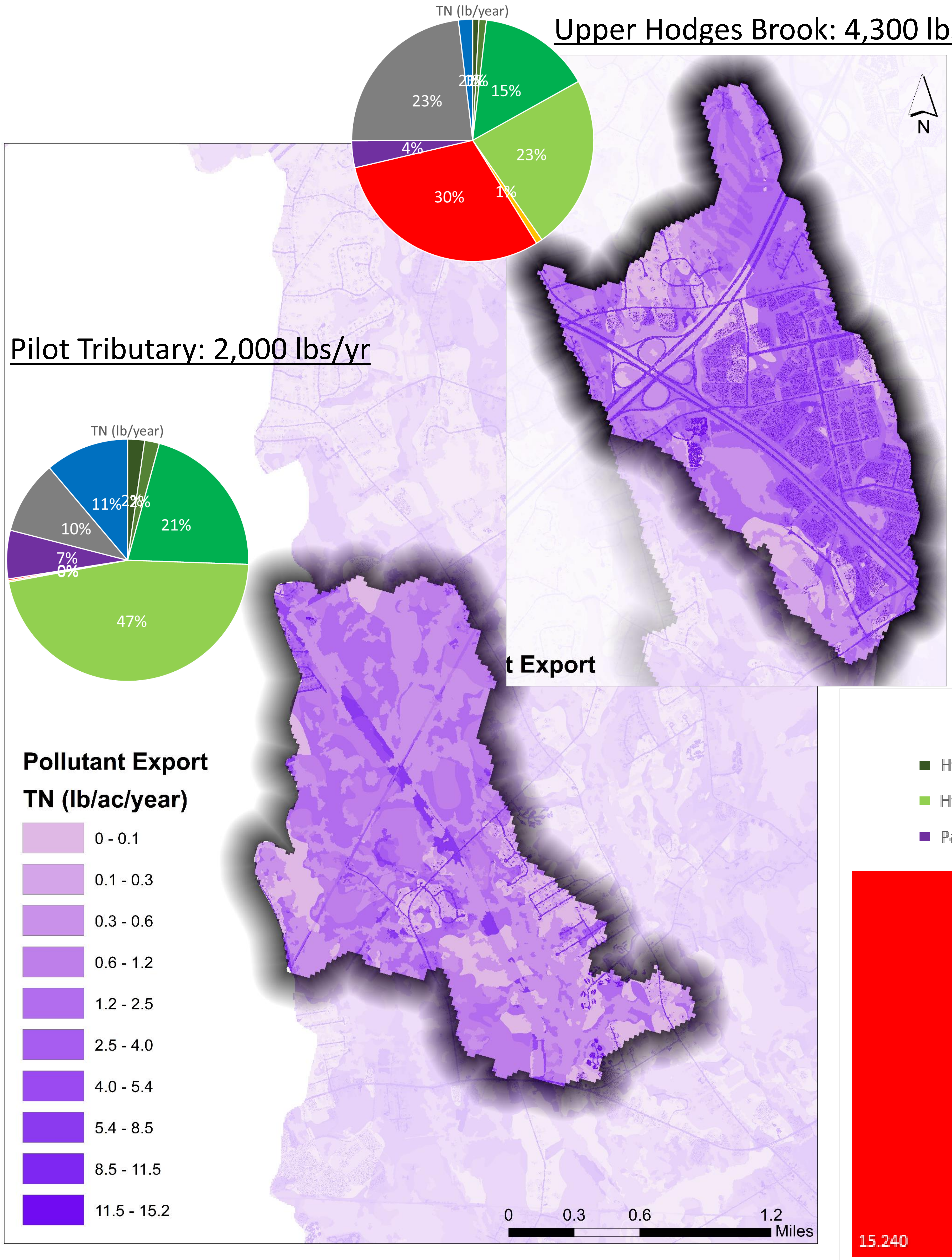


Impact of Land Cover on TN Export

High TN export is visible from roads and to a lesser extent, urbanized areas.

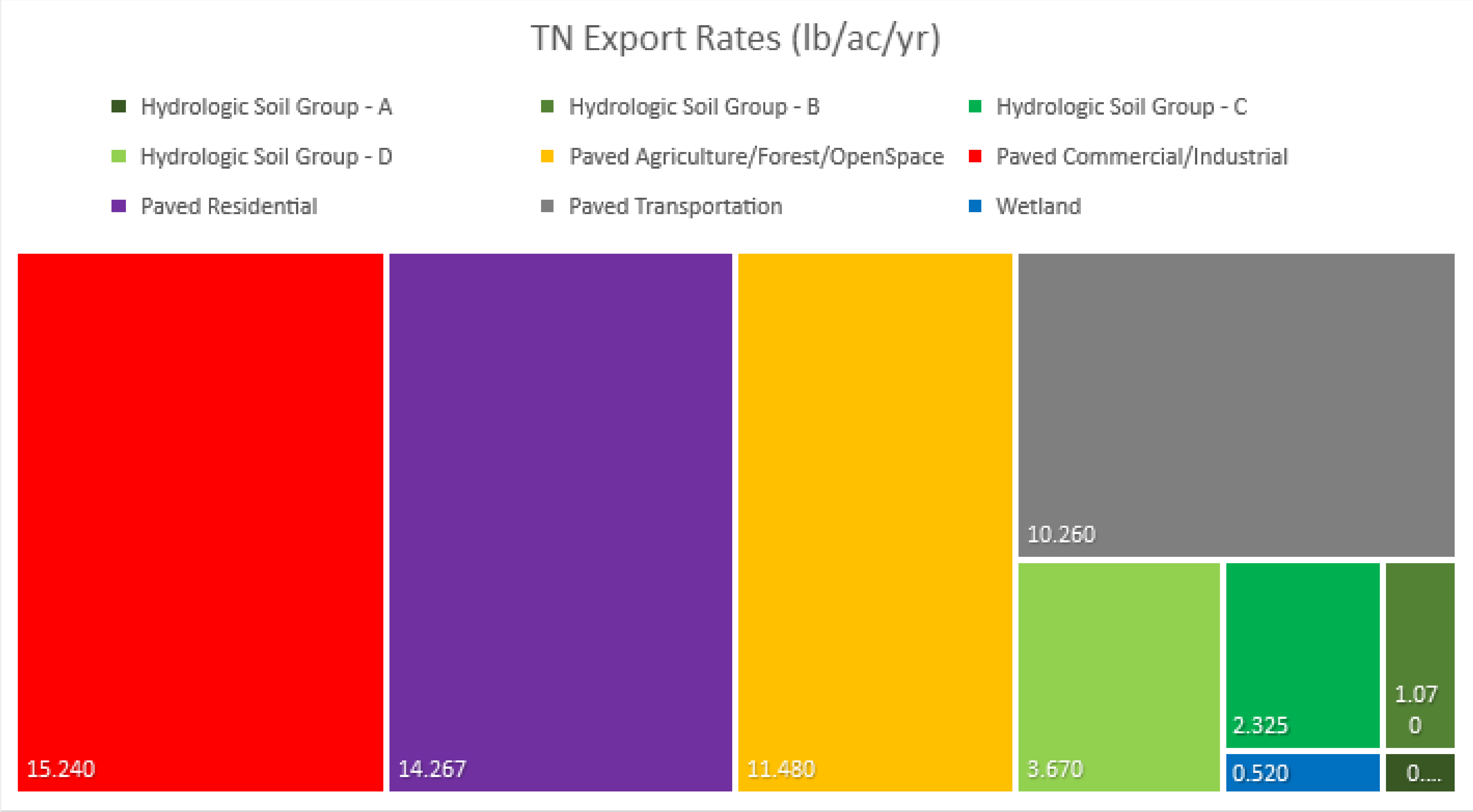
The bar chart below shows the highest TN yields are from paved areas that include residential, commercial/industrial, transportation, and agricultural/forest/open space land uses.

The pie charts show the TN load by source for the pilot tributary and Upper Hodges sub-watersheds.



Upper Hodges Brook: 4,300 lbs/yr

Pilot Tributary: 2,000 lbs/yr

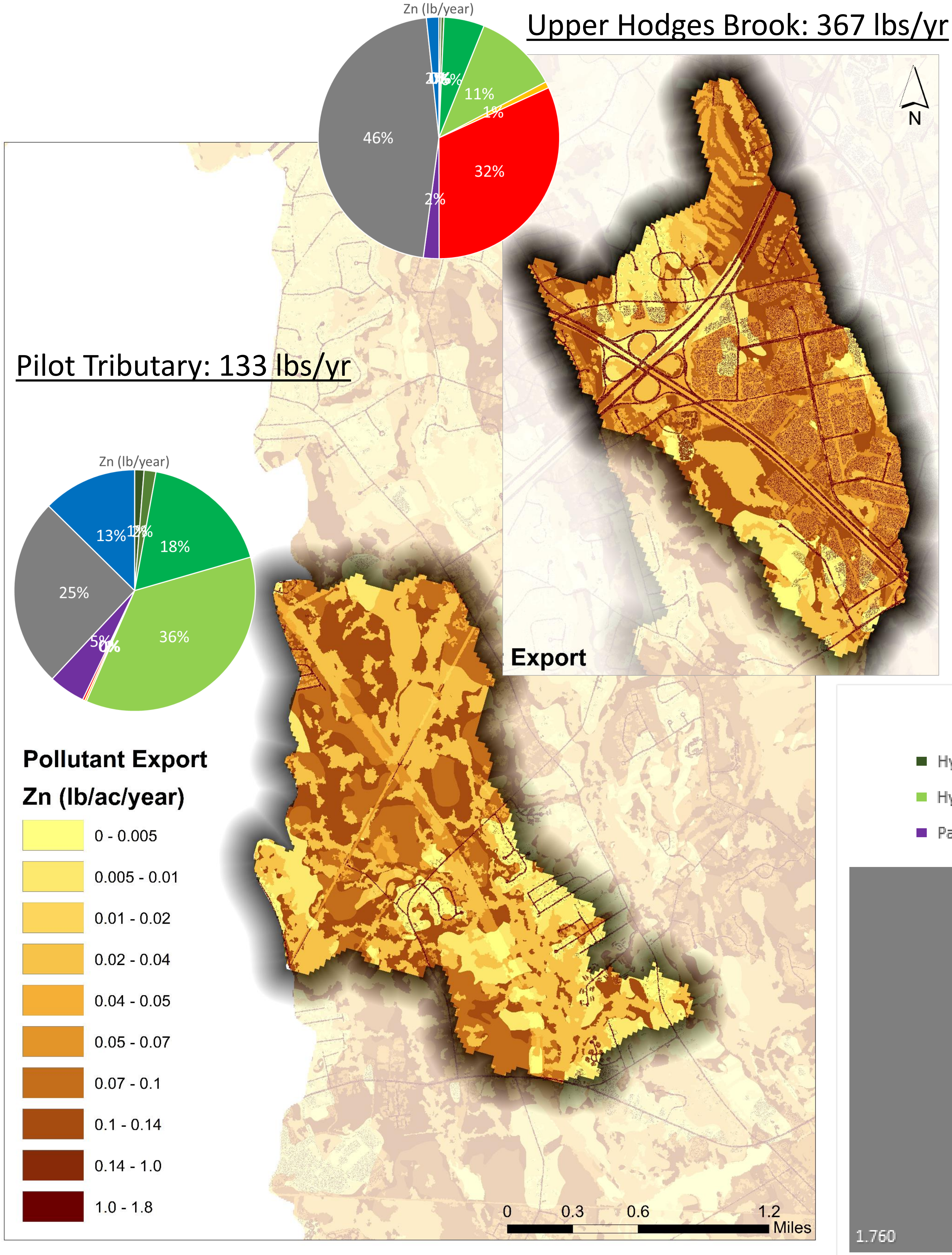


Impact of Land Cover on Zinc Export

Zinc is exported predominately from developed areas with roads and roofs.

The bar chart below shows the highest zinc yields are from paved areas that include transportation, commercial/industrial, agricultural/forest/open space, and residential land uses. from Note that the colors in the map are not associated with the colors in the bar chart below.

The pie charts show total Zn load by source for the pilot tributary and Upper Hodges sub-watersheds.



Upper Hodges Brook: 367 lbs/yr

Pilot Tributary: 133 lbs/yr