

## Using Public Domain Software to Plan and Manage Stormwater Runoff

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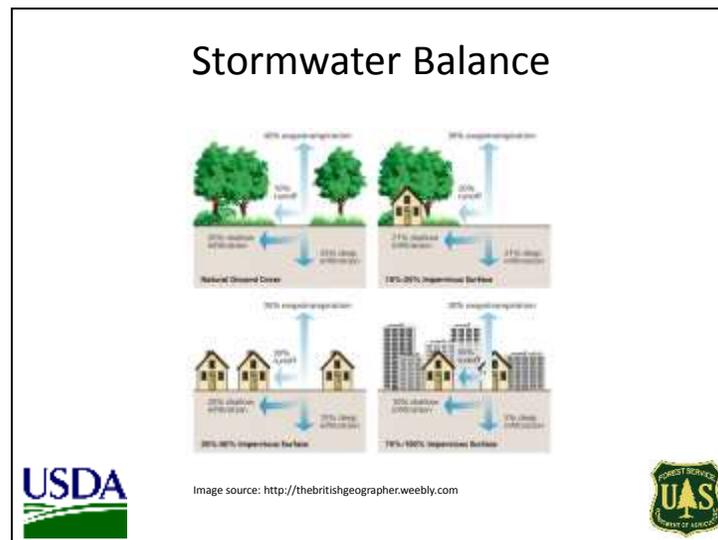
This presentation was given at the 2015 Georgia Association of Water Professionals Industrial Conference in Athens, GA March 18, 2015.

My goal for this presentation is to convince you that the urban forest is a valuable resource to your stormwater mitigation program, and there is public domain software available to you to help you quantify benefits and manage the resource to maximize those benefits.

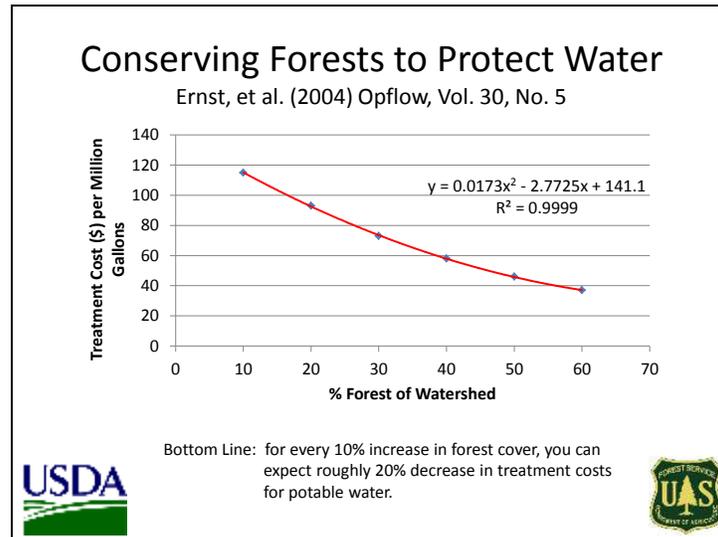
## Objectives of this Presentation

- Justify the use of urban forest management as the first leg of a stormwater treatment train (Green Stormwater Infrastructure)
- Introduce public domain software tools that quantify stormwater benefits of the urban forest
- Discuss how USFS and urban foresters can help stormwater managers achieve their goals





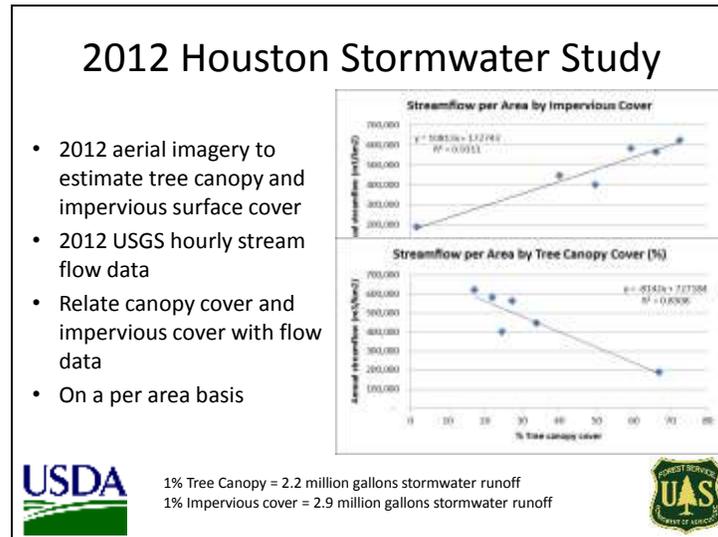
We have all seen this schematic showing how development (an increase in impervious surface cover and decrease in natural ground cover) increases stormwater runoff. Stormwater runoff is less than 10% pre-development and greater than 50% in ultra-urban settings.



In 2004, Caryn Ernst et al found that for every 10% increase in forest cover in a watershed that supplies drinking water there was about a 20% decrease in treatment costs. But that is water quality on the supply side.



More recently, in a preliminary study, I have been working with the Texas A&M Forest Service to quantify stormwater runoff in receiving streams around Houston, TX. Streamflow data from seven watersheds having varying percentages of tree canopy cover and impervious surface cover were studied and compared. These watersheds ranged from heavy tree canopy to the northeast to typical urban tree canopy/impervious surface cover to the southeast.



Using 2012 aerial imagery to estimate tree canopy and impervious surface cover and 2012 USGS hourly stream flow data, we were able to relate canopy and impervious cover with flow data on a per area basis.

As you would expect, there was a strong, positive relationship between impervious cover and stream flow, but unexpectedly, we also saw a strong, negative relationship between tree canopy cover and stream flow.

From this preliminary work, we can say that for every 1% tree canopy cover increase in the Houston area, we can expect a 2.2 million gallon reduction in stormwater runoff, but, outpacing that, for every 1% increase in impervious cover, we can expect almost 3 million gallons of runoff annually.

## What is the Urban Forest?

- *ecosystems of trees and other vegetation in and around communities that may consist of street and yard trees, vegetation within parks and along public rights of way and water systems. (American Forests)*
- *All publicly and privately owned trees within an urban area*
  - *Street trees*
  - *Yard trees*
  - *Remnant forests*
- Typically a city owns less than 10%



This would be a good time to explain exactly what the urban forest is.

**What Stormwater Benefits do Trees Provide and How Do We Quantify Them?**

<b>Benefits</b> <ul style="list-style-type: none"><li>• Interception</li><li>• Velocity reduction</li><li>• Stemflow</li><li>• Infiltration</li><li>• Transpiration<ul style="list-style-type: none"><li>– To allow for increased capacity</li></ul></li><li>• Percolation<ul style="list-style-type: none"><li>– Increase soil water recharge</li></ul></li><li>• Leaf area drives many of these benefits</li></ul>	<b>Tools to Quantify Benefits</b> <ul style="list-style-type: none"><li>• i-Tree<ul style="list-style-type: none"><li>– Design<ul style="list-style-type: none"><li>• Parcel-based interception</li></ul></li><li>– Streets<ul style="list-style-type: none"><li>• Interception by street trees</li></ul></li><li>– Eco<ul style="list-style-type: none"><li>• Interception/transpiration of UF</li></ul></li><li>– Hydro<ul style="list-style-type: none"><li>• Stormwater simulation model</li></ul></li></ul></li><li>• <a href="http://www.itreetools.org">www.itreetools.org</a></li><li>• Free software download</li></ul>
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Trees provide quantifiable stormwater benefits to a city. Leaves intercept rainfall and after reaching water-holding capacity allow throughfall to gradually release the excess as well as reduce rainfall velocity. Some excess water is directed down the stem to the soil where it infiltrates into the ground. Tree roots wick water from the soil to allow for increased soil-holding capacity. Roots also condition and fracture the soil to increase percolation and thus soil water recharge. Many of these benefits are driven by the amount of leaves or leaf area on the tree.

The US Forest Service has developed tools, called i-Tree, to help the stormwater manager quantify these benefits. Originally developed to help the natural resource manager manage the urban forest, these i-Tree tools have components that may be of value to the stormwater manager.

i-Tree Design is an on-line tool that could be used in an education program to help parcel owners better understand how trees planted around their property can be used to help intercept rainfall along with other environmental benefits.

i-Tree Streets allows a city to quantify the benefits and costs of its street tree population. One of the benefits reported is annual rainfall interception. Keep in mind that the street tree population of a city is around 5%.

i-Tree Eco takes a look at the benefits of the entire urban forest including annual rainfall interception and transpiration as well as the other co-benefits associated with trees (i.e. pollution removal, energy conservation, carbon sequestration, etc.).

Lastly, i-Tree Hydro is a stormwater simulation model developed by a stormwater engineer that focuses on changes to runoff and quality based on tree canopy cover and impervious cover. I will show how this tool has been used in ATL to help manage the urban forest for stormwater mitigation.

These tools can be downloaded for free from the itreetools website

## i-Tree Hydro Overview and Needs

<p><b>i-Tree Hydro Overview</b></p> <ul style="list-style-type: none"><li>• Simulation model for runoff volume and quality</li><li>• Emphasizes how land cover influences stormwater runoff</li><li>• Comparison of existing cover with proposed cover</li><li>• <a href="http://www.itreetools.org/resources/videos.php">http://www.itreetools.org/resources/videos.php</a><ul style="list-style-type: none"><li>– Hydro Vermont GI Webinar</li></ul></li></ul>	<p><b>i-Tree Hydro Needs</b></p> <ul style="list-style-type: none"><li>• Formatted DEM or TI</li><li>• Hourly streamflow data<ul style="list-style-type: none"><li>– USGS</li><li>– Self-formatted data</li></ul></li><li>• Hourly weather data<ul style="list-style-type: none"><li>– NOAA NCDC</li><li>– Self-formatted data</li></ul></li><li>• Land cover data<ul style="list-style-type: none"><li>– Tree/shrub cover</li><li>– Impervious surface cover</li><li>– Herbaceous/soil cover</li></ul></li><li>• Directly connected impervious</li></ul>
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i-Tree Hydro is a stormwater simulation model designed by a research stormwater engineer to model runoff quantity and quality based on the influences of land cover; mainly tree canopy cover and impervious surface cover. This can be at the watershed, municipal, or parcel scale.

It is a collaborative tool that encourages stormwater and natural resource professionals, as well as planners to work together to help solve their stormwater runoff issues.

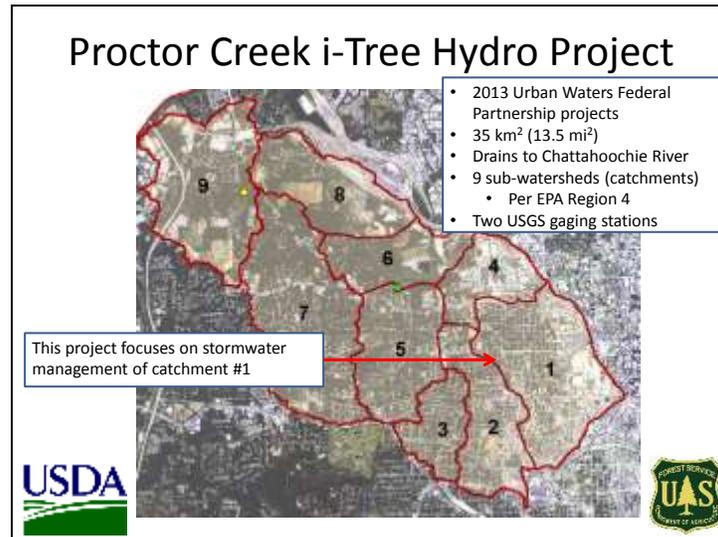
The tool allows for comparison of various land cover scenarios to help the city choose the best management strategy for the urban landscape.

To run a model, i-Tree Hydro requires several datasets. A properly formatted digital elevation model or topographic index is needed for the model to estimate stormwater velocities once on the ground. Hourly streamflow and weather data are needed to calibrate a watershed.

Both USGS streamflow and NCDC (National Climatic Data Center) weather datasets for 2005-2012 are preloaded into the tool and can be chosen from a pick-list, but if you want to model a watershed that does not have a USGS gaging station or you want to use your own weather data, that can be done also.

Land cover data can be estimated using remote sensing applications. i-Tree Canopy is a free on-line tool that can provide this information.

And lastly, an estimation of the percentage of directly connected impervious surfaces is needed to help estimate impervious stormwater flow.



I would like to share a project done in the Proctor Creek watershed in Atlanta using i-Tree Hydro and show how we used it to suggest components of a stormwater management plan.

As background, the Proctor Creek watershed is located in western Atlanta originating in west downtown and draining to the Chattahoochie River. It is approximately 13.5 square miles in area. In 2013, it was named as one of the Urban Waters Federal Partnership Projects because it is located in an economically depressed part of the city, has frequent events of CSO and other street flooding, and the stream is degraded.

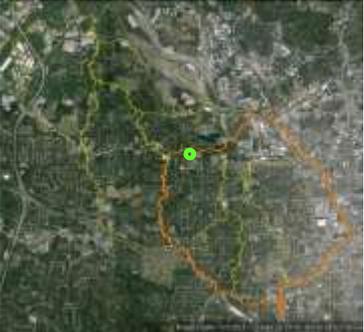
The Forest Service volunteered to be included in this partnership to help restore the stream by using these i-Tree tools.

The EPA (Region 4) delineated nine sub-watersheds within the entire watershed. The USGS maintains two stream gaging stations within the watershed, so we were able to use data from the station at Hortense Way (green dot) to calibrate the watershed or estimate predictive streamflow with existing weather and land cover data.

For this project, we focused on catchment #1 because of its observed reduction in tree canopy cover and increased impervious cover.

## Proctor Creek i-Tree Hydro Project

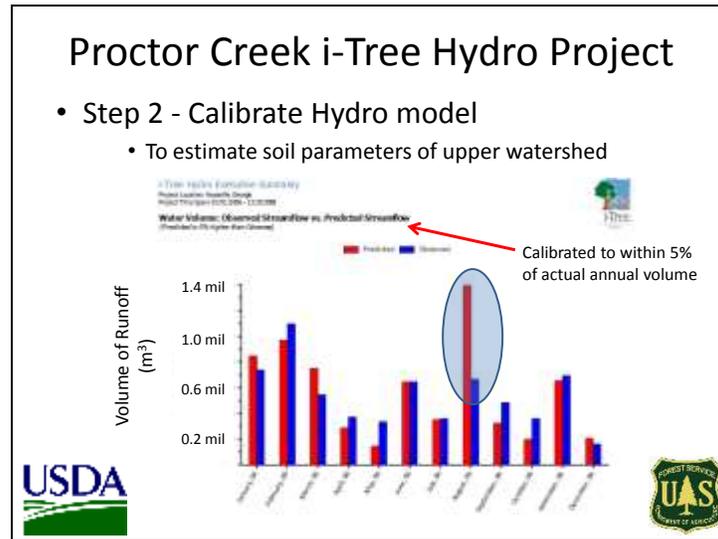
- Step 1 –
  - Prepare / load data in Hydro
    - Formatted DEM
      - Clipped to watershed
    - Land cover estimates
      - Using i-Tree Canopy
    - Weather & streamflow
      - Pre-loaded in Hydro
      - Choose location



The first thing we did was clip and format a 10 m DEM obtained from the USGS DEM website to fit our boundary.

We used i-Tree Canopy to estimate land cover percentages. These two datasets were loaded into the model.

We then chose the Hortense Way stream gaging station and the closest weather station to the watershed (Atlanta Industrial Airport just to the west).



We then ran the calibration function within the model to develop a predictive streamflow model for that portion of the watershed.

This graphic compares the monthly runoff volume from the gaging station observations with the predictive runoff model. Overall, we were able to calibrate our predicted runoff volume to within 5% of the actual, so we felt fairly confident in our predictive model.

I want to point out a downfall to using models. Because of our storm patterns here in GA during the summer, with intense pop-up showers, it could be raining where the weather station is located and not in the watershed of interest. As a result, anomalies such as what was observed in August can be common. This is the nature of modeling.

### Proctor Creek i-Tree Hydro Project

- Step 3 –
  - Develop management strategies based on current land cover conditions

Area	Size (km <sup>2</sup> )	% Tree Canopy	% Impervious	% Herbaceous	% Bare Soil
<b>Proctor Creek Watershed</b> <small>(from Jackson Pkwy streamflow gaging station)</small>	34.8	36.8	30.0	28.4	4.6
<b>Upper Proctor Creek</b> <small>(from Hortense Way streamflow gaging station)</small>	22.5	32.9	38.6	22.7	3.0
<b>Catchment 1</b>	6.6	22.1	51.7	20.2	2.5

– Increase tree canopy cover from 22% to 37%




After calibrating the watershed, we could then begin to suggest management strategies to help mitigate stormwater runoff.

Comparing land cover in catchment #1 with that of the entire watershed, we see that catchment #1 tree canopy cover is 40% lower than that of the entire watershed and impervious cover is 72% greater.

What if we could increase tree canopy cover to that of the entire watershed, from 22% to 37%? Knowing that trees will grow over time and canopy cover can grow over impervious cover, we can strategically plant trees in areas that will grow over streets and parking lots as well as maintain those trees that are currently growing over impervious surfaces.

## Proctor Creek i-Tree Hydro Project

- Step 4 –
  - Run Hydro model with alternative land cover parameters
  - Stormwater volume results

Treatment	Total Flow (million gallons)	Impervious Flow (million gallons)	Pervious Flow (million gallons)	Base Flow (million gallons)
Current condition	291	191	36.5	63.6
Proposed condition	279	178	38.1	63.3
Change	-12	-13	+1.7	-0.3
% change	4.0%	6.9%	4.6%	0.5%




Lastly, with our model calibrated, we ran the model to compare our current land cover with our proposed land cover conditions, and these were the results we got.

According to the i-Tree Hydro model, if we increased tree canopy cover from 22% to 37%, we can expect total streamflow to be reduced by 12 million gallons annually or 4%.

Impervious flow would be reduced by almost 7%. The model appears to divert a portion of that flow to pervious surfaces as it would be increased by 4.6%.

## Proctor Creek i-Tree Hydro Project

- Stormwater pollution results
  - Based on National Event Mean Concentration (EMC) Data

Treatment	Mean TSS (kg)	Mean Total P (kg)	Mean Total Kjeldhal Nitrogen (kg)
Current condition	67,429	271	1488
Proposed condition	64,040	257	1413
Change	-3389	-14	-75

Approximately 5% reduction in pollution loading




Using national Event Mean Concentration data, i-Tree Hydro estimates a 5% reduction in pollutant loading with the proposed increase in tree canopy cover.

I suspect this comes from an increase in rainfall interception and evaporation from the leaves of trees, but also with diverting a small percentage of runoff from impervious to pervious surface cover.

## Conclusions

- Urban tree canopy can help mitigate stormwater runoff and pollution loading
  - Through interception and velocity reduction
- Public domain tools (i-Tree) can help
  - Quantify stormwater benefits from the urban forest
    - To include trees into stormwater management goals
  - Manage the UF for co-benefits
    - Trees are multi-taskers
- The urban forest is the initial BMP of a GSI treatment train
- To maximize benefits manage the urban forest to increase leaf area
  - Larger trees have greater leaf area
  - Greater leaf area = greater benefits

## How can we work together?

- Are trees considered in your stormwater planning?
- What barriers prevent the use of trees as green infrastructure?
  - Trees don't fit or work everywhere
- What information is needed to help you consider trees/urban forest in your stormwater management plans?



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