i-Tree Hydro

Training Workshop
Georgia Tech Hotel and Conference Center
Atlanta, GA

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i-Tree is a Cooperative Initiative

i-Tree Hydro

- Model History

  - Born out of discussions between ESF (Ted Endreny) and USDA FS (David Nowak)

  - Wanted to replace curve number based runoff models with process based hydrological models

  - TOPMODEL -> OBJTOP -> UFORE -> i-Tree Hydro

i-Tree Hydro

Model History

- Based on Topographic Index and TOPMODEL concepts
  - TI – Beven and Kirkby, 1979; TOPMODEL – Beven (1995, 1997)
- Processes and routines added to TI/TOPMODEL framework
  - Publications:
    - Wang *et al.*, 2006; Wang et al., 2008; Wang, Endreny, et al., 2005; Wang, Hassett, et al., 2005; Yang et al., 2011; Yang and Endreny, 2013
- Ongoing model development
  - New i-Tree Hydro versions – approx. yearly
  - Research by Yang Yang, Tom Taggart and Emily Stephan

i-Tree Hydro

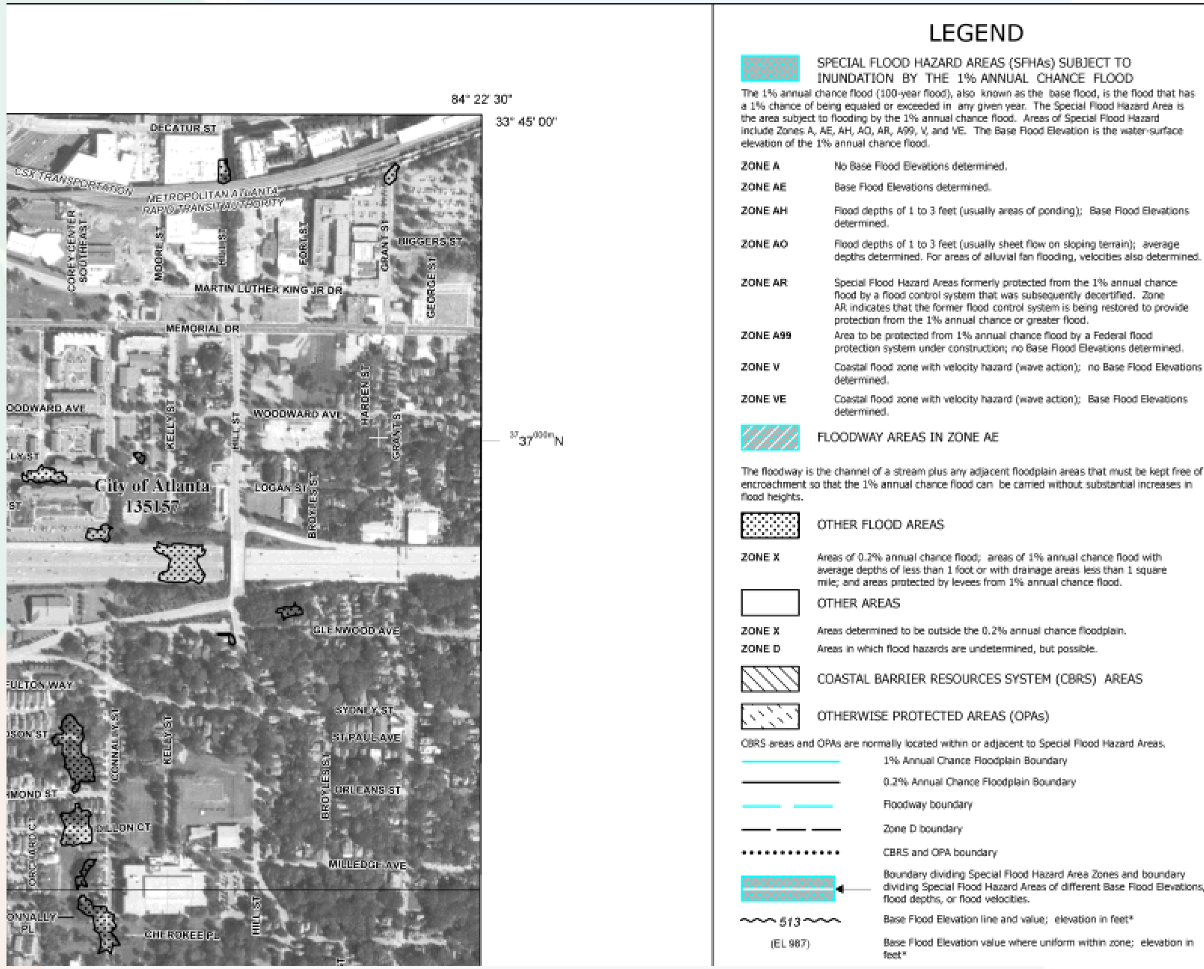
Introduction to Stormwater Management (ISM)

Introduction to Stormwater Management (ISM)

- Why is stormwater management important?

ISM: Regulatory & Other Drivers

- Quantity/Quality
  - FEMA
    - FIRMs
  - CWA
    - MS4 – NPDES permitting
    - CSOs
  - Others (NEPA, DOT, …)
- Ordinances
  - New v. existing construction



ISM: Prior Perspective (Pre-MS4 Regulation)

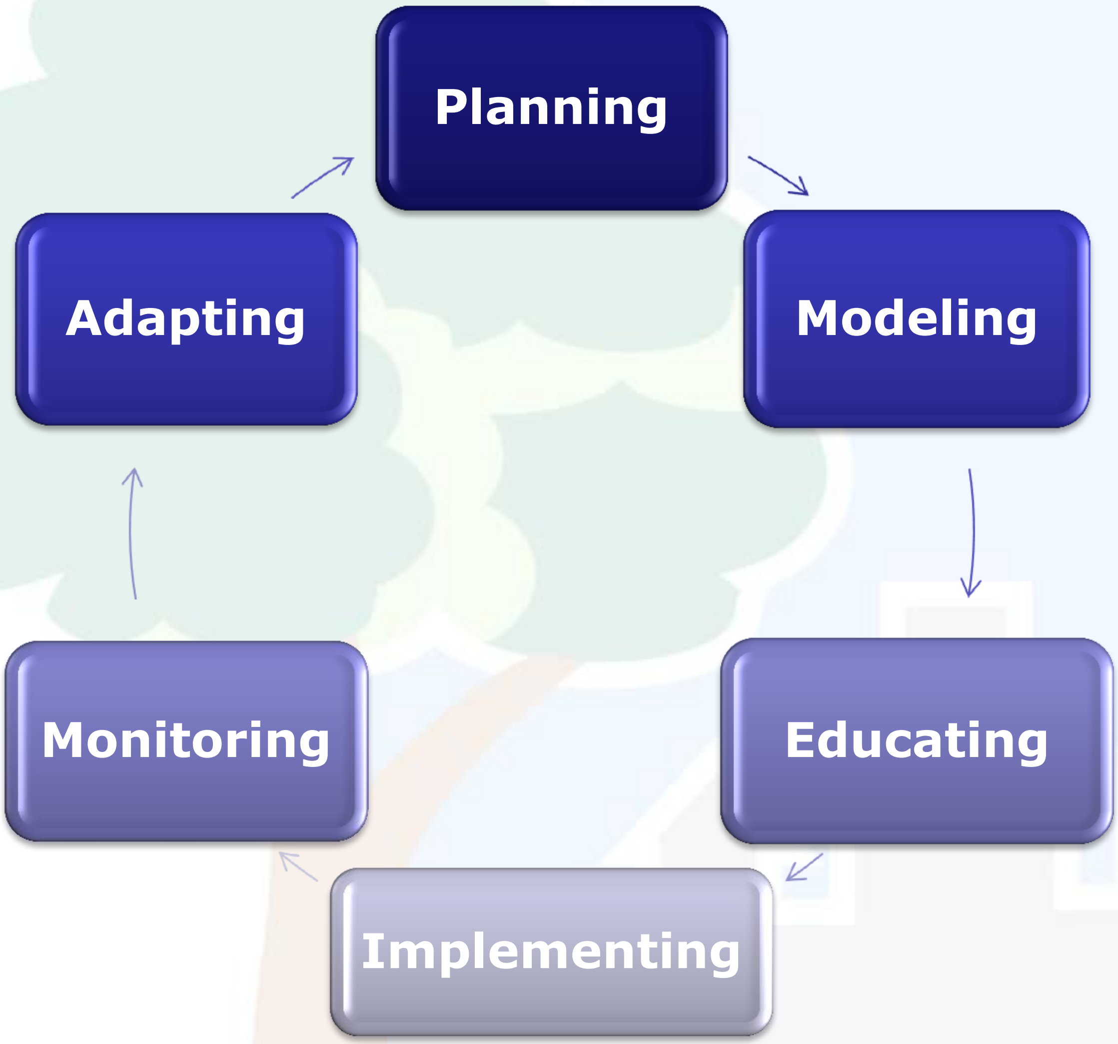
- Goals
  - Quantity
  - Quality
- Infrastructure (Gray)
  - Impervious Areas
  - Storage
  - Streets
  - Storm drains
  - Storm sewers
  - CSOs

ISM: Current Perspective

- Goals
  - Quality & Quantity
  - CWA MS4
  - Sustainability

- Infrastructure
  - I, S^4, C + f(GI, LID, SCM, BMP)
  - Hydrologic cycle
    - e.g., Retain, Infiltrate, Restore/maintain baseflow
    - e.g., Save the Rain, Green City – Clean Waters, NYC Green Infrastructure Plan.

ISM: Role of Managers



ISM: Role of Managers

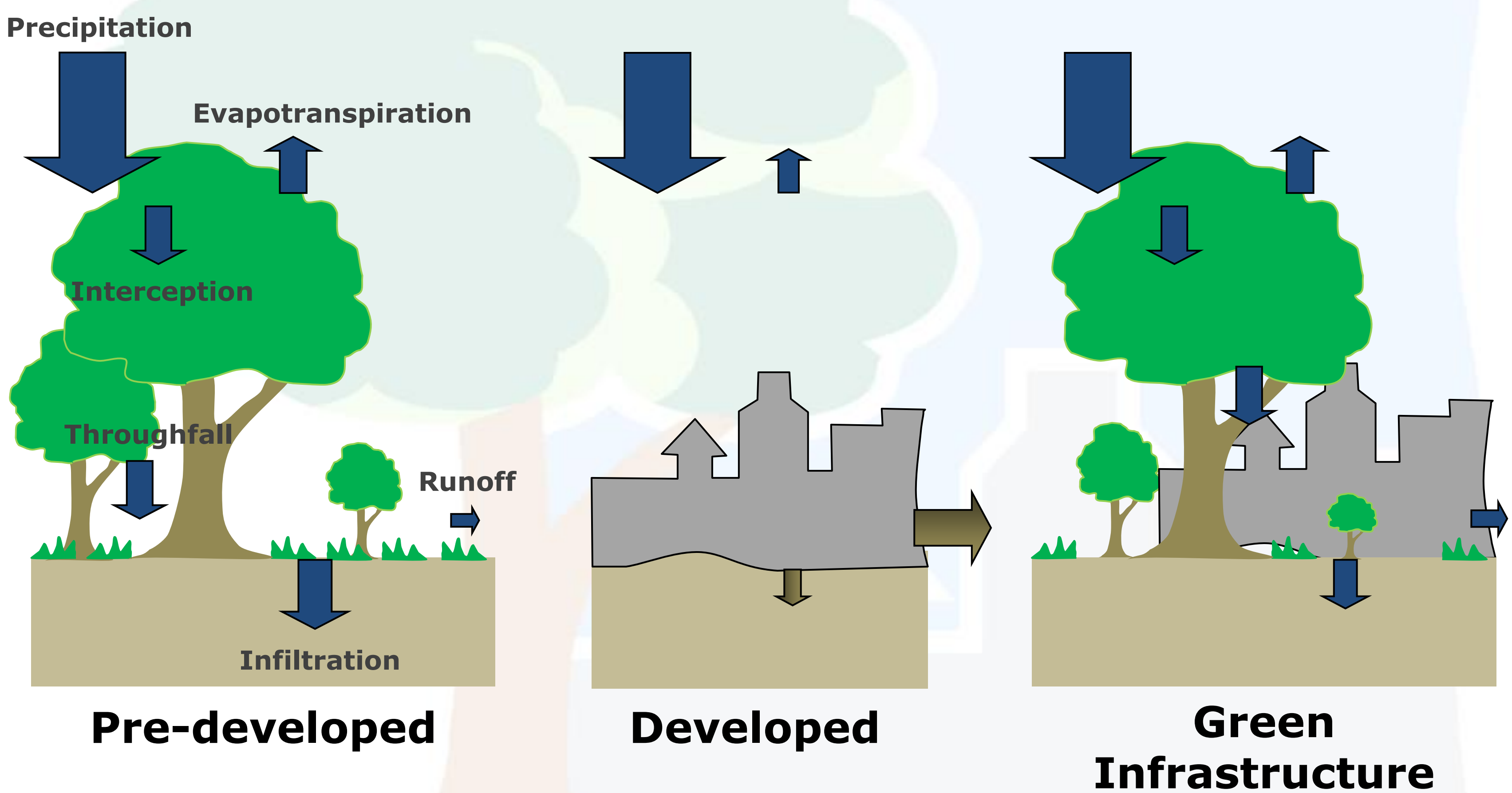
- What issues have you faced?

Stormwater Modeling

Hydrologic Principles

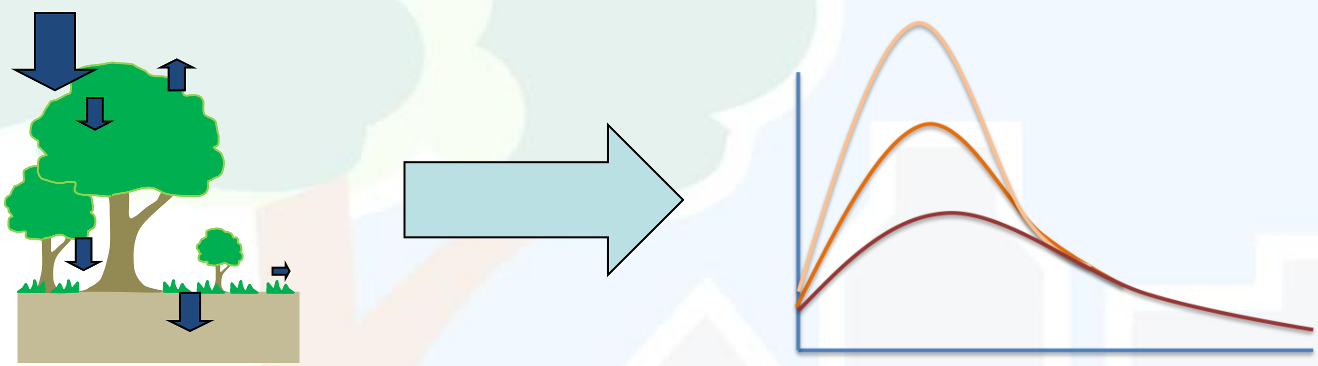
HP: Urban Forest Hydrology

- Natural vs. Disturbed Hydrological Cycle



HP: Conceptual Models

- Rainfall – runoff model
  - Transformation of rainfall into runoff
    - Effective precip -> Infiltration -> runoff generation
    - Runoff partitioning
      - baseflow, overland flow, shallow subsurface flow, etc.



  - Routing of runoff through watershed / to the outlet
    - Building of the hydrograph, timing of flow arrival

HP: Conceptual Models

- Inputs
  - Weather – Precip, temp, wind speed, net radiation, etc.
  - Streamflow – Hourly (or finer) discharge
  - Topography – error free , high res. DEMs
  - Land cover – High resolution aerial imagery, field surveys
  - Soil data – WS wide field data: K_{sat}, depth to water table, etc.
  - Potential Evaporation/ET – For all vegetation, weather

- *Unlimited! Complete!*

HP: Conceptual Models

- Processes
  - Interception
    - Different LAI values for diff species
    - Different leaf water storage depths
  - Stemflow
  - Throughfall process
    - Measured instead of estimated

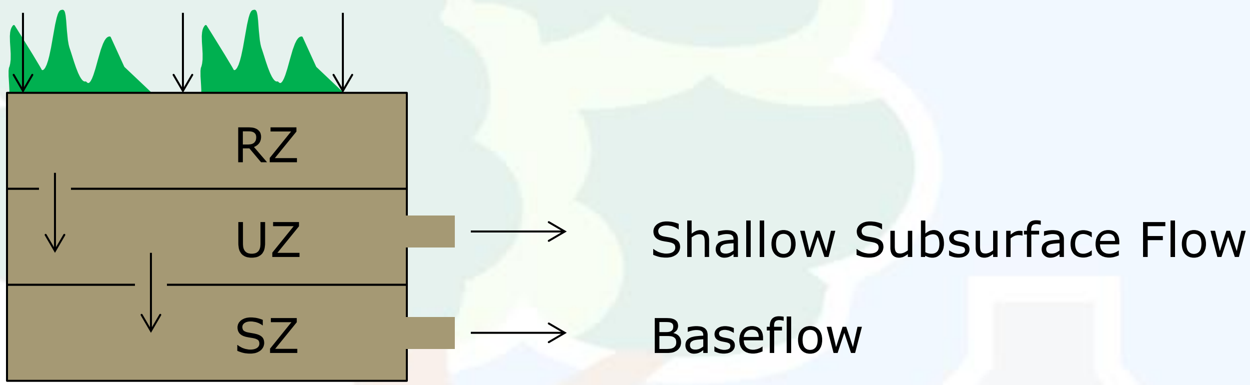
HP: Conceptual Models

- Processes (cont.)
  - Depression Storage
    - Storage depths change with landcover type, seasons?

  - Infiltration
    - Governed by saturation vs. infiltration excess
    - Variable soil properties – temporally, spatially
    - Know the underlying geomorphology

HP: Conceptual Models

- Processes (cont.)
  - Soil Moisture
    - Root zone / Unsaturated zone / Saturated Zone processes



  - Evaporation/Evapotranspiration (ET)
    - Values for each species, measured vs. estimated
    - Varies temporally (hourly, daily, seasonally)

HP: Conceptual Models

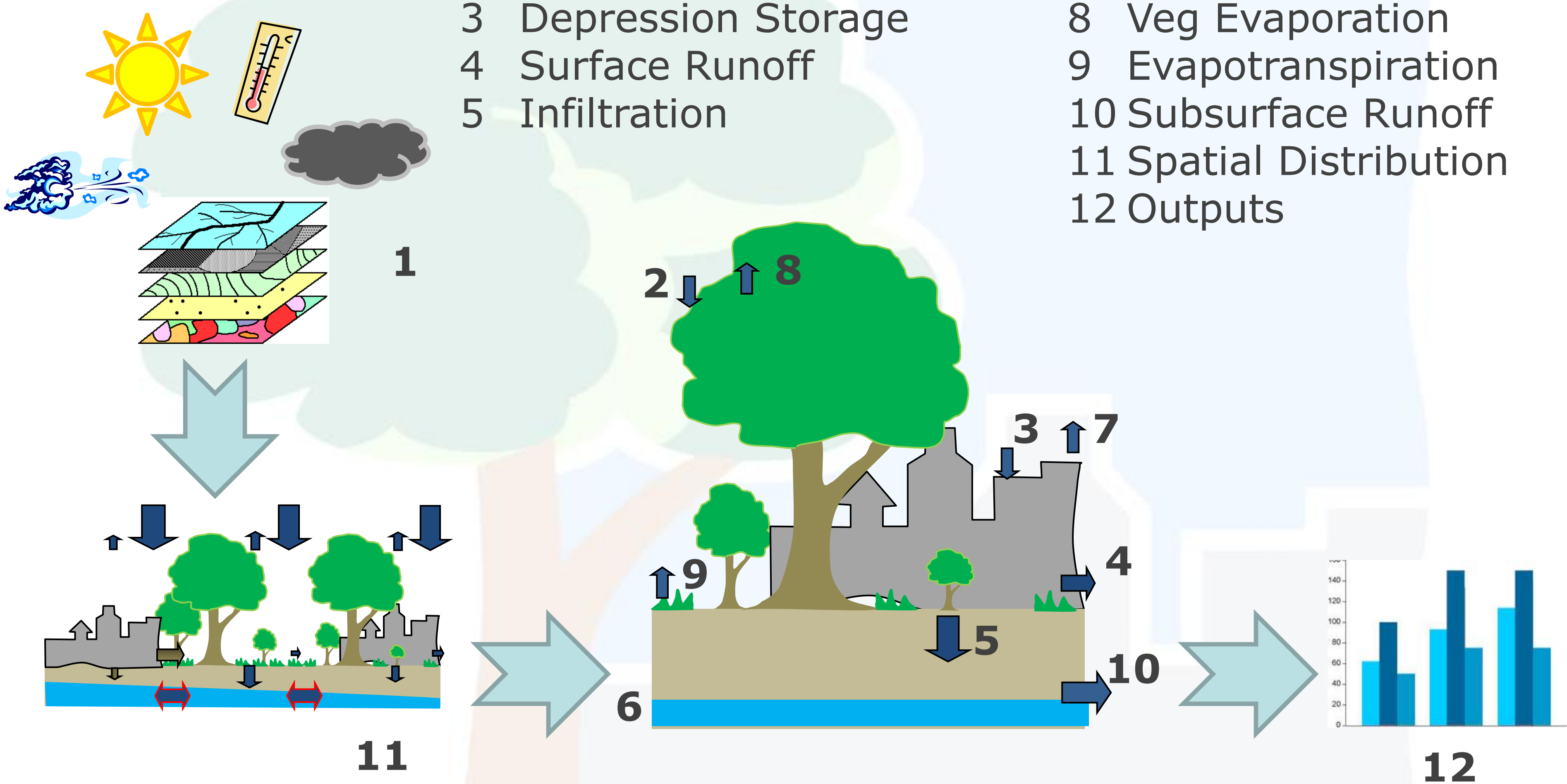
- Processes (cont.)
  - Runoff generation
    - Changes as saturated areas expand/contract
    - Perched water tables
    - Precip intensity driven seeps
  - Baseflow generation
    - Tracer experiments – old vs. new water
    - Quick flow – surface runoff vs. shallow subsurface
    - Rates of flow between soil zones

HP: Conceptual Models

- Outputs
  - Main: Predicted streamflow
    - Baseflow + Overland flow (Pervious + Impervious area flows)
    - Near perfect response across full domain of inputs
  - Others: Soil moisture, canopy interception, evaporation/ET, pollution loading/concentration, etc.
    - Broken up by time, space, landcover types, etc.

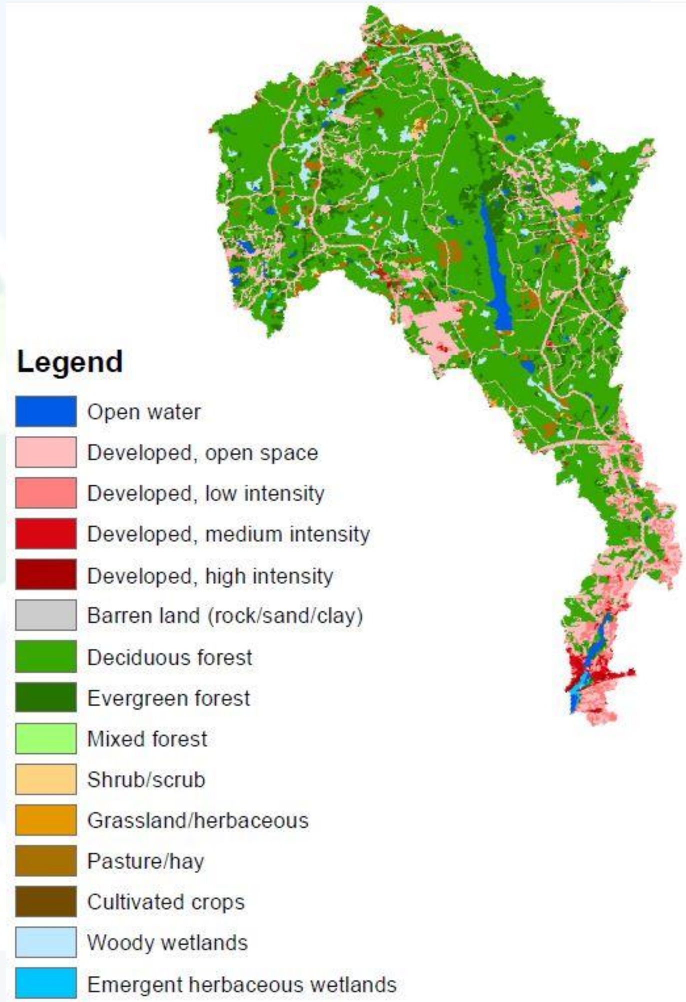
HP: Conceptual Models

1 Inputs
2 Canopy Interception
3 Depression Storage
4 Surface Runoff
5 Infiltration
6 Soil Moisture
7 Surface Evaporation
8 Veg Evaporation
9 Evapotranspiration
10 Subsurface Runoff
11 Spatial Distribution
12 Outputs



HP: Mathematical Model - Inputs

- Landcover
  - Distinct and well understood classes
  - For example, NLCD classes
    - Agriculture – pasture/hay, cultivated crops
    - Forest – mixed, deciduous, evergreen
    - Developed – High, Med, Low Density, Open space

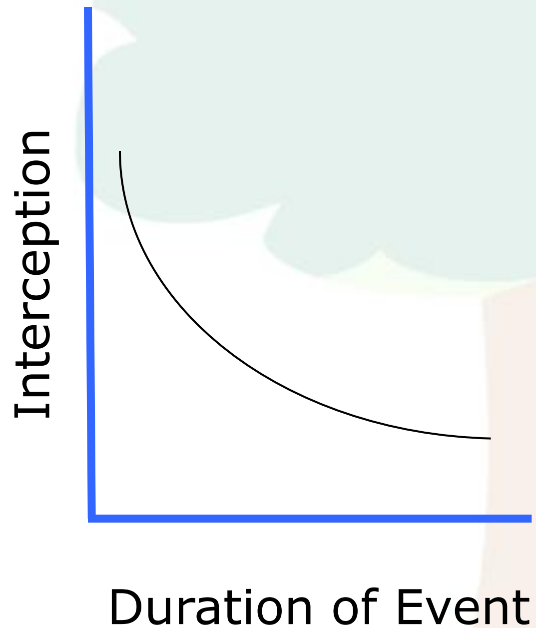


HP: Mathematical Model - Inputs

- Canopy Properties
  - Leaf Area Index (LAI) – One sided leaf area per square meter of canopy
    - Tree LAI + Tree bark LAI
    - Shrub/Herbaceous LAI + Bark LAI
  - Deciduous vs. Coniferous makeup
  - Leaf On/Off days
    - Dependent on local/regional weather

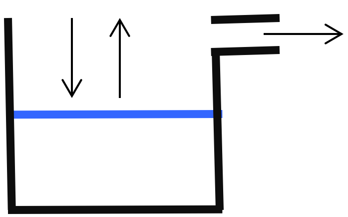
HP: Mathematical Model - Processes

- Interception
  - For a given LAI, given species, max storage depth
  - Drip rate contributing to throughfall



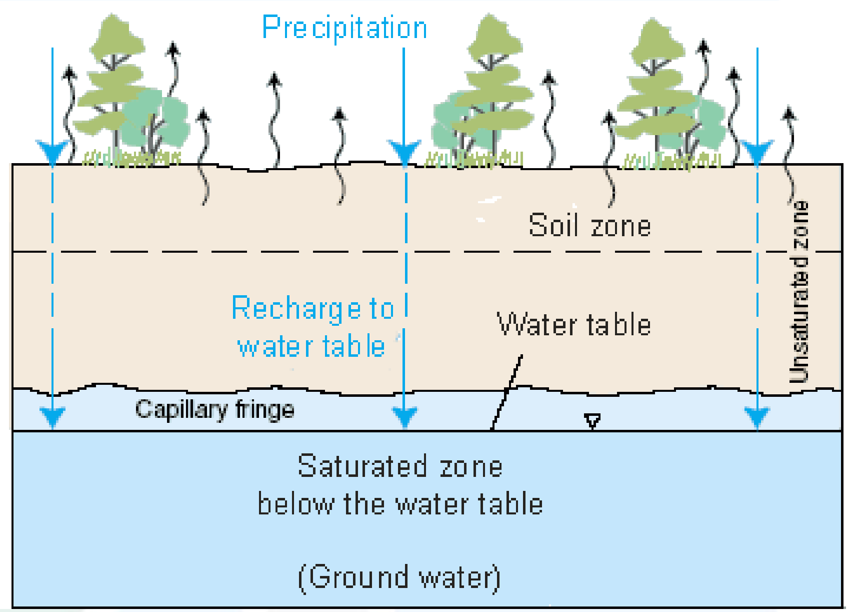
HP: Mathematical Model - Processes

- Depression storage
  - Simple store concept
  - Max storage depth values for different landcover types
  - Values are updated from precip/evaporation



HP: Mathematical Model - Processes

- Infiltration
  - Which governing equation?
    - Green-Ampt
    - Darcy's Law
    - Richard's
  - Macropore flow?
  - Capillary Fringe?



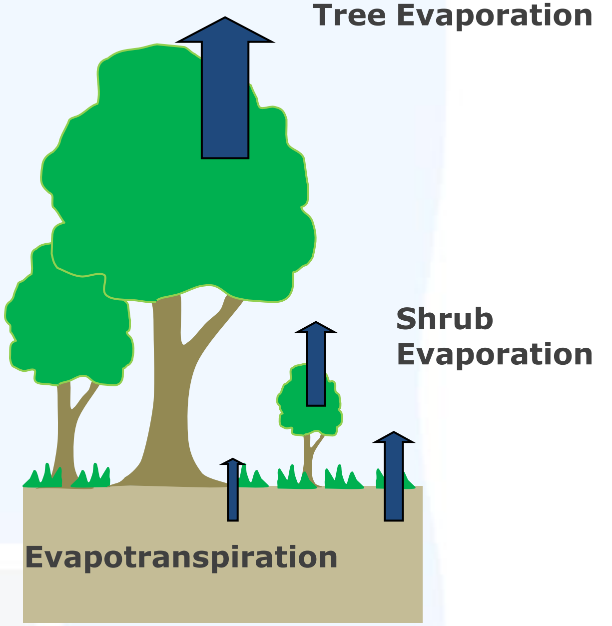
- Soil moisture
  - Depth of and rates of flow between zones
  - Root zone → Unsaturated zone → Saturated zone

HP: Mathematical Model - Processes

- Surface runoff
  - Impervious runoff
    - Throughfall/precip on impervious cover > depression storage
  - Pervious runoff
    - Precip/throughfall on infiltration/saturation excess runoff
  - Area weighted averages vs. tracking volumes
    - Depth/m^2 or total volume per area

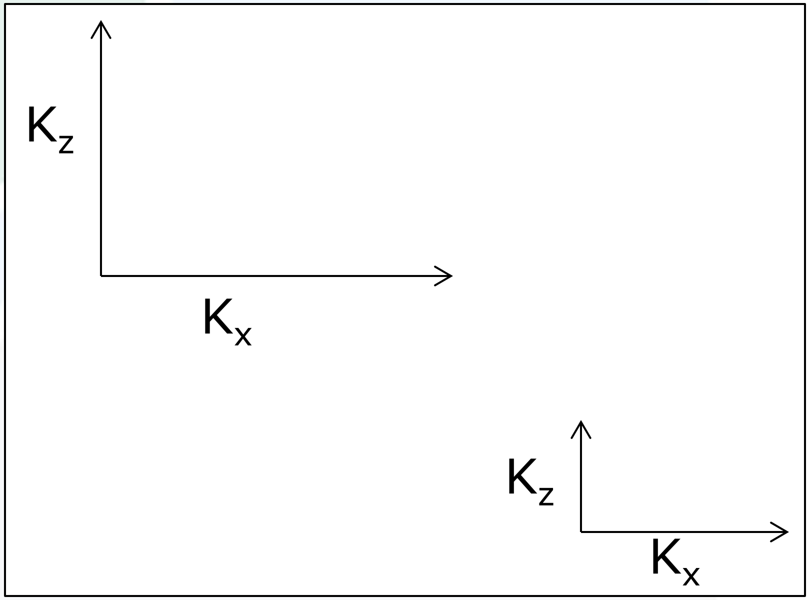
HP: Mathematical Model - Processes

- Evaporation and ET
  - What relationship governs
    - potential vs actual evaporation
  - Water balance vs. energy balance
    - Either could drive the model – typically not both



HP: Mathematical Model - Processes

- Subsurface flow/Infiltration
  - Equation governing the changes in hydraulic conductivity/transmissivity
    - vertically and horizontally



HP: Mathematical Model - Outputs

- Outputs
  - Predicted streamflow
    - Need equation governing the summation of different flows
    - Arriving at the correct place in the correct time?
  - Pollution
    - Event Mean concentration values
    - Build-up/wash-off routines
    - Export coefficients

HP: Hydraulic Considerations

- Pipes
- Pumps
- Channels
- Storm drains
- Stormwater storage tanks
- Water quality – deterioration/treatment
- Water quantity – accumulation/dispersal

HP: SWMM

- Hydraulic and hydrologic model
  - Dynamic rainfall-runoff simulation
  - Single event or long-term (continuous) simulation
  - Water quantity and quality

- 2 main components
  - Rain falls and runoff is generated on sub-catchment areas
    - Hydrologic routines/process
  - Routing portion transports runoff through a conveyance system
    - Pipes, channels, storage/treatment devices, pumps, and regulators
    - Hydraulic routines/processes

HP: Modeling Metrics

- Calibration
  - Method:
    - Determining optimal model parameter set
      - Optimization algorithm - PEST
    - Repeated model runs
      - Comparing predicted and observed values
    - Maximize goodness of fit metrics
  - Problems:
    - Equifinality – Different parameter sets, same optimum
    - Disagreement between field data and model parameters

HP: Modeling Metrics

- Validation
  - Using optimized parameter set to predict forward
    - Without further alteration/optimization
  - Necessary to build confidence in the model
    - Trust structure and calibrated parameter set
- Verification
  - Alter model structure or routines
    - Switch model routines – different governing equations
    - Revise model code – numerical solutions, code structure

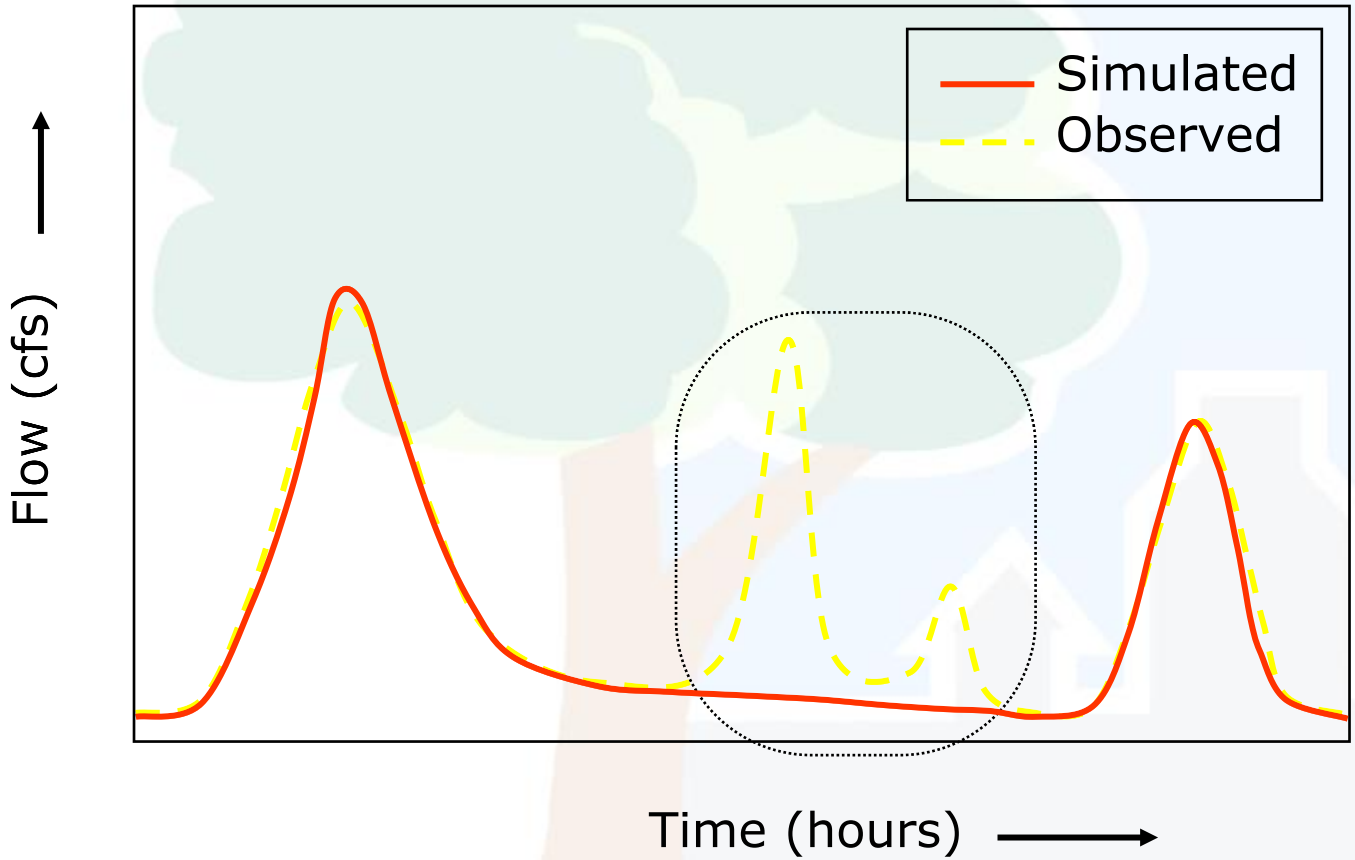
HP: Modeling Metrics

- Calibration Metrics
  - Values range from -∞ to 1
    - Negative – Worse than observed average value
    - Zero – Equal to observed average value
    - Positive – Better than observed average value
  - Volumetric Efficiency
    - Criss and Winston, 2008
  - Baseflow fit
    - Perrin et al., 2001
  - Peak flow fit
    - Nash – Sutcliffe Efficiency (1970)
  - Overall fit
    - Ye et al., 1997

$$NSE = 1 - \frac{\sum (Q_{\mathrm{calc}} - Q_{\mathrm{obs}})^2}{\sum (\overline{Q}_{\mathrm{obs}} - Q_{\mathrm{obs}})^2}$$

HP: Modeling Metrics

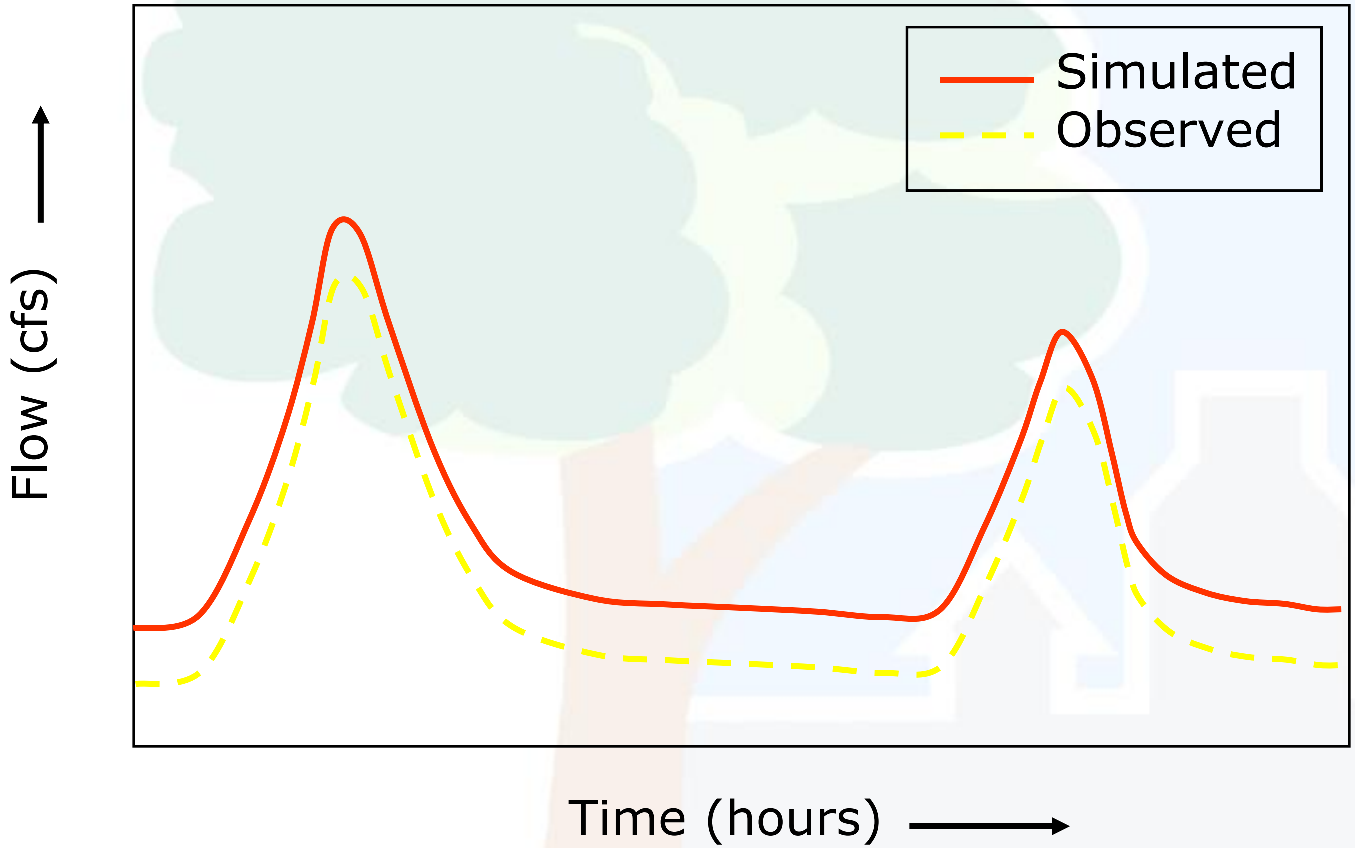
- Common calibration problems
  - Weather station isn't representative, gage errors



- Check weather station location, dominant weather patterns
- Check input data period for errors

HP: Modeling Metrics

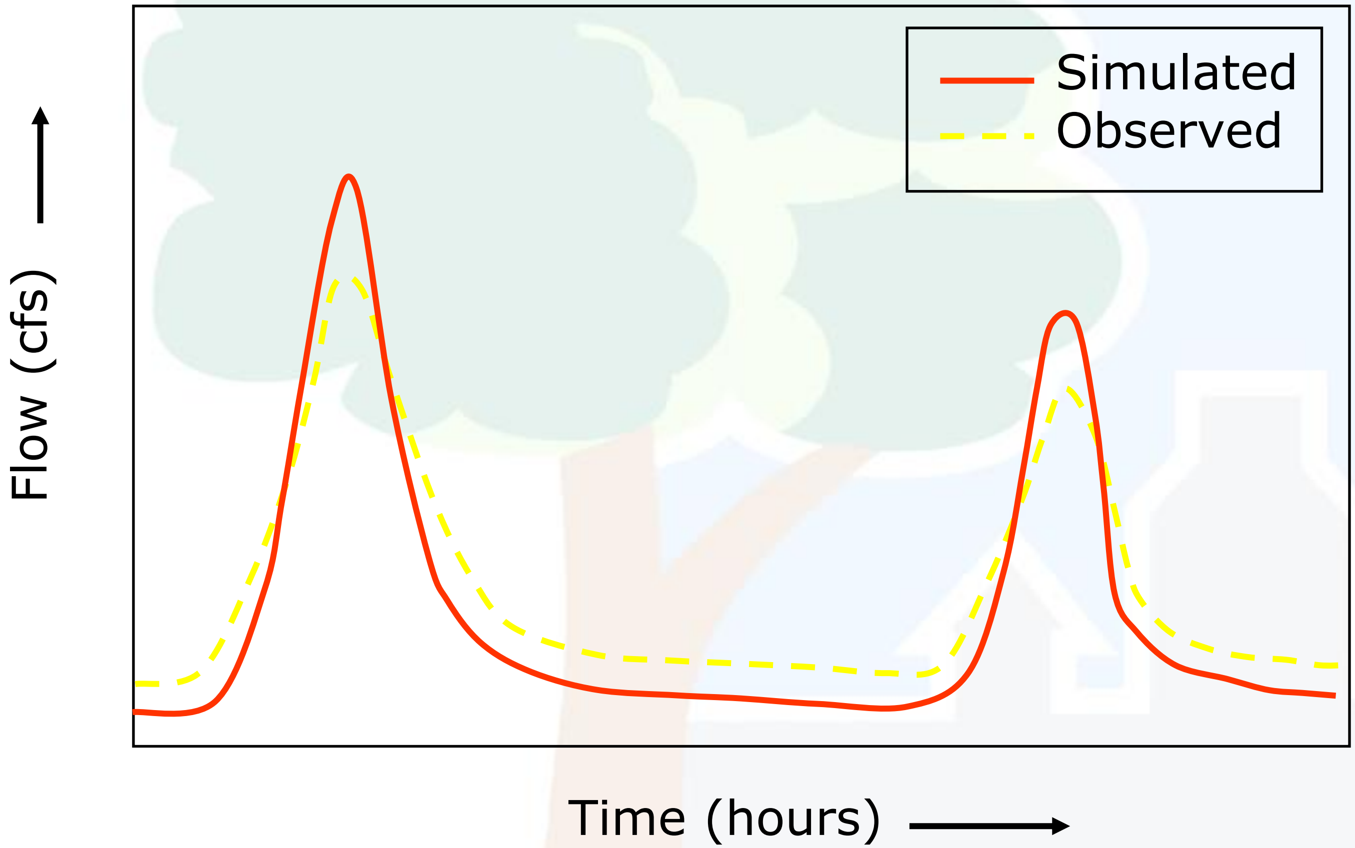
- Common calibration problems
  - High base flow, too little evapotranspiration



- Check landcover estimates
- Check weather data (net rad., temp, windspeed)
- LAI, K_{sat} values

HP: Modeling Metrics

- Common calibration problems
  - Incorrect partitioning of baseflow/overland flows



- Check landcover estimates
- Check contributing area/DEM footprint
- LAI, K_{sat} values

i-Tree Hydro

An Introduction to the Model

i-Tree is a Cooperative Initiative

i-Tree Hydro: An Introduction

- Model interfaces
- Model inputs
- Model outputs

i-Tree Hydro: New model interface

i-Tree Hydro

File Steps Outputs Help

Welcome to i-Tree Hydro!

[What is Hydro?]
[How to Run i-Tree Hydro]
[About the Sample Project]
[New Project Steps]

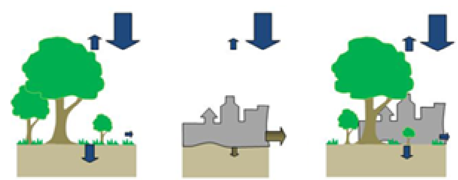
General References:

[i-Tree Hydro webpage]
[Hydrologic Cycle]
[Soil Profile]
[User's Manual]

What is Hydro?

i-Tree Hydro is a simulation tool that analyzes how land cover influences the volume and quality of runoff. It can analyze historical or future hydrological events and allow the user to contrast runoff volume and quality from existing land cover (referred to as the Base Case) with runoff from the Alternative Case land cover. The i-Tree Hydro model differs from other i-Tree products in the following ways:

- The model simulation area is loaded into the program either as a digital elevation model (DEM) file or as a topographic index (TI) file. It is not hand-delineated in the program by the user. If the user is interested in a watershed, they can load a DEM or TI file. If the user is interested in a city or parcel that is not defined by a single watershed they load a TI file.
- The model simulation can be run in calibration mode or non-calibration mode. For calibration runs the user loads observed streamflow data from a gauging station and the model will identify the optimal hydrological parameters to fit the observed streamflow data. Observed streamflow data are provided for thousands of watershed areas. For non-calibration runs the user can use previously calibrated parameters or independently set the land cover and hydrological parameter values by adjusting the default values that the model provides.



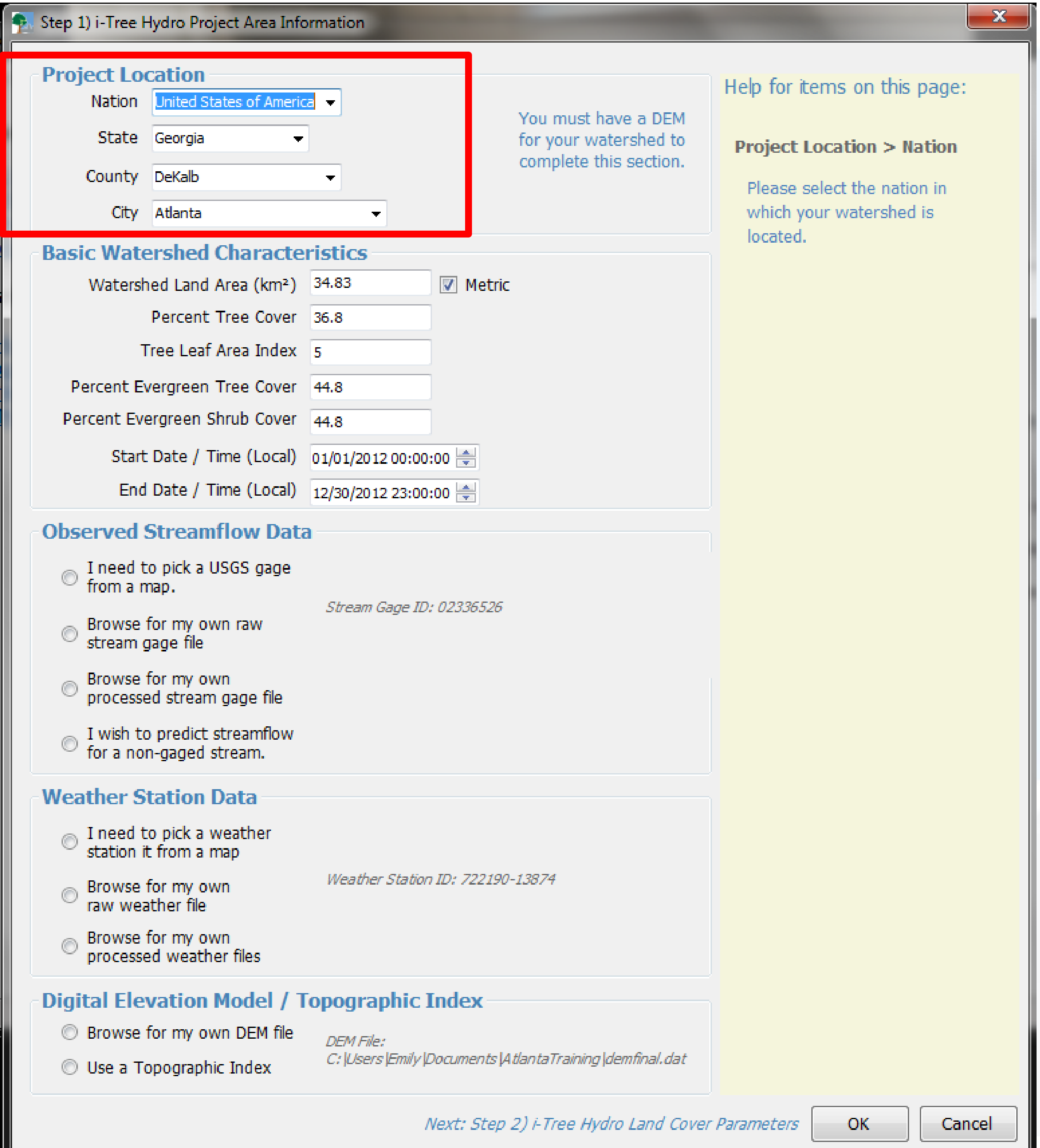
Current Project:

No project loaded.

i-Tree Hydro

i-Tree is a Cooperative Initiative

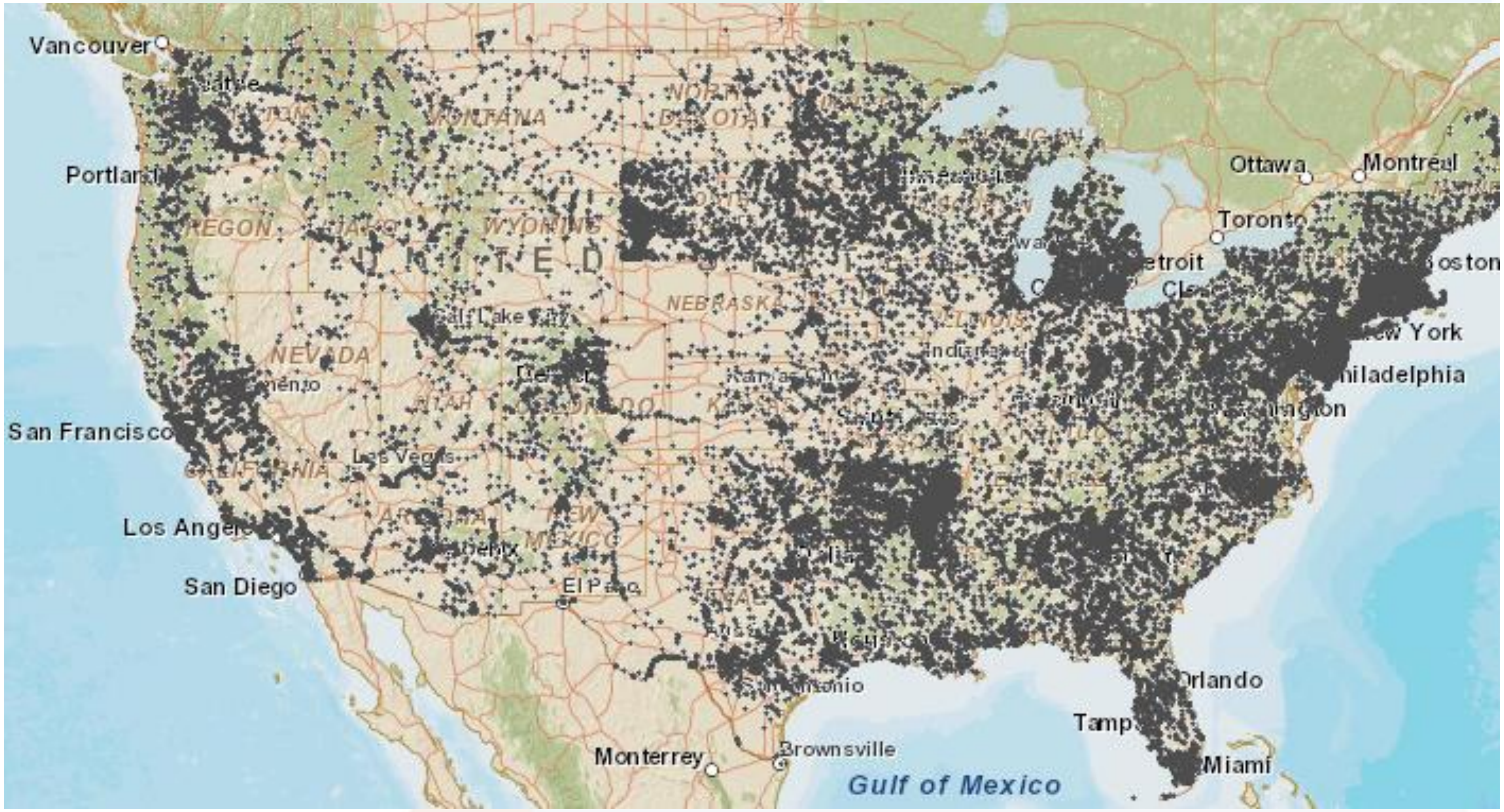
DAVEY Arbor Day Foundation sma Society of Municipal Arborists ISA Casey Trees ESF



Step 1

- Project Location
- Basic WS Info
- Streamflow
- Weather
- Topographic

i-Tree Hydro: Project Locations



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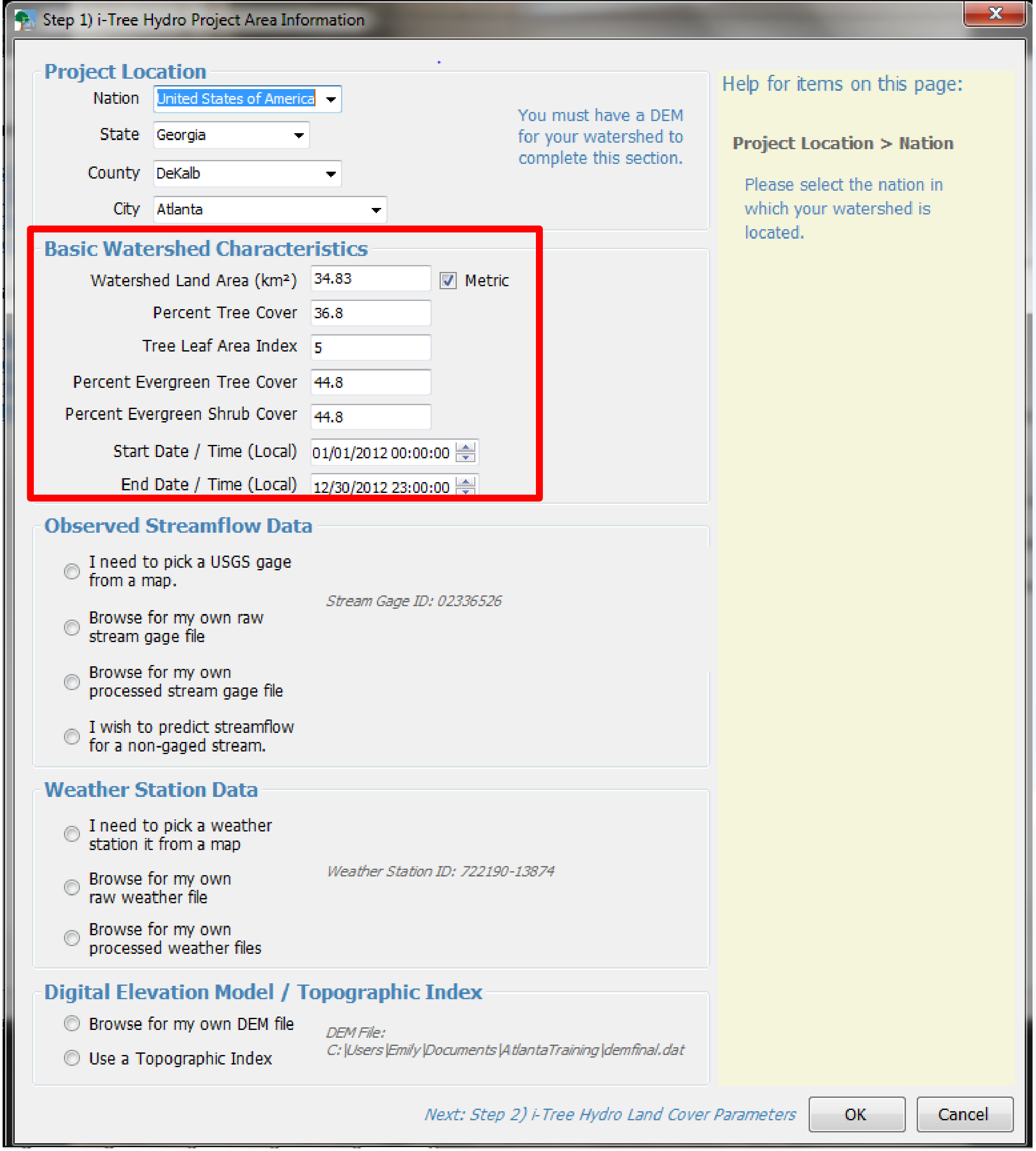

i-Tree

- **Step 1**
- Project Location
- Basic WS Info
- Streamflow
- Weather
- Topographic

i-Tree Hydro: Land Cover Data (via i-Tree Canopy)

How it works | Report | Export | Start Over | Exit | ?

i-Tree Canopy

Report by Area

Percent Cover (±SE)

Id	Cover Class	Latitude	Longitude
81	Tree - Pervious	44.42693	-73.052
82	Herbaceous	44.43781	-73.110
83	Tree - Pervious	44.43136	-73.090
84	Herbaceous	44.44449	-73.108
85	Impervious - Building	44.46066	-73.108
86	Herbaceous	44.41338	-73.078
87	Tree - Pervious	44.39344	-73.075
88	Herbaceous	44.44426	-73.054
89	Impervious - Road, Sidewalk	44.43173	-73.063
90	Herbaceous	44.44842	-73.050

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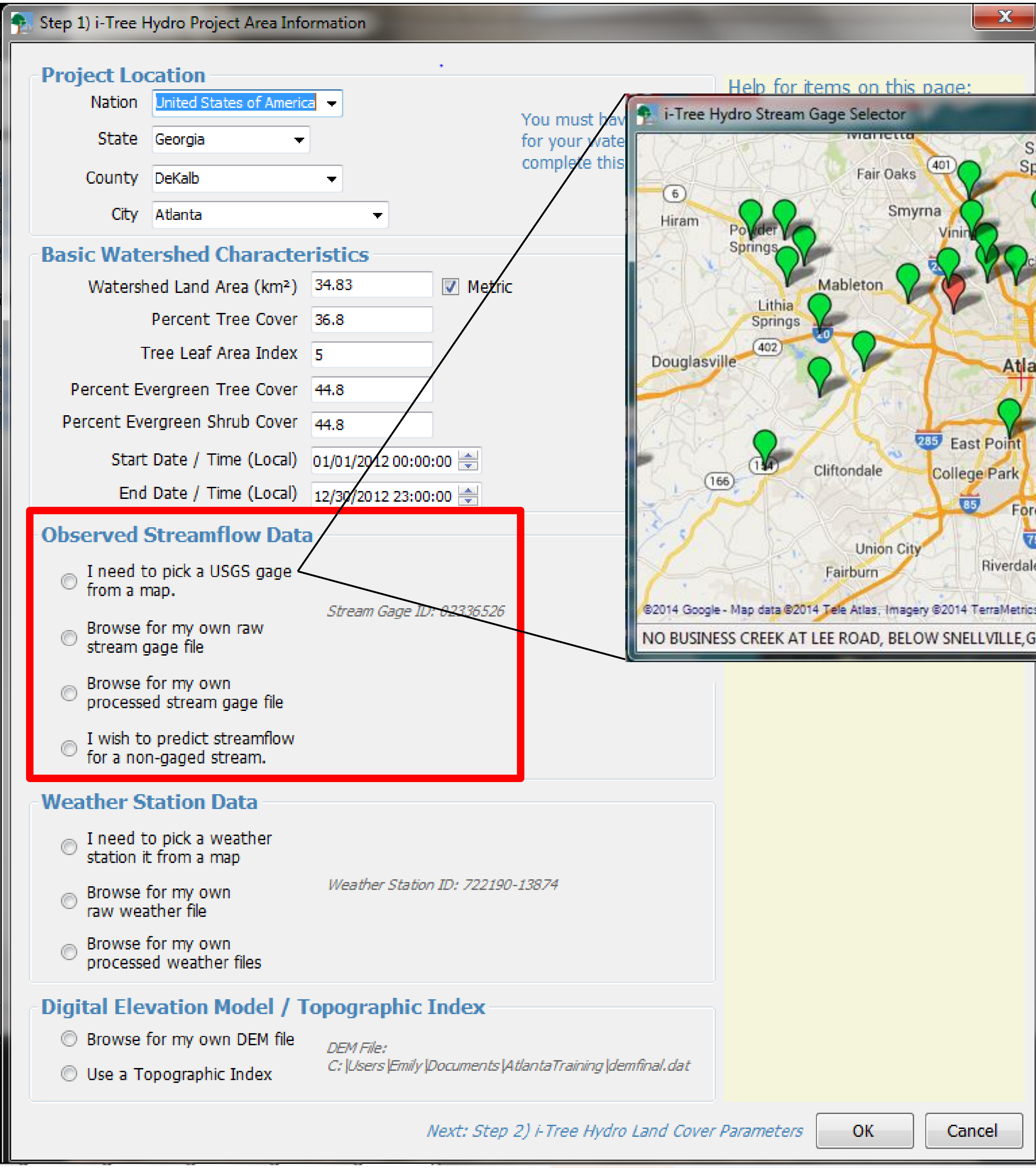
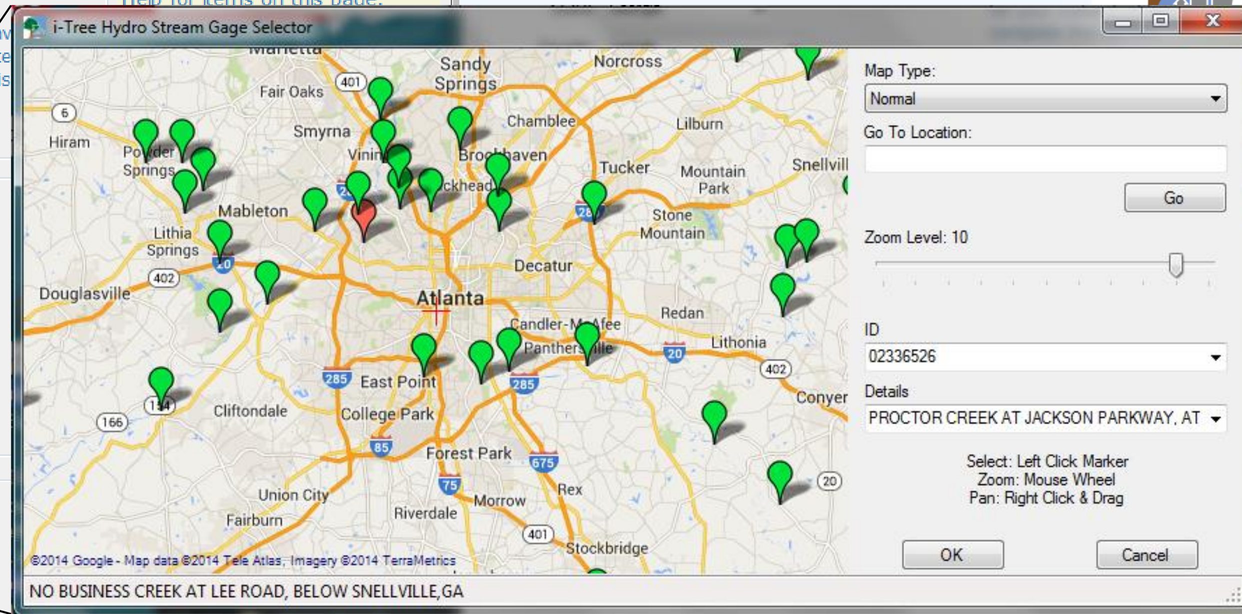
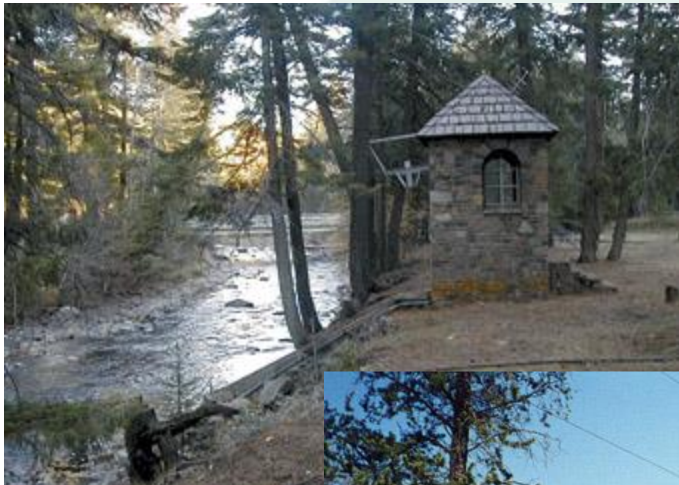




- Streamflow
- Weather
- Topographic

i-Tree is a Cooperative Initiative

i-Tree Hydro: Stream Data



QOBS.dat - Notepad

File Edit Format View Help

```
yyyymmdd    Hr:Min:Sec    Discharge(m/hr)

20110101    0:00:00       2.25638E-004
20110101    1:00:00       2.25638E-004
20110101    2:00:00       2.25638E-004
20110101    3:00:00       2.25638E-004
20110101    4:00:00       2.25638E-004
20110101    5:00:00       2.25638E-004
20110101    6:00:00       2.25638E-004
20110101    7:00:00       2.25638E-004
20110101    8:00:00       2.25638E-004
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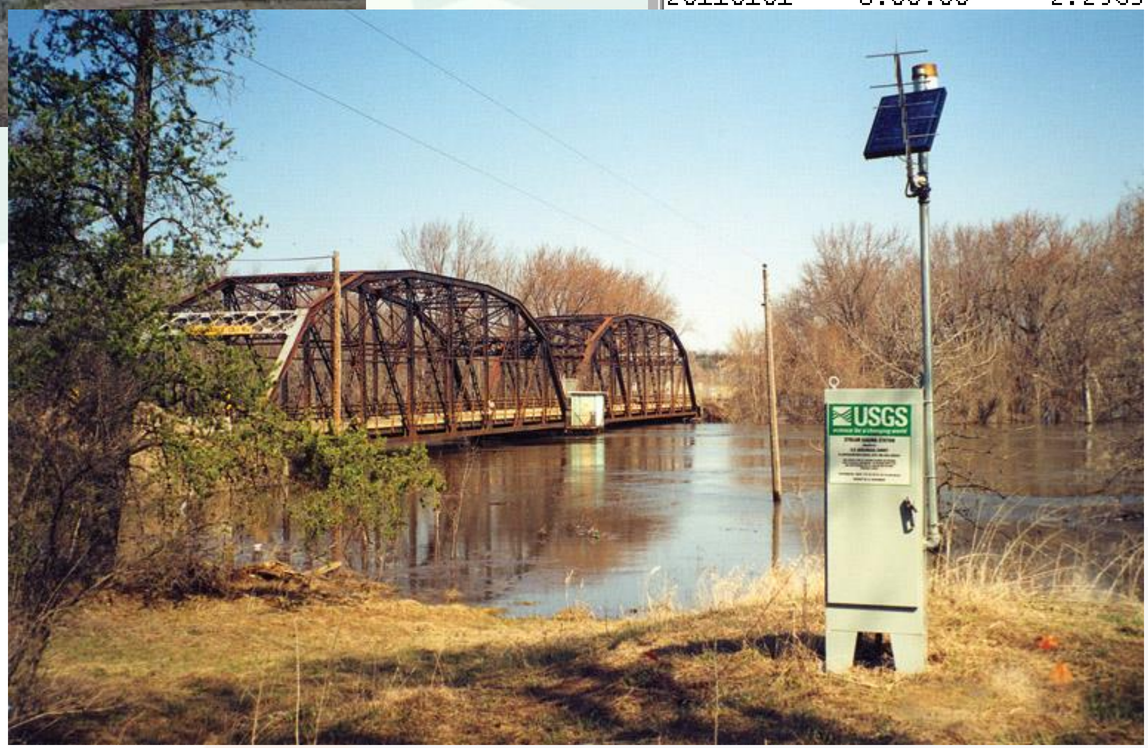

i-Tree Hydro: Weather Data

WeatherData.dat - Notepad

File Edit Format View Help

yyyymmdd	Hr:Min:Sec	Tair(F)	Tdew(F)	NetRad(W/m^2)	WndSpd(m/s)	Precip(m/hr)	Snow(m/hr)
20110101	00:00:00	42.70000000	34.90000000	0.00000000	3.44210997	0.00000000	0.00000000
20110101	01:00:00	40.00000000	34.00000000	0.00000000	2.23513634	0.00000000	0.00000000
20110101	02:00:00	42.10000000	34.10000000	0.00000000	3.48681270	0.00000000	0.00000000
20110101	03:00:00	42.90000000	35.00000000	0.00000000	2.68216361	0.00000000	0.00000000
20110101	04:00:00	42.00000000	35.00000000	0.00000000	2.68216361	0.00000000	0.00000000
20110101	05:00:00	36.85000000	36.00000000	0.00000000	0.00000000	0.00025400	0.00000000
20110101	06:00:00	36.76000000	36.00000000	0.00000000	1.01922217	0.00000000	0.00000000
20110101	07:00:00	36.00000000	36.00000000	0.00000000	1.34108181	0.00000000	0.00000000
20110101	08:00:00	35.31578947	35.31578947	12.50021015	0.00000000	0.00000000	0.00000000
20110101	09:00:00	36.00000000	36.00000000	53.31007742	0.44702727	0.00000000	0.00000000
20110101	10:00:00	37.00000000	37.00000000	88.96392811	0.00000000	0.00000000	0.00000000
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20110101	12:00:00	47.20000000	41.10000000	382.4534808	3.48681270	0.00000000	0.00000000
20110101	13:00:00	49.00000000	42.00000000	174.0454807	2.68216361	0.00000000	0.02540000
20110101	14:00:00	49.90000000	42.90000000	131.4296478	3.17389361	0.00000000	0.00000000
20110101	15:00:00	49.00000000	42.00000000	159.7079611	3.71032633	0.00000000	0.00000000
20110101	16:00:00	49.00000000	42.00000000	27.88483690	4.91729996	0.00000000	0.00000000
20110101	17:00:00	46.00000000	41.90000000	0.00000000	3.57621815	0.00000000	0.00000000
20110101	18:00:00	46.30000000	41.10000000	0.00000000	3.63582179	0.00000000	0.00000000
20110101	19:00:00	49.00000000	42.00000000	0.00000000	3.12919088	0.00000000	0.02540000
20110101	20:00:00	49.10000000	40.90000000	0.00000000	3.71032633	0.00000000	0.00000000
20110101	21:00:00	50.00000000	40.00000000	0.00000000	5.05140814	0.00000000	0.00000000
20110101	22:00:00	50.00000000	40.00000000	0.00000000	6.25838176	0.00000000	0.00000000
20110101	23:00:00	49.00000000	39.00000000	0.00000000	6.79481448	0.00000000	0.00000000
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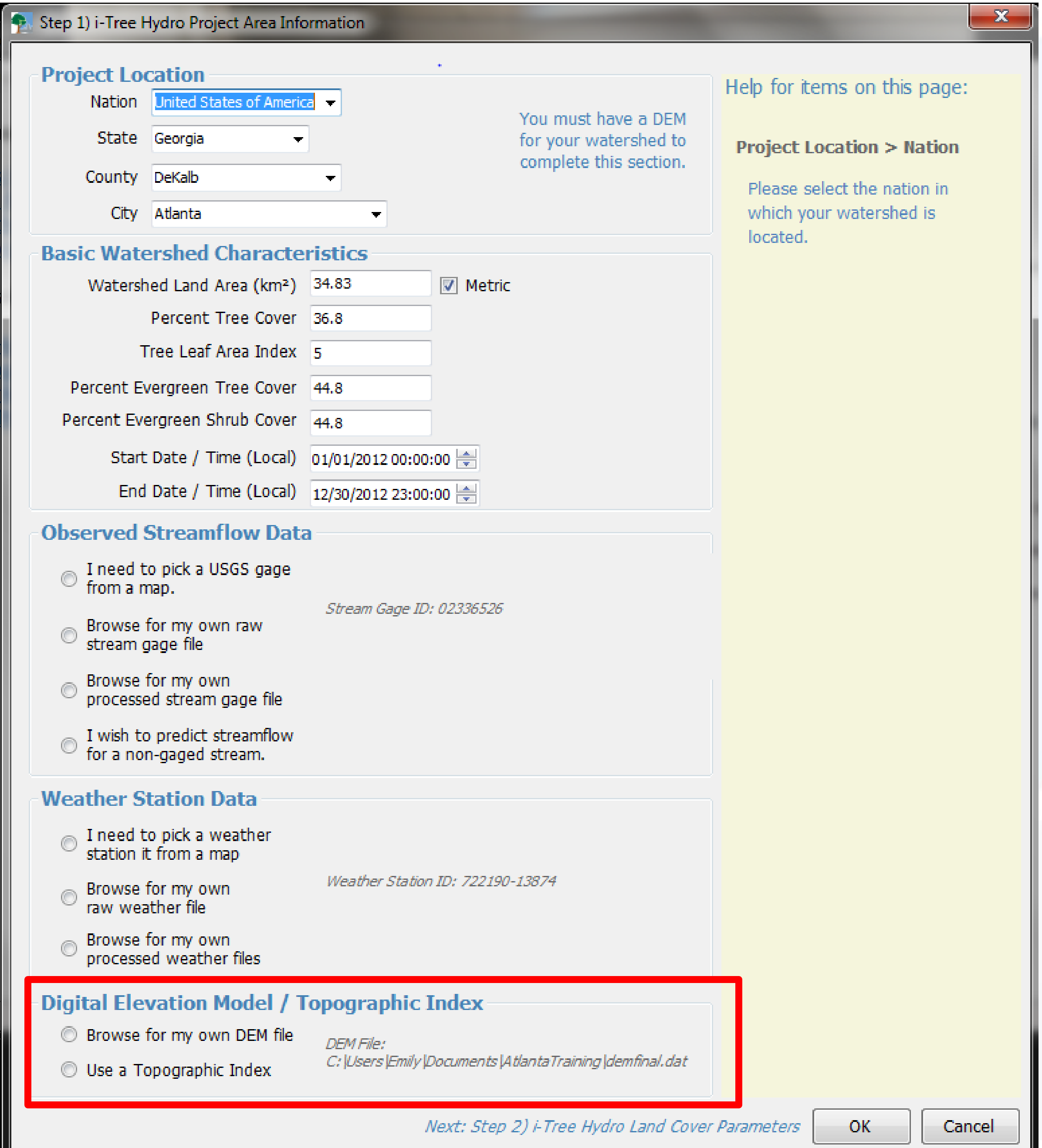

Step 1

- Project Location
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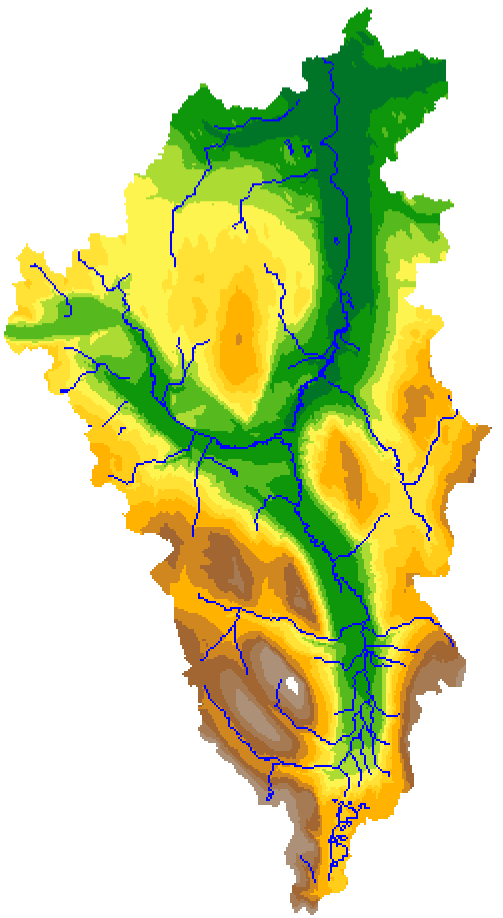
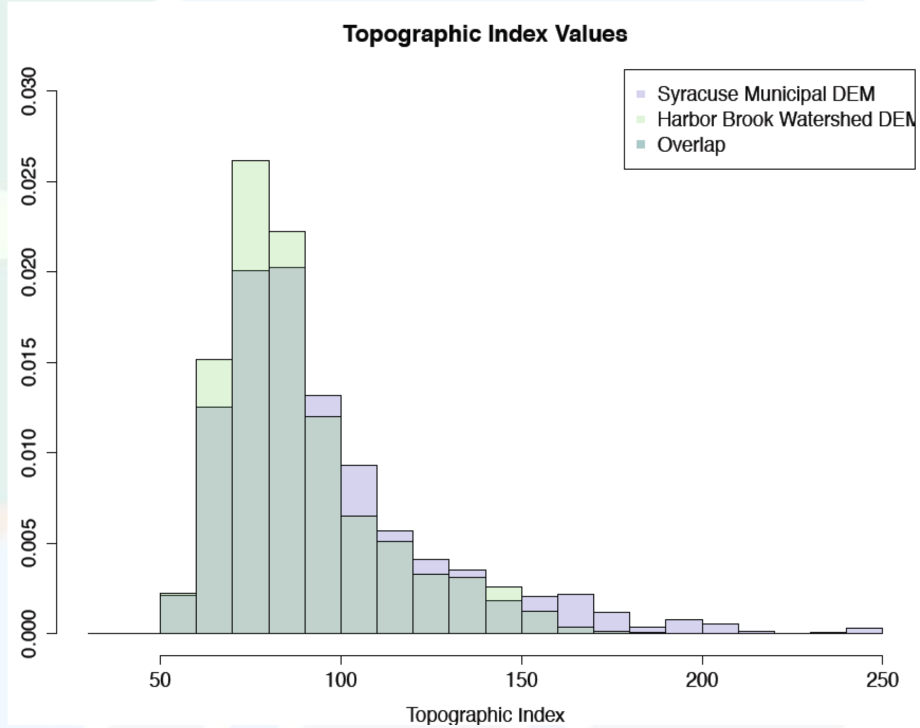
i-Tree Hydro: DEM vs Topographic Index Option

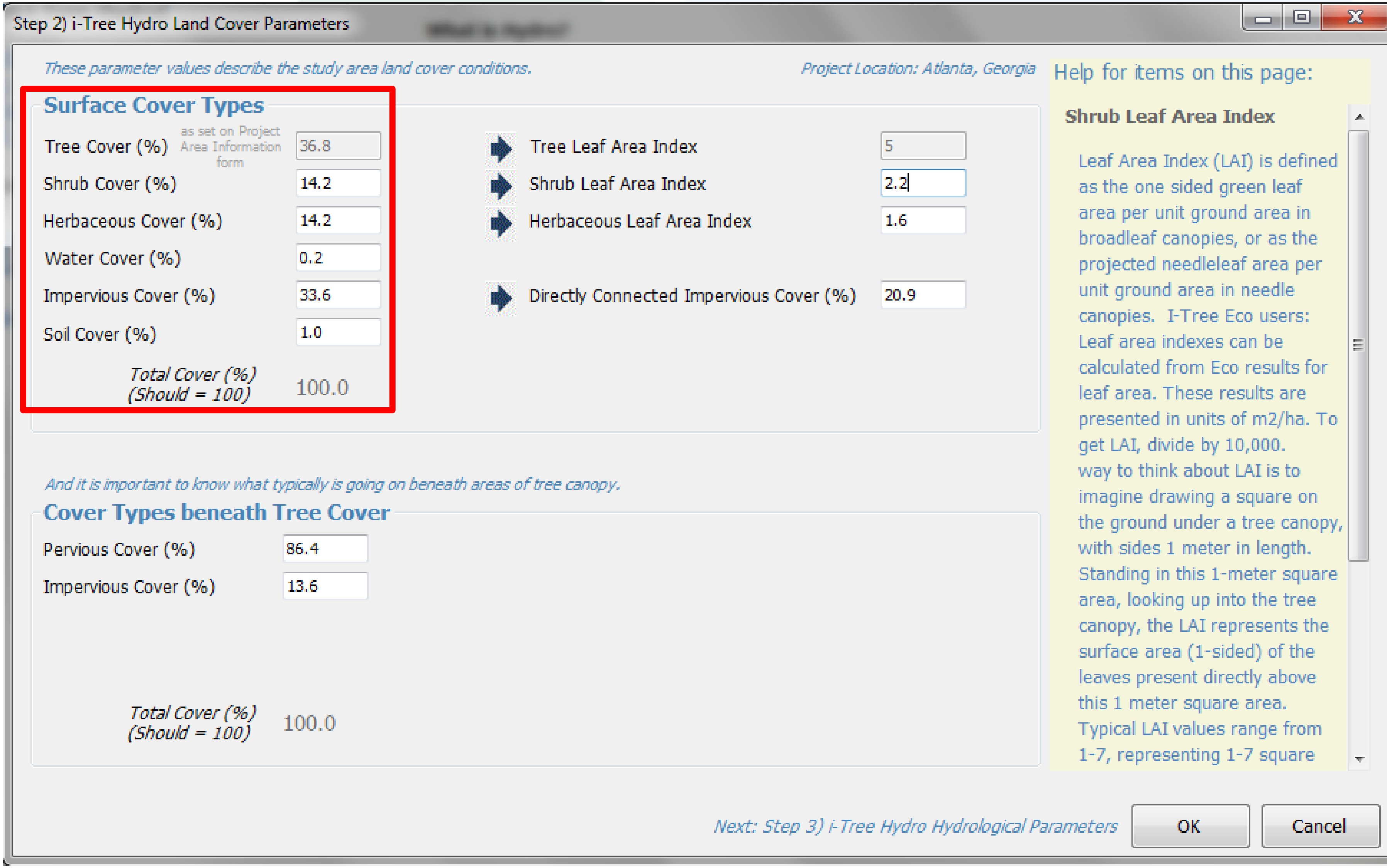




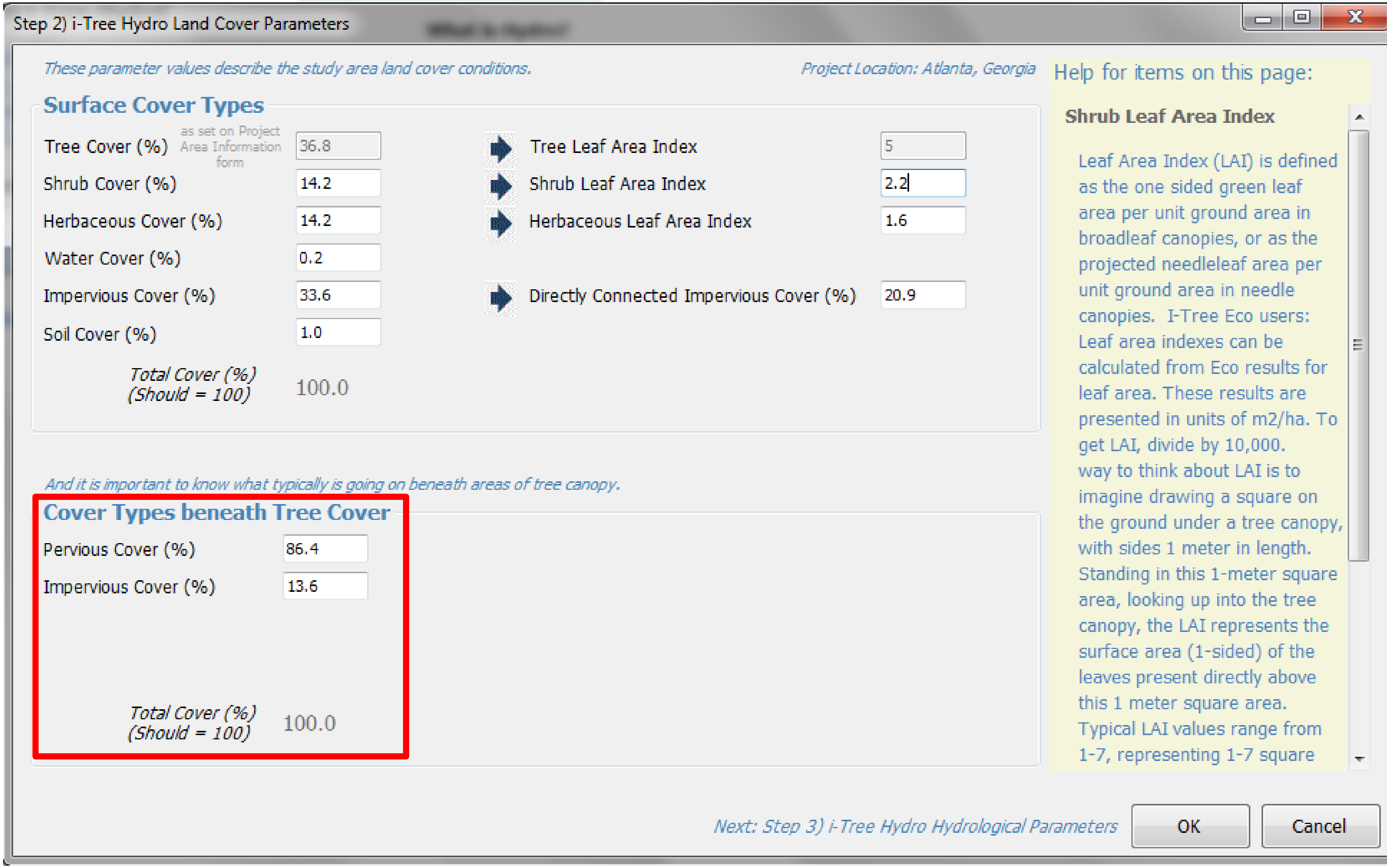
Digital Elevation Model (DEM)

Topographic Index from DEM

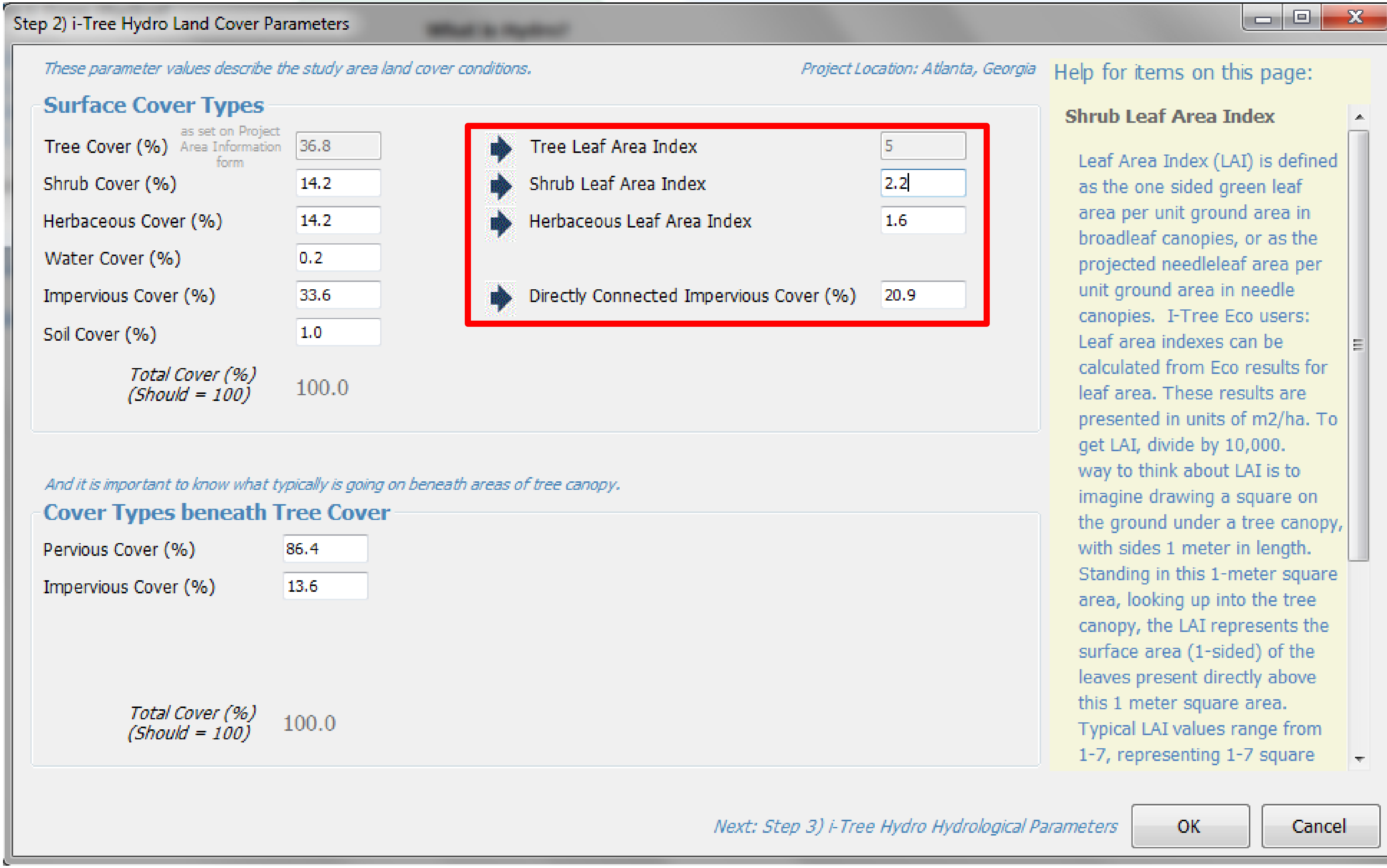
i-Tree Hydro: Land Cover Parameters



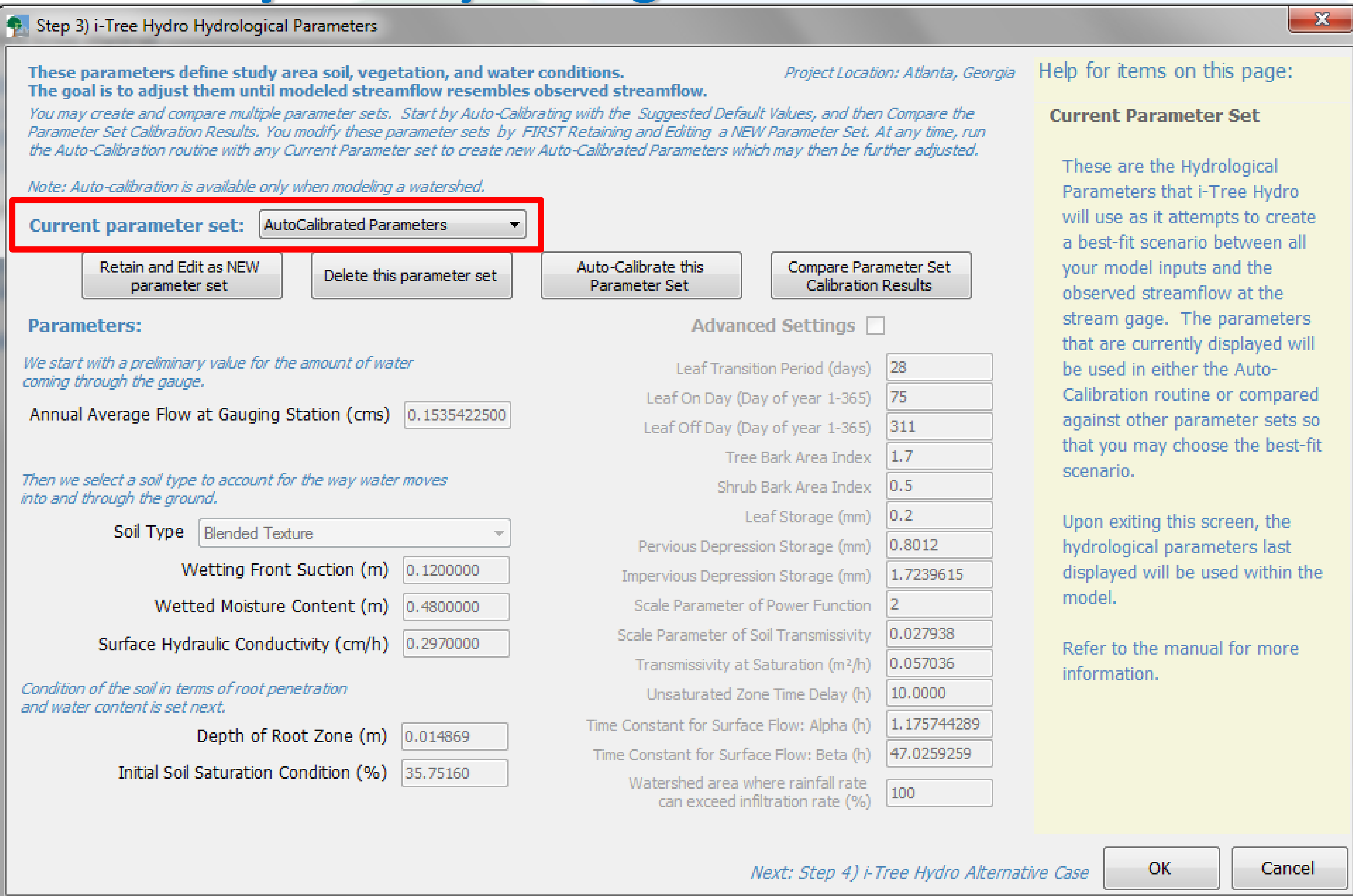
i-Tree Hydro: Land Cover Parameters



i-Tree Hydro: Land Cover Parameters

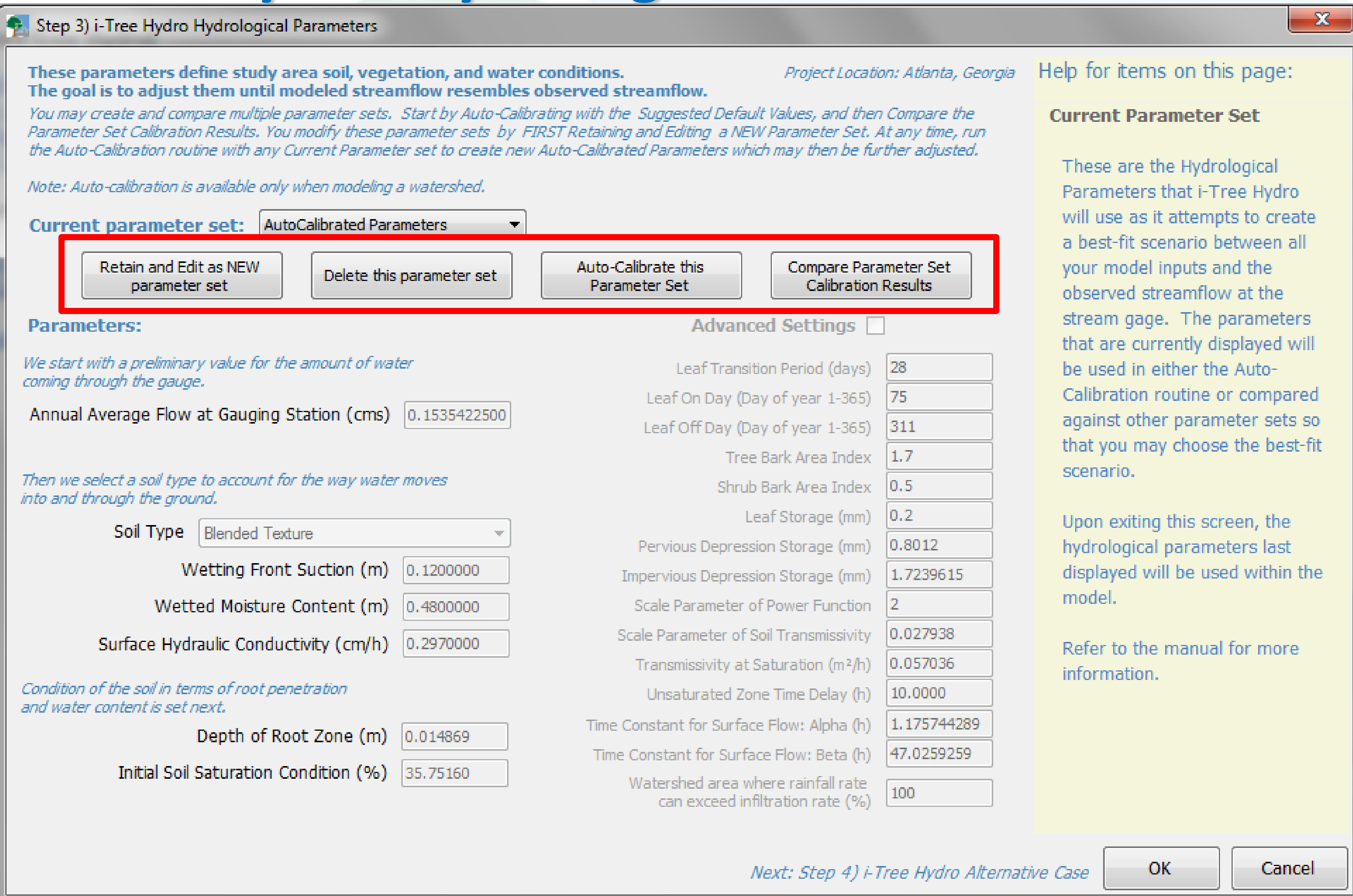


i-Tree Hydro: Hydrological Parameters



i-Tree is a Cooperative Initiative

i-Tree Hydro: Hydrological Parameters



i-Tree Hydro: Hydrological Parameters

Step 3) i-Tree Hydro Hydrological Parameters

These parameters define study area soil, vegetation, and water conditions.
The goal is to adjust them until modeled streamflow resembles observed streamflow.

Project Location: Atlanta, Georgia

You may create and compare multiple parameter sets. Start by Auto-Calibrating with the Suggested Default Values, and then Compare the Parameter Set Calibration Results. You modify these parameter sets by FIRST Retaining and Editing a NEW Parameter Set. At any time, run the Auto-Calibration routine with any Current Parameter set to create new Auto-Calibrated Parameters which may then be further adjusted.

Note: Auto-calibration is available only when modeling a watershed.

Current parameter set: AutoCalibrated Parameters

Retain and Edit as NEW parameter set | Delete this parameter set | Auto-Calibrate this Parameter Set | Compare Parameter Set Calibration Results

Parameters:

We start with a preliminary value for the amount of water coming through the gauge.

Annual Average Flow at Gauging Station (cms): 0.1535422500

Then we select a soil type to account for the way water moves into and through the ground.

Soil Type	Blended Texture
Wetting Front Suction (m)	0.1200000
Wetted Moisture Content (m)	0.4800000
Surface Hydraulic Conductivity (cm/h)	0.2970000

Condition of the soil in terms of root penetration and water content is set next.

Depth of Root Zone (m)	0.014869
Initial Soil Saturation Condition (%)	35.75160

Advanced Settings

Leaf Transition Period (days)	28
Leaf On Day (Day of year 1-365)	75
Leaf Off Day (Day of year 1-365)	311
Tree Bark Area Index	1.7
Shrub Bark Area Index	0.5
Leaf Storage (mm)	0.2
Pervious Depression Storage (mm)	0.8012
Impervious Depression Storage (mm)	1.7239615
Scale Parameter of Power Function	2
Scale Parameter of Soil Transmissivity	0.027938
Transmissivity at Saturation (m^2/h)	0.057036
Unsaturated Zone Time Delay (h)	10.0000
Time Constant for Surface Flow: Alpha (h)	1.175744289
Time Constant for Surface Flow: Beta (h)	47.0259259
Watershed area where rainfall rate can exceed infiltration rate (%)	100

Help for items on this page:

Current Parameter Set

These are the Hydrological Parameters that i-Tree Hydro will use as it attempts to create a best-fit scenario between all your model inputs and the observed streamflow at the stream gage. The parameters that are currently displayed will be used in either the Auto-Calibration routine or compared against other parameter sets so that you may choose the best-fit scenario.

Upon exiting this screen, the hydrological parameters last displayed will be used within the model.

Refer to the manual for more information.

Next: Step 4) i-Tree Hydro Alternative Case

OK | Cancel

i-Tree Hydro: Hydrological Parameters

Step 3) i-Tree Hydro Hydrological Parameters

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Next: Step 4) i-Tree Hydro Alternative Case

OK | Cancel

i-Tree

i-Tree is a Cooperative Initiative

i-Tree Hydro: Hydrological Parameters

Step 3) i-Tree Hydro Hydrological Parameters

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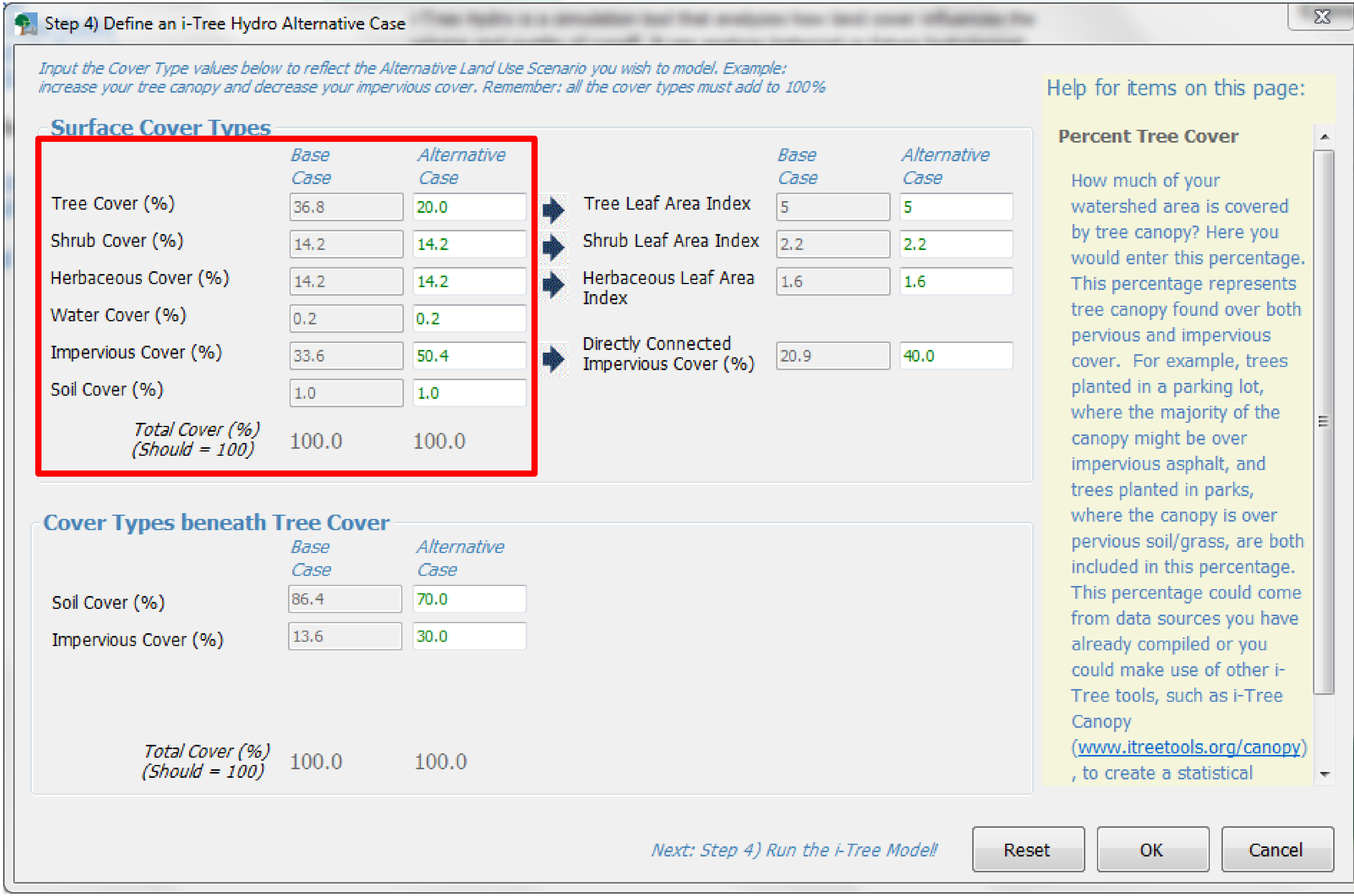
Next: Step 4) i-Tree Hydro Alternative Case

OK | Cancel

i-Tree Hydro: Alternative Case



i-Tree is a Cooperative Initiative

i-Tree Hydro: Alternative Case

Step 4) Define an i-Tree Hydro Alternative Case

Input the Cover Type values below to reflect the Alternative Land Use Scenario you wish to model. Example: increase your tree canopy and decrease your impervious cover. Remember: all the cover types must add to 100%

Surface Cover Types

	Base Case	*Alternative Case*
Tree Cover (%)	36.8	20.0
Shrub Cover (%)	14.2	14.2
Herbaceous Cover (%)	14.2	14.2
Water Cover (%)	0.2	0.2
Impervious Cover (%)	33.6	50.4
Soil Cover (%)	1.0	1.0
Total Cover (%) (Should = 100)	100.0	100.0

	Base Case	*Alternative Case*
Tree Leaf Area Index	5	5
Shrub Leaf Area Index	2.2	2.2
Herbaceous Leaf Area Index	1.6	1.6
Directly Connected Impervious Cover (%)	20.9	40.0

Cover Types beneath Tree Cover

	Base Case	*Alternative Case*
Soil Cover (%)	86.4	70.0
Impervious Cover (%)	13.6	30.0
Total Cover (%) (Should = 100)	100.0	100.0

Help for items on this page:

Percent Tree Cover

How much of your watershed area is covered by tree canopy? Here you would enter this percentage. This percentage represents tree canopy found over both pervious and impervious cover. For example, trees planted in a parking lot, where the majority of the canopy might be over impervious asphalt, and trees planted in parks, where the canopy is over pervious soil/grass, are both included in this percentage. This percentage could come from data sources you have already compiled or you could make use of other i-Tree tools, such as i-Tree Canopy (www.itreetools.org/canopy), to create a statistical

Next: Step 4) Run the i-Tree Model!

Reset OK Cancel

i-Tree Hydro: Alternative Case

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Soil Cover (%)	1.0	1.0
Total Cover (%) (Should = 100)	100.0	100.0

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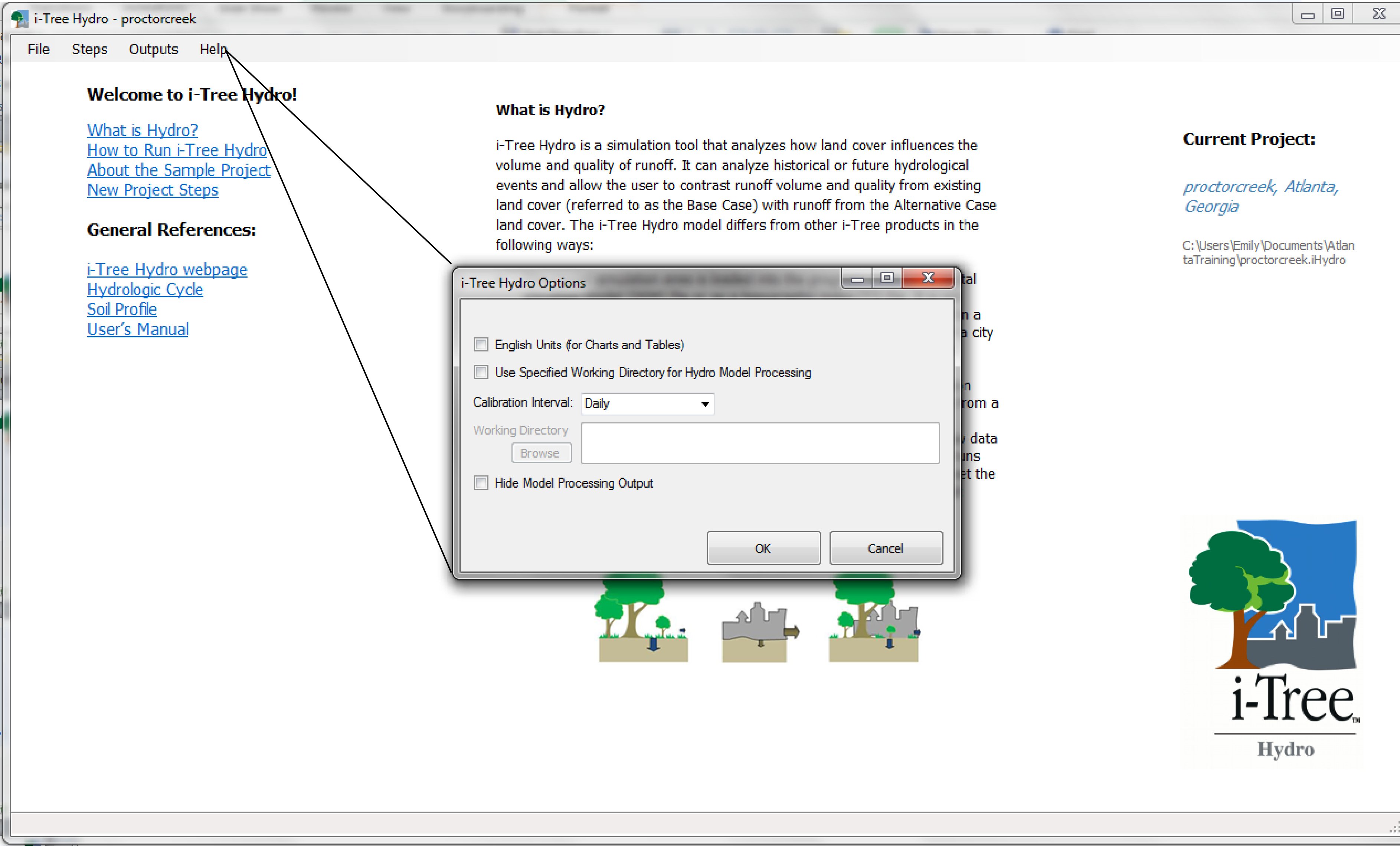
Next: Step 4) Run the i-Tree Model!

Reset OK Cancel

Calibration Time Step



i-Tree is a Cooperative Initiative

i-Tree Hydro

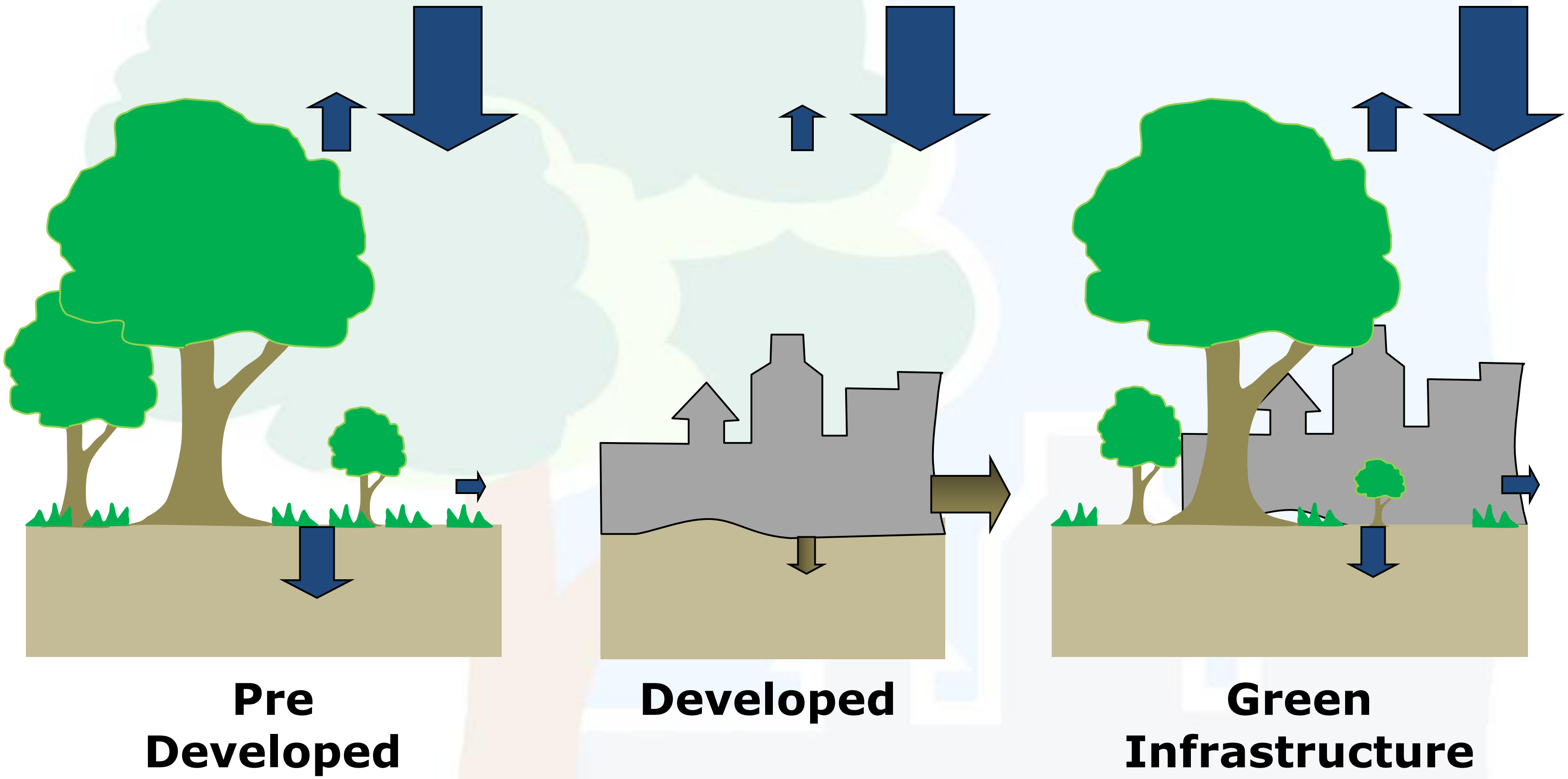
A Stormwater Management Model

Participant Introductions

- Name
- Position
- Reason for interest in i-Tree Hydro
  - What you hope to model?
  - What stormwater issues you hope to address?

i-Tree Canopy

Hydro: Urban Forest Hydrology



HP: Focus of i-Tree Hydro

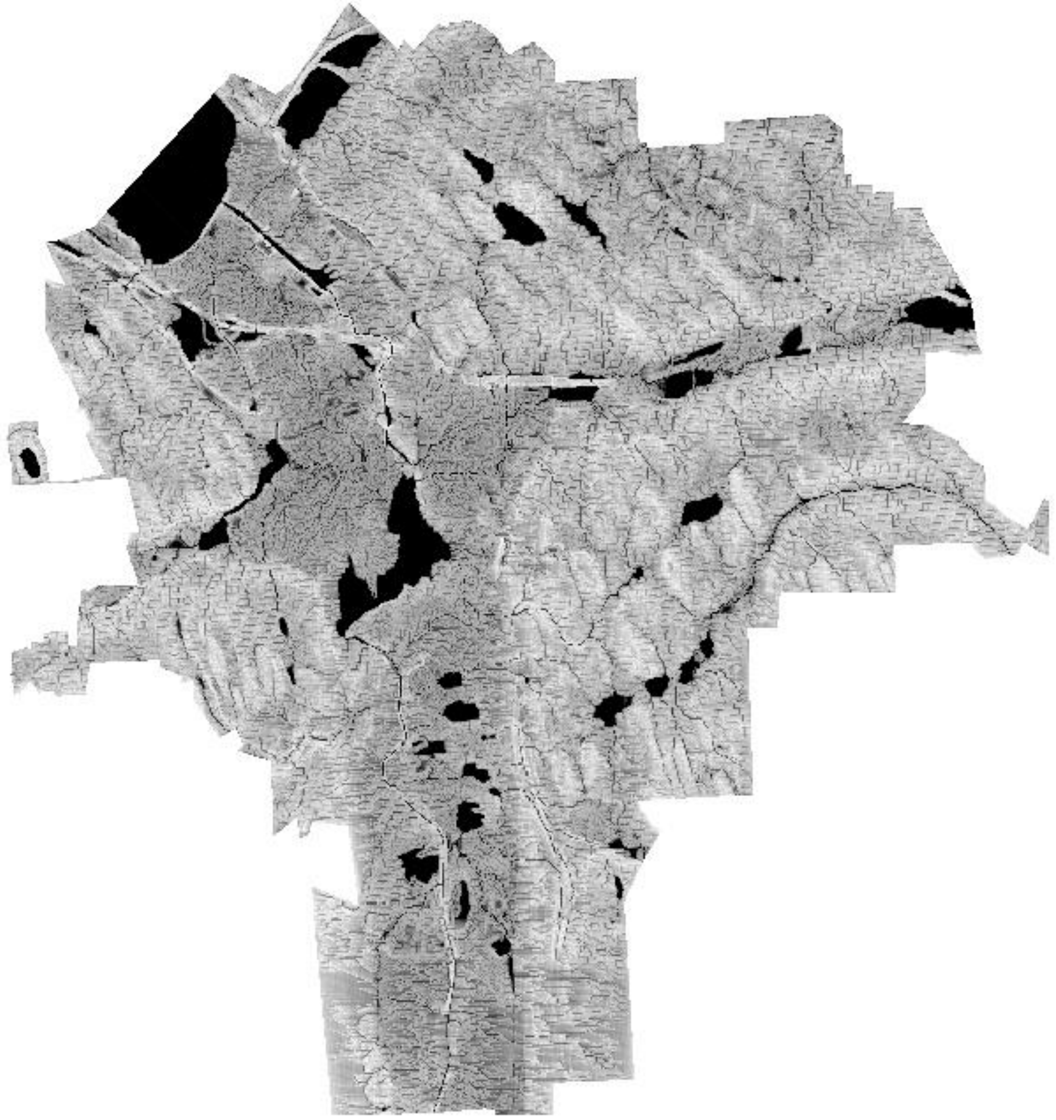
- Watershed scale 1st level analyses
  - vegetation and impervious cover effects on hydrology
- Model different tree cover/vegetative cover scenarios
  - Increase/decrease TC
  - Increase/decrease IC
  - Increase/decrease other WS landcover types
- Hydro quantifies hourly and total changes
  - stream flow, water quality

Hydro: Model Assumptions

- Topographic index
  - Affected by DEM resolution
  - Increasing DEM resolution – small cell sizes
    - TI values decrease for most cells
      - Minimum, median values decrease
    - TI values may increase for river/stream network cells
      - Maximum value may increase
  - Decreasing DEM resolution – larger cell sizes
    - Has the opposite effect

Hydro: Model Assumptions

TI Syracuse, NY



Hydro: Model Assumptions

- Topographic index

Table 8. Minimum, Median, and Maximum Values of ln (a), ln (1/tan B), and ln (a/tan B) Distributions Computed at Grid Cell Resolutions for a Section of the 1:24,000-Scale Nuremburg Quadrangle Digital Elevation Model

Variable	Data Resolution, m	Distribution Statistic		
		Minimum	Median	Maximum
Total change		0.48	0.34	0.90
ln (a/tan B)	30	2.93	5.76	16.14
ln (a/tan B)	60	3.74	6.70	16.11
ln (a/tan B)	90	4.41	7.00	16.03
ln (a/tan B)	120	4.72	7.10	15.96
Total change		1.79	1.34	−1.97

Source: Wolock and Price, 1994.

Hydro: Model Assumptions

- Hydraulic Conductivity – Transmissivity
  - Same everywhere in the watershed
  - Decay profiles – decays with soil depth
    - Exponential vs. Power

$$K_s(z) = K_o \exp(-fz) \qquad\qquad K_s(z) = K_o(1 - fz)^n$$

- Default model setting is power law decay
- Changed in hydrological parameters screen

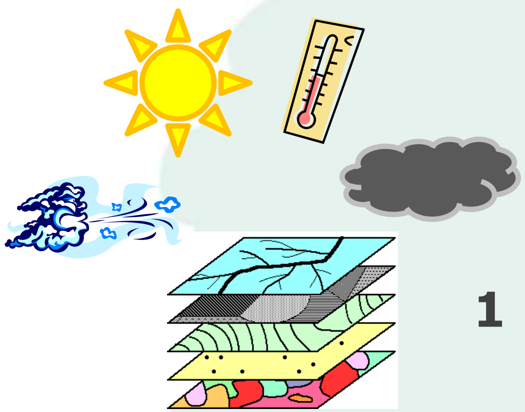
Hydro: Model Assumptions

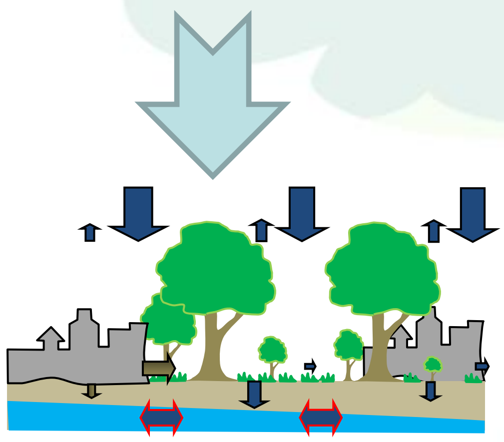
- Saturation/infiltration excess
  - Effects pervious areas
    - Tree cover over pervious, shrub/herbaceous, bare soil
  - Percentage of watershed area that is controlled by infiltration excess – rest is saturation excess
- Land cover
  - Average or sampled – typically only an estimation
  - DCIA value – estimated
  - Problems with NLCD resolution

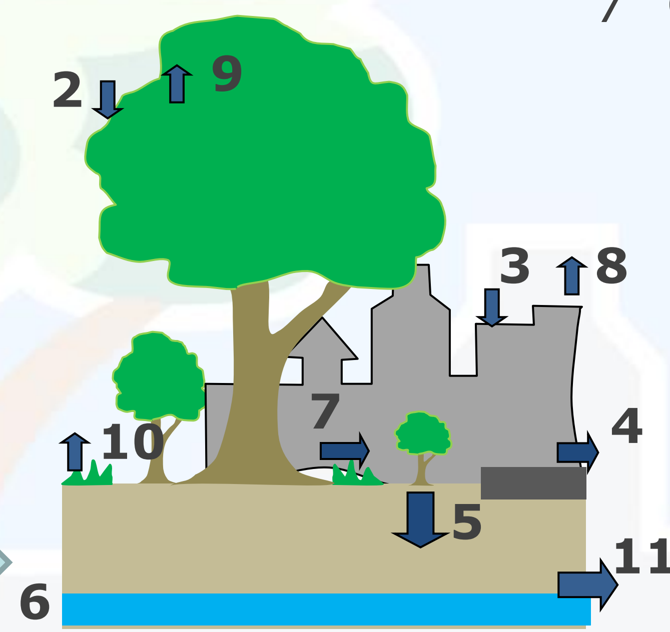
Hydro: Hydro Conceptual Models

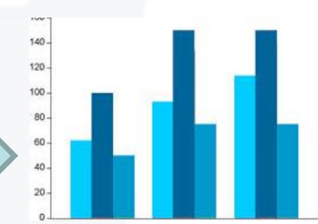
1 Inputs
2 Canopy Interception
3 Depression Storage
4 Impervious Runoff
5 Infiltration
6 Soil Moisture

1 Pervious Runoff
2 Surface Evaporation
3 Veg Evaporation
4 Evapotranspiration
5 Subsurface Runoff
6 Spatial Distribution
7 Outputs



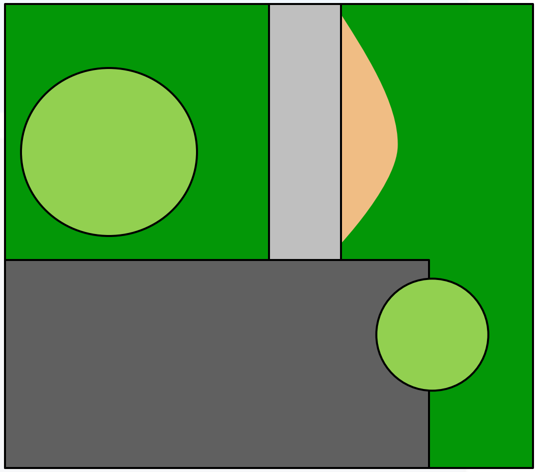






Hydro: Mathematical Model – Inputs

- Landcover
  - 5 main classes:
    - Bare Soil
    - Shrub/Grass/Herbaceous (SV)
    - Impervious Area
    - Tree Cover over Impervious Area
    - Tree Cover over Pervious Area



Hydro: Mathematical Model – Inputs

- Canopy Properties
  - Leaf Area Index (LAI) – One sided leaf area per square meter of canopy
    - Tree LAI + Tree bark LAI
    - Shrub/Herbaceous LAI + Bark LAI
  - Deciduous vs. Coniferous makeup
  - Leaf On/Off days

Source: Aguilar, M.A. et al., 2010

Hydro: Mathematical Model – Processes

- Interception
  - f(TC%, SV%, LAI)
    - Open space vs. canopy coverage, leaf on/off days, etc.

- Depression storage
  - f(Landcover type, Depression depth)
    - Pervious vs. Impervious - Different depression storage maxes

Hydro: Mathematical Model – Processes

- Surface runoff
  - f(Depression storage, Infiltration process, Soil moisture status)
    - Depression storage filled?
    - Saturated soil? Rainfall intensity greater than infiltration rate?
    - Model user sets ratio of infiltration to saturation excess soils

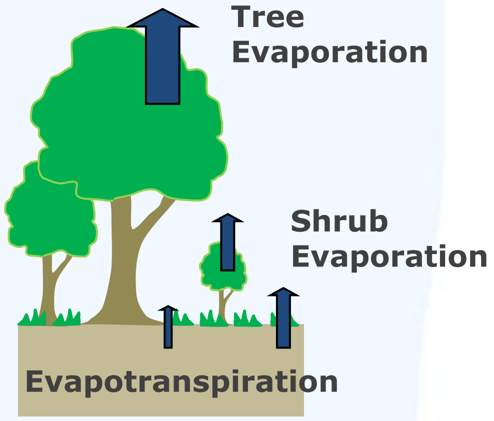
Hydro: Mathematical Model – Processes (cont.)

- Infiltration
  - f(K_{sat}, Rainfall intensity, Infiltration process)
  - Infiltration excess – Modified Green-Ampt routine
  - Saturation excess – unconstrained flow into rootzone

- Soil moisture
  - Root zone → Unsaturated zone → Saturated zone
  - f(Infiltrated water, ET, Intra-zone flow rates, Baseflow generation, etc.)

Hydro: Mathematical Model – Processes (cont.)

- Evaporation and ET
  - Tree > Shrub > ET
  - Potential Rates
    - Penman-Montieth
    - Evap - f(temp, net radiation, wind speed, etc.)
    - ET - f(temp,…, soil + canopy resistances)
  - Actual Rates
    - f(water availability, Storage/Rootzone depth, LAI, etc.)



Hydro: Mathematical Model – Processes (cont.)

- Subsurface flow
  - f(K_{sat}, Average soil moisture deficit, Recession rate)

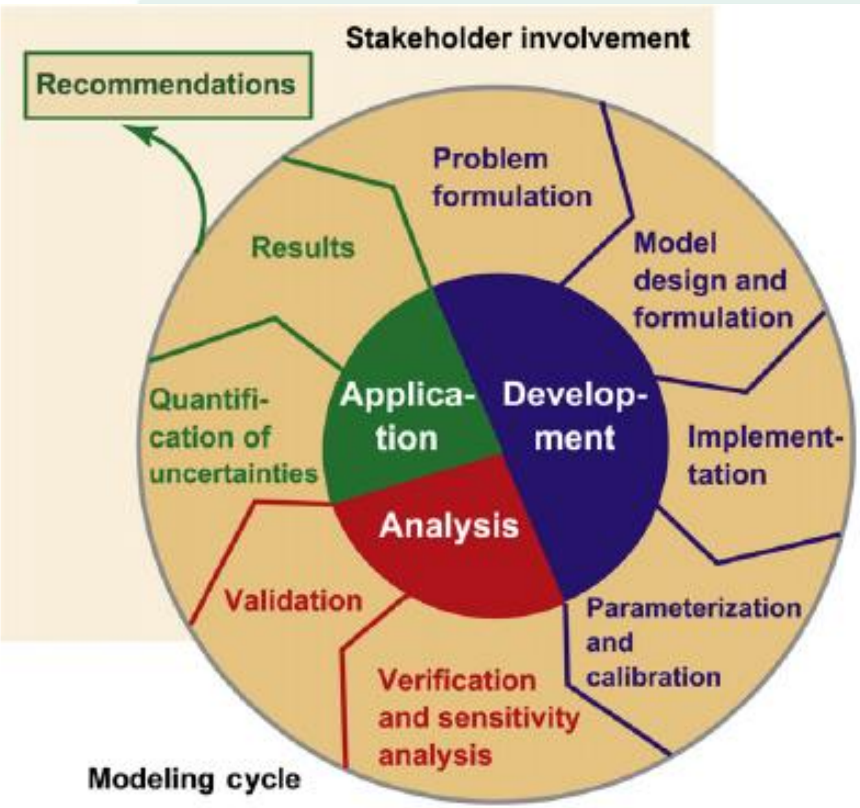
- Streamflow Prediction
  - Baseflow – f(Subsurface flow)
    - Specific discharge
  - Overland runoff – f(Pervious and Impervious flow)
    - Per landcover percentage/area

Hydro: Mathematical Model - Outputs

- Outputs
  - Predicted streamflow
    - Baseflow + Overland flow (Pervious + Impervious area flows)
  - Pollution – Loading estimates
    - Total pollutant mass
    - Based on EMC values – from NURP

User Guided Development

- TRansparent And Comprehensive Ecological (TRACE)



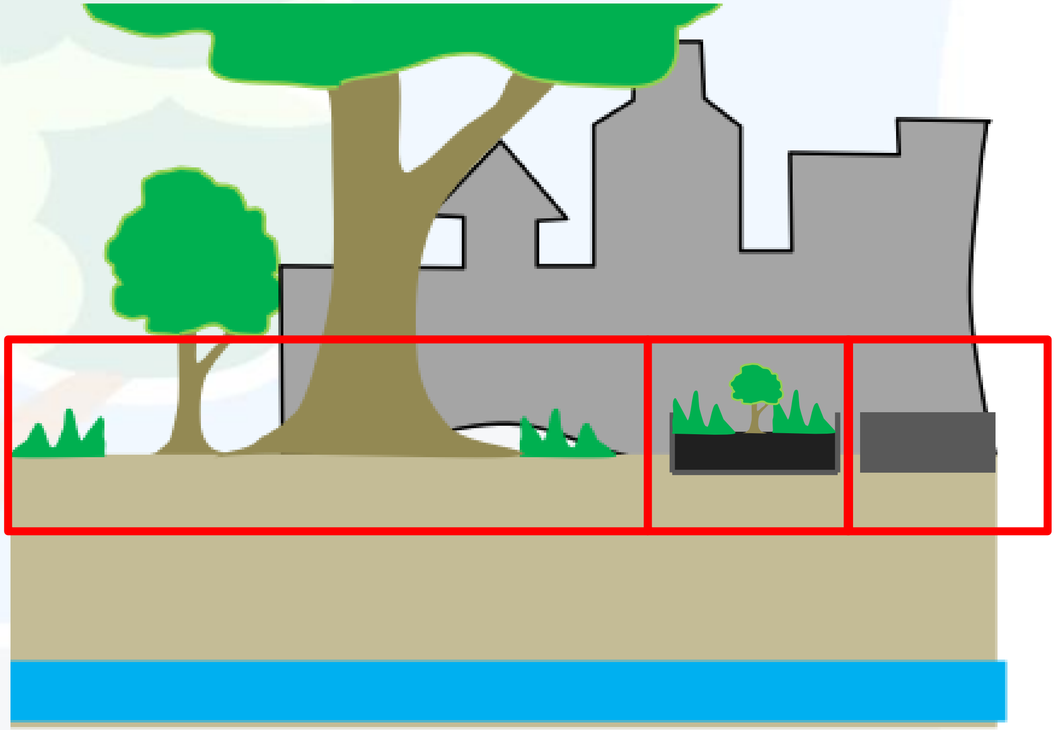
1. Model development
   - Problem formulation
   - Design and formulation
   - Model description
   - Parameterization
   - Calibration
2. Model testing and analysis
   - Verification
   - Sensitivity analysis
   - Validation
3. Model application
   - Results
   - Uncertainty analysis
   - Recommendation

Current Model Development

- Semi-Distributed Green Infrastructure
  - Extend current model for specific GI processes
    - Percentage of the watershed with GI

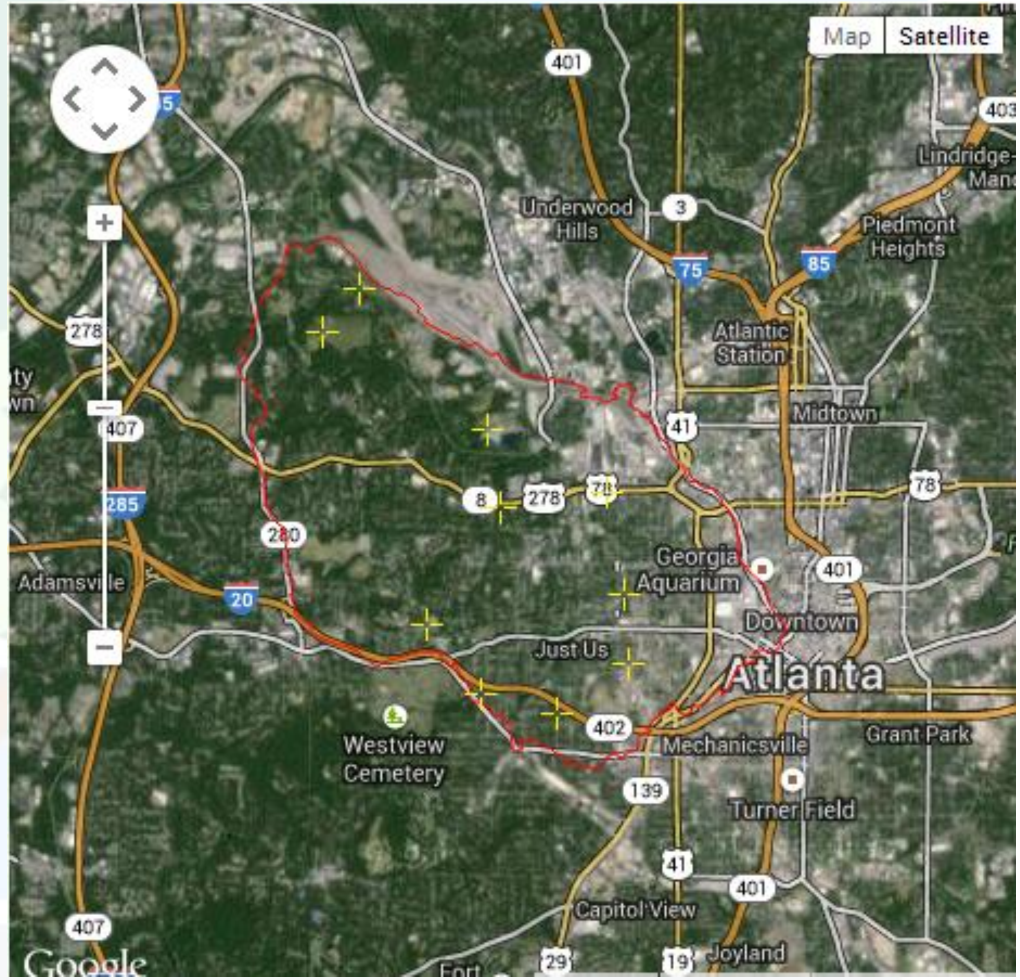
Land Cover Types

- Pervious
- Impervious
- Green Infrastructure
  - Retention/Detention Ponds
  - Rain Barrels
  - Rain Gardens
  - Green Roofs
  - Stormwater storage infrastructure

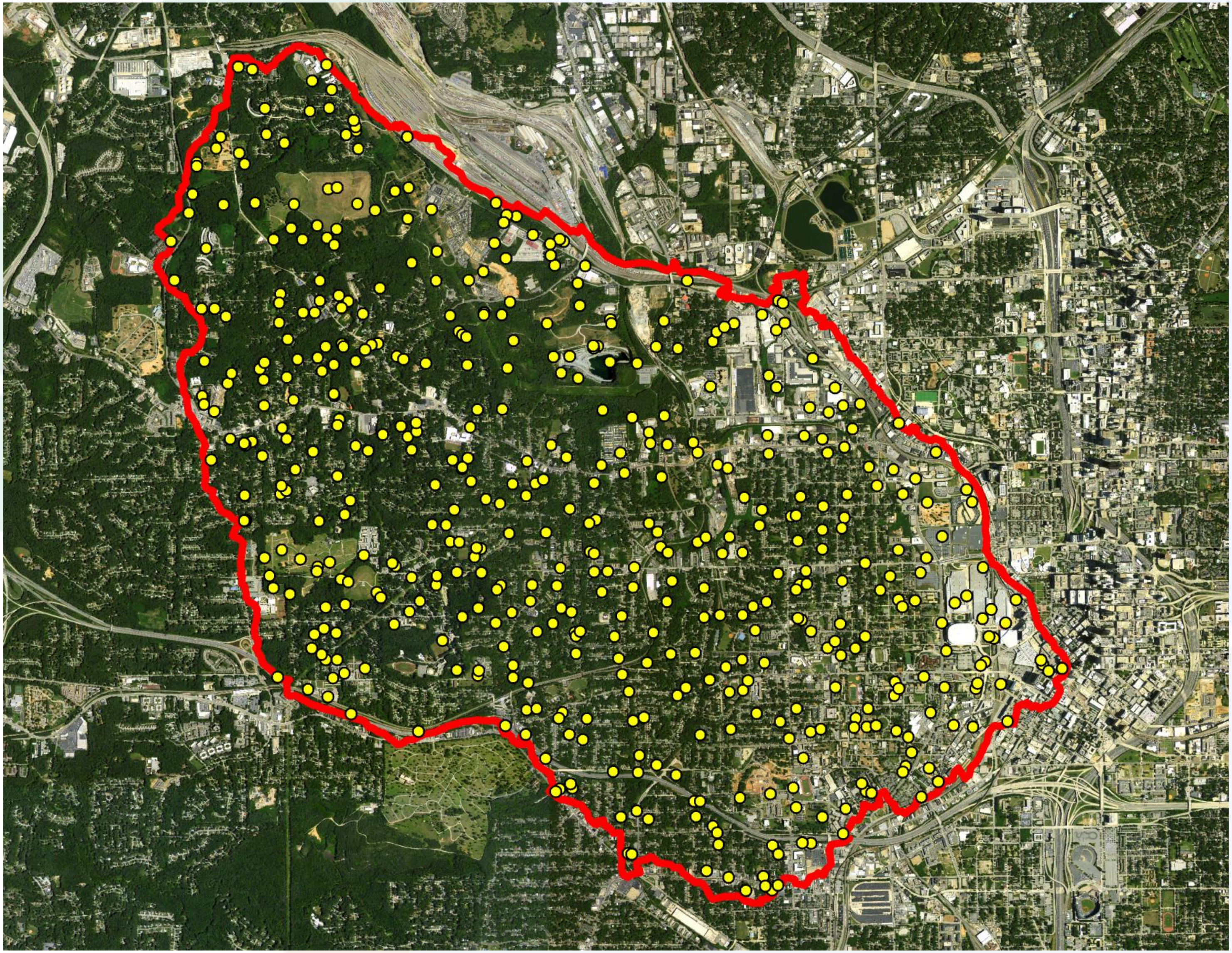


Proctor Creek Project

- Watershed area: 34.83 km^2
- USGS stream gauge: 02336526 Proctor Creek at Jackson Parkway, Atlanta, GA
- Weather station: Atlanta Hartsfield Int'l 722190-13874



Proctor Creek Project



i-Tree is a Cooperative Initiative

Proctor Creek Project

Catalog	Feature			Counts	Percentage
1	Grass/herbaceous			142	28.40%
2	Tree/shrub - pervious			159	31.80%
3	Tree/shrub - impervious			25	5.00%
4	impervious-building			62	12.40%
5	impervious-road			87	17.40%
6	impervious-other			1	0.20%
7	water			1	0.20%
8	soil/bare ground			23	4.60%
9	agricultural land			0	0.00%
10	shrub			0	0.00%
			Total:	500	100.00%

5 subject catalog		
	Statistics (number)	
	Tree+Impervious	25
	Tree/shrub - pervious	159
	Impervious	151
	Soil	23
	Short Vegetation	142
	Total	**500**
	Statistics (percentage)	
	Tree+Impervious	5.00%
	Tree	31.80%
	Impervious	30.20%
	Soil	1.00%
	Short Vegetation	28.40%
	Total	**100.00%**
	Evergreen %	44.8

Georgia Tech Campus

- Boundary file
  - Shape file provided
- Area: 1.695 sq km
- Land cover inputs
  - 1000 points in i-Tree Canopy
  - TPC – 9.8%
  - TIC – 9.2%
  - IC – 55.1%
  - SV – 21.3%
  - BS – 4.6%

Total TC = 19%

Total IC = 64.3%

Georgia Tech Campus – Sample Points

i-Tree is a Cooperative Initiative

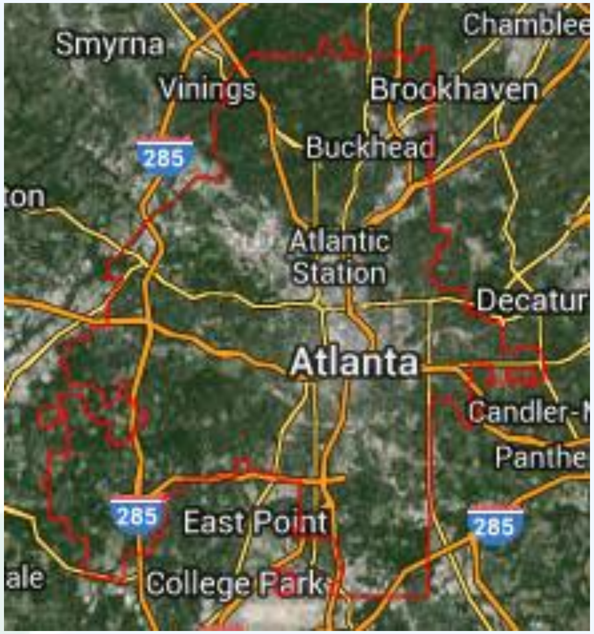
Georgia Tech Campus

- Hydrologic Parameters
  - Pulled from the calibrated Proctor Creek data set
  - Can be adjusted – Field tests, soils maps, etc.

- Alternative scenario
  - Replace some grass/shrubs with trees
  - Replace impervious cover with trees and grass/shrubs
  - Reduce DCIA through disconnecting IA areas

Atlanta Municipal Area

- Boundary file
  - US Census 2000 Places
- Area: 342.86 sq km
- Land cover inputs
  - 750 points in i-Tree Canopy
  - TPC – 31.5%
  - TIC – 6.8%
  - IC – 34.26%
  - SV – 20.133%
  - BS – 6.267%



Total TC = 19%

Total IC = 64.3%

Atlanta Municipal Area

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Make your own project

- From provided project datasets
  - Watershed area
  - Non-watershed area
- Discharge data
  - Watershed may have associated gage data
    - Match USGS gage ID with watershed ID
  - Non-watershed area will not have discharge data
- Weather data
  - From provided NCDC dataset