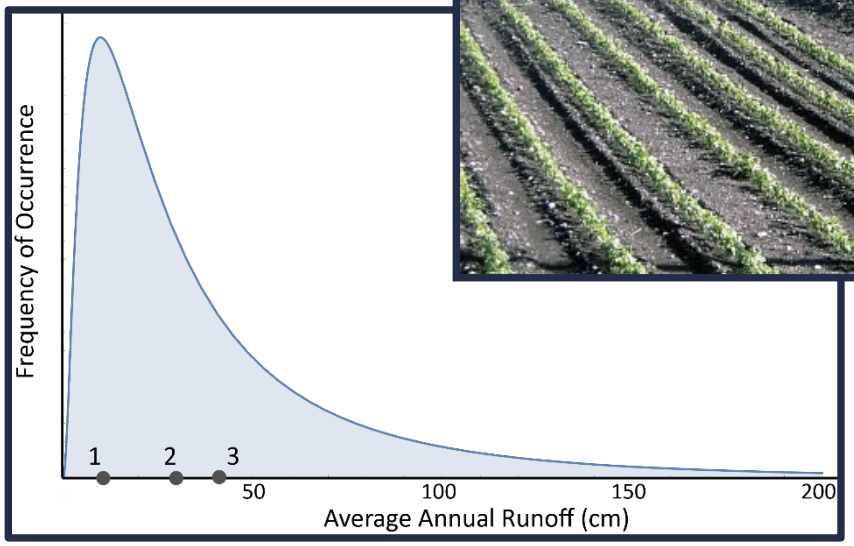
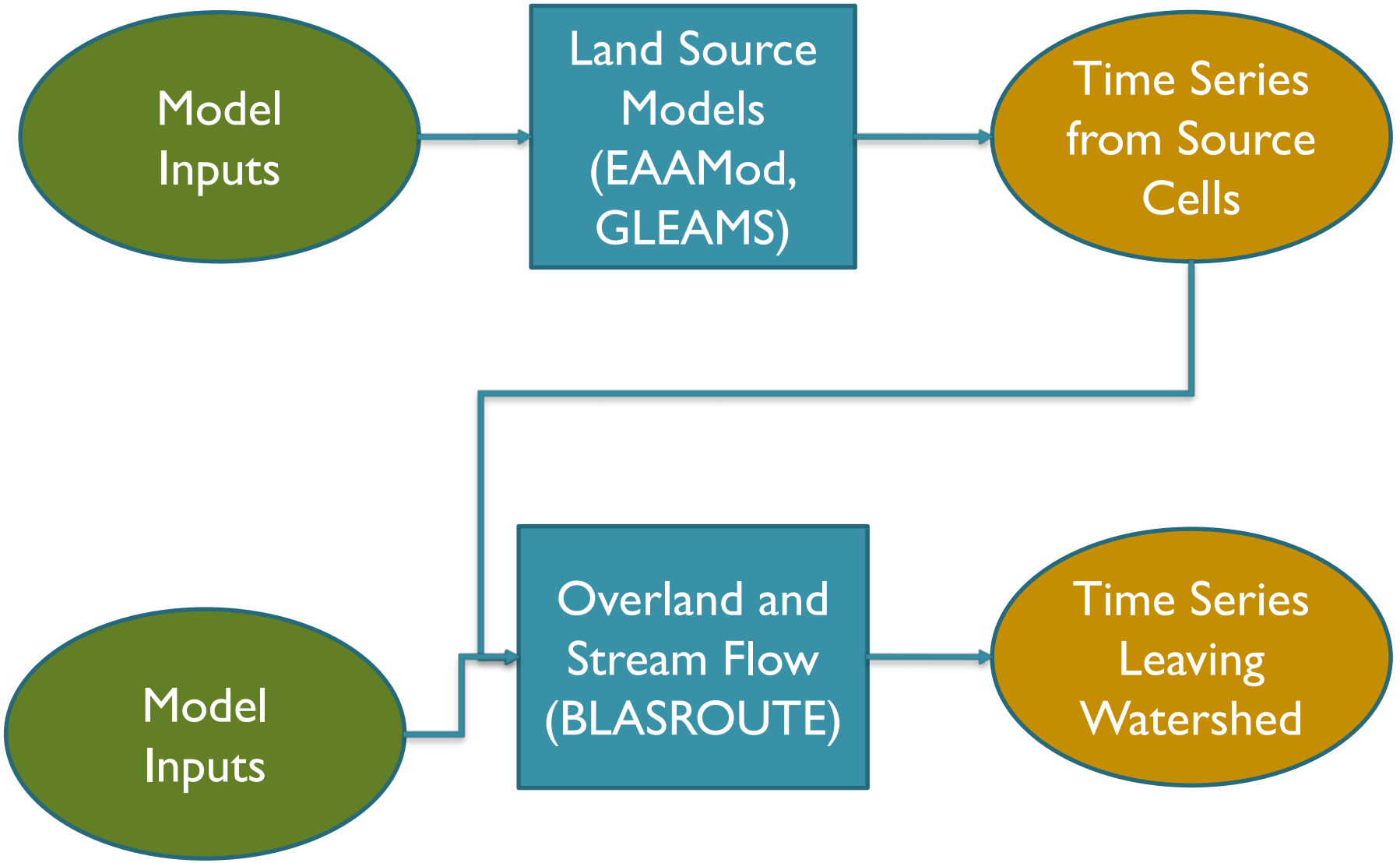
Watershed Assessment Model (WAM)
Sensitivity and Uncertainty Analysis



Andrew James and Del Bottcher

Soil and Water Engineering Technology, Inc.

WAM Model Concept



Why do Sensitivity and Uncertainty Analyses?

- WAM is a complex hydrologic and water quality simulation model that requires many parameters, such as:
- Soil characteristics:
  - Hydraulic conductivity, curve numbers.
- Land use practices:
  - Fertilizer applications, crop parameters
- Hydrologic parameters:
  - Stream channel dimensions, hydraulic structure information.
- Over a thousand parameters in aggregate.

Why do Sensitivity and Uncertainty Analyses?

- These analyses are done to see how a model performs when the inputs aren't known precisely.
- Inputs to a model such as WAM will *always* have some degree of uncertainty.
- We want to quantify how these uncertainties affect model output/predictions in terms of accuracy and reliability.

Goals

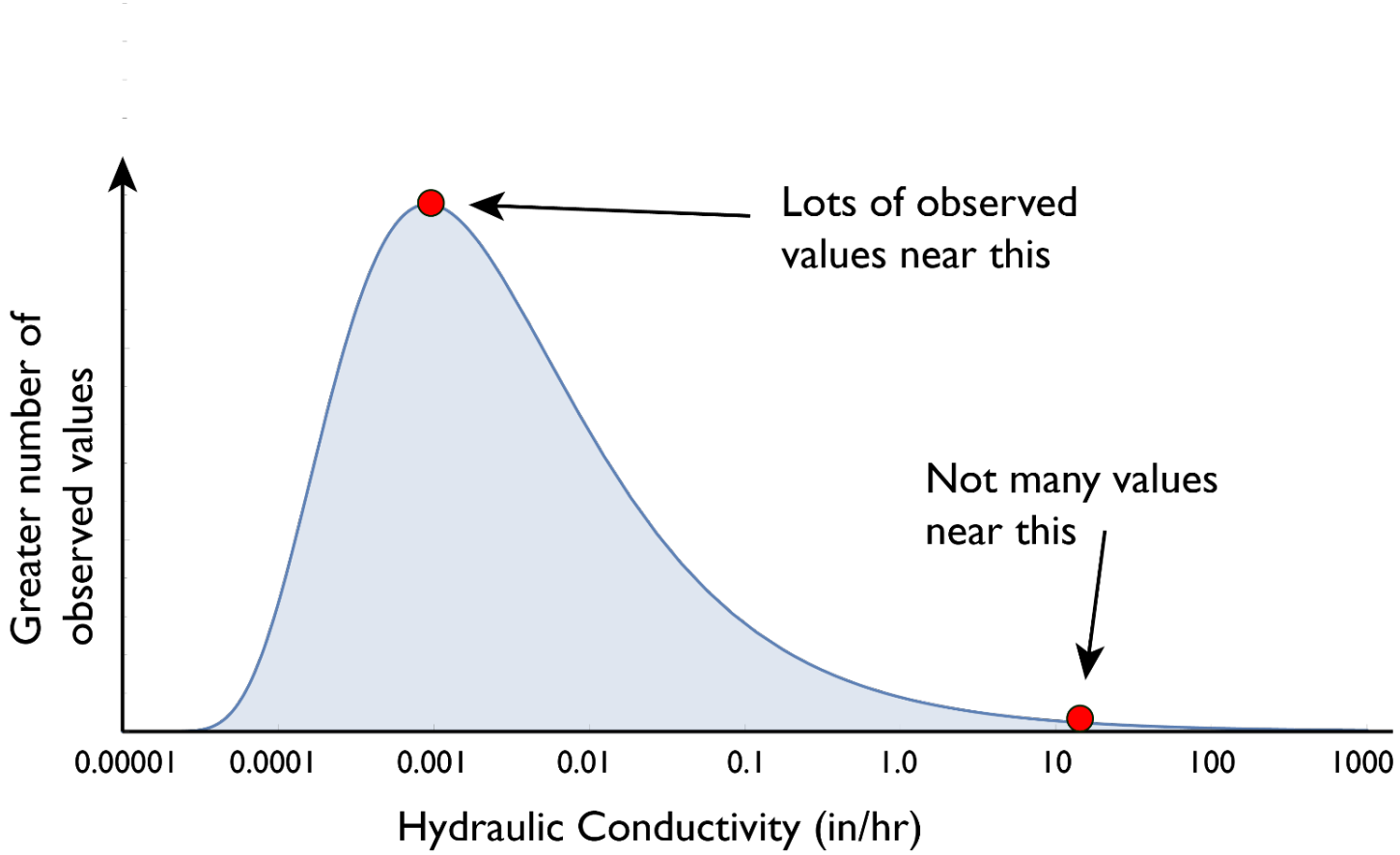
- Quantify the overall uncertainty in the model outputs as influenced by the input data and model algorithm uncertainties.
- Attribute the degree of uncertainty in the outputs back to the inputs.
- Identify the important model parameters for recalibration and evaluate the robustness of the model algorithms.
- Develop a framework to answer additional questions about uncertain parameters as they arise.

Just What IS a Sensitivity and Uncertainty Analyses?

- Of all the parameters used in the model, some are influential, others are not.
- The question is: which are which?
- This is important, since we don't want to waste our time trying to pin down values of parameters that have little or no impact on the final model results.
- We want to spend our time on the parameters that *do* matter.

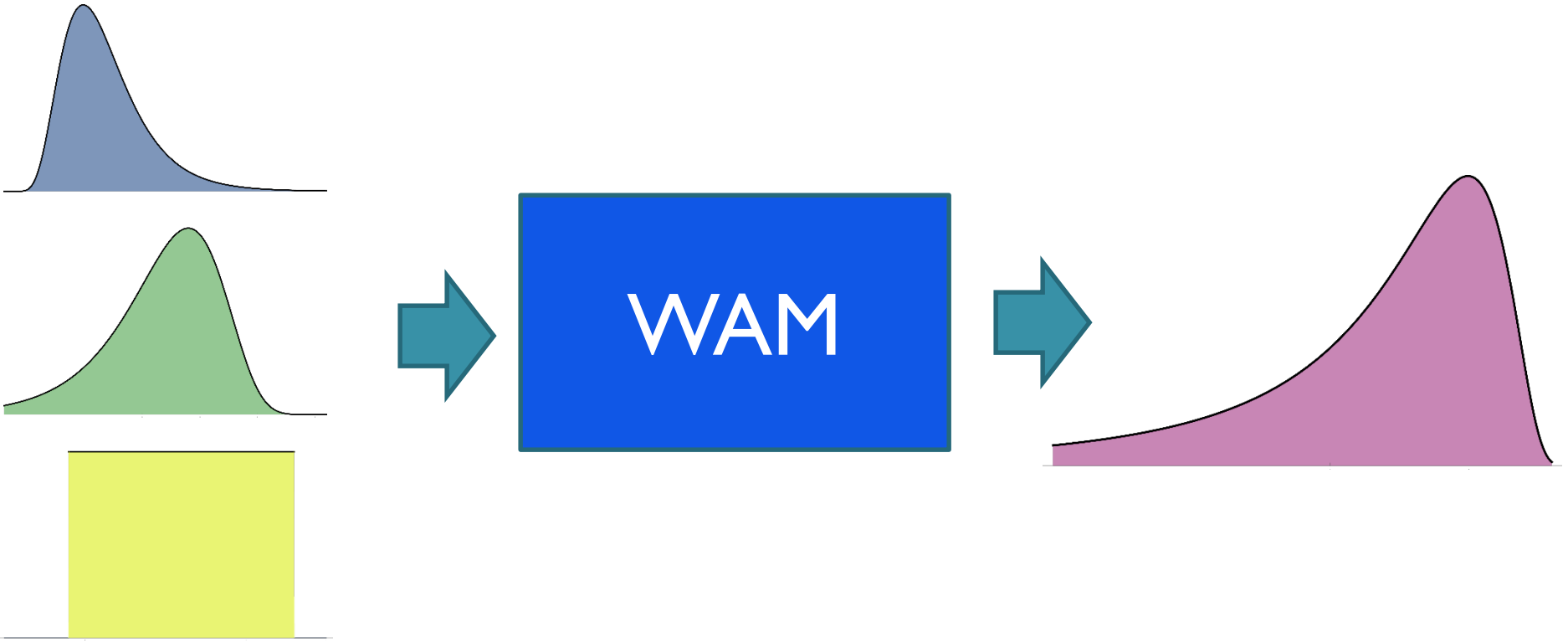
Input Uncertainty

- Typically, we assume that each parameter has some distribution of values, for example soil hydraulic conductivity:



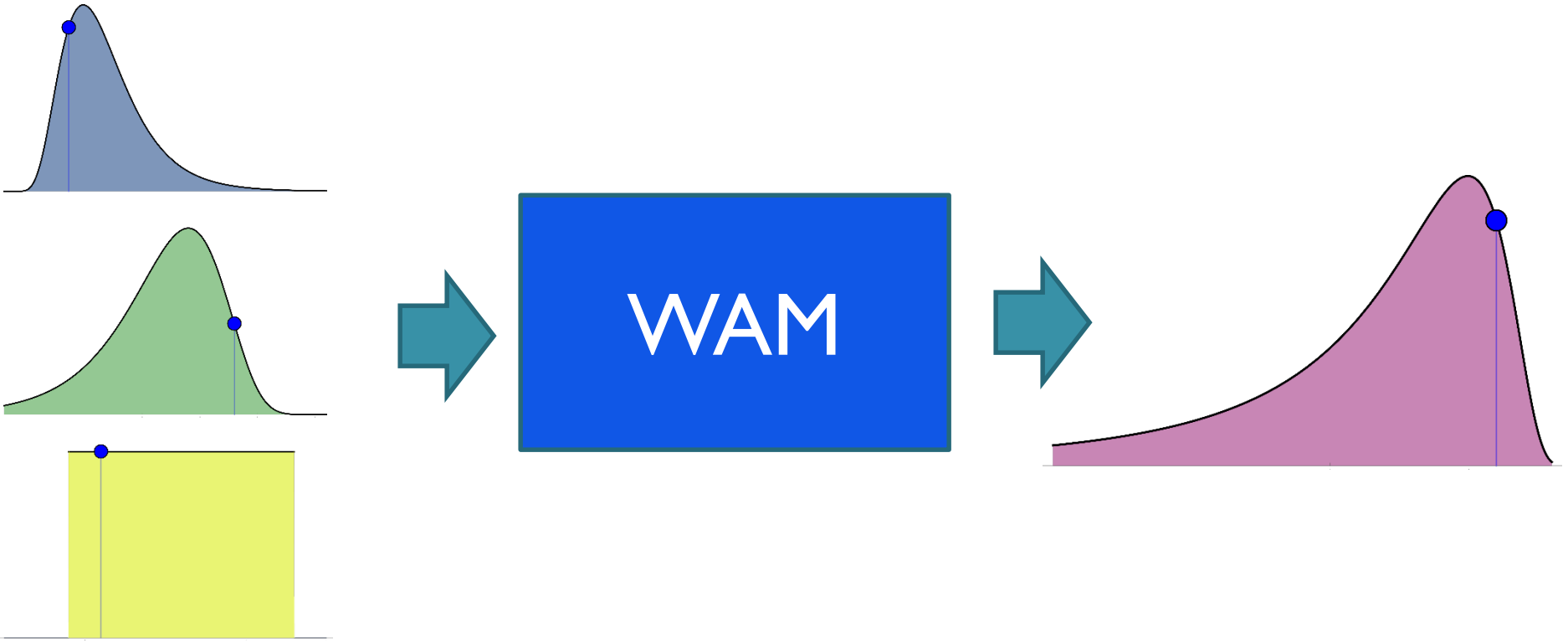
Uncertainty Analysis

- So how does that uncertainty in measured or estimated input quantities propagate through the model to shape the derived quantity, i.e., the model output?



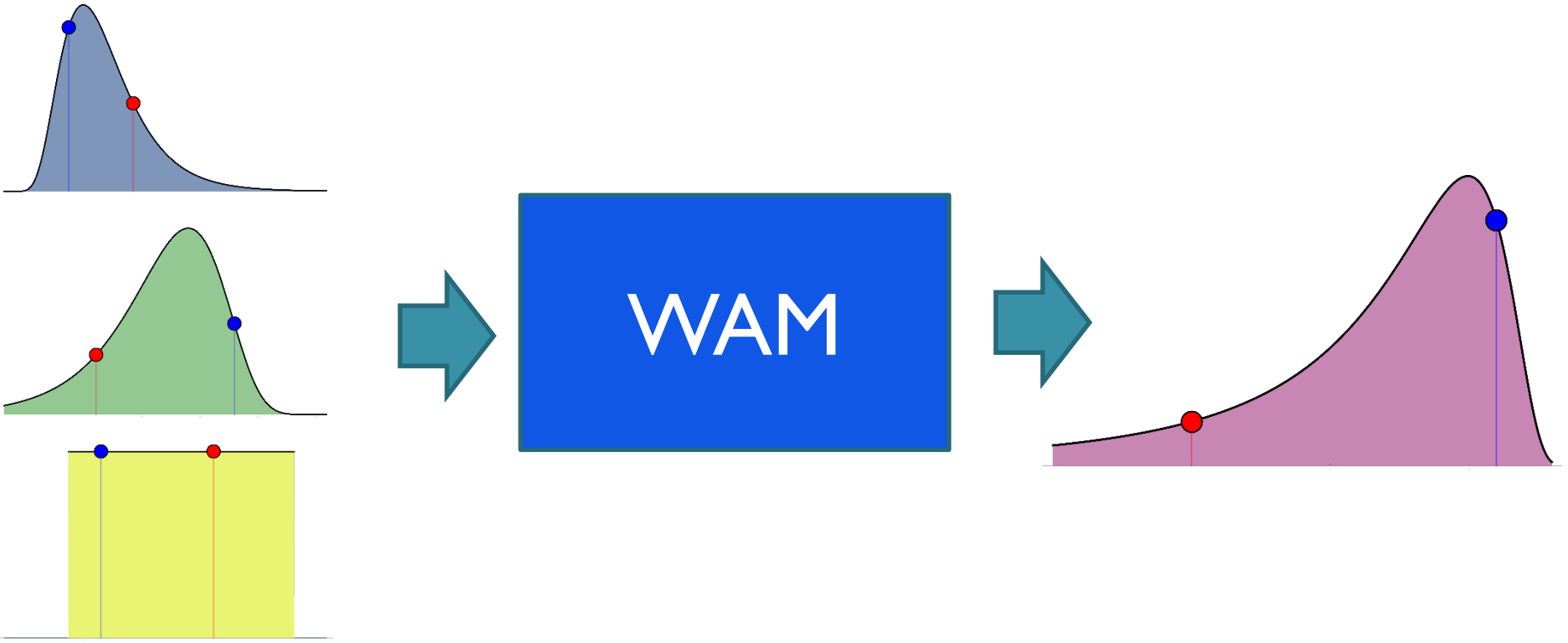
Uncertainty Analysis

- So how does that uncertainty in measured or estimated input quantities propagate through the model to shape the derived quantity, i.e., the model output?



Uncertainty Analysis

- So how does that uncertainty in measured or estimated input quantities propagate through the model to shape the derived quantity, i.e., the model output?



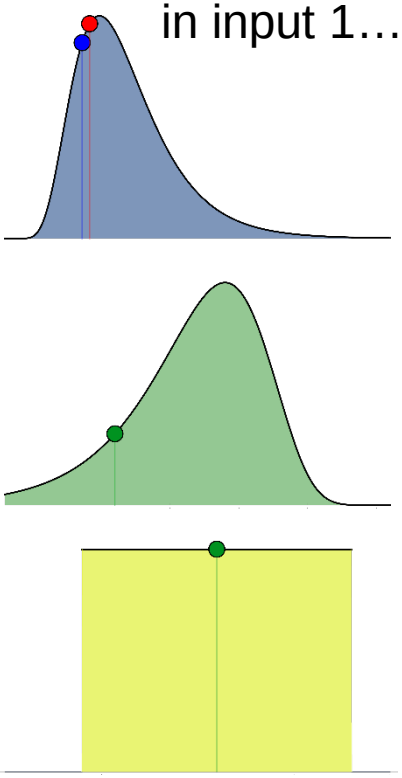
Sensitivity Analysis

- Focuses on how the uncertainty in model output can be partitioned among the sources of uncertainty in the model inputs.
- Complementary to an uncertainty analysis, it is done as part of the same set of simulations.
- Tests the robustness of model results in the presence of uncertainty.
- Highlight those model inputs that cause significant uncertainty in the output predictions.

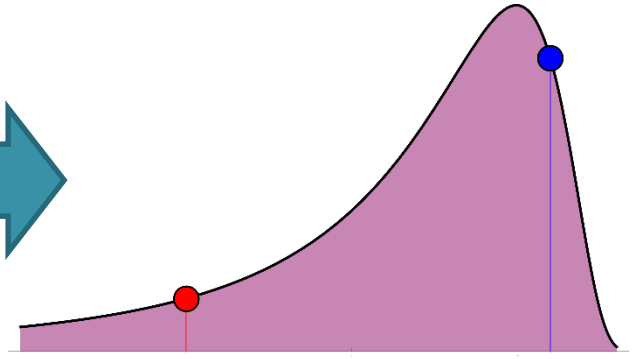
Sensitivity Analysis

- Qualitatively, what does this mean?

Little change in input 1…



… but a big change in the outputs



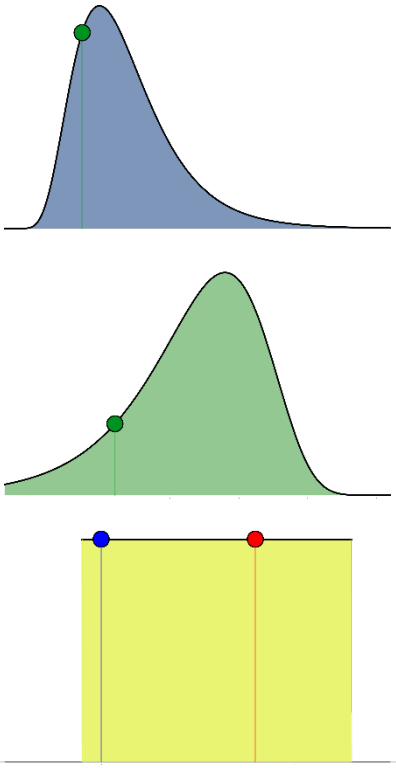
The model is very sensitive to input 1

Model Inputs

Model Outputs

Sensitivity Analysis

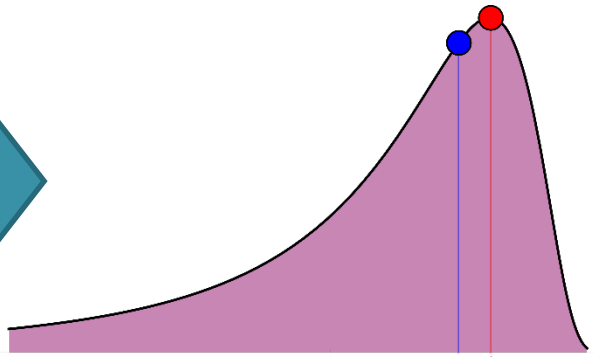
- Alternatively, if the model is insensitive to input 3…



Model Inputs

Big change
in input 3…

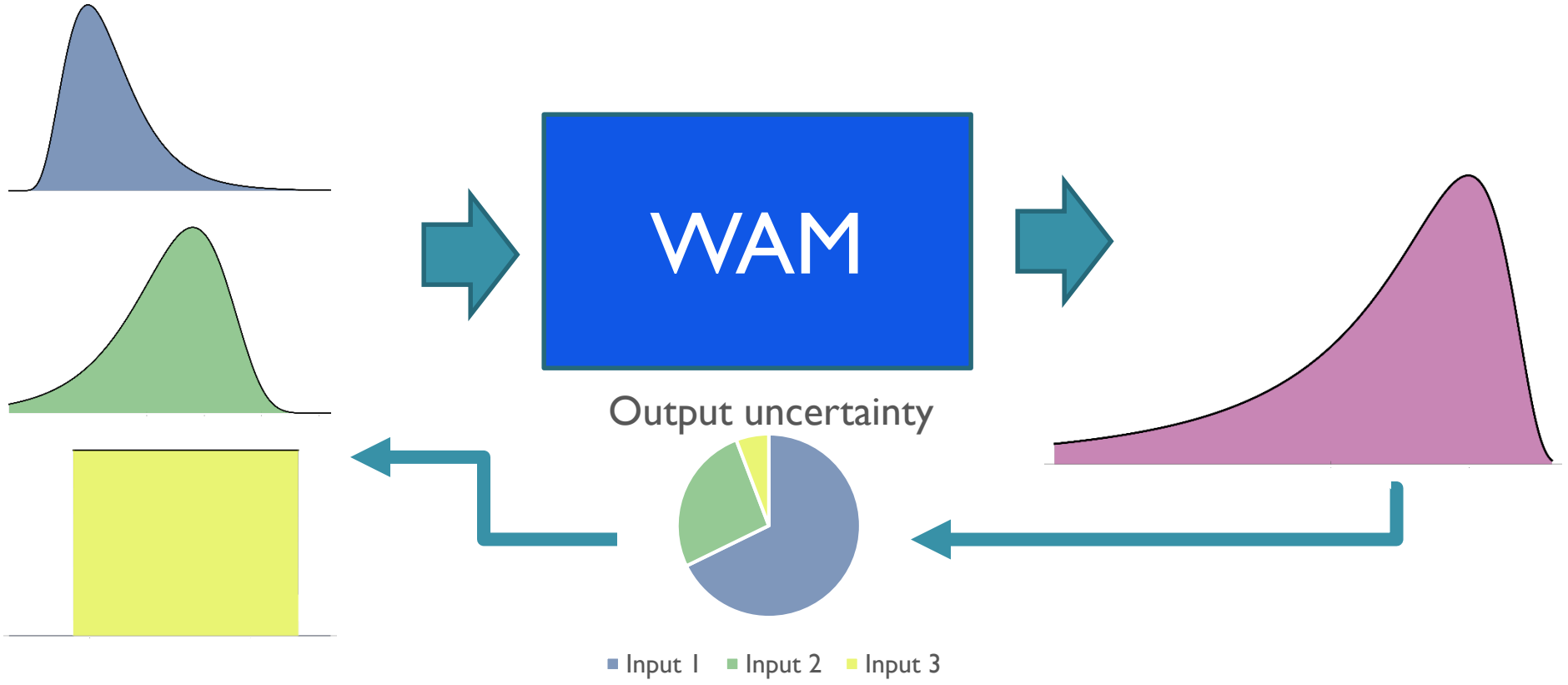
… gives only a small
change in the outputs



Model Outputs

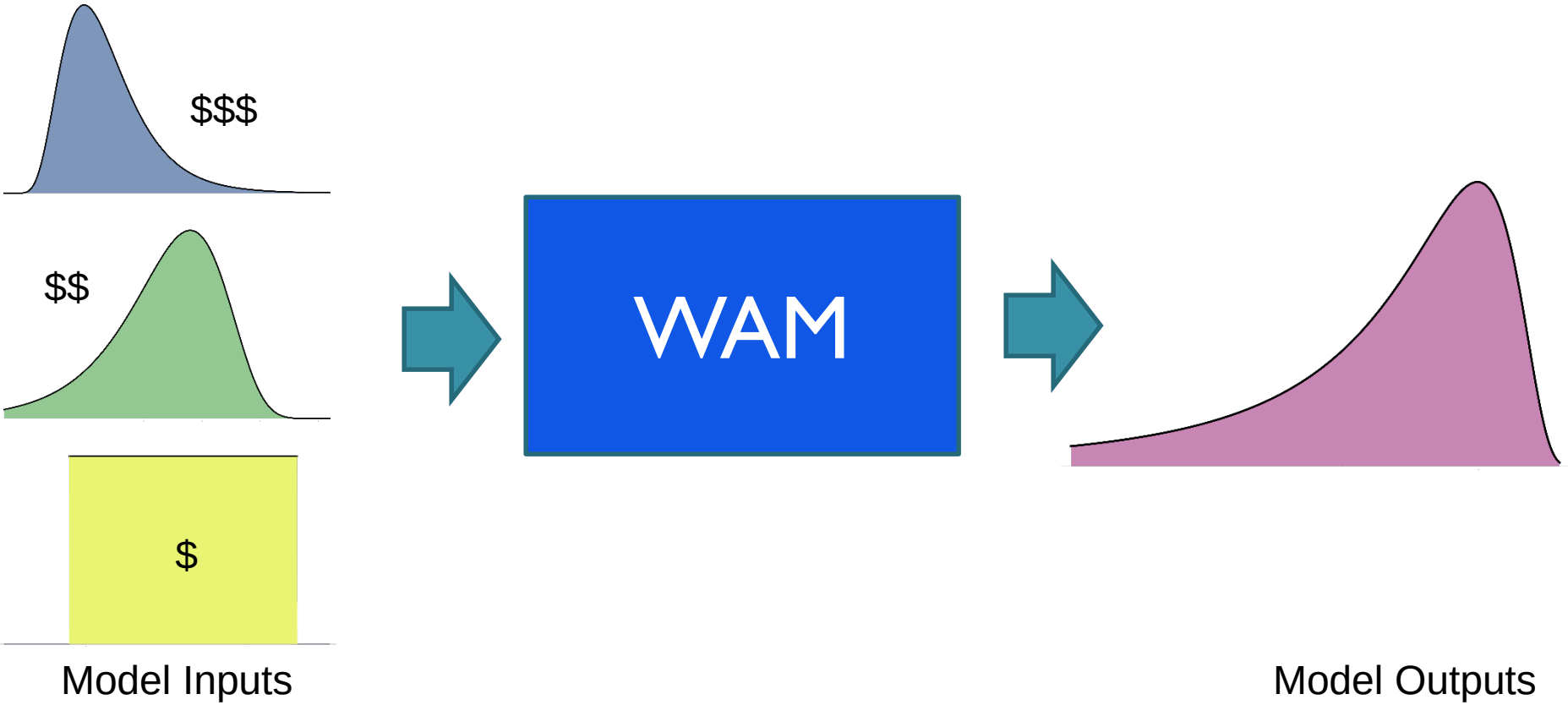
Sensitivity Analysis

- Decompose the uncertainty in the model output and apportion it among the inputs



Sensitivity Analysis

- With this type of feedback, try to get as much information about input 1 as possible, and not bother as much trying to get lots of information about input 3.



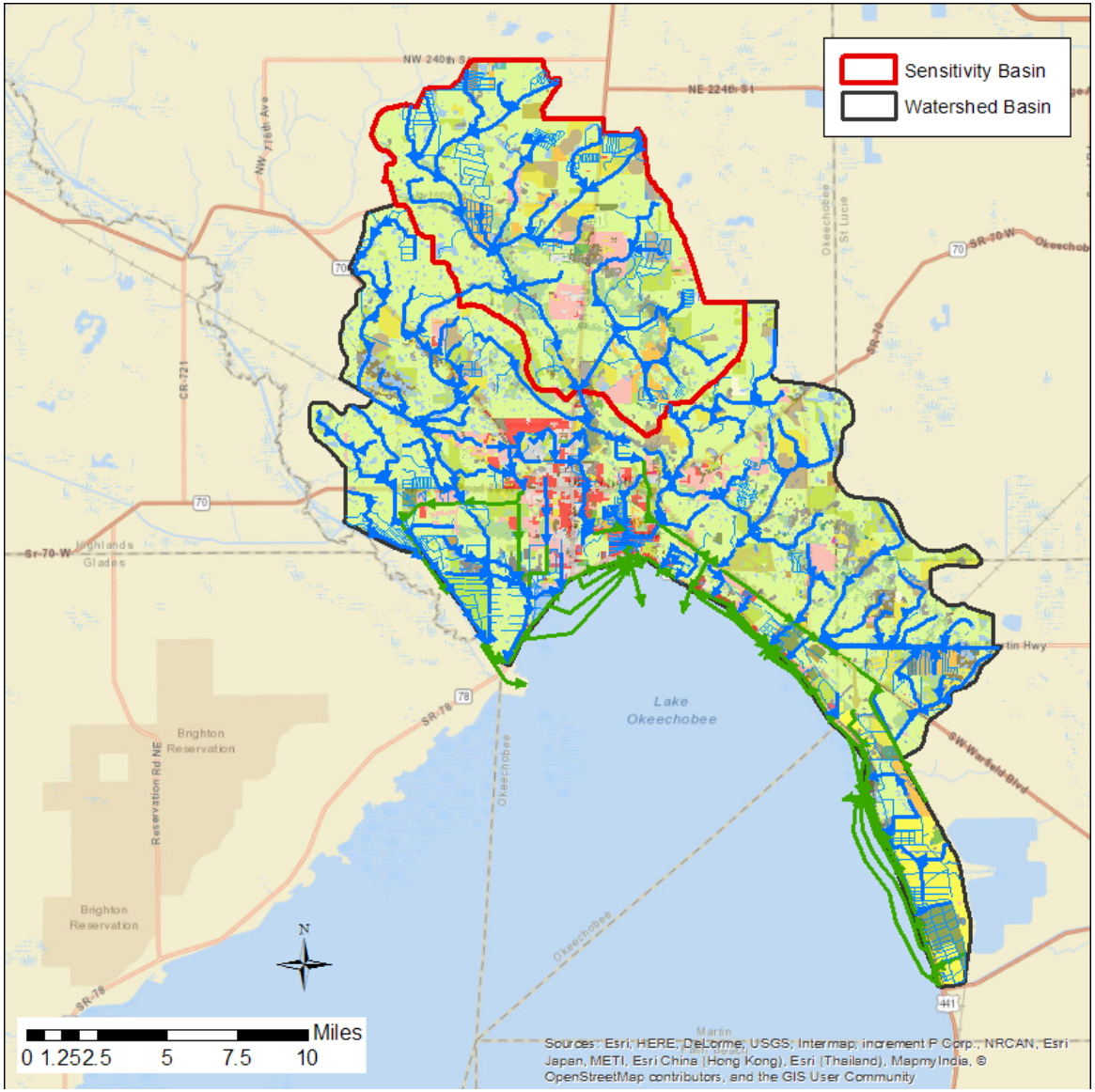
Uncertainty and Sensitivity Analyses Project Steps

- Literature Review
- Selection of Study Basin
- Sensitivity and Uncertainty Analysis for WAM Sub-models:
  - BUCSHELL (EAAMod and GLEAMS)
  - BLASROUTE (overland and streams)

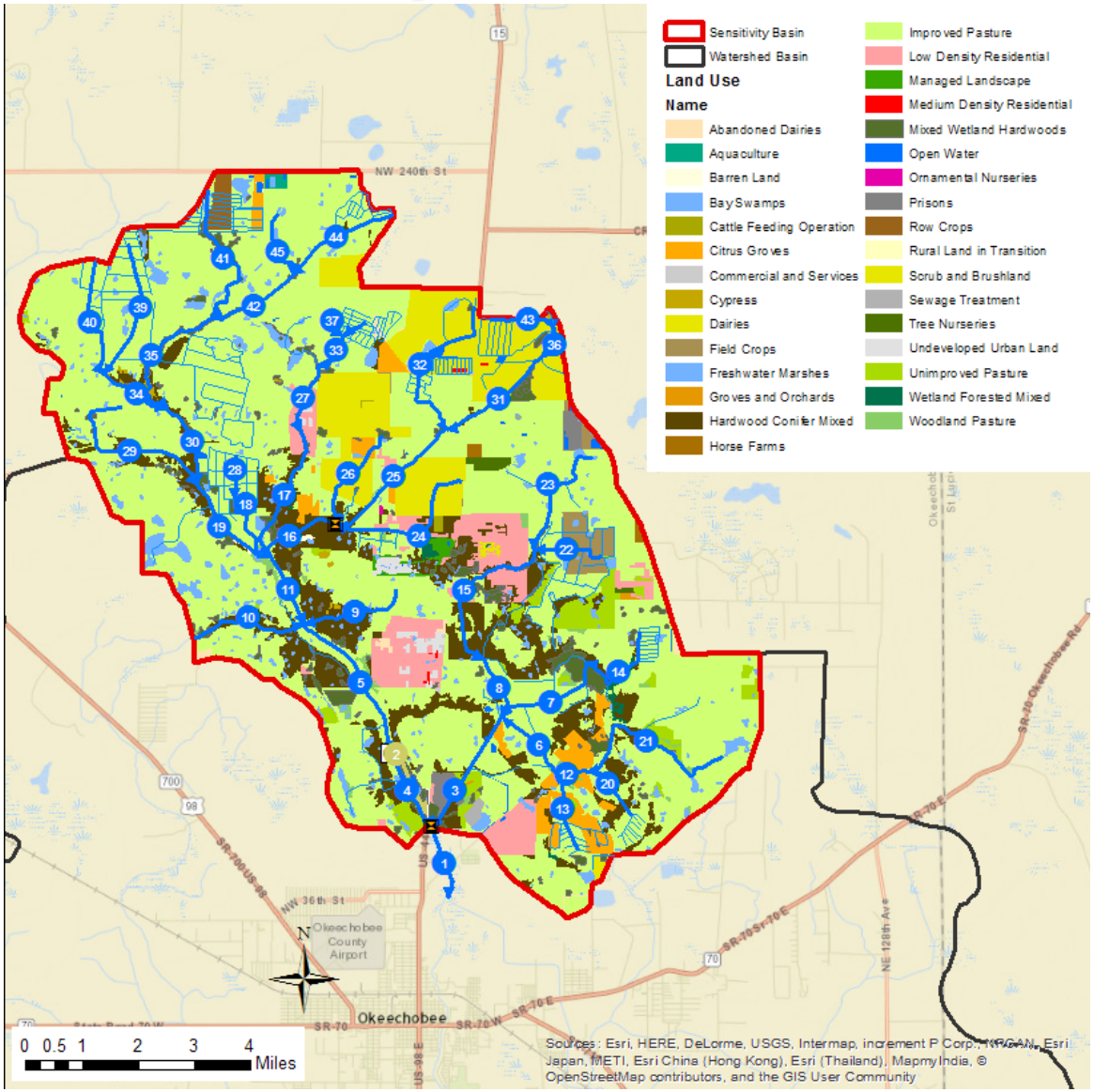
Selection of Study Basin

- Necessary for BLASROUTE, which requires a stream/canal network.
- Large enough to encompass a representative range of land uses, soil types, and streams for the LOW.
- Small enough to run the needed number of simulations.

Taylor Creek/Nubbin Slough Model Domain



Sensitivity Model Domain



Sensitivity Domain Land Uses

Land Use	Acres
Improved Pasture	36,636
Hardwood Conifer Mixed	6,016
Dairies	5,006
Low Density Residential	2,637
Freshwater Marshes	2,490
Mixed Wetland Hardwoods	1,858
Citrus Groves	1,337
Unimproved Pasture	1,242
Field Crops	558
Woodland Pasture	407
Open Water	331
Other	2,105
Total	60,623

The Details…

- Run a large set of simulations, varying the parameters across a reasonable range of values. Then the output is evaluated for each combination of inputs.
- Two steps:
  - A "screening" analysis, wherewe vary all of the parameters over a relatively small random sampling to quickly cull out the ones that have little influence (less than 1%-2%)
  - Then a more detailed analysis that varies the influential parameters from step one over many simulations.
- Overall, in the neighborhood of 250,000 simulations total.
- Can't look at each combination of the parameters since the simulation time would take far too long.

Results: What is Important?

- For the land source models (EAAMod, GLEAMS) soil, nutrient, and weather parameters dominate.
- EAAMod:
  - Runoff is most influenced by irrigation/drain controls, soil layer conductivity and ET. Retention time and area are next most influential.
  - Nutrient loads are most influenced by reaction rates (for TN) and partitioning coefficients (TP). TP is also strongly influenced by the initial ("legacy") phosphorus in the soil. The amount of fertilizer applied is quite influential for some land uses (e.g., row crops).

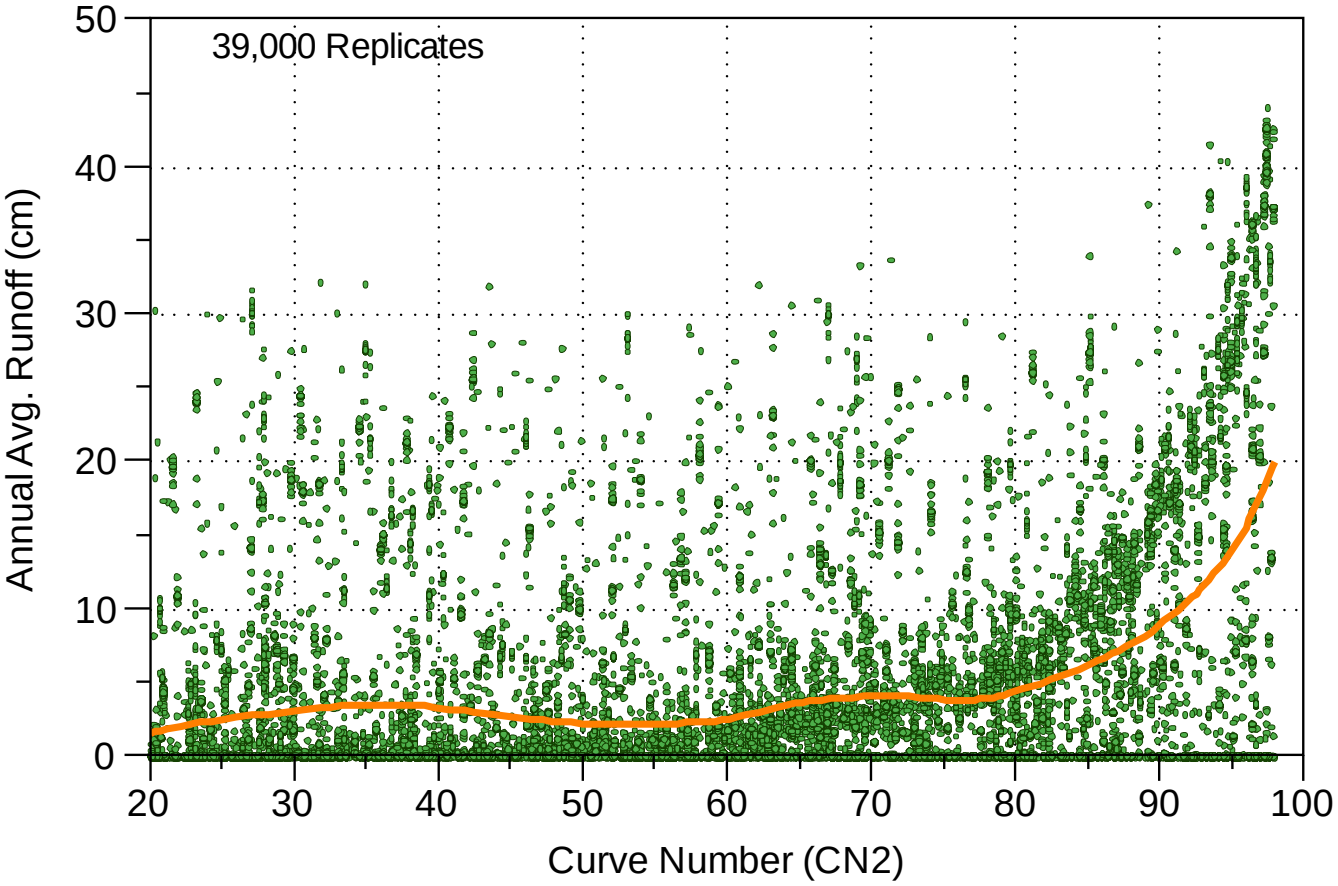
Results: What is Important?

- GLEAMS:
  - Runoff and percolation is most influenced by the soil curve number, followed by soil conductivity.
  - Nutrient loads tend to be strongly influenced by the same parameters that influence runoff and percolation since they carry the nutrients. In addition, loadings are influenced by waste loading rates (urban and pasture land uses) and human/animal density. Land uses without humans or animals show sensitivity to fertilization rates.

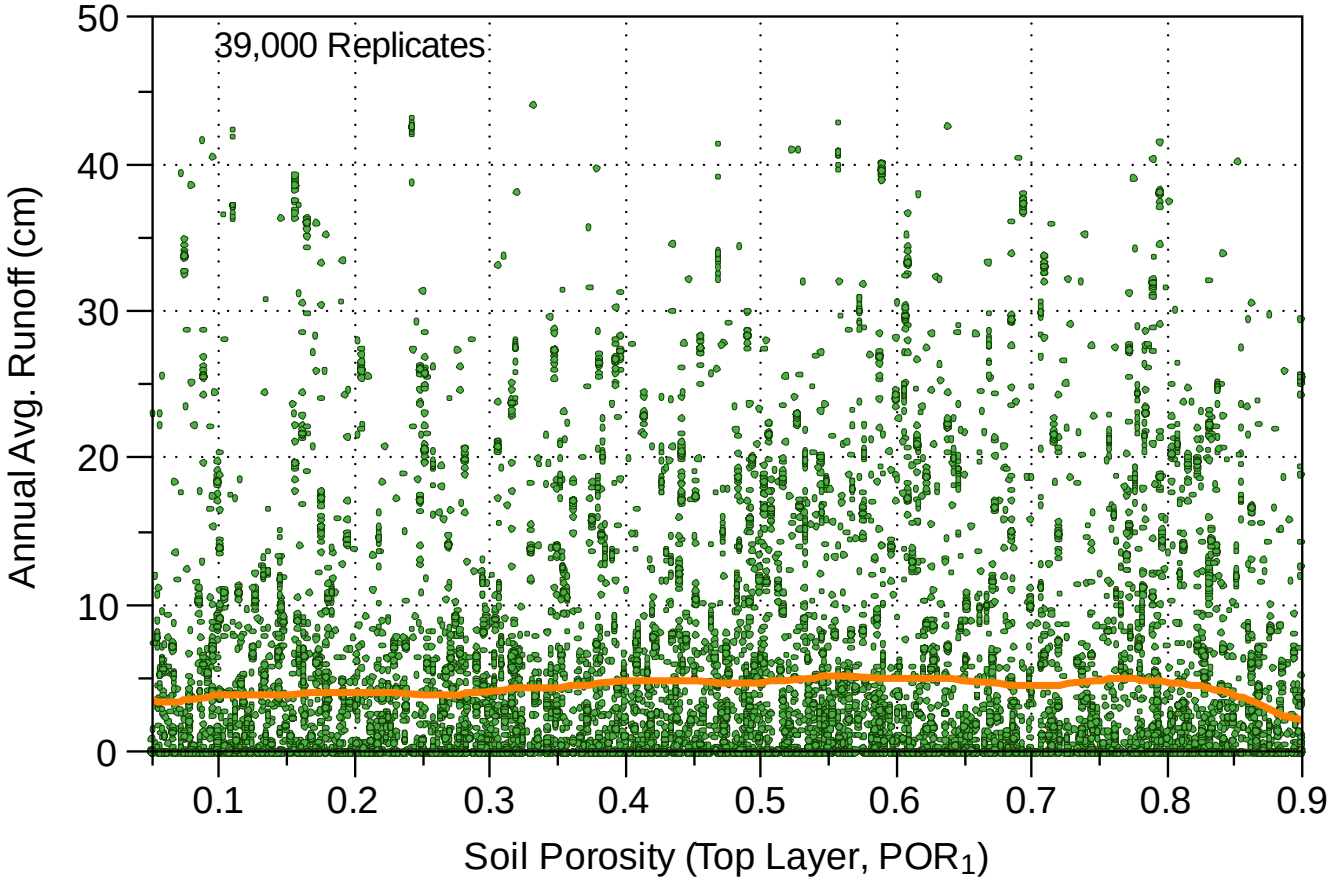
Results: What is Important?

- BLASROUTE:
  - Still in progress, only screening results.
  - Channel parameters (profiles, Manning's N, channel leakage to groundwater) most influential.
  - Attenuation coefficients for TN and TP.
  - Structure controls particularly important for STA.

Questions?


39,000 Replicates
Annual Avg. Runoff (cm)
Curve Number (CN2)
0
10
20
30
40
50
20
30
40
50
60
70
80
90
100

Not Very Sensitive



Analysis Setup
Land Source Models

- Input: All of the parameter values to be tested are generated and those inputs are fed into the model, which is run one time for each set of model parameters.
- Output: The land source models (GLEAMS and EAAMod) simulate the amount of water running off the land surface and/or infiltrating to groundwater as well as the nutrient loads leaving with the water.
- Analysis: See how the water volume and nutrient loads vary according to the input parameters. If an output varies a lot as a function of a parameter, that parameter is determined to be influential.

Land Source Models

- The main land uses in the LOW were used as templates for a number of land uses and the parameters were varied within these templates.
- The primary land uses are:
  - Urban (low, medium, and high density residential).
  - Pasture lands (improved, unimproved, woodland).
  - Groves (citrus).
  - Row and field crops.
  - Native.
- The first four were all evaluated with and without retention.

Analysis Setup
Overland and Stream Flow

- Input: As before, the parameter values are generated and those inputs are fed into the model, which is run one time for each set of model parameters.
- Output: The routing model (BLASROUTE) simulates water and nutrients transported to the nearest stream/canal and then route them to the watershed outlet.
- Analysis: See how the water volume and nutrient loads vary within a given stream reach according to the input parameters.

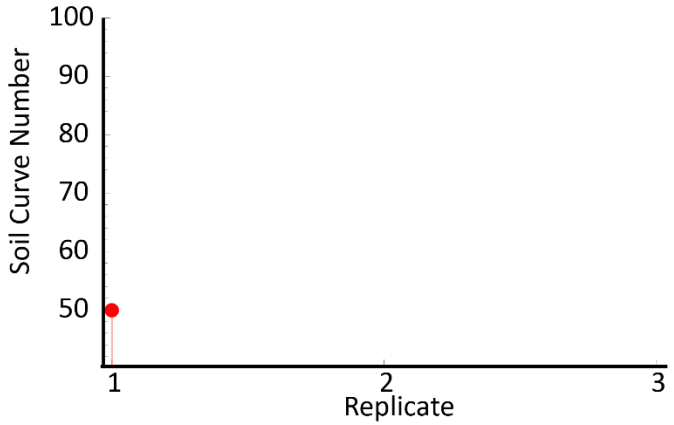
Uncertainty and Sensitivity Analyses Work Plan

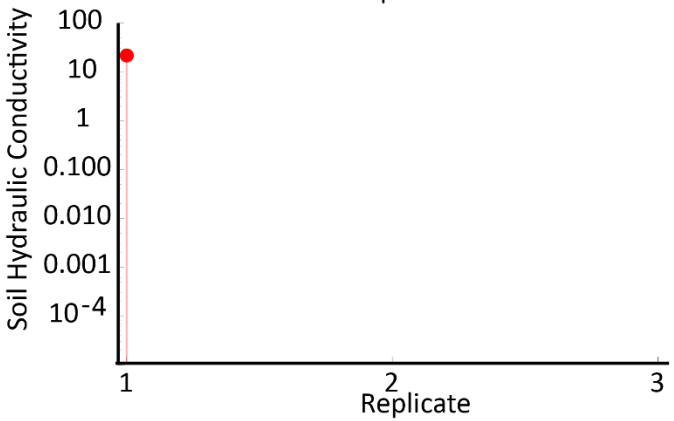
- Literature Review: Brief literature review of sensitivity analysis/uncertainty analysis, survey of applicable sensitivity analysis/uncertainty analysis methods, discussion of advantages and disadvantages of each method, and justification of the selected method.
- Selection of Optimal Study Basin: Description of method for the selection of basins within the modeled sub-watersheds where a sensitivity analysis/uncertainty analysis will be conducted.
- Sensitivity Analysis: Description of selected sensitivity analysis process to be used for evaluating model input parameters' influence on model outputs.
- Uncertainty Analysis: Data uncertainty, structural uncertainty in WAM, and approach to calculating predictive uncertainty.

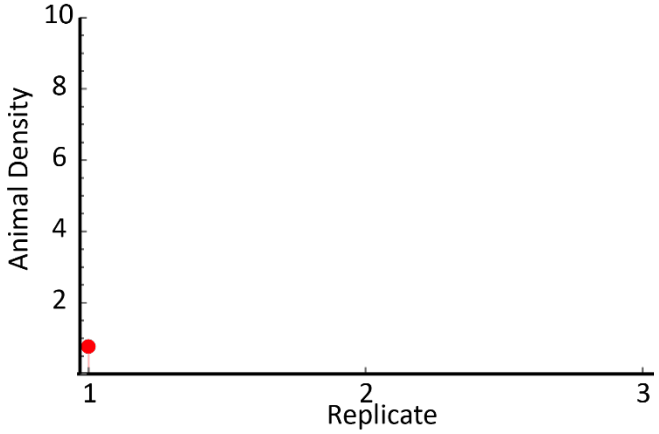
Uncertainty and Sensitivity Analyses

- Model Recalibration: Method for the recalibration process, if found to be necessary, to be conducted for any of the sub-watersheds. The entire process shall be documented and shall contain at a minimum:
  - Description of time periods for recalibration/verification.
  - Description of geographic areas and updated land use.
    - Note: FDACS is working on updating the Land Use data for northern watersheds
  - Tabular statistical methods for comparison of measured versus modeled data.
  - List of key parameters used in recalibration based on sensitivity analysis.
- Results: Summary of sensitivity analysis/uncertainty analysis methods and the selected method, results from application of sensitivity analysis/uncertainty analysis to the selected basins, identification of future specific work to be done to improve WAM and its results in those basins, and in all other applicable Lake Okeechobee basins.

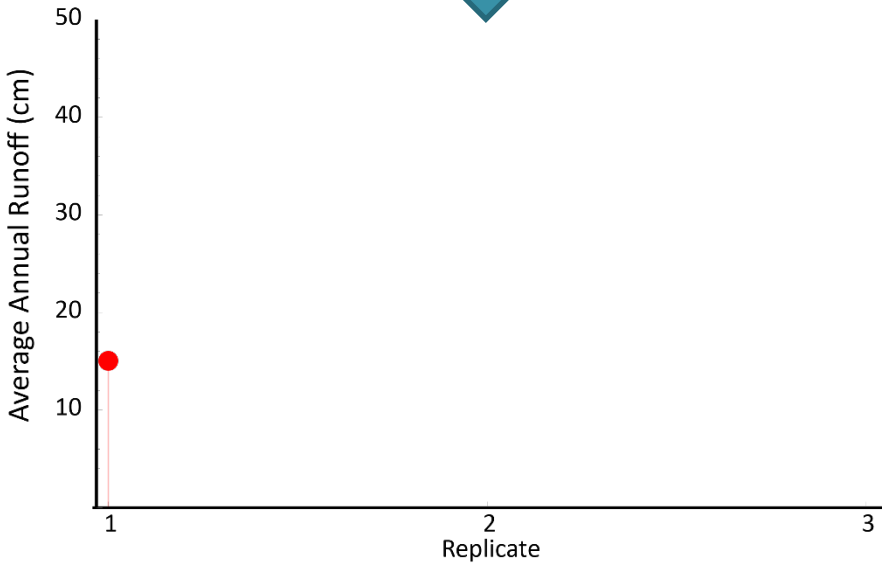
Example





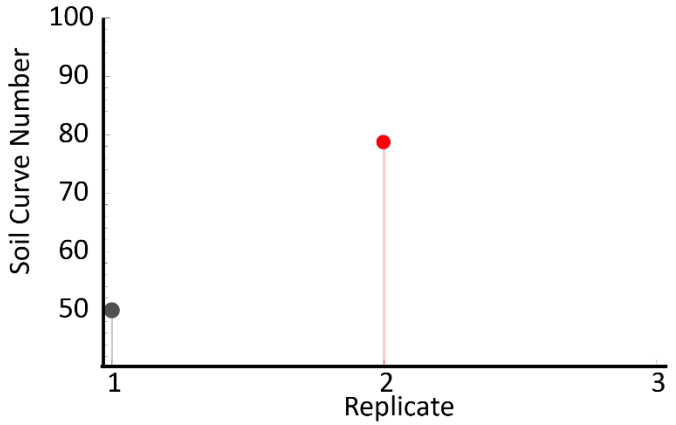


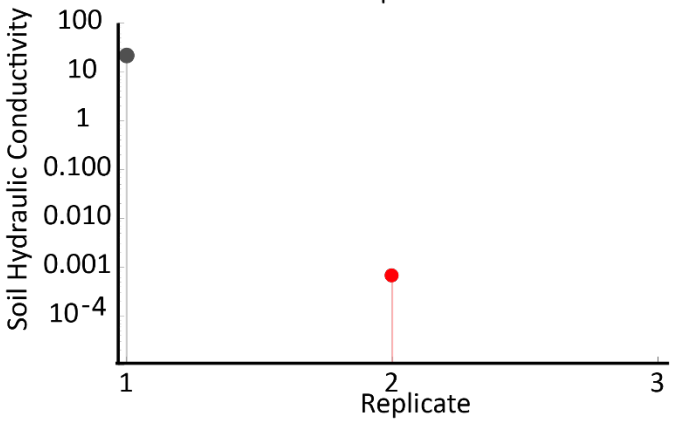
Land Source Models (GLEAMS)

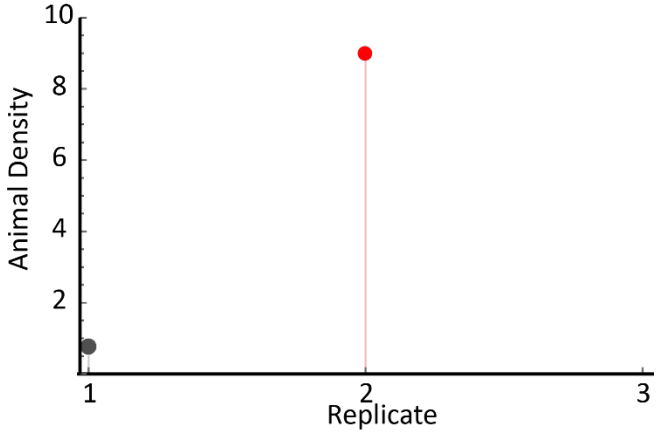


For illustration only.

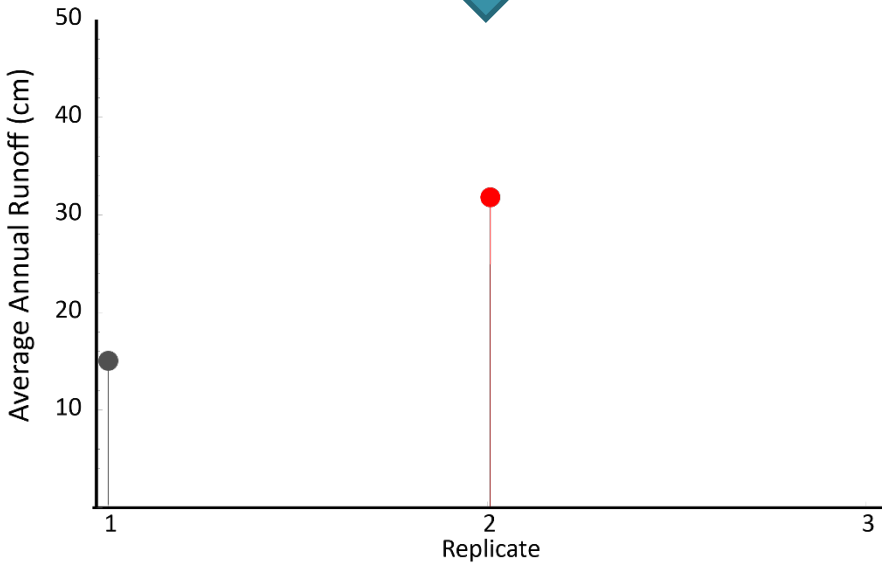
Example





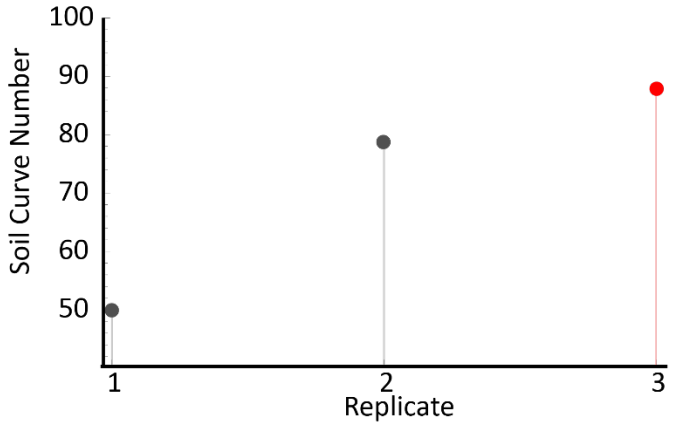


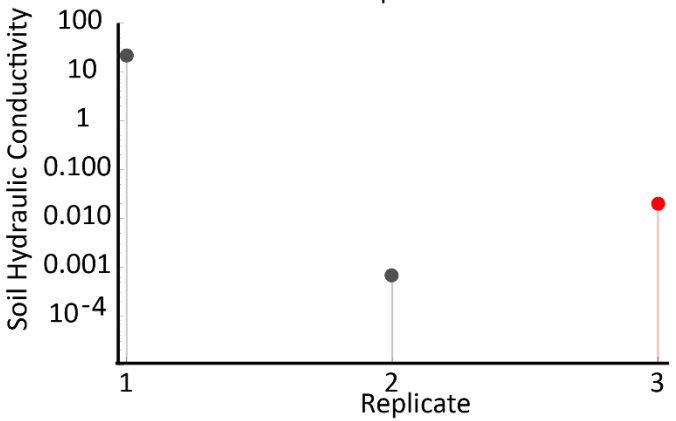
Land Source Models (GLEAMS)

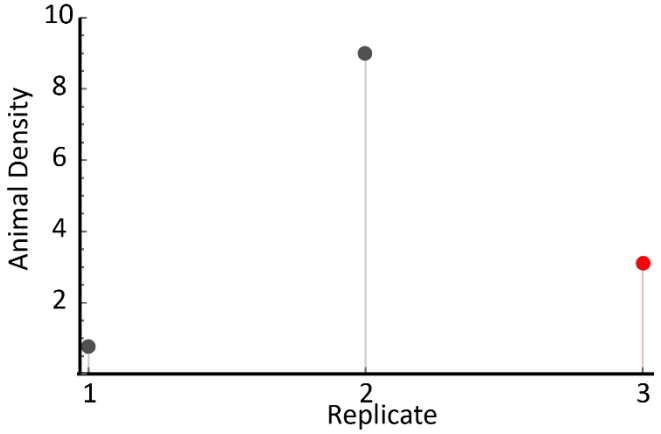


For illustration only.

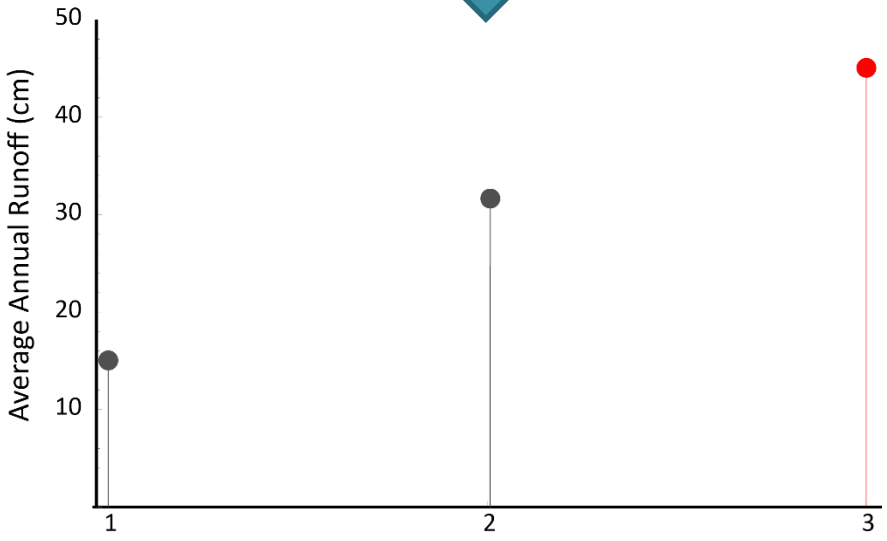
Example





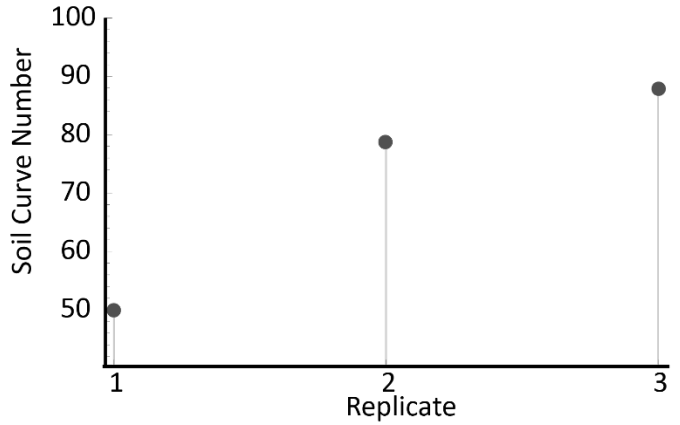


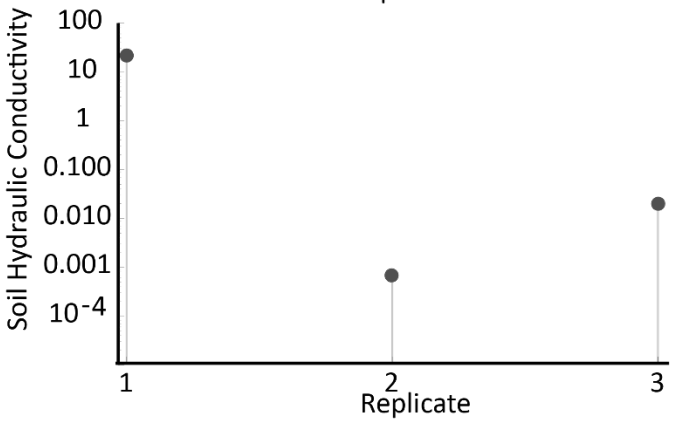
Land Source Models (GLEAMS)

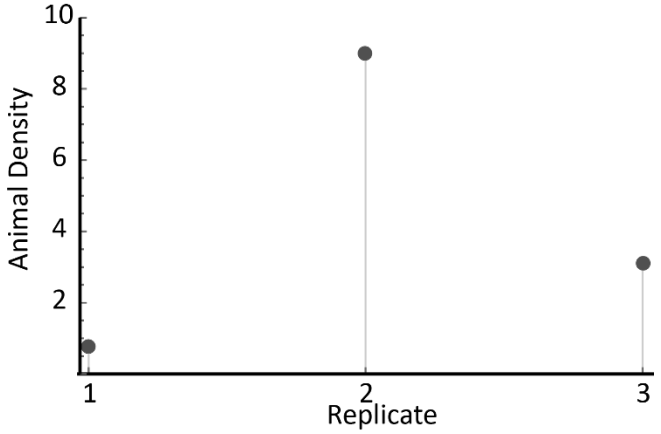


For illustration only.

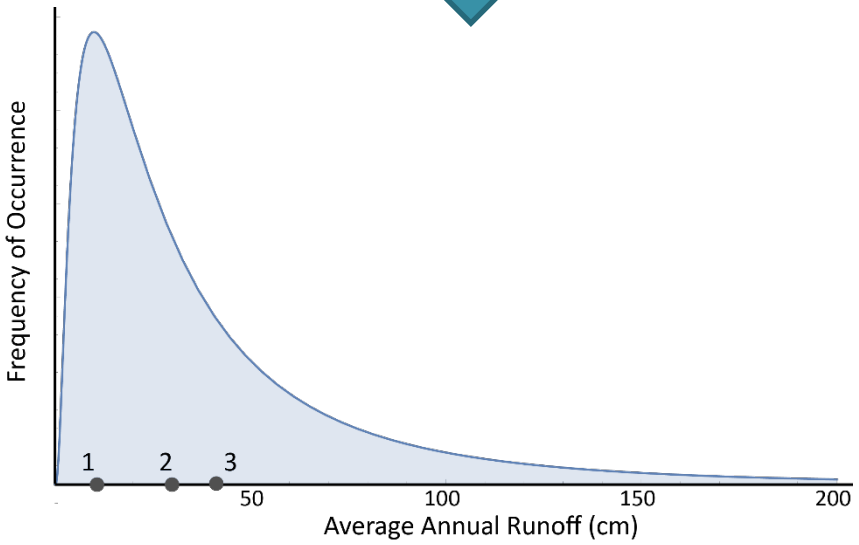
Example





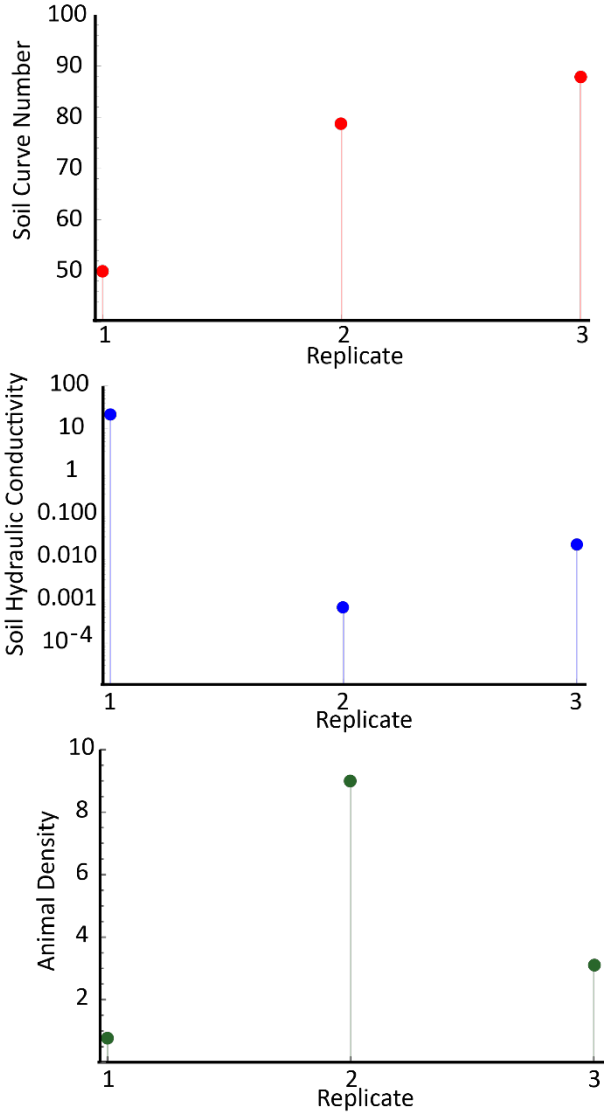


Land Source Models (GLEAMS)

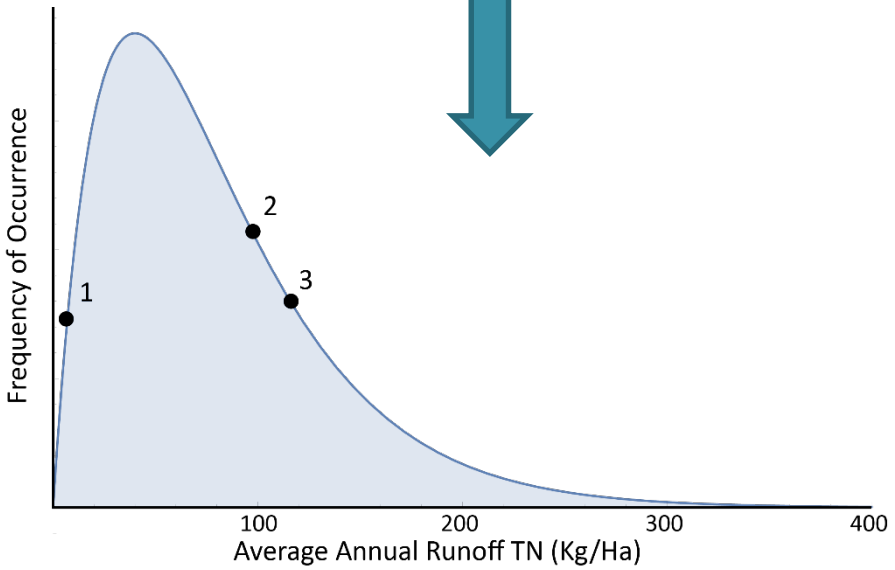


For illustration only.

Example



Land Source Models (GLEAMS)



For illustration only.