The Spatial and Temporal Factors that Characterize Hydrologic Response

LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

Office of Technology Services

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What is Risk?

Risk is Expected Loss…

Frequentist:

$$R(\theta,\delta) = \mathrm{E}_\theta\, L(\theta,\delta(X)) = \int_X L(\theta,\delta(x))\, \mathrm{d}P_\theta(x)$$

Where:

- ***δ()*** = **Decision Rule**
- ***X*** = **Data**
- θ = **Parameters**

Bayesian:

$$\rho(\pi^*,a) = \int_\Theta L(\theta,a)\, \mathrm{d}\pi^*(\theta)$$

Where:

- ***L***(θ,*a*) = **Loss Function for action, *a***
- **π** * = **Posterior Distributor of θ**
- θ = **Parameters**

What is a Model?
An Abstraction of Reality

- Constructed to capture reality and better understand how hydrologic systems work
- Designed in the context of decision support, to provide information for operations/management
- Implies a spatial domain related to a drainage basin
- Require a temporal resolution that satisfies model use objectives (annual, monthly, daily, hourly, ...)

Model Components

$$q = f(x, y, z, t) + €$$

Where:

q = Output

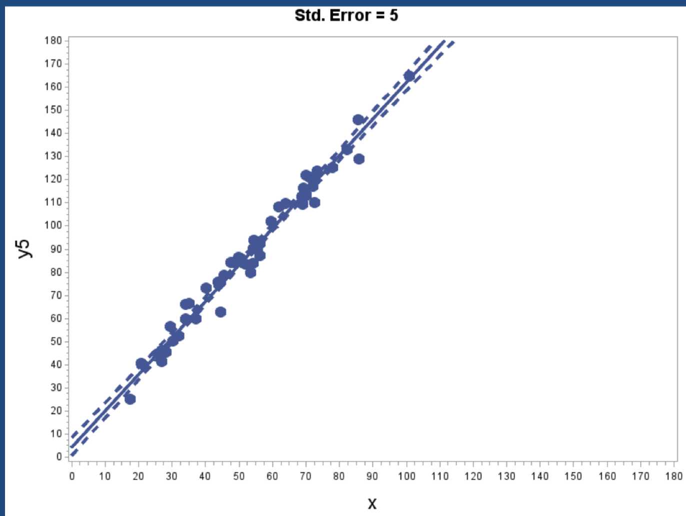
f() = Model of "known" relationship(s) between inputs and outputs

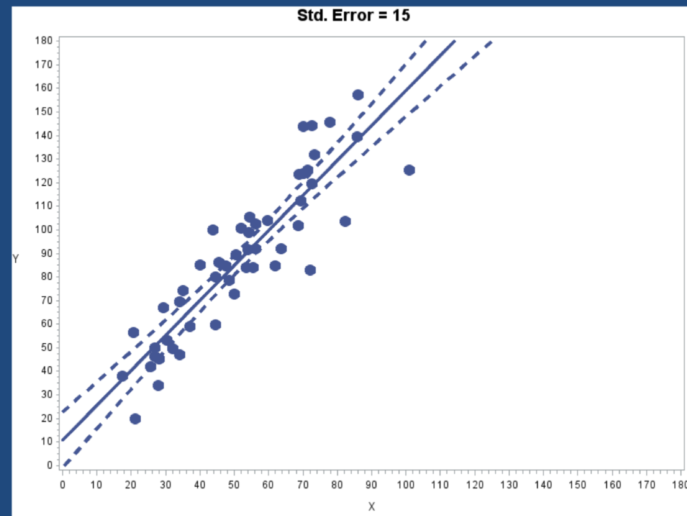
x, y, z = Input Watershed characteristics

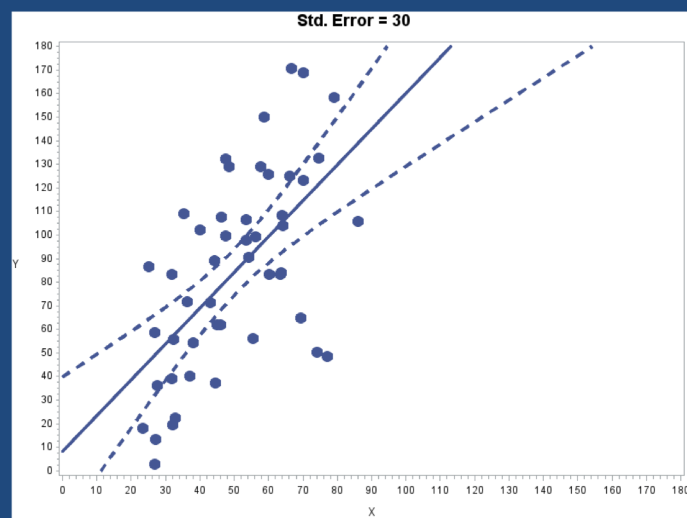
t = Input Time elements

€ = Error – Unexplained behavior and Intrinsic variability

Intraisic Variability is a Characteristic







Same mode (slope), different variance.

- Model variability is a characteristic of the watershed,
- Hydrology is consistent across basins.
- Spatial patterns of basin charactertistic modify response.

What is a Geospatial Model?

- Represents elements as “spatial objects,” based on geographic information systems (GIS) concepts, data, and technology

- Able to model the relationships between data elements

  - Juxtaposition – What elements are adjacent to each other and where do elements overlap?

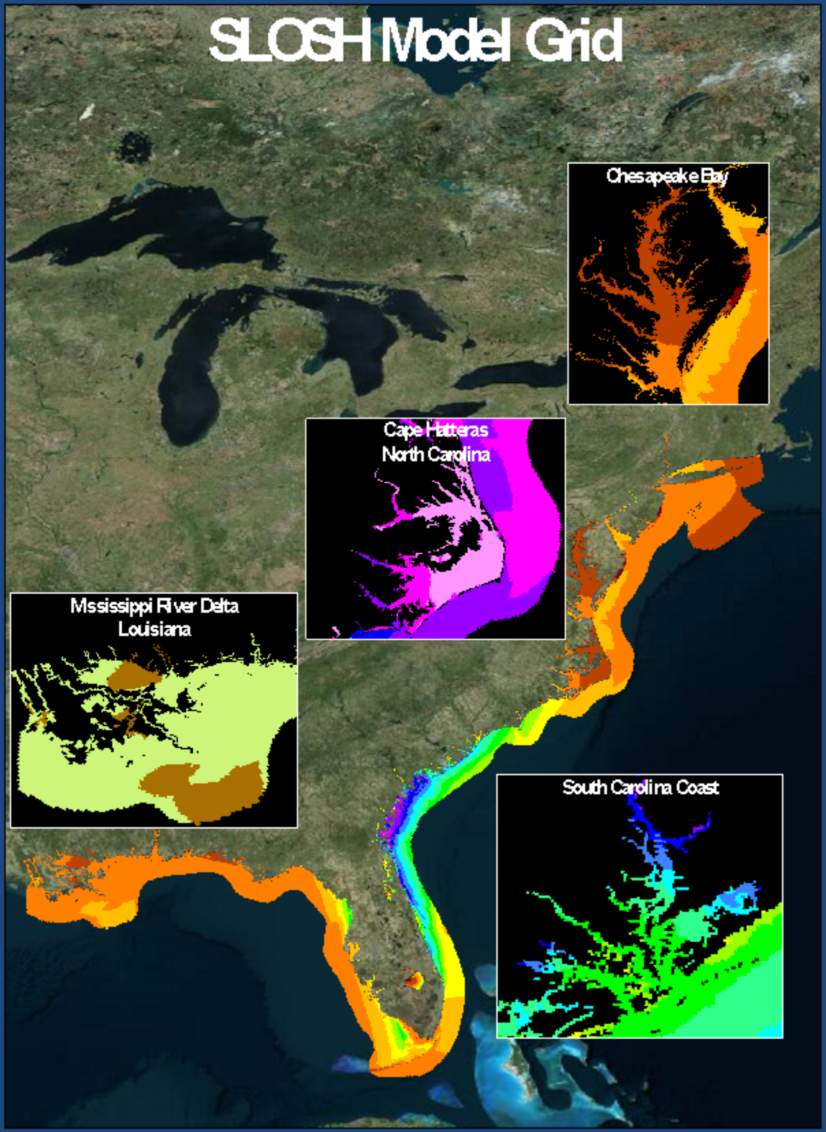
  - Topology – How are elements connected (upstream/downstream relationships)?

Two Kinds of Flooding Damage

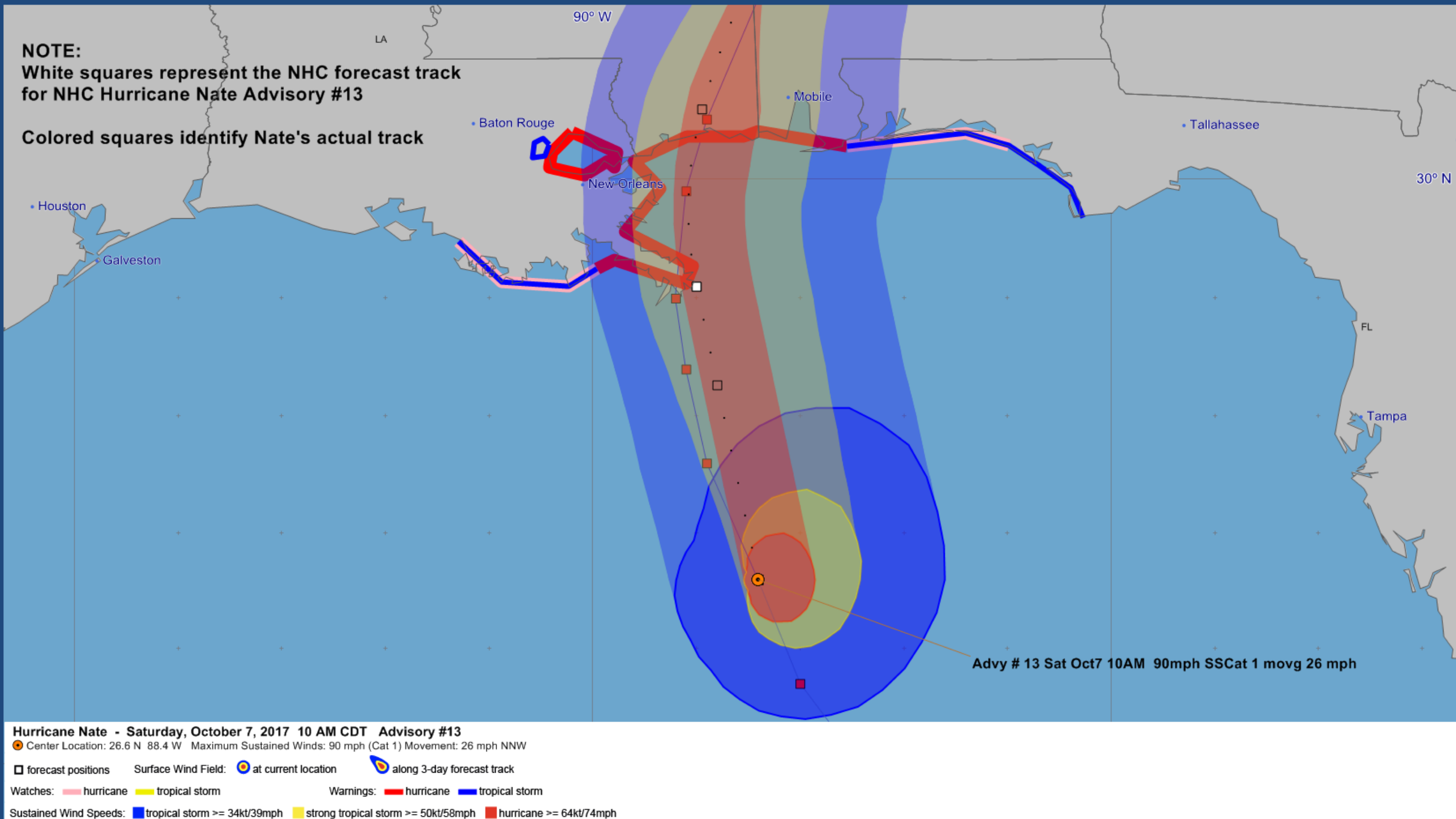
- Rising Water – water that originates downstream Damage occurs through inundation of property
  - Storm surge
  - "Backwater" flooding
  - Tidal flooding
- Flowing Water – water that originates upstream Damage occurs from the force of flowing water
  - Flash floods, Tsunamis
  - Riparian/fluvial/channel flooding

Storm Surge – A Rising Water Flood

- Inundation occurs from the coast, upstream, and inland
- The National Hurricane Center SLOSH Model (Sea, Lake, and Overland Surges from Hurricanes), "p-Surge"
  - Output
    - Polygons in GIS or NetCDF
    - Water Level Elevation or Above Ground Inundation Depth
    - At 10%, 20%, 30%, 40%, 50% Exceedance Probabilities

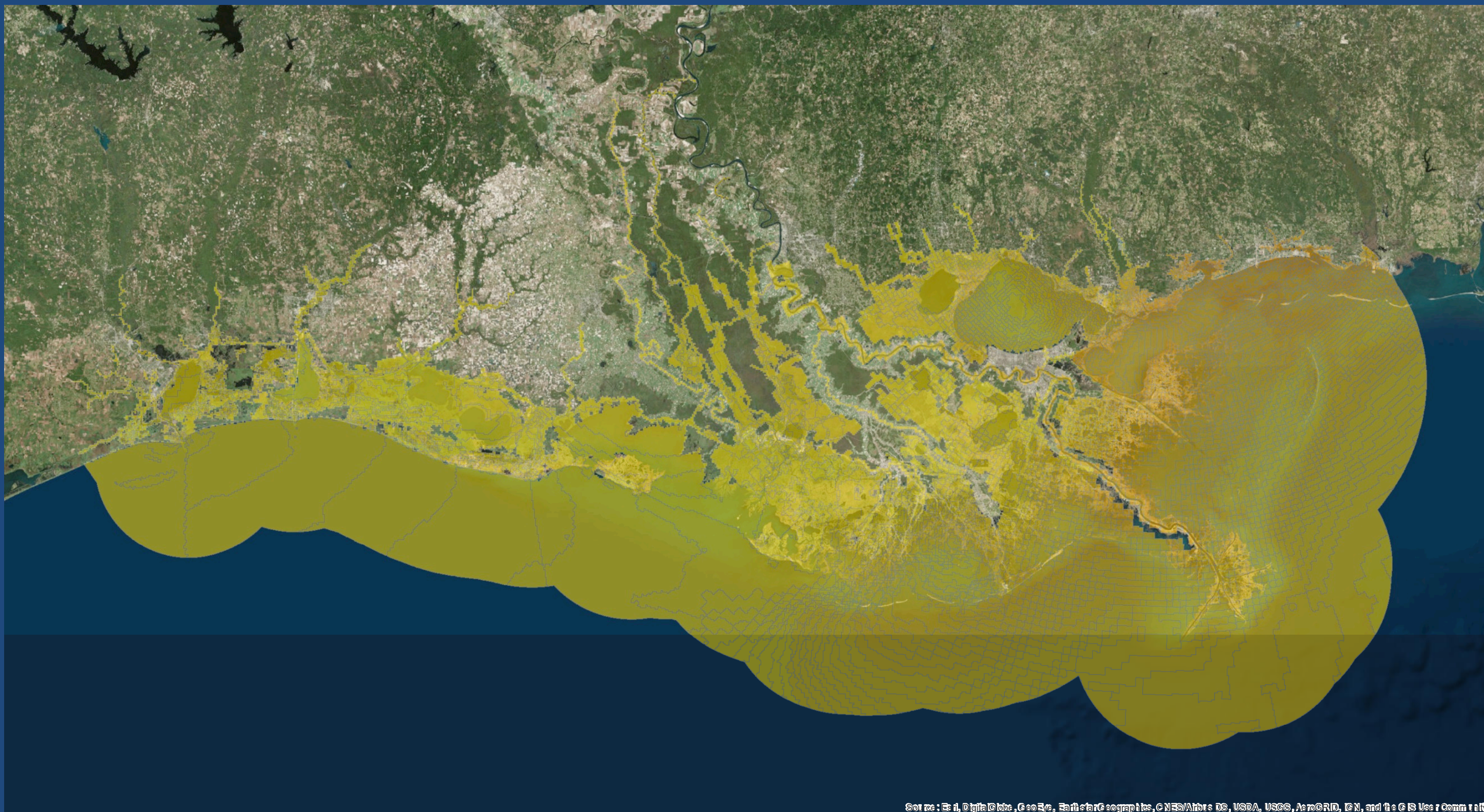


Hurricane Nate 2017



Advisory #13 Wind Swath

NHC Storm Surge Data Grid



2017 Hurricane Nate Advisory #8

NHC Storm Surge Data Products

- Planning, Mitigation, and Prior to Forecasts – Products based on *Monte Carlo* simulation outcomes from SLOSH:
  - MEOW (Maximum Envelopes of Water) - based on specific storm direction, category, forward speed, and tide
  - MOM (Maximum of MEOWs) – “Worst Case” scenario for a given storm classification

- Operational –

  p-Surge, real-time forecasts, every six (6) hours, from a *Monte Carlo* simulation, parameterized from the

Decision Support – Calculating Depth

2017 Hurricane Nate NHC Advisory #8 difference of forecast SLOSH storm surge water level and road elevation. Road points are located every 4 mili-miles (21.12 ft). The NHC reports the 10% risk, and calls it the “maximum regret” forecast. The 50% Exceedance is the “median” and represents the value that is exceeded by ½ of the forecast simulations and below which ½ of the observations fall. In other words, there is a 50/50 chance of water levels been above or below these values.

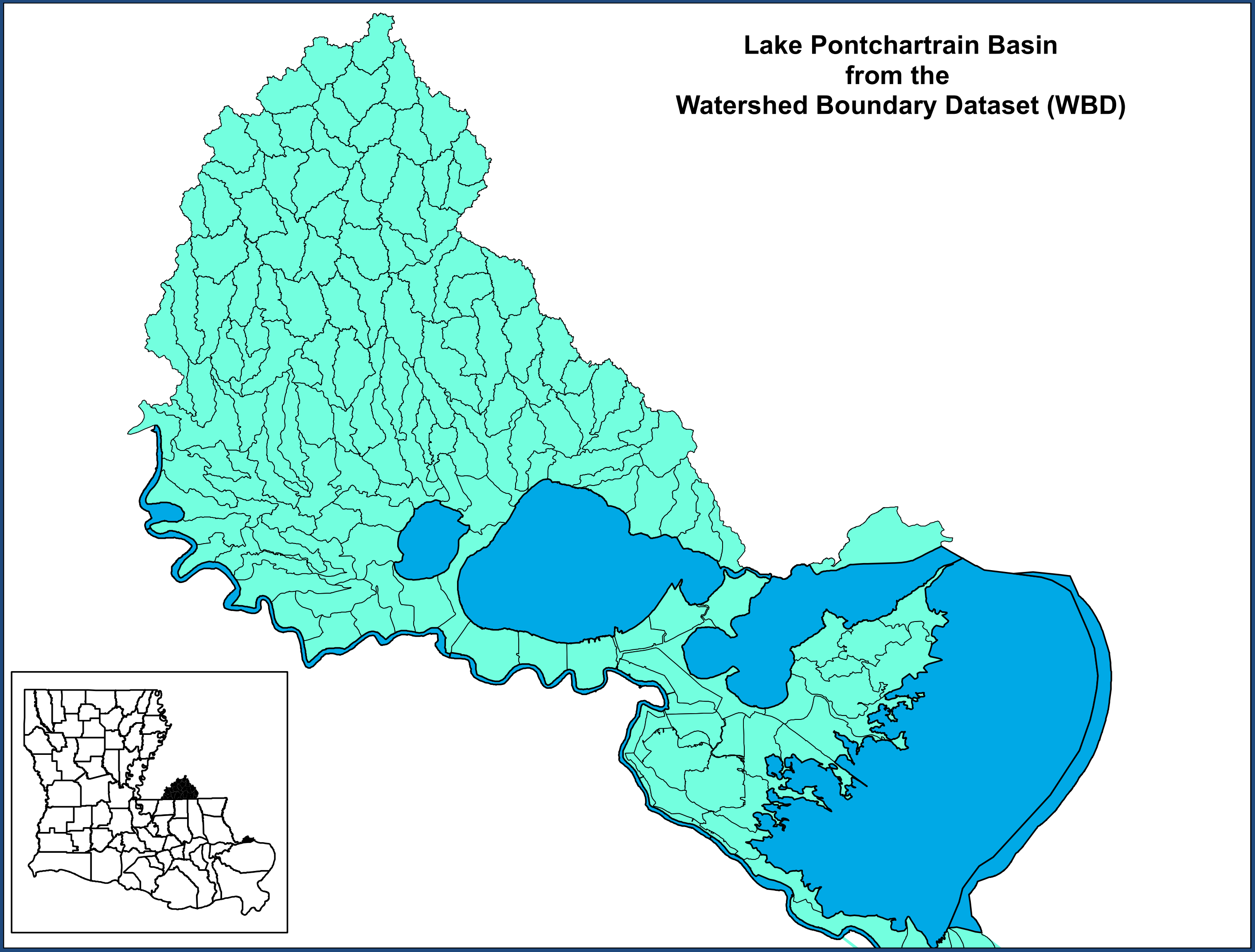
Decision Support – Interpreting Risk

2017 Hurricane Nate NHC Advisory #8 analysis of road elevation v. forecast SLOSH storm surge water levels. Road points are located every 4 mili-miles (21.12 ft). The 10% risk, “maximum regret” forecasts 141.82 miles of flooded roads. The 50% (median, or 50/50) risk, floods 89.98 miles. This also implies that there are 51.84 miles of roads that lie between 10% and 50% risk. The NHC reports the 10% data to the public. However, for operational purposes, the 50% is easier to interpret. Among the 40% of simulations, there are 30.53 miles of “dry” roads.

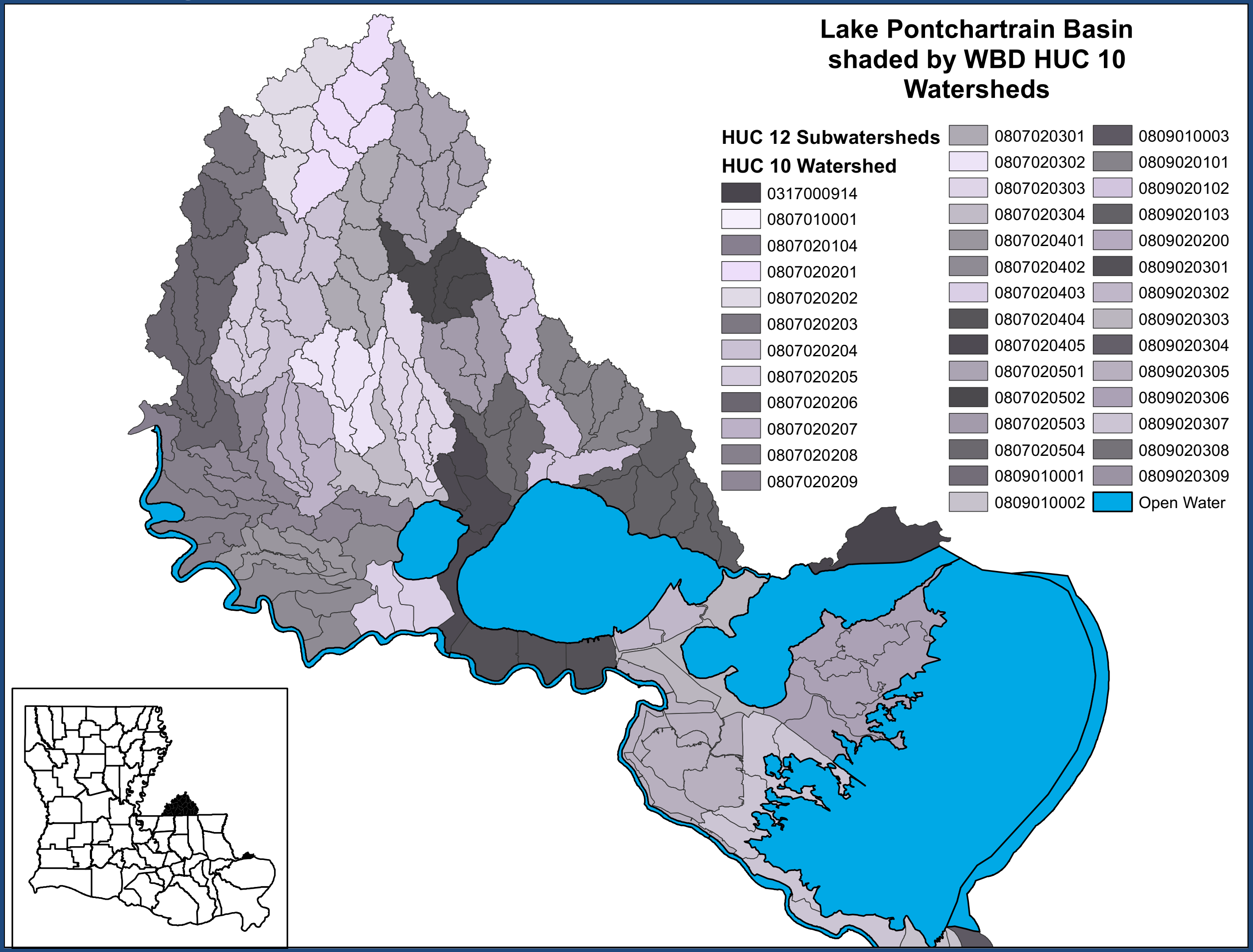
Storm Surge Issues

- Timing – Advisories are released every six (6) hours, but they do not provide, “arrival time”
- NHC releases public advisories based on:
  - 10% Exceedance – “Maximum Regret” estimate
    These values have a 1 in 10 chance of occurring. The rest (90%) likely contain water levels at critical elevations that are not quantified.
  - “Above Ground Level” (AGL) – “Depth above normally dry land” (Water Level Elevation – land Elevation) = depth average over large areas.
    - Ignores local high and low Spots,
      Depth is overestimated at local highs and underestimated for local low spots.
    - AGL is useless for analysis of known, target elevations.
      You cannot outrace an elevation from a depth and there is no way to back calculate.

2016 “Great Flood” in Baton Rouge

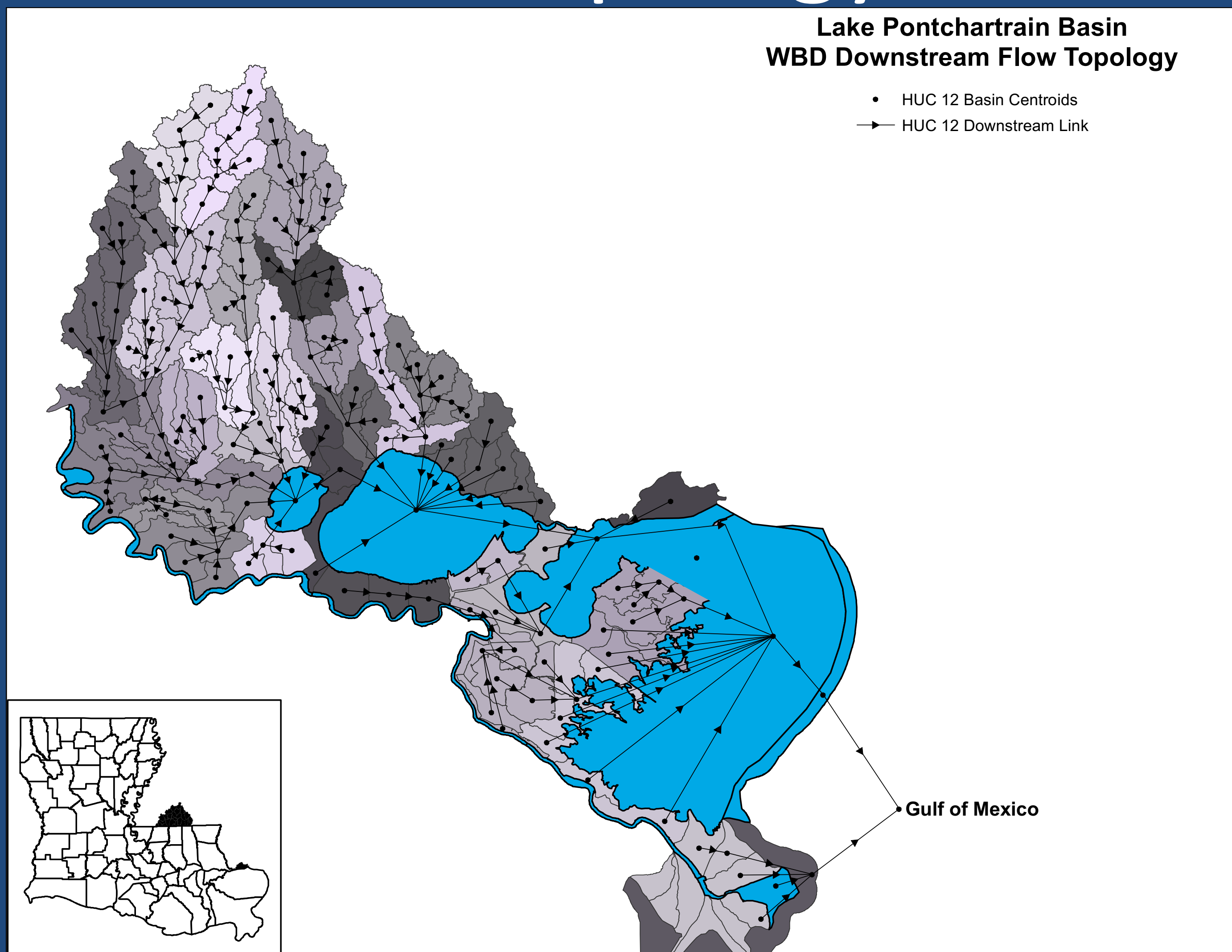


Lake Pontchartrain Basin by HUC-10 Watersheds



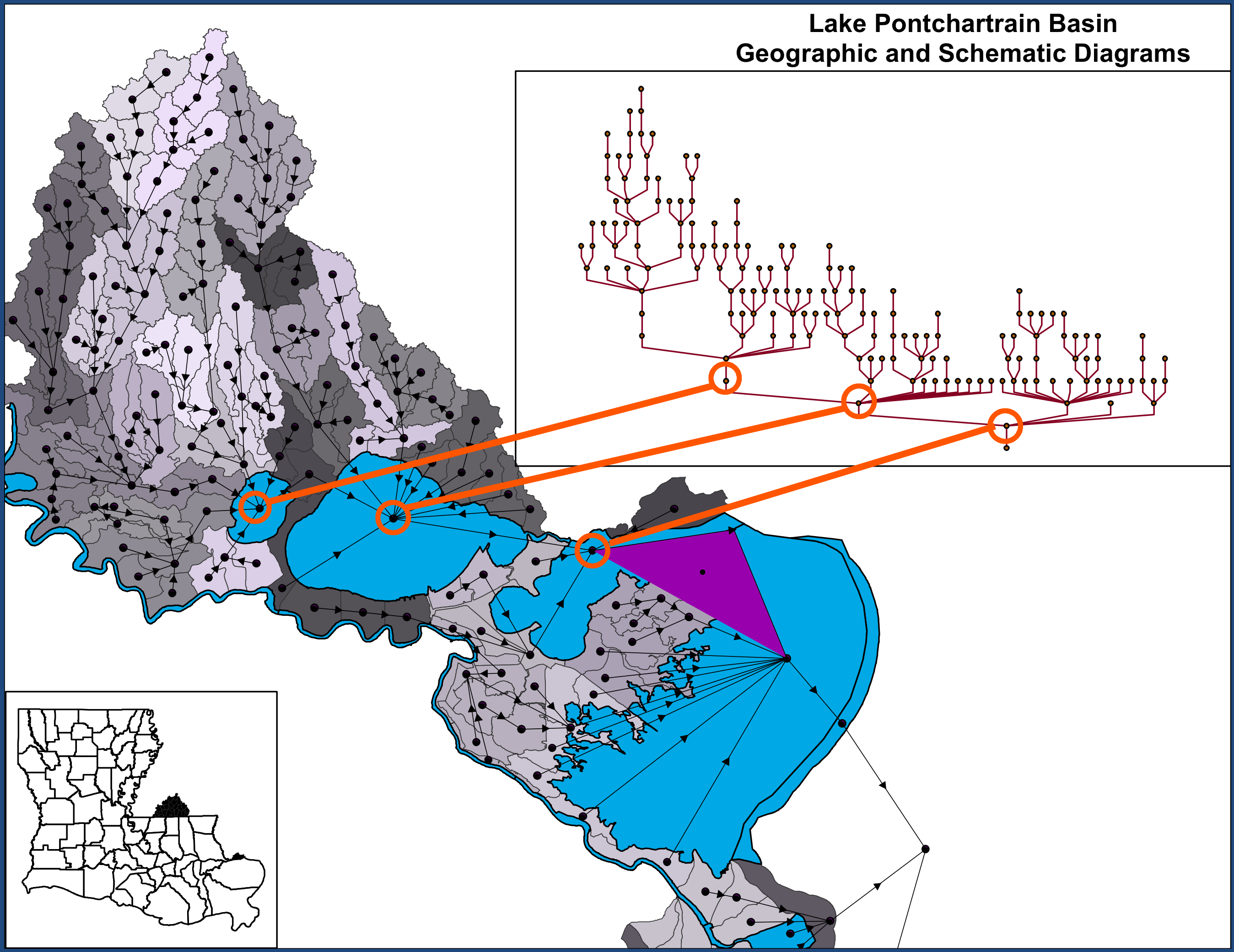
The drainage network is comprised of numerous narrow, north to south sub-drainages that conduct runoff from the top of the watershed to points where they combine.

Lake Pontchartrain Basin Downstream Topology Schematic



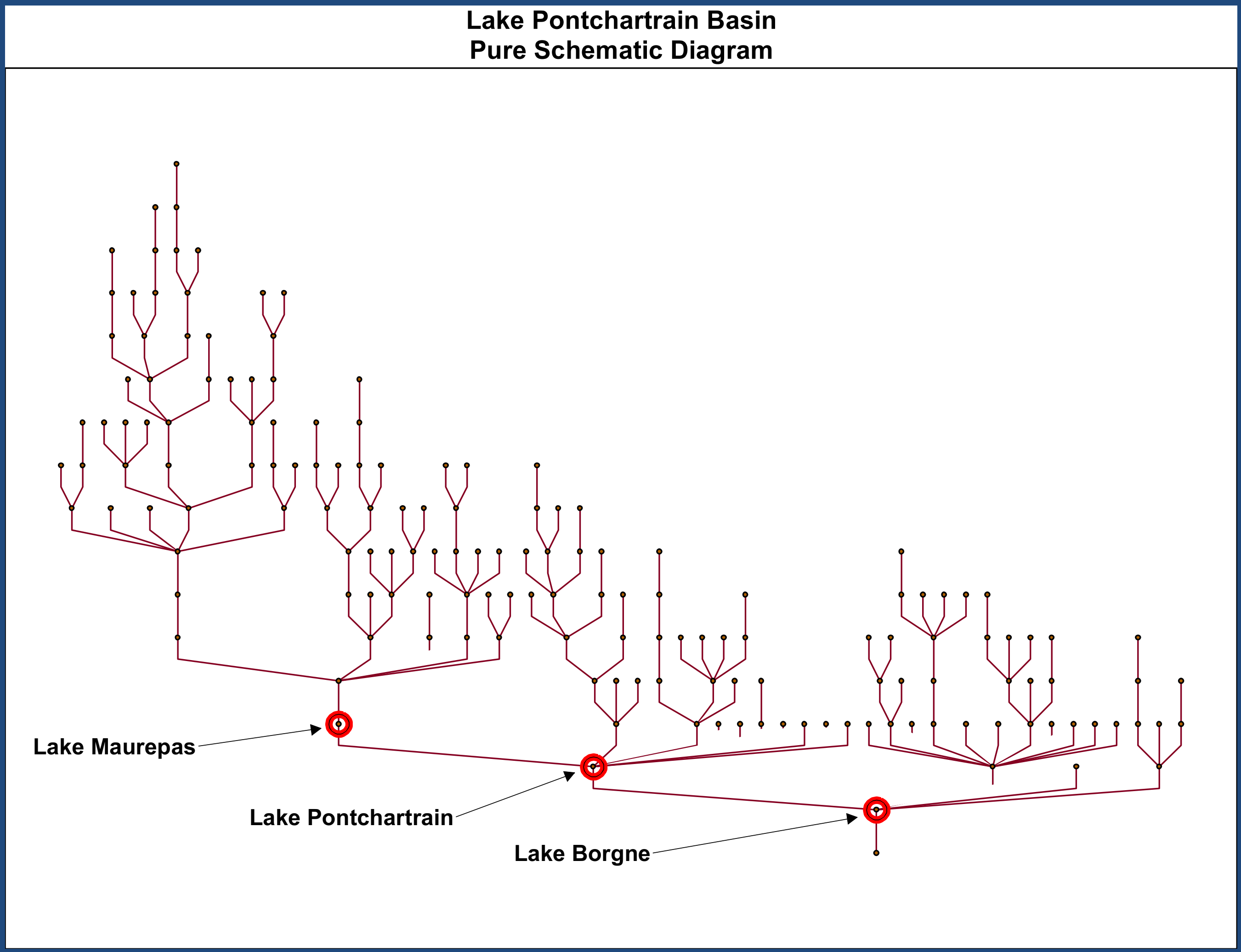
A schematic visualization of the basin drainage pattern. This clearly depicts the drainage network in geographic space.

Lake Pontchartrain Basin Geographic and Schematic Diagrams



Maps and diagrams are linked allowing selections to be propagated between them. The schematic depiction of these basins provides a clear view of their topology

Lake Pontchartrain Basin Hierarchical Smart Tree Diagram



The diagram provides a simplified depiction of the topology of the Lake Pontchartrain Basin. Up and downstream traces can be executed and transferred to the map.

For More Information

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