Hydrological Modeling Report for Upper Leaf Basin

1. Basin & Gauge Map

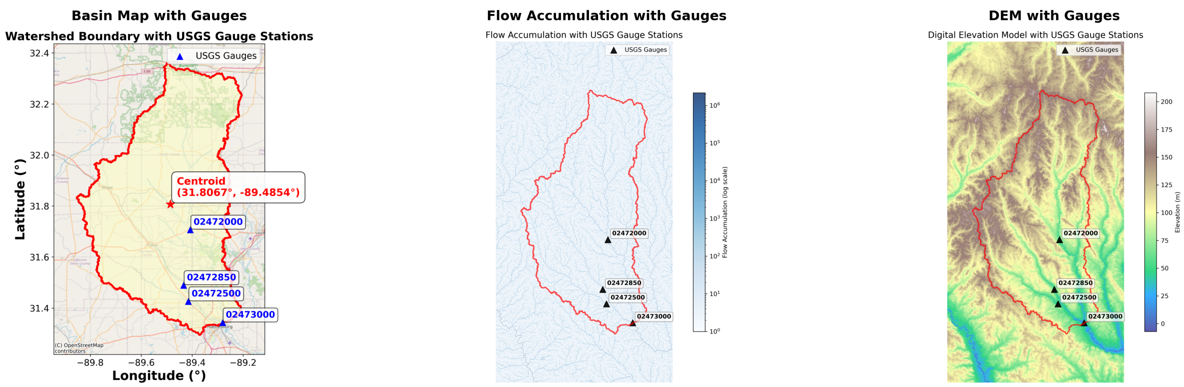

Figure 1: Basin & Gauge Map

The Upper Leaf Basin covers an area of approximately 4540.54 km^2 and stretches along a predominantly north-to-south orientation. The USGS gauge #02473000 is located near the basin outlet at coordinates (31.343056, −89.280278). Other gauges include 02472000, 02472500, and 02472850, as indicated in Figure . Higher elevations exist toward the northern boundary, while flatter floodplain areas are located toward the southeast.

2. Fundamental Basin Data

Figure outlines key terrain and hydrological properties for the Upper Leaf Basin: - **DEM**: Elevations exceed 200 m in the north, transitioning to near 0 m to the south.
- **Flow Accumulation Map (FAM)**: Reveals a dendritic drainage network converging into the main stem near the outlet.
- **Drainage Direction Map (DDM)**: Demonstrates downslope flow from ridges to valleys, marking a moderate relief with a generally dense stream network.

3. Introduction to the Basin

The Upper Leaf Basin is part of the Leaf River system in the southeastern United States. Its climatic conditions feature episodic precipitation events, especially during late winter and early spring. Land use generally includes a mix of forested regions, agricultural fields, and urbanized corridors that impact runoff patterns. The basin's shape and topography influence the timing and magnitude of flows

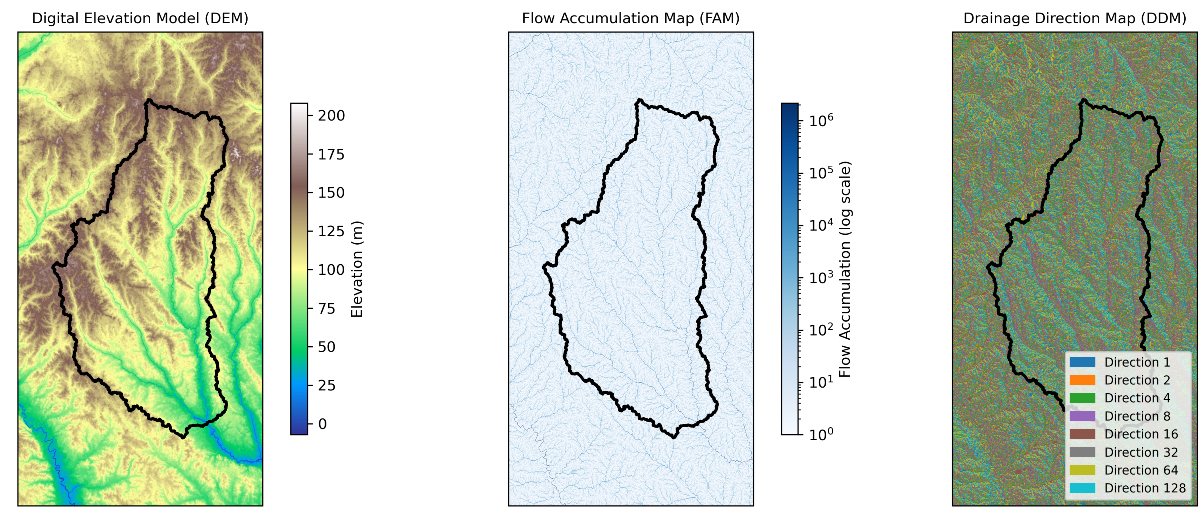

Figure 2: Fundamental Basin Data

observed at the downstream gauge.

4. Simulation vs Observation

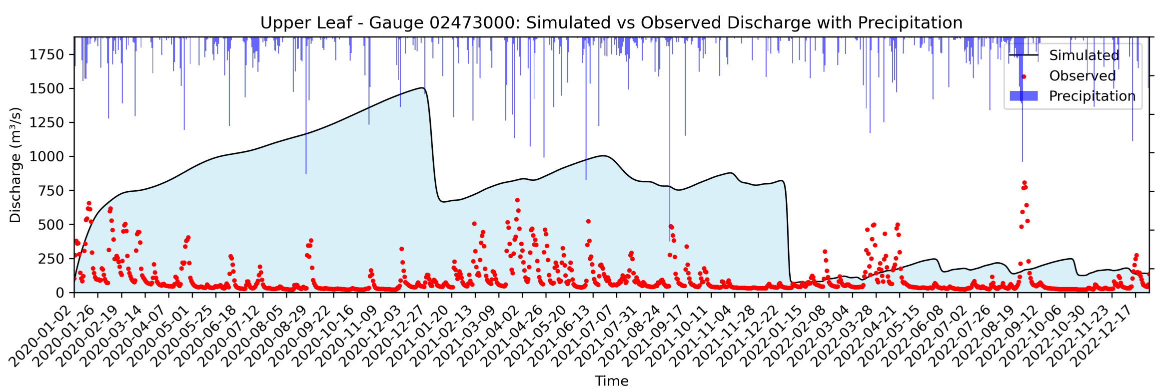

Figure 3: Simulation vs Observation

Figure compares simulated streamflow (black line, blue-shaded area) to observed USGS daily mean flows (red markers), along with daily precipitation (blue bars) over the modeling period (2020-01-01 to 2022-12-31):

- **Precipitation** peaks appear mostly in late winter and spring, causing rising river flows.

- **Simulated Flow** captures the broad seasonal fluctuations and main recession limbs. However, high-flow spikes tend to be overestimated, and occasional timing mismatches appear.

- **Observed Flow** shows a similar overall pattern but with differences in event peaks and durations.

5. Run Arguments (Basin Details)

Argument	**Value**
Basin Name	Upper Leaf
Basin Area (km^2)	4540.54
Simulation Period	2020-01-01 to 2022-12-31
USGS Gauge #	02473000
Gauge Location (lat, lon)	31.343056, –89.280278

6. Model Performance Metrics

Performance Metric	**Value**
Nash-Sutcliffe Efficiency (NSCE)	-34.416
Kling-Gupta Efficiency (KGE)	-5.222
Correlation Coefficient (r)	-0.045
Bias (m^3/s)	569.51 (562.8%)
RMSE (m^3/s)	717.95

These results show the simulation overestimates flows substantially. The negative NSCE and KGE values indicate poor agreement between observed and simulated hydrographs. A correlation near zero highlights weak synchronization of daily flow variations. The large positive bias underscores a significant overprediction.

7. CREST Model Parameters

7.1 Water Balance Parameters

Parameter	**Value**	**Description**
Water capacity ratio (WM)	220.0	Maximum soil water capacity (mm). Higher value → soil holds more water, reducing runoff.
Infiltration curve exponent (B)	1.3	Controls runoff partitioning. Higher value → less infiltration, increasing runoff.
Impervious area ratio (IM)	0.3	Represents urbanization. Higher value → more direct runoff.

Parameter	Value	Description
PET adjustment factor (KE)	0.7	Scales potential evapotranspiration. Higher value → more PET, reducing runoff.
Saturated hydraulic conductivity (FC)	3.0	Soil infiltration rate (mm/hr). Higher value → easier infiltration, reducing runoff.
Initial soil water value (IWU)	15.0	Initial soil moisture (mm). Higher value → less capacity, more runoff initially.

7.2 Kinematic Wave (Routing) Parameters

Parameter	Value	Description
Drainage threshold (TH)	1.0	Flow accumulation threshold (km^2). Higher value → fewer channels.
Interflow speed multiplier (UNDER)	0.3	Higher value → faster subsurface flow.
Interflow reservoir leakage coefficient	0.05	Higher value → increased drain rate from interflow reservoir.
Initial interflow reservoir value (ISU)	0.2	Initial subsurface water content. Higher value → earlier peak flows.
Channel flow multiplier (ALPHA)	0.6	Parameter in Q = A . Higher value → slower routing in channels.
Channel flow exponent (BETA)	2.0	Parameter in Q = A . Higher value → flow response more sensitive to cross-section.
Overland flow multiplier (ALPHA0)	0.4	Similar to ALPHA but for non-channel cells. Higher value → slower overland flow.

8. Conclusion and Discussion

1. **Overall Performance**
   The simulation shows significant overestimation of flow as reflected by negative efficiency metrics, large positive bias, and weak correlation. These findings may stem from parameter settings that favor excessive runoff production or insufficient storage capacity.

2. **Warmup Period Considerations**
   Given the extreme bias ($> 560\%$), an expanded warmup period may be necessary. Often, 3–6 months of simulated time is used prior to official performance evaluation. Parameter refinements or model structure enhancements could also help address excessive runoff generation.

3. **Recommendations**

- Extend the simulation period to include a robust warmup segment that ensures initial state variables and storages equilibrate.

- Refine parameter calibration, particularly those related to soil moisture capacity (WM), infiltration (B), and channel routing (ALPHA, BETA).

- Examine the meteorological forcing data (e.g., precipitation) for potential overestimation that fuels excessive modeled flows.

- Consider including more spatially distributed rainfall inputs or improved evapotranspiration representation.

- Evaluate land use and impervious area assumptions to account for any over- or under-estimation in runoff.

4. **Next Steps**

   - Re-calibrate the CREST model using multi-objective methods (e.g., focusing on NSE and bias).

   - Investigate split-sample (period-based) validations to confirm model robustness.

   - Explore assimilation of satellite-based soil moisture or observed reservoir levels to further constrain model states.

Implementing these steps may improve overall accuracy, reduce bias, and yield simulations that better align with observed flow dynamics, ultimately enabling more reliable basin-scale water resource assessments.