Little Bighorn Basin Hydrological Analysis

The Little Bighorn basin is located in Montana and Wyoming, encompassing an area of 3359.4 km². This report details a hydrological simulation conducted for the period from 2020-01-01 to 2022-12-31, focusing on USGS gauge #06294000 (45.735812, -107.557305). The simulation was performed using the CREST hydrological model.

Basin & Gauge Map

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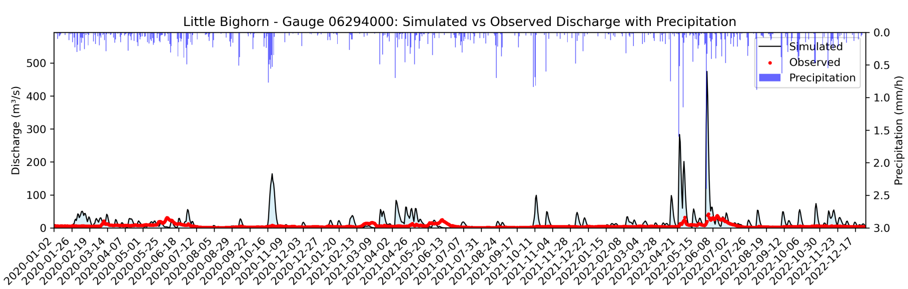
The Little Bighorn basin, outlined in red, spans a significant elevation range. The northern portion of the basin is at higher elevations, draining southwards. Three USGS gauges are present. Gauge **06294000** is located in the headwaters of the basin. Gauges **06289820** and **06289821** are co-located downstream, near the southern outlet. The centroid of the basin is located at approximately (45.2088°, -107.4667°). The flow accumulation map confirms the flow path from the headwaters (06294000) to the lower basin gauges.

Fundamental Basin Data

Fundamental Basin Data

The Digital Elevation Model (DEM) shows a clear topographic gradient, with high elevations in the north and west transitioning to lower elevations in the south and east. The Flow Accumulation Map (FAM) displays the drainage network, with higher accumulation values indicating major stream channels. The Drainage Direction Map (DDM) illustrates the primary flow directions, which are predominantly southwards. The drainage density appears moderate, with a well-defined channel network visible in the FAM and DDM.

Simulation vs Observation



The simulation plot shows three curves:

- **Simulated (black line):** Model-predicted discharge.

- **Observed (red dots):** Actual discharge measurements at gauge 06294000.
- **Precipitation (blue bars):** Rainfall data used as input to the model.

The simulation generally captures the overall hydrograph shape but underpredicts the magnitude of several peak flow events, especially the large peak around 2022-05-15. There is a noticeable lag between some precipitation events and the simulated/observed discharge peaks, although the simulated peak appears to be too fast. The model appears to underestimate the baseflow, and has a low bias in general. The simulation has better performance during periods of low flow, with a closer match between the simulated and observed values.

Model Performance Metrics

Metric	Value
Nash-Sutcliffe Efficiency (NSCE)	-32.376
Kling-Gupta Efficiency (KGE)	-4.073
Correlation Coefficient	0.325
Bias (m^3/s)	9.83
Bias (%)	164.1
Root Mean Square Error (RMSE)	32.66

CREST Parameters

Water Balance Parameters

Parameter	Value	Unit	Description
Water capacity ratio (WM)	200.0	mm	Maximum soil water capacity
Infiltration curve exponent (B)	2.0	-	Controls water partitioning to runoff
Impervious area ratio (IM)	0.02	-	Represents urbanized areas
PET adjustment factor (KE)	0.75	-	Affects potential evapotranspiration
Soil saturated hydraulic conductivity (FC)	90.0	mm/hr	Rate at which water enters soil
Initial soil water value (IWU)	25.0	mm	Initial soil moisture

Kinematic Wave (Routing) Parameters

Parameter	Value	Unit	Description
Drainage threshold (TH)	75.0	km^2	Defines river cells based on flow accumulation
Interflow speed multiplier (UNDER)	1.8	-	Higher values accelerate subsurface flow
Interflow reservoir leakage coefficient (LEAKI)	0.6	-	Higher values increase interflow drainage rate
Initial interflow reservoir value (ISU)	0.0	-	Initial subsurface water
Channel flow multiplier (ALPHA)	2.2	-	In Q = A equation. Higher values slow wave propagation in channels.
Channel flow exponent (BETA)	0.85	-	In Q = A equation. Higher values slow wave propagation in channels.
Overland flow multiplier (ALPHA0)	2.5	-	Similar to ALPHA but for non-channel cells. Higher values slow overland flow.

Run Arguments

Argument	Value	Unit	Description
Basin Area	3359.4	km^2	Total area of the Little Bighorn basin
Start Date	2020-01-01	-	Simulation start date
End Date	2022-12-31	-	Simulation end date
Gauge ID	06294000	-	USGS gauge identifier
Gauge Latitude	45.735812	°	Latitude of the gauge
Gauge Longitude	-107.557305	°	Longitude of the gauge

Conclusion/Discussion

The hydrological simulation for the Little Bighorn basin, while capturing the overall hydrograph shape, exhibits significant discrepancies compared to observed streamflow data. The extremely poor NSCE and KGE values indicate a major mismatch between the simulation and reality. The large positive bias suggests a systematic overestimation of streamflow by the model, further corroborated by the high RMSE value.

Several factors might contribute to this poor performance:

- **Parameter Calibration:** The CREST model parameters may not be optimally calibrated for the Little Bighorn basin. The default parameters might not accurately represent the basin's unique hydrological characteristics. Sensitivity analysis and calibration techniques should be employed to refine parameter values.

- **Input Data Quality:** The accuracy of the precipitation data is crucial for hydrological modeling. Errors or biases in the precipitation data can propagate through the model and affect the simulated streamflow. The source and quality of the precipitation data need to be carefully evaluated.
- **Model Structure:** The CREST model, while widely used, might not fully capture all the relevant hydrological processes in the Little Bighorn basin. The model structure might need to be modified or enhanced to better represent the basin's hydrology.
- **Warmup Period:** The simulation period might not include a sufficient warmup period for the model to reach a stable state. However, the bias is positive (164.1%), so a warmup period is likely not the primary issue. A negative bias exceeding 90% would typically indicate the need for a longer warmup to saturate soil moisture stores.
- **Spatial Resolution:** The spatial resolution of the model might be too coarse to capture the spatial variability of hydrological processes within the basin. A finer-resolution model might be necessary to improve simulation accuracy.

Recommendations:

1. **Parameter Calibration:** Conduct a thorough parameter calibration exercise using observed streamflow data. Employ optimization algorithms to find the parameter values that minimize the difference between simulated and observed streamflow.
2. **Data Quality Assessment:** Evaluate the accuracy and reliability of the precipitation data used as input to the model. Consider using multiple precipitation datasets or bias correction techniques to improve data quality.
3. **Model Structure Evaluation:** Assess the suitability of the CREST model structure for the Little Bighorn basin. Explore potential modifications or enhancements to better represent the basin's hydrological processes.
4. **Simulation Period:** While not the primary concern given the positive bias, ensure the simulation period is representative of the long-term hydrological behavior of the basin.
5. **Spatial Resolution:** Investigate the impact of spatial resolution on simulation accuracy. If feasible, increase the model resolution to better capture spatial variability within the basin.
6. **Consider alternative models**: Given the poor model performance, consider evaluating other hydrological models that may be better suited to the Little Bighorn basin.

Next Steps:

- Perform a sensitivity analysis of the CREST model parameters to identify the parameters that have the greatest impact on simulated streamflow.
- Implement a parameter calibration procedure using observed streamflow data to optimize the model parameters.

- Evaluate the impact of different precipitation datasets on simulation accuracy.
- Consider incorporating additional data sources, such as evapotranspiration data or snow cover data, into the model.
- Explore the use of more advanced hydrological models to improve simulation accuracy.