Mad-Redwood Basin Hydrological Analysis

1. Introduction to the Mad-Redwood Basin

The Mad-Redwood basin, encompassing an area of 3684.31 km², is a coastal watershed located in northern California. This report presents a hydrological analysis of the basin, focusing on the period from 2020-01-01 to 2022-12-31. The analysis utilizes the CREST hydrological model, with a specific focus on USGS gauge #11481000 (40.909572, -124.060896) as the primary point of evaluation. This report details the model setup, simulation results, performance metrics, and recommendations for future improvements.

2. Basin & Gauge Map

The basin exhibits a distinct north-south orientation along the Pacific coastline. Key USGS gauge locations are strategically positioned throughout the watershed, providing valuable streamflow data. The gauge network includes several key stations. From upstream to downstream, the apparent main branch gauges are approximately: `11530500`, `11482500`, `11481200`, `11481000`, `11528700`, `11480410`, and `11480390`. Gauge `11481000` appears to be located near the centroid (40.8709°, -123.9213°). The topography indicates steeper slopes in the northern parts of the basin, potentially influencing runoff dynamics.

Basin & Gauge Map

3. Fundamental Basin Data

The Digital Elevation Model (DEM) reveals significant topographic relief within the Mad-Redwood basin, ranging from near sea level to elevations exceeding 2500 meters. The higher elevations are concentrated in the northern and eastern regions, likely leading to orographic precipitation patterns. The Flow Accumulation Map (FAM) clearly delineates a primary river channel and its associated tributary network converging downstream. The logarithmic scale of the FAM accentuates the increasing flow accumulation along the main channel. The Drainage Direction Map (DDM) illustrates the dominant flow pathways, with a consistent pattern of water converging into the main channel and its tributaries. The relatively high drainage density evident in the DDM suggests a well-developed stream network, which can contribute to a rapid hydrologic response to precipitation events.

Fundamental Basin Data

4. Simulation vs Observation

The following figure compares the simulated and observed discharge at USGS gauge #11481000, along with precipitation data. The simulated discharge generally captures the overall trend of the observed discharge, including the timing of several peak flow events. However, the model tends to overestimate the magnitude of peak flows, particularly during smaller events. There are also instances where the simulated peak discharge occurs slightly earlier than the observed peak, indicating a potential lag in the model's response. The simulation of baseflow appears to be reasonably accurate. Discrepancies in peak magnitude and timing suggest that further calibration is needed to enhance the model's accuracy, especially in capturing peak discharge events.

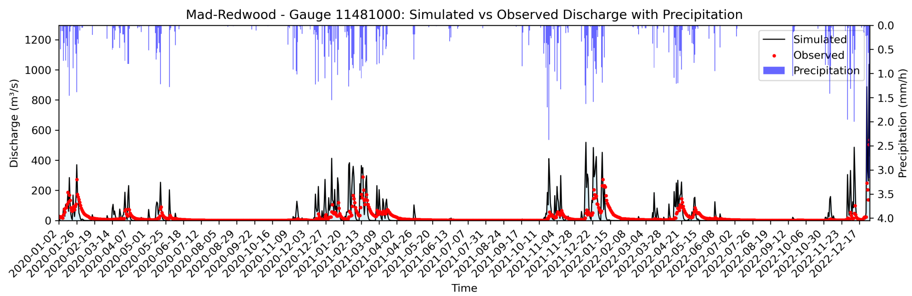

Figure 1: Simulation vs Observation

5. Model Performance Metrics

The following table summarizes the key performance metrics for the CREST model simulation.

Metric	Value
Nash-Sutcliffe Efficiency (NSCE)	-1.162
Kling-Gupta Efficiency (KGE)	-0.116
Correlation Coefficient (r)	0.696
Bias (m^3/s)	10.32
Bias (%)	48.8
Root Mean Square Error (RMSE) (m^3/s)	62.90

The negative NSCE and KGE values indicate that the model's performance is worse than simply using the mean of the observed data as a predictor. While the correlation coefficient shows a moderate positive correlation, the high bias and RMSE values suggest significant discrepancies between the simulated and observed streamflow.

6. CREST Model Parameters

The following table lists the key parameters used in the CREST model simulation.

Parameter	Value	Description
Water Balance Parameters		
Water capacity ratio (WM)	200.0	Maximum soil water capacity (mm)
Infiltration curve exponent (B)	10.0	Controls water partitioning to runoff
Impervious area ratio (IM)	0.05	Represents urbanized areas
PET adjustment factor (KE)	0.9	Affects potential evapotranspiration
Soil saturated hydraulic conductivity (FC)	75.0	Rate at which water enters soil (mm/hr)
Initial soil water value (IWU)	25.0	Initial soil moisture (mm)
Kinematic Wave (Routing) Parameters		
Drainage threshold (TH)	50.0	Defines river cells based on flow accumulation (km²)
Interflow speed multiplier (UNDER)	2.0	Accelerates subsurface flow
Interflow reservoir leakage coefficient (LEAKI)	0.7	Increases interflow drainage rate
Initial interflow reservoir value (ISU)	0.0	Initial subsurface water
Channel flow multiplier (ALPHA)	0.5	Affects wave propagation speed in channels (Q = A)
Channel flow exponent (BETA)	0.6	Affects wave propagation speed in channels (Q = A)
Overland flow multiplier (ALPHA0)	0.8	Affects overland flow speed

7. Run Arguments (Basin Details)

While specific run arguments beyond parameters were not provided, the following details are relevant to the simulation setup:

Detail	Value
Basin Area	3684.31 km²
Simulation Start Date	2020-01-01
Simulation End Date	2022-12-31

Detail	Value
Target USGS Gauge	#11481000
Gauge Location (Lat, Lon)	(40.909572, -124.060896)

8. Conclusion/Discussion

The CREST model simulation for the Mad-Redwood basin, while capturing some aspects of the observed hydrograph, exhibits significant limitations in accurately predicting streamflow, as indicated by the poor performance metrics (NSCE and KGE). The model's tendency to overestimate peak flows and the presence of a timing lag suggest that further calibration is necessary.

Given the negative NSCE and KGE values, a warm-up period is not the primary concern. The fundamental model structure and parameterization require attention. The bias of 48.8% indicates a systematic overestimation of streamflow.

Recommendations:

- **Parameter Calibration:** Conduct a thorough calibration of the CREST model parameters, focusing on parameters that influence peak flow generation and timing, such as the infiltration curve exponent (B), soil saturated hydraulic conductivity (FC), and channel flow parameters (ALPHA, BETA). Consider using optimization algorithms to find parameter sets that minimize the discrepancies between simulated and observed streamflow.
- **Data Quality Assessment:** Evaluate the quality and completeness of the observed precipitation and streamflow data. Erroneous or missing data can negatively impact model performance.
- **Model Structure Evaluation:** Consider refining the model structure to better represent the hydrologic processes within the Mad-Redwood basin. This could involve incorporating additional components, such as groundwater storage, or using a more sophisticated routing scheme.
- **Spatial Resolution:** Investigate the impact of spatial resolution on model performance. Increasing the resolution of the input data (e.g., DEM, land cover) may improve the model's ability to capture the spatial variability of hydrologic processes.
- **Simulation Period:** Extend the simulation period to include a wider range of hydrologic conditions. This will provide a more robust assessment of the model's performance.
- **Evapotranspiration:** Evaluate the accuracy of the potential evapotranspiration (PET) estimates used in the model. Consider using alternative PET methods or calibrating the PET adjustment factor (KE).

By addressing these recommendations, the accuracy and reliability of the CREST model simulation for the Mad-Redwood basin can be significantly improved. Future work should focus on refining the model to better represent the complex hydrologic dynamics of this important coastal watershed.