Evaluation of Flood Inundation Mapping Activities at the NOAA National Water Center

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Background and Sources

Height Above Nearest Drainage (HAND) is a geoprocessing technique that converts a Digital Elevation Model (DEM) to a Relative Elevation Model (REM) depicting the elevation of the surrounding terrain above the river to which it drains. Using the REM and associated rating curve, a flood inundation map (FIM) and depth grid are generated.

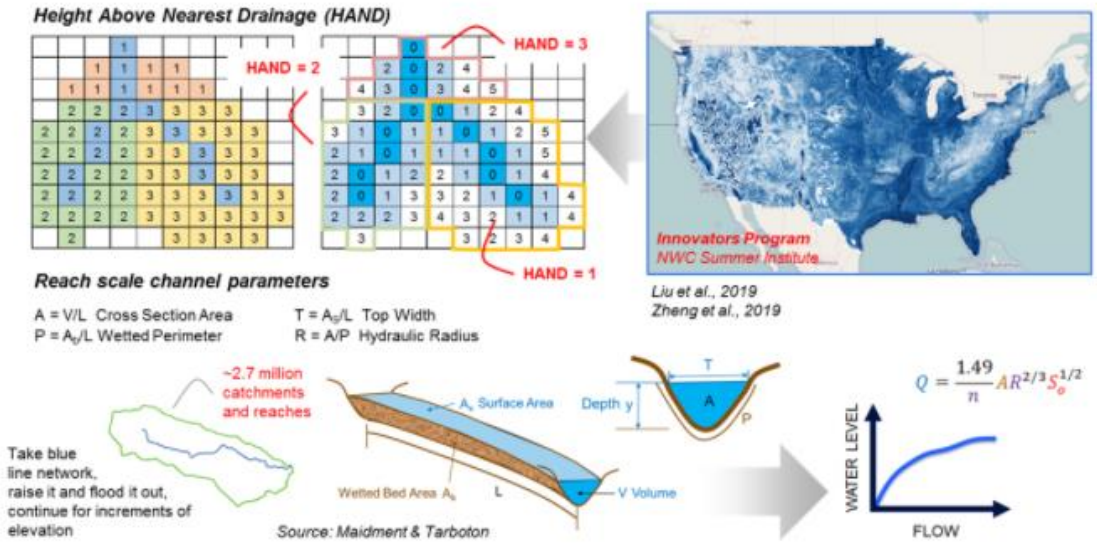
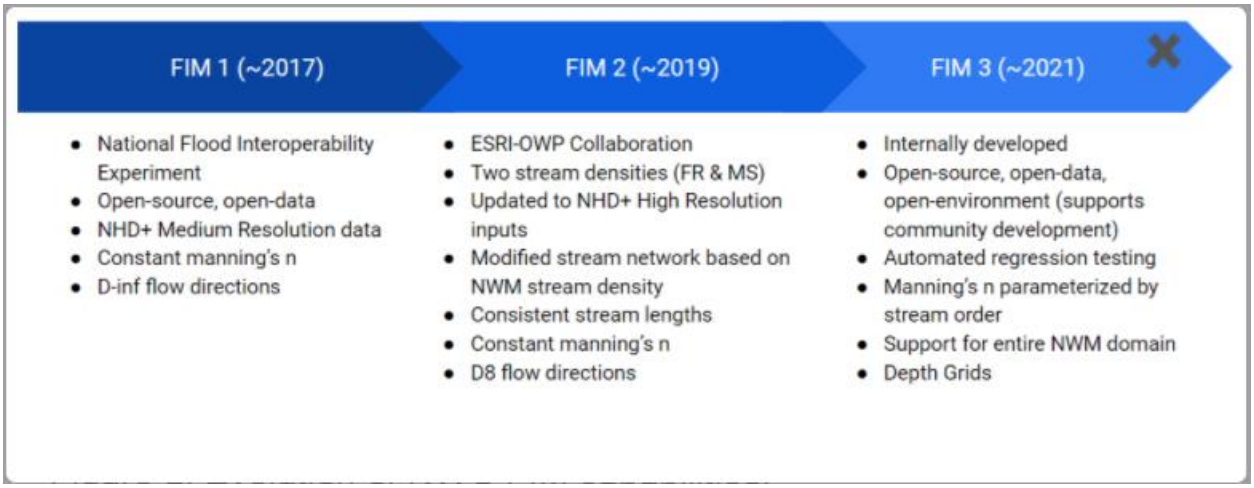


Figure 1: Height Above Nearest Drainage Methodology.

The open source National Water Center (NWC) FIM v3 code accepts spatially-varied Manning's roughness. For more information on FIM v3 see, "Forecast Flood Inundation Mapping at Continental Scale from National Water Model River Discharges" (H111-0027).



Methods

The flood inundation map is evaluated against a benchmark dataset and divided into four categories (True Positive, False Positive, False Negative, and True Negative) and these categories comprise a 2x2 contingency table.

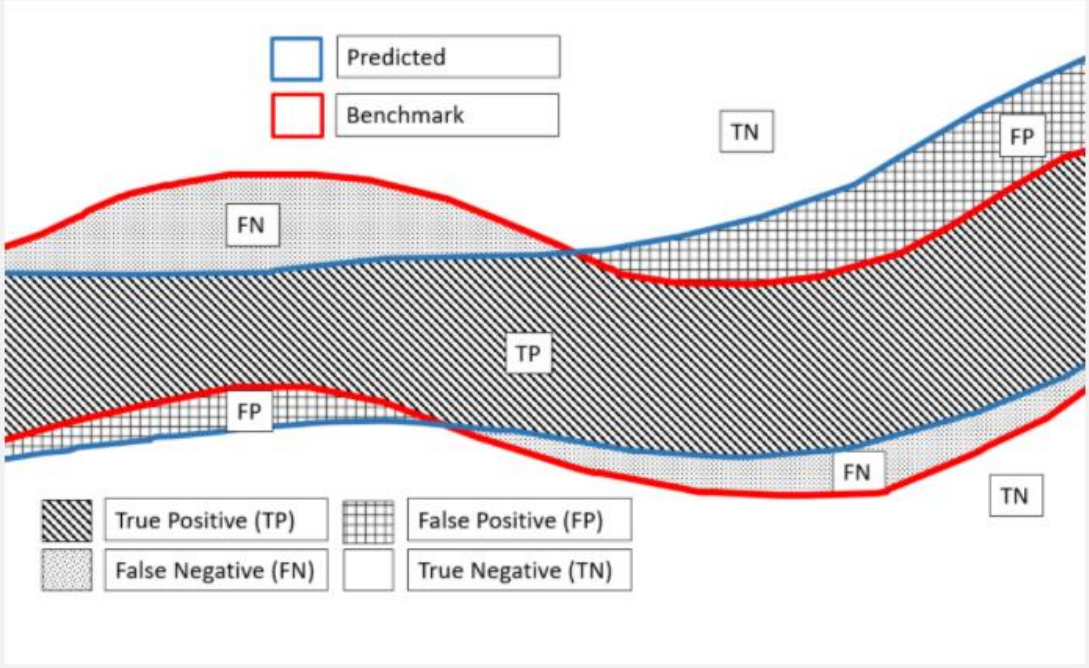


Figure 3: Example contingency map.

Contingency Table		Benchmark	
		Wet	**Dry**
Predicted	**Wet**	True Positive	False Positive
	Dry	False Negative	True Negative

Figure 4: Example contingency table.

Statistical metrics such as critical success index (CSI), false alarm ratio (FAR), and probability of detection (POD) and others are calculated using the contingency table.

Metric	Formula	Target Score	Answers the Question*
Critical Success Index (CSI)	$\frac{True\ Positives}{True\ Positives + False\ Negatives + False\ Positives}$	1	How well did the forecast correspond to the observed?
Probability of Detection (POD)	$\frac{True\ Positives}{True\ Positives + False\ Negatives}$	1	What fraction of the observed was correctly forecast?
False Alarm Ratio (FAR)	$\frac{False\ Positives}{True\ Positives + False\ Positives}$	0	What fraction of the predicted actually did not occur (i.e., were false alarms)?
*https://www.cawcr.gov.au/projects/verification/#Methods_for_dichotomous_forecasts			

Figure 5: Statistical metrics calculated using a 2x2 contingency table

Datasets

FIM maps are evaluated against benchmark, or "truth", datasets to assess overall performance as well as guide version-on-version improvement. Benchmark datasets are developed using the US Army Corps of Engineers HEC-RAS model. Sources of benchmark datasets include:

FEMA Base Level Engineering (BLE) studies

Watershed (HUC-08) studies, across New Mexico, Texas, and Oklahoma, on the FEMA Base Flood Elevation viewer (https://webapps.usgs.gov/infrm/estBFE/) feature inundation maps for the 1% and 0.2% annual chance flood events. FIM maps are generated using flows from the FEMA datasets and are then compared to the benchmark inundation maps.

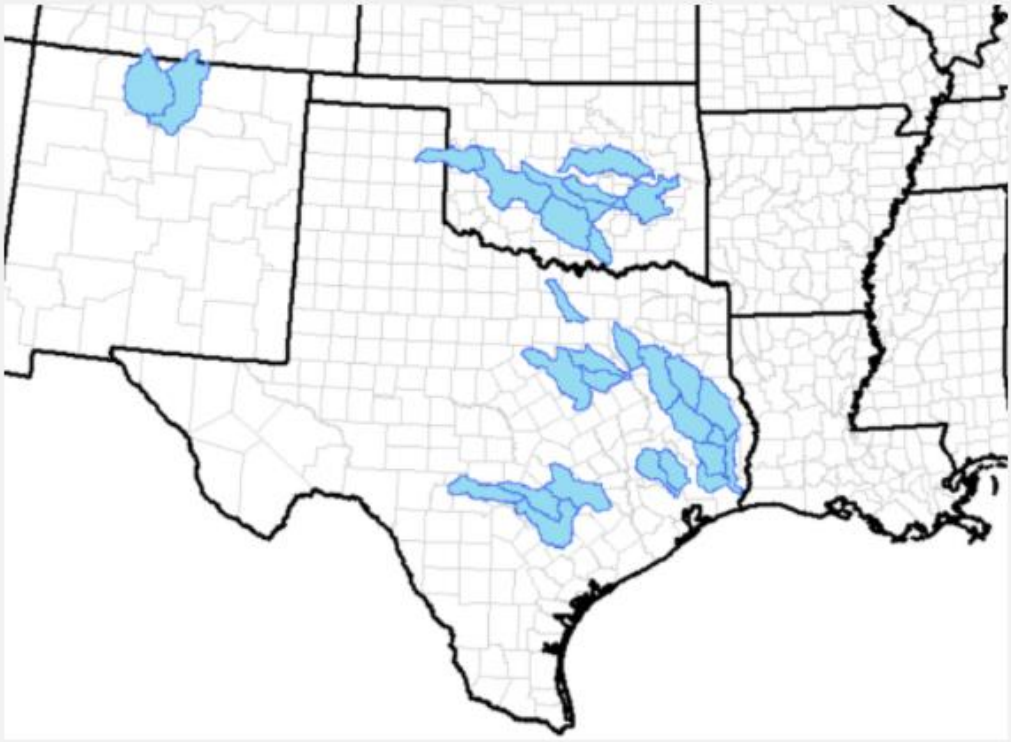


Figure 6: 28 HUC-08 watersheds where FIM maps were evaluated against BLE datasets.

Stream scale NWS flood inundation libraries

High quality inundation studies at NWS Advanced Hydrologic Prediction Service (AHPS) locations contain static floodmap libraries extending across a wide range of flows. These studies are available from NWS and USGS sources:

- NWS (https://water.weather.gov/ahps/inundation.php)
- USGS (https://fim.wim.usgs.gov/fim/).

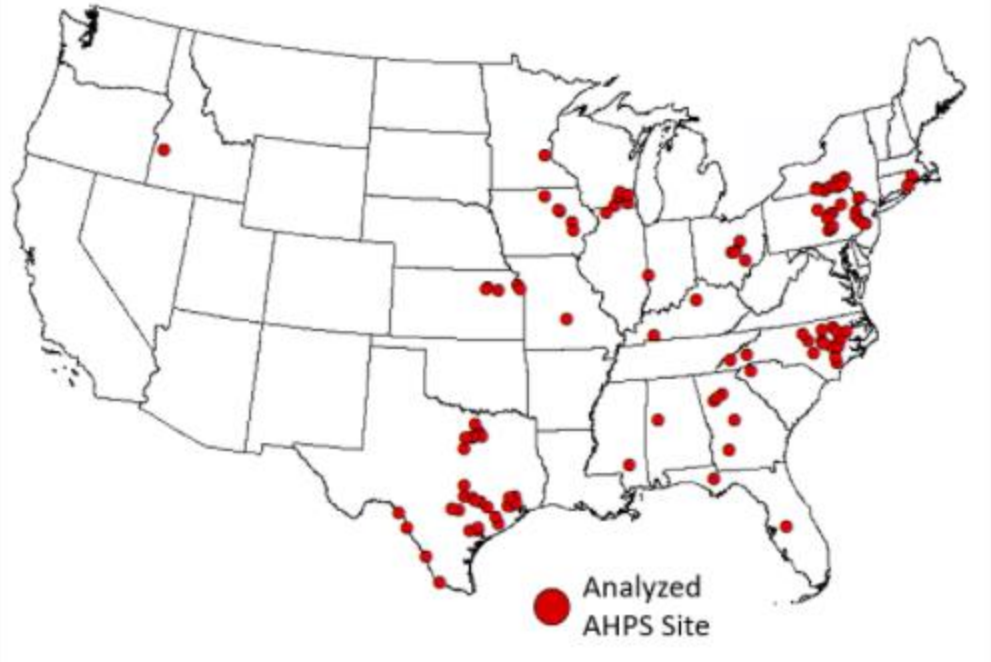


Figure 7: Location of 117 analyzed AHPS sites

For this evaluation HAND-based FIM maps for 117 AHPS sites were created using flows corresponding to action, flood, moderate, and major flood stages and were then compared to the AHPS static inundation library.

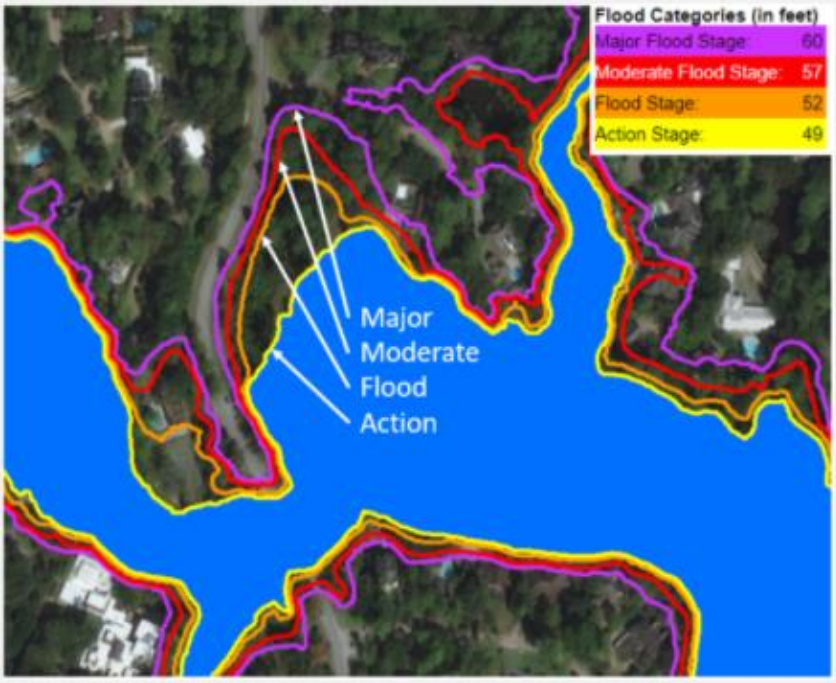


Figure 8: Example of Action, Flood, Moderate, and Major flood stages at an AHPS site

Results and Conclusion

FEMA BLE Evaluation

FIM maps evaluated against FEMA BLE datasets showed version-on-version improvement (FIM v1 vs FIM v2). FIM ability to match the benchmark dataset showed CSI approaching 0.60 for FIM v2 with the highest CSI scores occuring at the most severe flooding event (500 year).

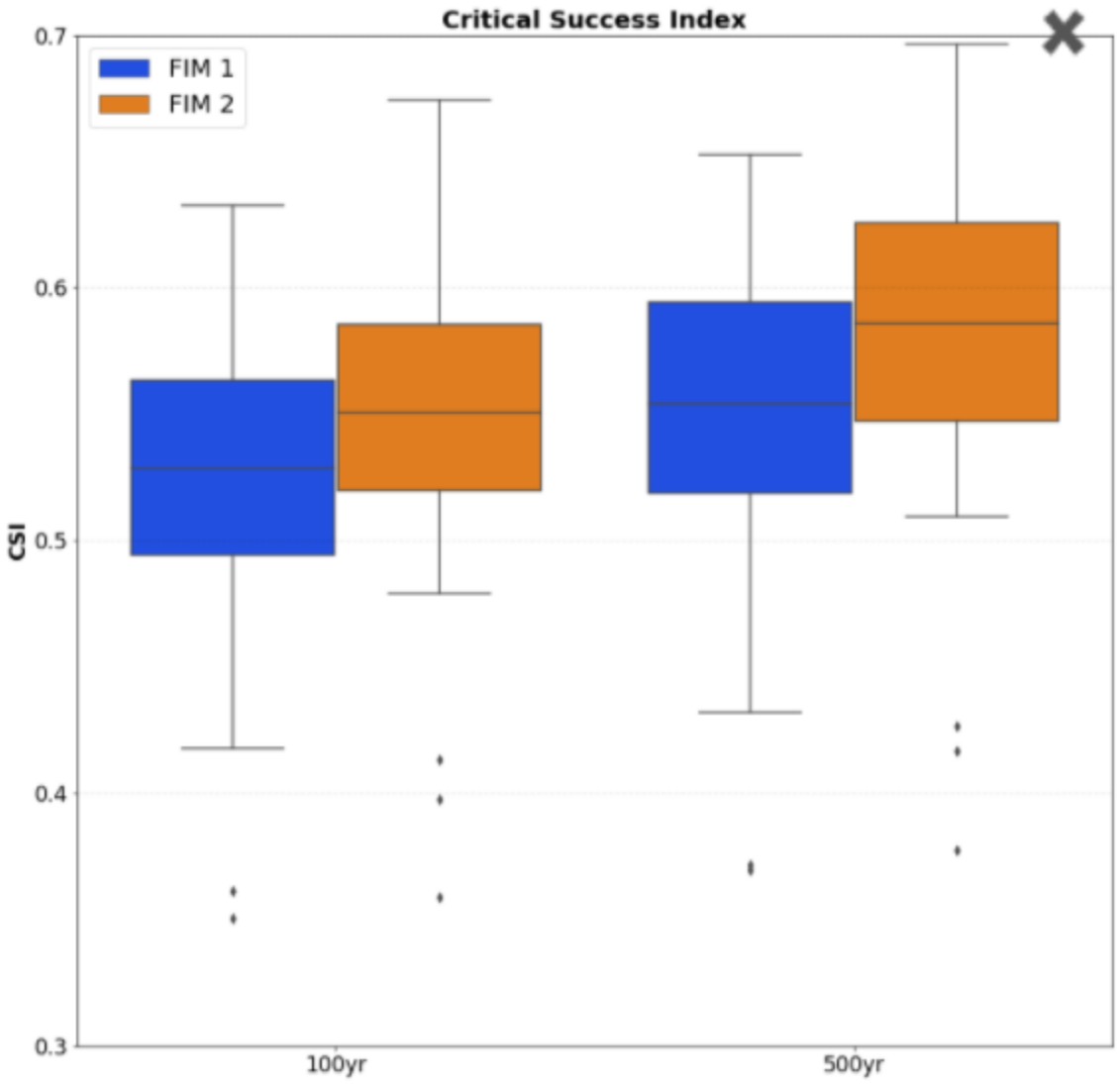


Figure 9: CSI scores for 28 HUC 08 watersheds using BLE as benchmark for the (100yr) and the 500yr flood events.

	1% Annual Chance		0.2% Annual Chance	
	FIM 1 Average	FIM 2 Average	FIM 1 Average	FIM 2 Average
CSI	0.52	0.55	0.55	0.57
FAR	0.20	0.18	0.18	0.16
POD	0.60	0.62	0.62	0.65

Figure 10: Mean CSI, FAR, and POD across all 28 HUC 08 watersheds.

AHPS Evaluation

FIM maps evaluated against NWS inundation libraries also showed version-on-version improvement (FIM v1 vs FIM v2). FIM ability to match benchmark datasets showed CSI approaching and even exceeding 0.6. Additionally, CSI scores increased as flood severity increased (action stage to major stage).

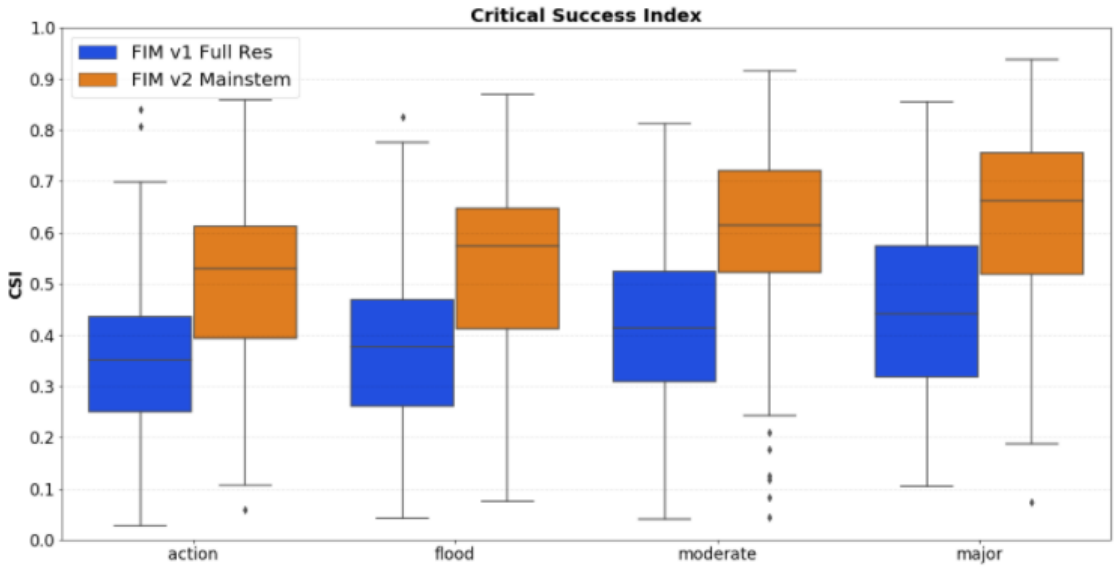


Figure 11: CSI scores across 117 AHPS locations with AHPS library as benchmark.

FIM v1 (FIM v2)	Action	Flood	Moderate	Major
CSI	0.35 (0.51)	0.38 (0.54)	0.42 (0.60)	0.45 (0.63)
FAR	0.58 (0.42)	0.51 (0.35)	0.42 (0.24)	0.34 (0.19)
POD	0.76 (0.85)	0.72 (0.82)	0.67 (0.78)	0.64 (0.76)

Figure 12: Average CSI, FAR, POD scores 117 AHPS sites.

Conclusion

These evaluation activities demonstrated that:

- NWC FIM achieved version-on-version improvement across both benchmark datasets.
- FIM reasonably matched benchmark datasets with FIM v2 CSI approaching and even exceeding 0.60.
- CSI scores improved as flooding severity increased.

Looking forward, these evaluations will be repeated to include FIM v3 to guide development efforts and to assess version-on-version performance.

Sources

Liu, Yan Y., et al. "A CyberGIS integration and computation framework for high-resolution continental-scale flood inundation mapping." JAWRA Journal of the American Water Resources Association 54.4 (2018): 770-784.

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