WATER-R2O
National Science Foundation
Research Traineeship

FastPLN: High-resolution Rapid Flood Mapping at Scale

Brodie Alexander[1], David Weiss[2], Xingong Li[3], Jude Kastens[2], Junho Song[4], James Halgren[5]

H23R-1458
Tue, 16 Dec 2025
14:15 - 17:45 CST

Abstract

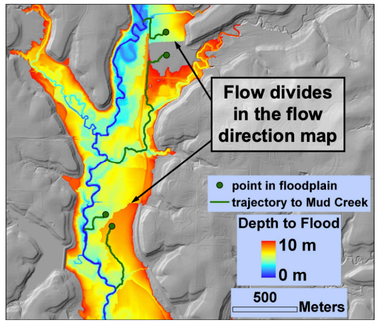
Recent catastrophic flood events have highlighted the need for reliable, accurate, and timely information about when, where, and to what extent flooding will occur. While many areas of hydrologic modeling and forecasting have been rapidly improving, Flood Inundation Mapping (FIM) remains constrained by limited accuracy and high computation cost of available models. To address these concerns, and to provide a path to high-resolution rapid FIM, we have developed **FastPLN: a Rust reimplementation of the mathematics and logic behind the University of Kansas' FLDPLN model.** The FastPLN model initializes a flood zone to be the pixels of a given stream reach and then **expands the flood boundary iteratively using a priority queue sorted by lowest cost to flood** until the maximum flood depth is reached. Because the cost function models backfill and spillover flooding, the outputs are entirely free of the discontinuities associated with backfill-only FIM models. The resulting maps are almost identical to those of the FLDPLN model while being 300-400x faster to compute.

Limitations of Existing Models

Height Above Nearest Drainage (HAND):

HAND is fast, but only models backfill flooding. Because of this, **HAND-based models struggle to accurately model flooding in areas with flow direction divides**. This usually manifests as sharp discontinuities along ridges where depth changes in blunt steps.

Because this feature of HAND-based models often shows up in flat, flood-prone areas, backfill flooding alone is insufficient

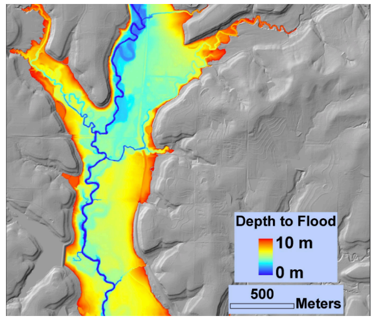


Discontinuities caused by flow direction divides (Jude Kastens et. al 2024)[2]

FLDPLN:

FLDPLN models backfill and spillover flooding, but has major up-front computational costs. Because of this, deployment of operational mapping in new areas can be delayed due to the lead time required to re-run the model when hydroconditioning changes are made in DEMs. Once this conditioning is done, **FLDPLN has been demonstrated to generate high quality FIM maps in near real-time[1].**

Additionally, **high memory usage means study area size is often limited by how much RAM is available on the host computer**.



FLDPLN map with discontinuities smoothed by spillover flooding (Jude Kastens et. al 2024)[2]

Methodology: A Recipe for Scalability

Starting from first principles, a spillover-aware static FIM model was written in Rust to implement the mathematical framework described by Jude Kastens et. al [2][3].

Selected portions of the FLDPLN source code were then ported from MATLAB to Rust in order to better match certain implementation specifics of how FLDPLN works.

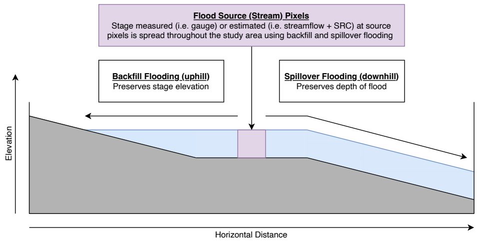
Various modifications were then made to this base model in order to achieve the following goals without violating the mathematical principles that make the model work.

- **simplify model operation**
- **increase computation speed**
- **reduce memory usage**

The resulting model is highly similar to FLDPLN, with a few key differences:

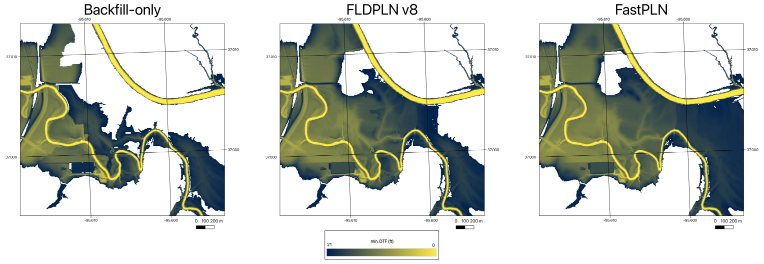
1. the flood boundary is expanded by pulling from a **priority queue** rather than expanding in discrete steps
2. raster data are stored in **sparse matrices**
3. backfill and spillover flooding happen **concurrently** rather than sequentially

While (2) serves mainly to reduce memory usage, the combination of (1) and (3) means that the most optimal location is always chosen for flood spreading, resulting in outputs which are fully free of discontinuities.



FLDPLN Mathematical Model

Preliminary Results



- FastPLN is around 300-400x faster than FLDPLN on identical hardware
- FastPLN is observed to calculate minimum Depth to Flood (DTF) values equal to or lower than FLDPLN for each pixel
- FastPLN obtains an equal or larger inundation extent than FLDPLN, with some preliminary results indicating possible downstream over-inundation
- Where FLDPLN outputs have some discontinuities up to the step size in magnitude, FastPLN outputs have no discontinuities at all

Runtime Comparison for Study Areas in Kansas

	Verdigris River	Osage River	Big Blue River
FLDPLN V8-B	5h 26m[1][Linux]	6h 29m[2][Win]	2h 37m[2][Win]
FastPLN	1m 35s[1][Linux]	1m 58s[2][Linux]]	1m 10s[2][Linux]

[1] = Intel i7-13700 / 64 GB RAM
[2] = Intel i9-13900K / 128 GB RAM
[Win] = Windows 11
[Linux] = Ubuntu 24.04

Future and Ongoing Goals

- Evaluate model accuracy against the FLDPLN model as well as real flood events
- Work with KU Team to integrate faster computational techniques back into FLDPLN
- Continue to explore routes for optimization of computational resource use
- Explore ways to improve DX of hydroconditioning DEMs
- Development of a GUI or integration into existing graphical tooling
- Explore and characterize methods of reducing downstream over-inundation

Conclusions

- FastPLN produces similar outputs to FLDPLN while taking an order of magnitude less time
- By using less memory, FastPLN enables running much larger datasets and better takes advantage of parallelism
- By using a priority queue to expand the flood boundary, FastPLN produces maps free of discontinuities while also reducing code complexity and repeated work
- Since FastPLN always expands through the least cost route, it allows flooding to spread further downstream than FLDPLN, causing over-inundation

Acknowledgements

- Kansas Applied Remote Sensing (KARS) FIM team for their support in obtaining, running, and understanding the FLDPLN model; access to DEM data for comparison runs; and interpretation and evaluation of model outputs
- Water R2O-NRT for financial support [see full statement below]

References

[1] *Kansas Inundation Mapping*. https://kars.ku.edu/pages/kansas-inundation-mapping

[2] Jude Kastens, Xingong Li, David Weiss, James Halgren, Jim Coll, Ken Ekpetere, Junho Song, Jack Edwards. (2024) *Operational Flood Inundation Mapping in Kansas & Implications for Water Infrastructure*. https://ceae.ku.edu/sites/ceae/files/documents/2024%20Environmental%20Conf/Operational%20Flood%20Inundation%20Mapping%20in%20Kansas%20%26%20the%20Implications%20for%20Water%20Infrastructure-%20Jude%20Kastens.pdf

[3] Jude Kastens. (2008). *Some New Developments on two Separate Topics: Statistical Cross Validation and Floodplain Mapping*. https://kuscholarworks.ku.edu/entities/publication/412fc4da-4fd8-4f22-b761-d1aab2b2fd99

[1]Department of Electrical and Computer Engineering, The University of Alabama, AL 35487
[2]Kansas Biological Survey & Center for Ecological Research, The University of Kansas, KS 66047
[3]Department of Geography & Atmospheric Science, The University of Kansas, KS 66047
[4]Alabama Water Institute, The University of Alabama, AL 35487
[5]Department of Civil and Construction Engineering, Brigham Young University, UT 84602

NSF
CIROH
The University of Alabama
Alabama Water Institute
Research What Matters Most

This project is supported by the National Science Foundation Research Traineeship (NRT), Research to Operations in Data-driving Hydrologic Forecasting and Decision-making (Water-R2O) (NSF Grant #2152140), at The University of Alabama

AGU25
New Orleans, LA | 15–19 December 2025