WebHLM: A Client-Side Web Environment for Hydrologic Modeling and Education

Gregory Ewing[1], Ricardo Mantilla[2], Witold Krajewski[1], and Ibrahim Demir[1]. (1) University of Iowa, Iowa City, IA, US; (2) University of Manitoba, Winnipeg, MB, CA.
Contact: Gregory-ewing@uiowa.edu

INTRO

- Client-side (i.e., JavaScript,) compute speeds now approach languages traditionally used for simulation and modelling (i.e., C Code.)
- These advances present an opportunity to leverage client-side compute for hydrologic simulation and modelling tasks.

METHODS

1. Implemented operational rainfall-runoff models using only modern web standards (i.e., JavaScript.)
2. Implemented an asynchronous, adaptive step size numerical solver with dense output interpolation, purpose-built for directed tree ODEs.
3. Compared JavaScript performance with C Code performance.
4. Developed interactive, in-browser user interface with iterative feedback from hydrology educators.

RESULTS

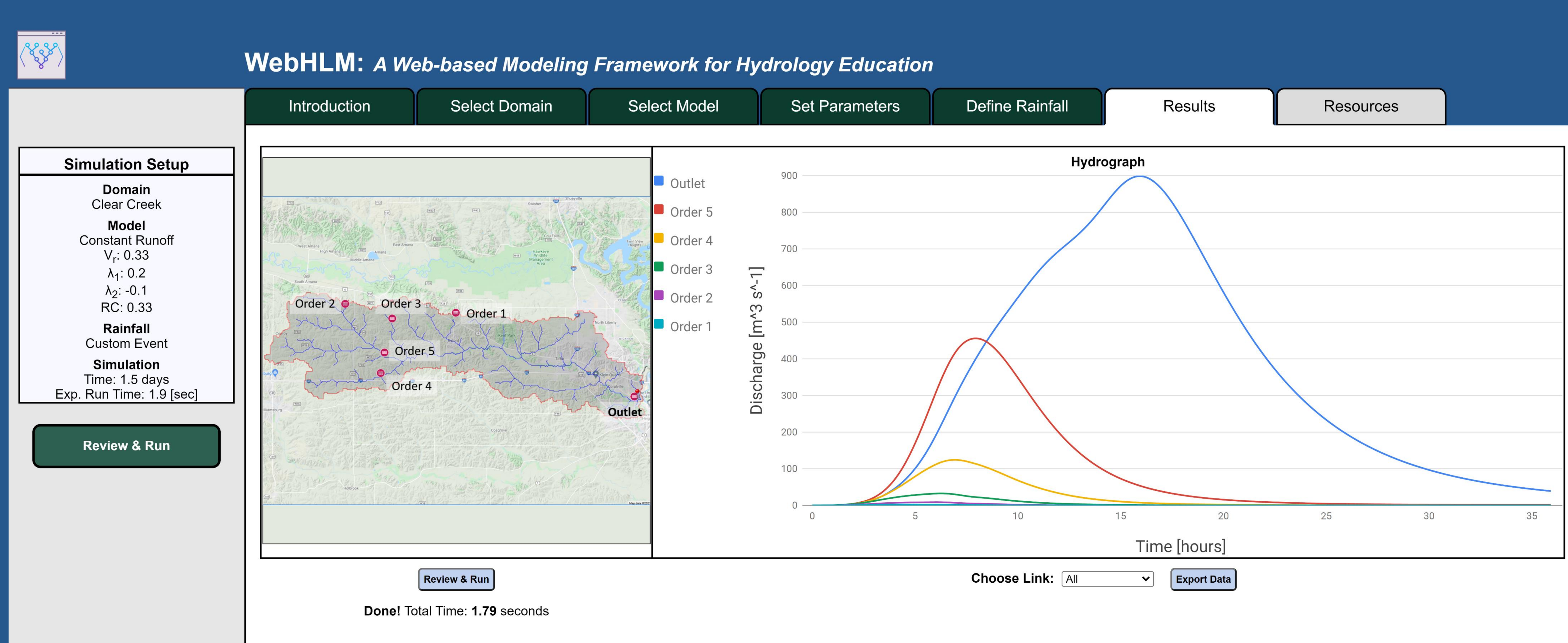
- All computation performed in-browser
- JavaScript code successfully replicates results from operational code
- JavaScript speed on the order of C Code (8:1)
- Capable of large-scale forecasting: 100 seconds (wall time) to simulate 3 weeks of a 12,600 Km^2 domain
- Currently used in hydrology course at two universities.

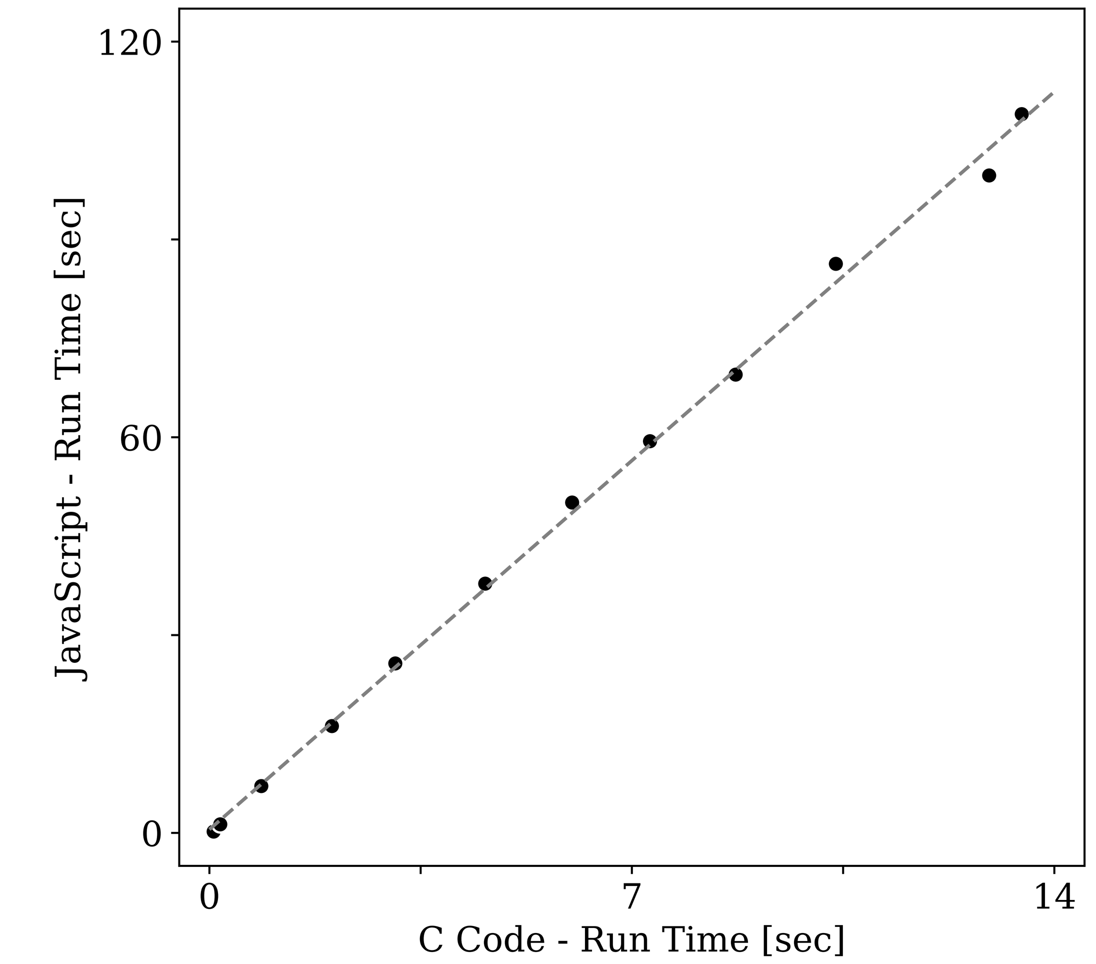
DISCUSSION

- Client-side simulation to play a central role in interconnected ecosystem of web-ready hydrologic tools
- Current version can support standalone client-side applications
- Future work will increase speeds via parallelization (Web Workers) and optimization (WebAssembly)
- Possible future where networked client machines perform large-scale, parallel computing tasks (e.g., forecasting and/or research)

Fast, large-scale hydrologic modelling is possible in modern web browsers, using only client-side compute resources.

Try our rainfall-runoff model, in any browser!

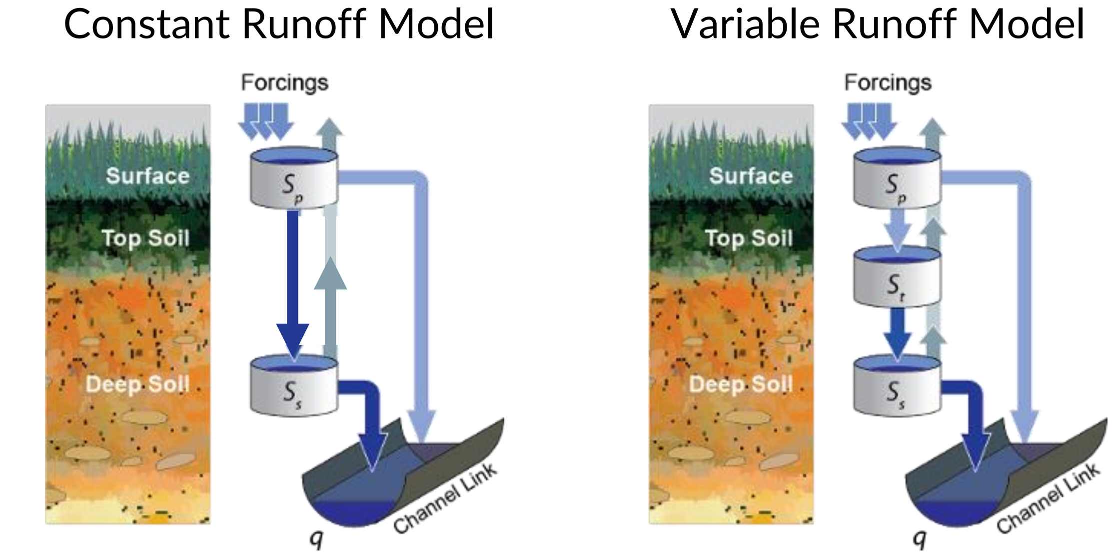




Simulations of river networks of increasing size and uniform rainfall forcing were used in both languages. All simulation runs simulate a 24-hour period. Simulation results are plotted with a linear regression line fitted to the data. The slope of the line is 8.0, R^2 = 0.99, and n = 12.

Watershed Area (Km^2)	Model Elements	Time Simulated (days)	Simulation Run Time (seconds)
10	60	1	0.2
104	772	1.5	1.3
640	4807	4	7.1
1700	11522	8	16.2
12600	81854	20	99.7

Constant Runoff Model   Variable Runoff Model



$$\frac{dq}{dt} = \frac{1}{\tau}\left(\frac{q}{q_r}\right)^{\lambda_1}\left(-q + (q_{pc} + q_{sc}) \cdot (A_h/60.0) + q_{in}(t)\right)$$
$$\frac{ds_p}{dt} = p(t) \cdot c_1 - q_{pc} - e_p$$
$$\frac{ds_s}{dt} = p(t) \cdot c_2 - q_{sc} - e_s.$$

State equations at each hillslope for the constant runoff model

Relevant Literature

Krajewski, W.F., Ceynar, D., Demir, I., Goska, R., Kruger, A., Langel, C., Mantillla, R., Niemeier, J., Quintero, F., Seo, B.C., Smallll, S.J., Weber, L.J., Young, N.C., 2017. **Real-time flood forecasting and information system for the state of Iowa**. Bull. Am. Meteorol. Soc. https://doi.org/10.1175/BAMS-D-15-00243.1

Mantilla, R., 2007. **Physical Basis of Statistical Scaling in Peak Flows and Stream Flow Hydrographs for Topologic and Spatially Embedded Random Self-similar Channel Networks Analysis** (Thesis).

Small, S.J., Jay, L.O., Mantilla, R., Curtu, R., Cunha, L.K., Fonley, M., Krajewski, W.F., 2013. **An asynchronous solver for systems of ODEs linked by a directed tree structure**. Adv. Water Resour. 53, 23–32. https://doi.org/10.1016/j.advwatres.2012.10.011

Iowa Flood Center, 2018. Iowa-Flood-Center/asynch: A numerical library for solving differential equations with a tree structure. **https://github.com/Iowa-Flood-Center/asynch**

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