Validation of a New GIS Tool to Rapidly Develop Simplified Dam Break Models

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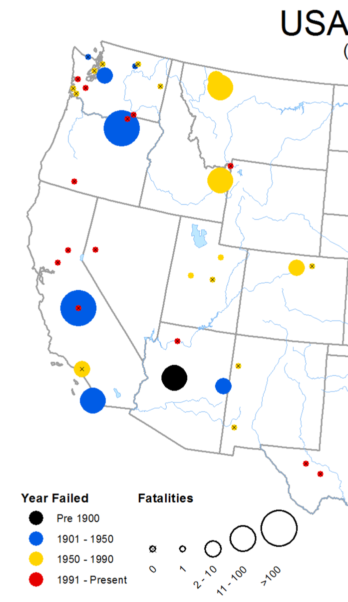
NWS and Dam Breaks

NWS Responsibility: Issue accurate and timely forecasts for floods resulting from dam failures to protect lives and property.

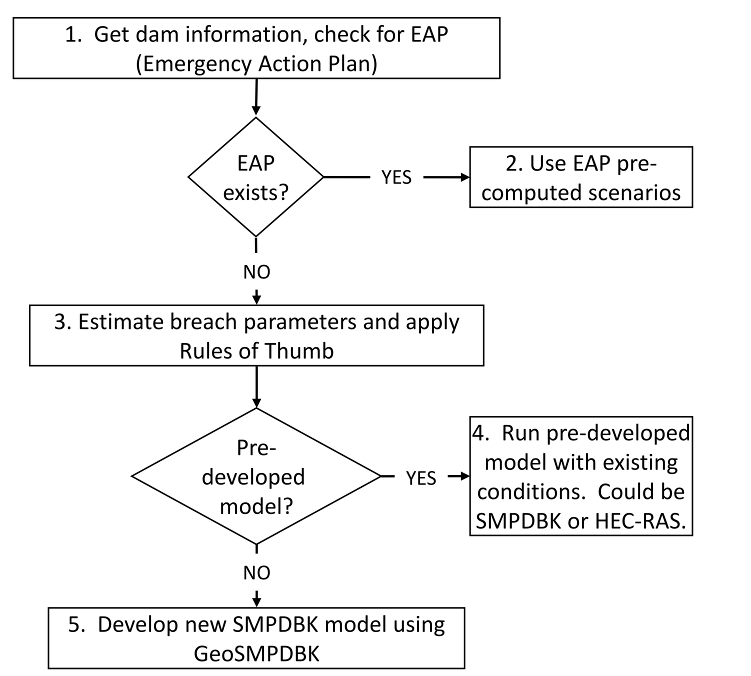


"From Jan. 1, 2005 through Jan. 1, 2009, state dam safety programs reported 132 dam failures and 434 "incidents" - episodes that, without intervention, would likely have resulted in dam failure." (ASDSO, 2011)

Existence of EAPs Reported in the 2009 National Inventory of Dams (NID)

	Failure or mis-operation will cause:	Number of Dams	No. of Dams with no Record of EAP	
Low Hazard	minimal property destruction	57,400	56,300	*98%*
Significant Hazard	significant property destruction	12,700	9,700	*76%*
High Hazard	loss of human life and significant property destruction	13,900	6,900	*50%*
	Total	84,000	72,900	*87%*

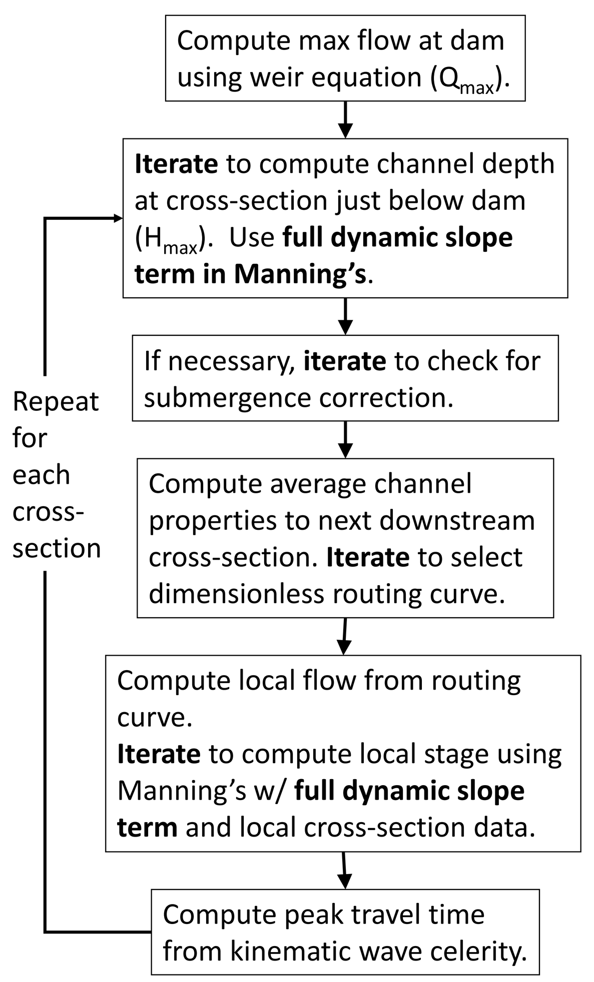
Recommended process to develop quantitative forecasts.



- 50% of high hazard dams have no record of an Emergency Action Plan in the 2009 NID.
- NWS needs the ability to produce quantitative forecasts for all dams that pose a risk to life or property.
- NWS forecasters pre-develop SMPDBK models for high priority dams when other models or model results (e.g. EAPs) are not available.
- SMPDBK Models can also be developed on-the-fly if necessary.
- GeoSMPDBK is a new GIS pre-processor to support SMPDBK model development.

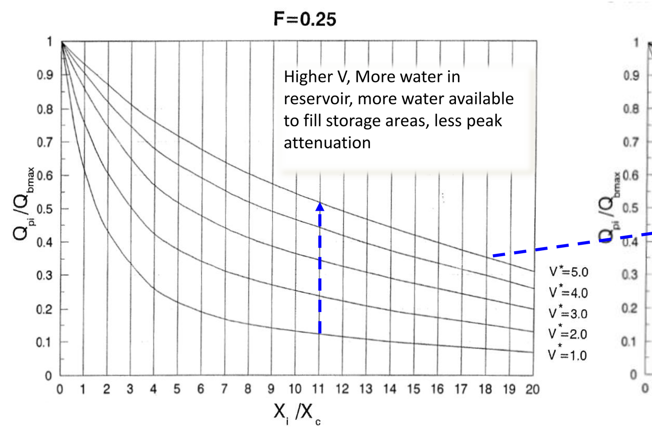
Simplified Dam Break (SMPDBK)

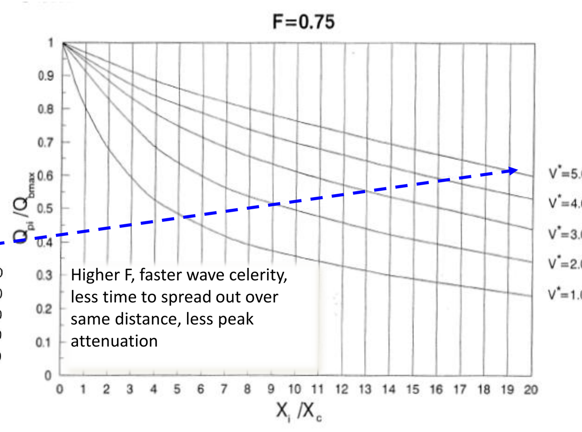
SMPDBK is simple to use but the underlying algorithms are not so simple:



SMPDBK Features

- Provides peak flows, peak depths, and time-to-peak at any downstream point
- Why simpler to use than dynamic 1D models?
  - Requires fewer cross-sections
  - Guaranteed stability
  - Does not require explicit upstream and downstream boundary conditions
- Key limitations
  - No backwater
  - No reservoir inflows during an event
  - Cannot model dams in series or downstream levees

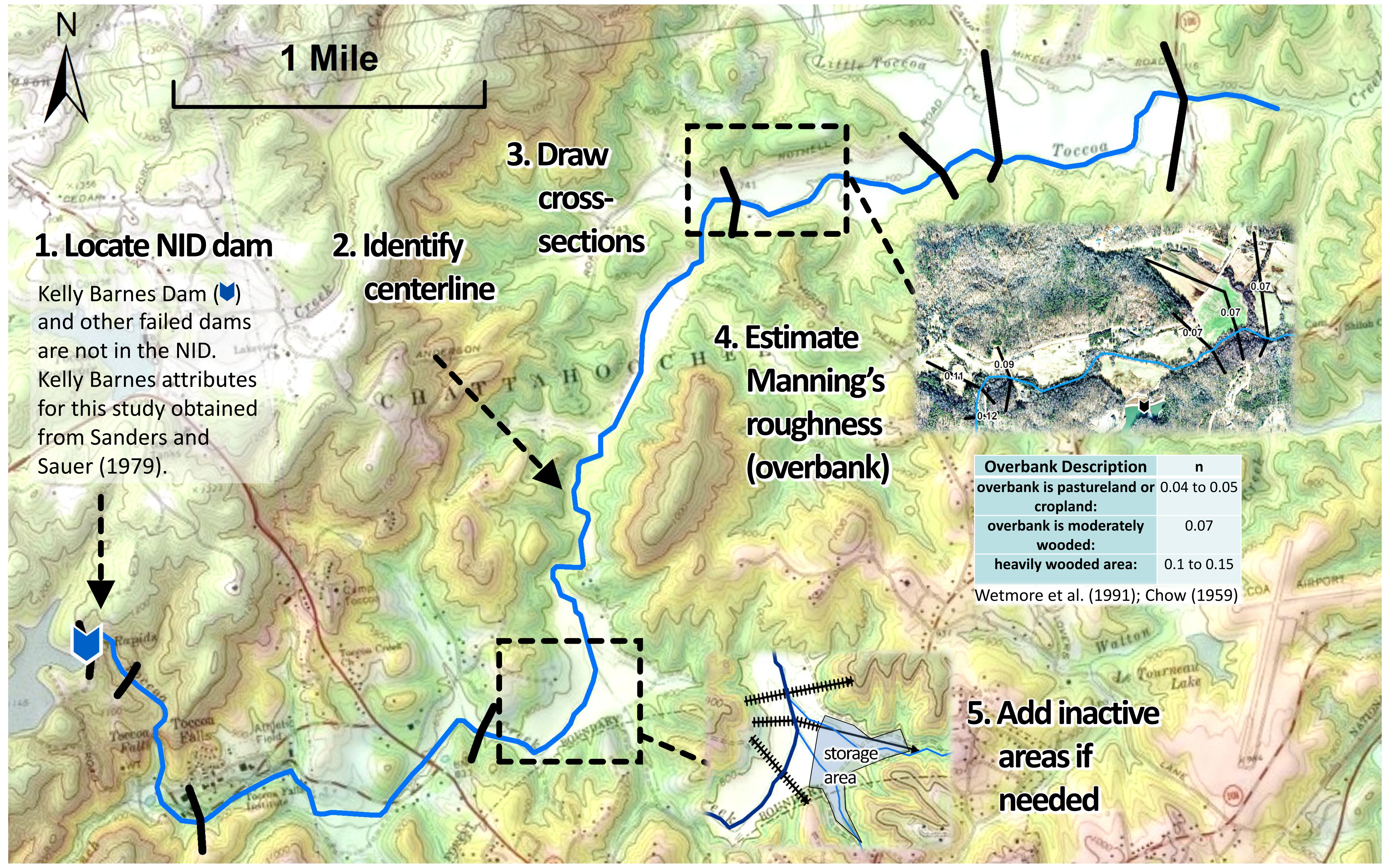




Dimensionless Routing Curves

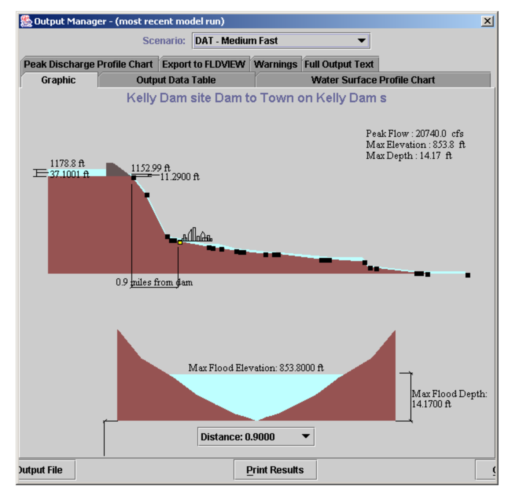
- Curves derived from full DAMBRK model used to estimate peak flow downstream
- Higher reservoir volume, less attenuation of peak flow
- Higher Froude (F) number, less attenuation of peak flow

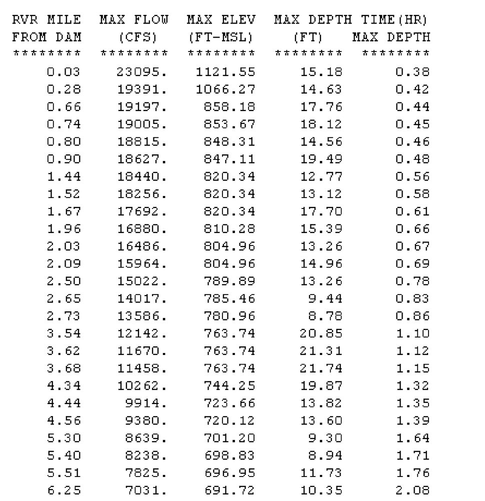
GeoSMPDBK: Rapid SMPDBK Model Development



6. Generate SMPDBK input file

7. Execute SMPDBK





GeoSMPDBK Features and Inputs

- Designed to build a SMPDBK model in less than 30 minutes
- Requires ArcGIS desktop with spatial analyst extension

Input	Default Source	Comments
NID	USACE	Provides dam type, height, and storage volume
Digital Topographic Maps	ESRI Web Mapping Service	Used for spatial reference and orientation
Imagery	ESRI Web Mapping Service	Used to estimate Manning's n
DEM	NHDPlus 30-m DEM	Any DEM can be used; more accurate DEM preferred where available
Stream lines	NHDPlus Hydrography	Any digital line work can be used to define flow path

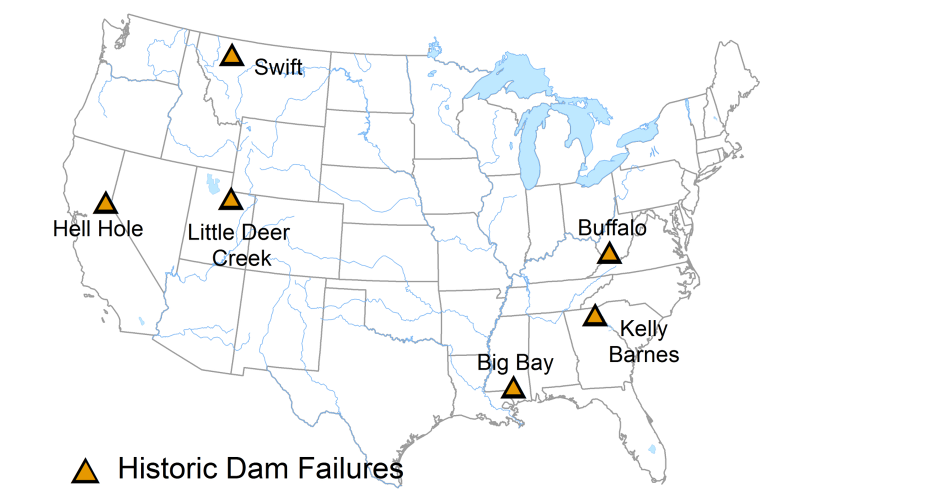
Hindcast Validation

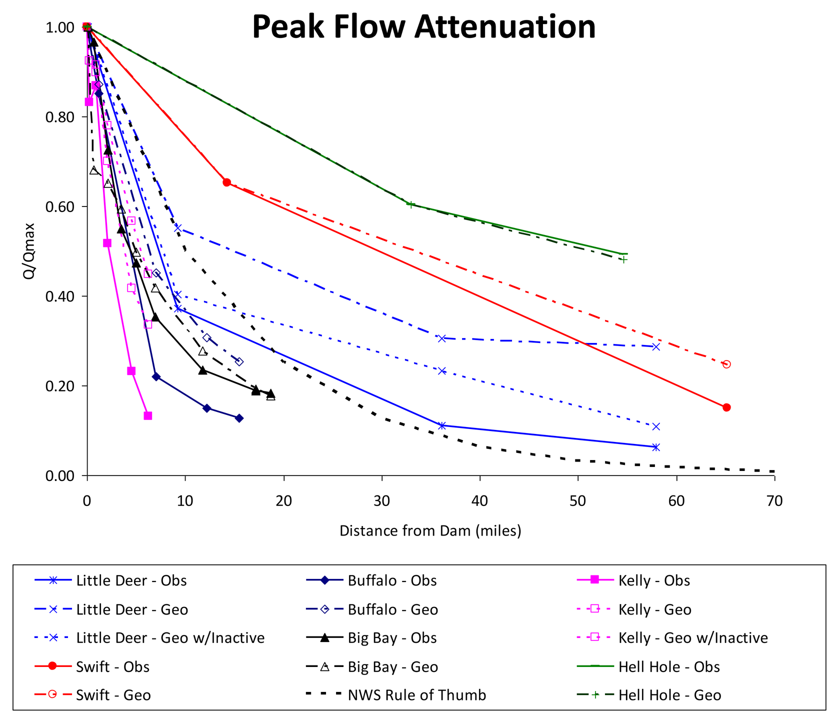
Validation Method

- Hindcasts used only forecast-available data (e.g. no post-event observed breach data was used)
- Breach parameters computed from empirical models
- Used only readily available DEM data
- Compared GeoSMPDBK to Rules of Thumb and observed data
- Performed no calibration against high water marks or other data

Historic Dam Failures Studied

Name	State	Year Failed	Dam Height (ft)	Water Level at Time of Failure (ft)	Volume in Reservoir prior to flood (acre-ft)	Primary Reference
Little Deer	Utah	1963	86.0	75.1	1,000	Rostvedt et al. (1968)
Swift Dam	Montana	1964	189.0	157.0	30,004	Boner and Stermitz (1964)
Hell Hole	California	1964	220.0	115.2	24,811	Scott and Gravlee (1968)
Buffalo Creek	West Virginia	1972	46.0	46.0	392	Davies et al. (1972)
Kelly Barnes	Georgia	1977	38.0	37.1	630	Sanders and Sauer (1979)
Big Bay	Mississippi	2004	51.3	44.5	14,200	Yochum et al. (2008)





Mean Absolute Flow Prediction Errors

	No. of Sections with Obs. Flow	Mean absolute percent error for flow prediction relative to observed			GeoSMPDBK Pct. Error/ Rules of Thumb Pct. Error	
		Rules of Thumb	GeoSMPDBK Initial	GeoSMPDBK w/ Inactive	Initial	w/ Inactive
Little Deer	*3*	49	274	127	5.59	1.51
Swift Dam	*2*	89	20		0.22	-
Hell Hole	*2*	94	13		0.14	-
Buffalo Creek	*4*	33	14		0.42	-
Kelly Barnes	*5*	109	67	39	0.62	0.54
Big Bay	*5*	29	16		0.60	-

Average Mean Absolute Percent Flow Error over 6 Dams:

- Rules of Thumb: 67%
- GeoSMPDBK-based models: 38% (using the results w/inactive areas where available)

Elevation Prediction Errors

Dam Name	River Station	HWM Elevation (ft)	Predicted Elevation (ft): GeoSMPDBK model with NHDPlus 30-m DEM	Predicted Elevation (ft): GeoSMPDBK Model with NED 10-m DEM	Error using 30-m DEM (ft)	Error using 10-m DEM (ft)
Kelly	D	1064.6	1074.6	1066.3	10.0	1.7
	E	845.5	853.8	847.1	8.3	1.6
	F	804.7	800.6	805.0	4.0	0.29
	G	715.8	717.5	720.1	1.7	4.3
Mean absolute error (ft)					**6.0**	**2.0**
Big Bay	495418	245.8	246.0	243.0	0.1	2.8
	489003	227.0	220.1	221.7	6.9	5.3
	480714	218.0	220.1	214.5	2.1	3.6
	471891	204.6	197.4	206.5	7.2	1.9
	461552	193.7	180.5	195.5	13.2	1.8
	435769	166.7	161.4	166.1	5.3	0.6
	406278	139.2	137.8	138.6	1.4	0.7
	398757	127.7	124.3	123.6	3.4	4.1
Mean absolute error (ft)					**4.9**	**2.6**

Note:All elevations are feet above NAVD 88.

More recent 10-m DEM from National Elevation Dataset (NED)

For comparison, detailed post-event analysis for Big Bay using HEC-RAS (Yochum et al. 2008) yielded an average error of 0.9 ft.

Conclusions

- GeoSMPDBK is a new, robust, and efficient tool for NWS forecasters to develop SMPDBK model inputs (either in advance of or during emergencies).
- Even with relatively coarse 30-m DEM data, GeoSMPDBK substantially improves upon Rules of Thumb for flow prediction.
- For elevation predictions, results using a more accurate 10-m DEM substantially improve on results from the NHDPlus 30-m DEM.
- A more detailed post-event model can further improve elevation predictions, but we cannot conclude from this study if these post-event gains can be realized in forecast mode.

Recommended Future Work

- Add flood mapping capability to GeoSMPDBK.
- Develop a server-based version of GeoSMPDBK.
- Reduce reliance on old SMPDBK science by partnering with FEMA, USACE, USGS, Bureau of Reclamation, USDA and others on dam break model sharing and model building tools.