Assessing residential property values at risk to federally-overlooked flooding: The case of Utah, USA

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1. Introduction

Flooding is the costliest disaster globally as well as in the U.S., and flood events have been increasing in magnitude and frequency due to climate change (Swain et al., 2020). Critical to mitigating the impacts of floods is understanding where they are likely to occur through flood inundation mapping. In the U.S., the Federal Emergency Management Agency (FEMA) creates these maps to delineate Special Flood Hazard Areas (SFHAs) in official Flood Insurance Rate Maps (FIRMs) as areas with a predicted 1% annual chance of flooding. These maps are used to regulate flood insurance requirements and rates through FEMA's National Flood Insurance Program (NFIP) and to guide flood hazard mitigation.

To create FIRMs, FEMA commissions small scale maps using hydrological and historical flood data. The process of creating and revising these maps is costly and time consuming (U.S. House of Representatives, 2020), leading to large coverage gaps. FEMA has mapped only one third of the nation's streams and rivers for flood risk, and many counties lack digitized flood maps or have ones that have not been updated this century (Association of State Floodplain Managers, 2020). Additionally, FEMA only maps fluvial and coastal flood risks, not measuring the threat of pluvial flooding, which is the most common type of flooding in the U.S. As these maps inform floodplain management decisions and guide the NFIP, a lack of accurate coverage has substantial impacts on flood risk management. FEMA has made recent improvements, including moving away from their binary (presence/absence) model to one that depicts risk levels, however, the core cost and time challenges to making and updating their maps remain.

Recent advances in computational capacities have supported new approaches to flood modeling using fine-scale data for large areas, allowing for the development of more accurate, comprehensive, and current flood risk maps than those created by FEMA. One of the leading models was produced by Bates et al. (2021), which covers the U.S. at a 10-meter resolution and integrates hydrological process modeling

with fine-scale data on hydrological features, terrain, and flood defense infrastructure to estimate flood risk. Multiple studies have validated this model (Sampson et al., 2015; Wing et al., 2017).

Utah exhibits the largest difference in the number of properties at risk between the Bates et al. (2021) and FEMA models of any U.S. state by a large margin (First Street Foundation, 2020), suggesting it is the state where the FEMA flood maps may be the most inadequate (First Street Foundation, 2020). The combination of large discrepancies between FEMA and Bates et al. (2021) flood predictions and Utah having the fastest growing population indicates that an expanding number of people and their Utah homes are at substantial, yet mostly unrecognized, risk of flooding. To date, however, no published studies have comprehensively assessed flood risks in Utah. Additionally, most studies that have critically assessed FEMA flood maps have only examined impacts from past flood events or proportions of areas or populations at risk (Messager et al., 2021), but have not evaluated risks to buildings. In this study, we assess the number of residential properties in Utah that have buildings at flood risk based on multiple maps created using the FEMA and Bates et al. (2021) flood models. Additionally, we estimate the monetary value of these buildings and compare them to the monetary value of residential property covered by NFIP policies. We focus on Utah flood risk only, with our analysis broken down by county.

2. Methods

We utilized a combination of data sources and methods to assess flood risk. We used FEMA digital FIRMs along with Bates et al. (2021) maps, both of which depict 100-year flood risk, to create six flood risk maps (Table 1 and Figure 1). We obtained land parcel data from the state and counties. These data were collected from 24 of the 29 Utah counties. We could not obtain digital parcel data from five smaller Utah counties, which together contain <1.4% of the state's population. Those counties were excluded from the study. The parcel datasets included assessed U.S. dollar (USD) values for 22 Utah counties. We also obtained data on all active Utah flood insurance policies with coverage through the NFIP from FEMA. All building and NFIP policy monetary values were adjusted to 2024 USD values.

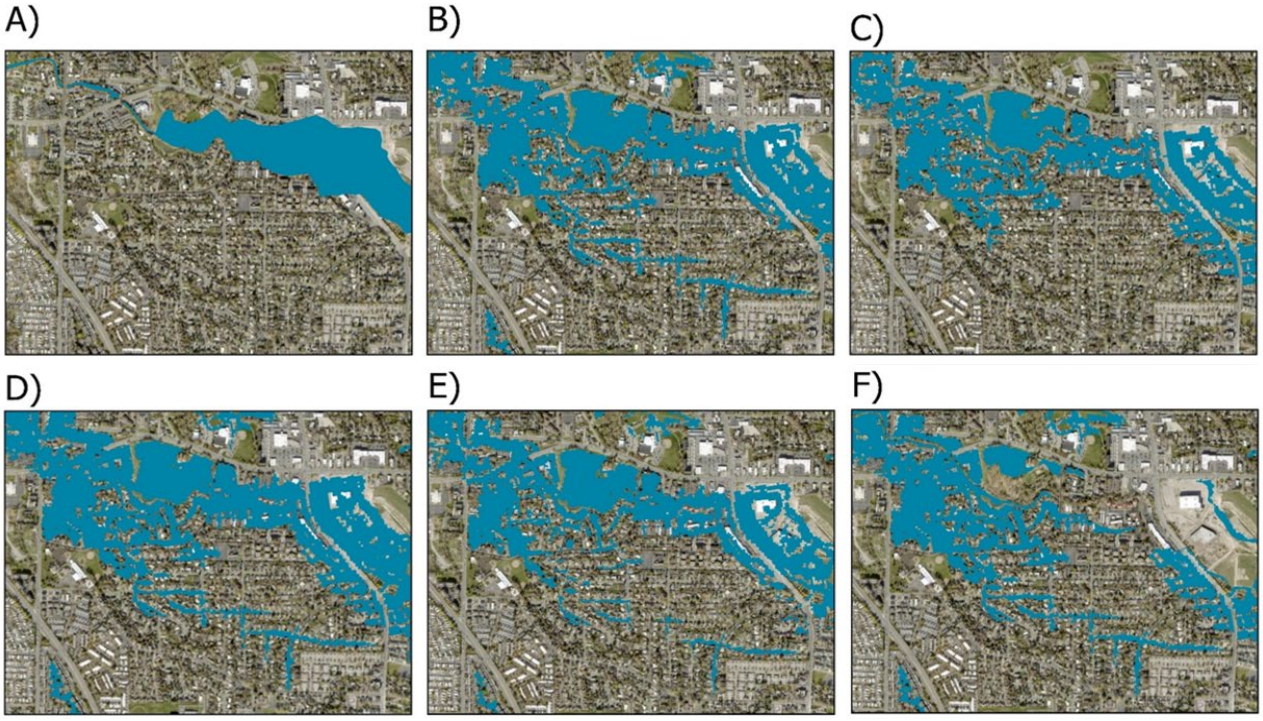
Additionally, we produced a building footprint map to measure flood risk to buildings as precisely as possible. Most building footprints came from a layer created by Microsoft (2019) using

imagery from year-2018. We supplemented this layer for the four most populous counties (Salt Lake, Utah, Davis, and Weber) by creating updated building footprints using high resolution imagery and an existing machine learning model. We then used the footprint layer to identify the residential parcels of land in each of the six maps that had buildings in areas at risk of 100-year flooding. The impacted parcels were analyzed to estimate counts of residential parcels with buildings at risk of flooding based on each flood map by county, as well as the associated assessed monetary values at risk.

Table 1. Detailed descriptions of flood risk maps.

Map name	**Description**
FEMA 100 year	FEMA flood risk map showing areas with a predicted 1% annual flood risk
Bates pluvial	Bates et al. (2021) map of Utah showing areas with pluvial flood risk with a 100-year return interval
Bates fluvial	Bates et al. (2021) map of Utah showing areas with fluvial flood risk with a 100-year return interval
Bates combined	Bates et al. (2021) map of Utah showing areas with any fluvial or pluvial flood risk with a 100-year return interval
Bates damaging combined	The Bates et al. (2021) combined map filtered to only include areas with predicted 100-year flood depths of ≥30 cm
Federally-overlooked	Areas at risk using the combined Bates et al. (2021) map that are not at 100-year flood risk according to the FEMA map

Figure 1. Section of Salt Lake County showing. (A) FEMA, (B) Bates pluvial, (C) Bates fluvial, (D) Bates combined, (E) Bates damaging combined, (F) Federally-overlooked flood risk maps.



3. Results

As shown in Table 2, 5.5% (or 52,106) of Utah's residential properties have buildings at predicted risk to damaging 100-year flooding (≥30 cm in depth) based on the Bates et al. (2021) combined model with 8.8% (83,736) at predicted risk to flooding of any depth. Only 0.7% (6,215) of residential properties in Utah have buildings at predicted flood risk based on FEMA maps. Thus, there are ~13.5 times as many residential parcels with buildings at risk in the Bates et al. (2021) map compared to the FEMA maps statewide. The largest discrepancies between the counts of residential properties with buildings at risk based on the Bates et al. (2021) combined map vs. the FEMA maps are in the rapidly growing Wasatch Front counties. In Davis County, there are 50 times as many residential parcels with buildings at 100-year flood risk in the Bates et al. (2021) map vs. the FEMA maps, and Utah (18 times), Weber (17 times), Tooele (15 times) and Salt Lake (14 times) counties also exhibit large discrepancies.

In terms of federally-overlooked flood risk, 8.7% (82,224) of Utah's residential parcels have buildings at risk of flooding beyond FEMA SFHAs as per the Bates et al. (2021) combined map, which is alarming. A comparison of Utah's residential properties with buildings at predicted risk to Bates et al. (2021) pluvial vs. fluvial flooding reveals a key limitation of the FEMA maps. The count of residential properties with buildings at risk to pluvial flooding is twice that at risk to fluvial flooding statewide as per Bates et al. (2021), and the pattern of more pluvial than fluvial flood risk applies to all but four Utah counties (Table 2). While FEMA maps are designed to measure Utah's fluvial flood risks, results from our analysis indicate that by not accounting for pluvial flood risks, FEMA maps may dramatically underestimate the overall threat of flooding to Utah's residential properties.

Across the 22 Utah counties for which we had assessed values of residential buildings, there is over 26.6 billion USD in non-land residential property value at risk to damaging flooding (Table 2). The total amount of residential property value covered by active NFIP policies in those 22 Utah counties is USD 1.6 billion. Therefore, less than 6.0% of the non-land residential property value at risk to damaging flooding as per Bates et al. (2021) in Utah is covered under the NFIP.

Table 2. Results showing (A) the count of residential parcels with buildings at risk, and (B) the percentage of residential parcels with buildings at risk for each map. Assessed non-land property value at-risk of damaging floods are shown in millions of 2024 inflation adjusted USD.

	Bates Damaging		Bates Combined		Bates Fluvial		Bates Pluvial		Federally Overlooked		FEMA		Assessed Value (in millions 2024 USD)	NFIP Building Insured Value (in millions 2024 USD)
County	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**		
Beaver	68	2.88%	128	5.43%	65	2.76%	101	4.28%	128	5.43%	Not Mapped		17.74	0.58
Box Elder	651	4.37%	1028	6.90%	130	0.87%	949	6.37%	1017	6.83%	138	0.93%	178.18	11.65
Cache	870	2.54%	1378	4.02%	420	1.22%	1168	3.40%	1312	3.82%	287	0.84%	267.72	32.82
Carbon	260	2.79%	1190	12.75%	218	2.34%	1084	11.62%	1067	11.44%	409	4.38%	48.60	8.44
Davis	6306	6.07%	9349	8.99%	1926	1.85%	8056	7.75%	9312	8.96%	185	0.18%	3189.46	220.49
Duchesne	236	4.75%	338	6.80%	278	5.59%	129	2.60%	338	6.80%	Not Mapped		44.12	1.47
Garfield	67	4.48%	338	22.58%	257	17.17%	102	6.81%	338	22.58%	Not Mapped		8.96	4.50
Grand	116	3.50%	177	5.34%	104	3.14%	140	4.23%	152	4.59%	135	4.07%	34.55	31.69
Iron	1205	7.00%	2019	11.73%	414	2.41%	1834	10.66%	2019	11.73%	0	0.00%	410.33	31.92
Juab	164	4.54%	472	13.07%	378	10.47%	155	4.29%	466	12.90%	37	1.02%	20.90	2.07
Kane	164	5.50%	215	7.21%	52	1.74%	212	7.11%	215	7.21%	Not Mapped		42.13	10.91
Millard	95	2.29%	230	5.55%	110	2.65%	154	3.71%	230	5.55%	Not Mapped		28.00	6.37
Morgan	437	11.52%	562	14.81%	211	5.56%	537	14.15%	544	14.33%	129	3.40%	226.26	14.60
Piute	49	18.28%	72	26.87%	9	3.36%	71	26.49%	72	26.87%	Not Mapped		6.20	2.06
Salt Lake	16321	5.18%	27403	8.70%	14382	4.57%	16879	5.36%	26934	8.55%	1875	0.60%	8133.93	555.51
San Juan	39	1.88%	50	2.41%	11	0.53%	45	2.17%	50	2.41%	Not Mapped		5.76	1.92
Sevier	53	1.42%	517	13.88%	484	12.99%	67	1.80%	497	13.34%	52	1.40%	No Data	No Data
Summit	1426	10.64%	1813	13.53%	326	2.43%	1733	12.93%	1692	12.62%	341	2.54%	241.74	142.64
Tooele	972	4.53%	1401	6.53%	141	0.66%	1301	6.06%	1397	6.51%	94	0.44%	202.76	20.38
Uintah	231	2.36%	374	3.82%	85	0.87%	323	3.30%	296	3.03%	294	3.01%	No Data	No Data
Utah	13149	5.93%	21139	9.53%	8372	3.78%	15021	6.78%	20888	9.42%	1116	0.50%	9624.86	254.74
Wasatch	345	2.55%	422	3.12%	30	0.22%	420	3.10%	411	3.03%	47	0.35%	141.98	46.35
Washington	1734	2.89%	2395	4.00%	316	0.53%	2191	3.66%	2271	3.79%	451	0.75%	974.47	78.17
Weber	7148	8.77%	10726	13.15%	2099	2.57%	9253	11.35%	10578	12.97%	624	0.77%	2813.02	115.45
State Total	52106	5.49%	83736	8.83%	30818	3.25%	61925	6.53%	82224	8.67%	6215	0.66%	26661.67	1594.69

4. Discussion and Conclusion

At state and county levels in Utah, a substantial proportion of the flood risks to buildings on residential properties identified with Bates et al. (2021) maps are overlooked by FEMA maps. Since flood risks in these locations are unrecognized by FEMA, people who reside there are (a) not required to maintain flood insurance and (b) likely unaware that they are at risk of flooding.

While our economic assessment does not assess all predicted economic costs associated with 100-year flooding, our findings show a substantial amount of residential building value at risk of flooding, with a small proportion of that amount covered under the NFIP. A flood at the lower bound of potentially "damaging" (i.e., ~30 cm) may not destroy a home, yet may cause severe damage and substantial recovery costs. Based on FEMA's flood loss estimates of average homes due to 30cm of flooding, the predicted damage cost in Utah (based on Bates combined damaging flood risk map) is over 2 billion dollars from 100-year floods and over 20 million each year (FEMA, 2023).

Our use of building footprints to estimate the flood risk to buildings is a major contribution, as land within a parcel may be within a flood zone while buildings may not. The high-resolution Bates et al. (2021) flood data that we used in connection with the building footprint data produced more precise risk estimates than we could have generated using the FEMA maps. We specifically examined residential properties, however similar methods could be used to assess the risk of flooding to critical infrastructure such as medical, first responder, and educational structures. We plan to extend this novel flood risk assessment approach within and beyond Utah.

Our study has limitations that should be addressed via future research. The use of building footprints to assess flood risks provides a critical improvement vis-à-vis prior research, however, because we delineated footprints with machine learning, error is inherent. Additionally, these methods identify all buildings on residential properties, capturing risks to houses as well as other buildings. Finally, our results are only as accurate as the source data. While we have no reason to believe that there are widespread errors in the parcel data, a small number of parcels may have misclassified or missing data.

We have shown that Utah has a substantial number of residential properties with buildings at risk of flooding, with an extremely high proportion of those building-level flood risks being overlooked by FEMA. This large amount of unrecognized flood risk may lead to substantial under preparation for flooding at state, local and household levels. The fact that the FEMA flood mapping approach does not adequately account for pluvial flooding is of major concern. Additionally, the state of Utah communicates flood risk to the public using FEMA's flood maps, which do not exist for 12 out of Utah's 29 counties and inadequately represent flood risks elsewhere. Based on our findings, the information Utahns are being given to orient their flood risk planning decisions is inaccurate and leaves substantial portions of the state with no information at all.

As flood risks are expected to increase and the population of Utah continues to grow, we recommend that Utah utilizes more accurate mapping to communicate and plan for flooding. Flood risk assessments at the level of the individual residence based on Bates et al. (2021) maps are available for free online and could be used by the state to communicate flood risk with the public. Along with improved flood risk communication, it is critical that communities have access to state-of-the-science flood risk maps when zoning new developments and planning for floods.

Overall, we have shown large discrepancies between FEMA and Bates et al. (2021) estimates of flood risk in Utah, suggesting that the knowledge orienting human adjustment to flood risk statewide is currently inadequate. Embracing new knowledge from emerging advances in the science of flood risk assessment would greatly increase Utahns' capacities to create policies and programs that successfully mitigate the impacts of flooding.

5. References

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