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Effects of Digital Elevation Model Resolution on Estimates of Flood Damage in Westbrook, Maine

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Abstract

Accurate predictions of flood damage and economic losses are increasingly important as historically low-probability floods have become more common. Digital elevation models (DEMs) are essential to flood modeling as they define stream channel and floodplain morphology, the accuracy of which influence estimates of flood damage. The city of Westbrook, Maine experiences episodic flooding of the Presumpscot River; therefore, flooding in Westbrook was simulated with HAZUS, a model created by the Federal Emergency Management Agency. The model is designed to assess the costs associated with hazard scenarios including riverine flooding. HAZUS was run for a 100-year return period flood with both 1/3 arc-second (10 m) and 1 arc-second (30 m) DEMs. The 1/3 arc-second DEM represents the highest resolution currently available for the study area. Preliminary results, based on a census-block-level structure inventory provided with the model, suggest that DEM resolution has a significant impact on damage and economic loss estimates that vary by census block and structure type. Further modeling using parcel-level inventory data for Westbrook will refine these results.

Westbrook and the Presumpscot River

The economy of Westbrook, Maine has centered historically on the mill industry and transportation corridor associated with the Presumpscot River. From its founding in the 19th century wood and other products have been produced and transported through Westbrook.

The river drops 15 m (from 23 m to 8 m) along its 10 km course through the city. Saccarappa Falls and Congin Falls provided water power for early mills and dams were constructed later as the mill industry in the city flourished.

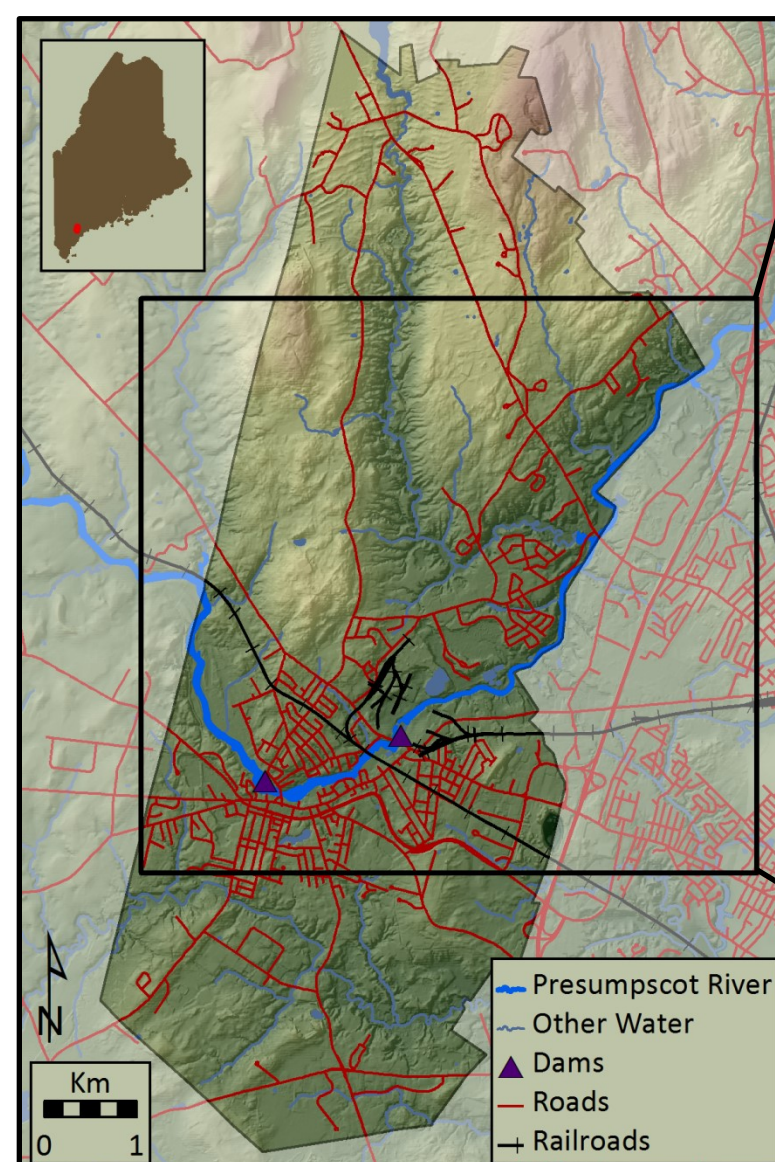


Figure 1: Westbrook, Maine.

Presumpscot River Flooding in Westbrook

The Presumpscot River occasionally floods the city of Westbrook, but in recent decades the frequency of flooding has increased (Figure 2), including the 1996 500-year flood with a volume 68 percent greater than any other recorded event in the 20th century for Westbrook (Hodgkins and Stewart, 1997). Therefore, accurate modeling of the extent, depth, and geography of the floodplain, as well as an accurate inventory of the property, people and activity in the flood zone are increasingly important for emergency preparedness and response. Fast moving water, inundated homes, and impassable roads (illustrated in Figure 3 for the flood of February 2010) represent three flood-related hazards.

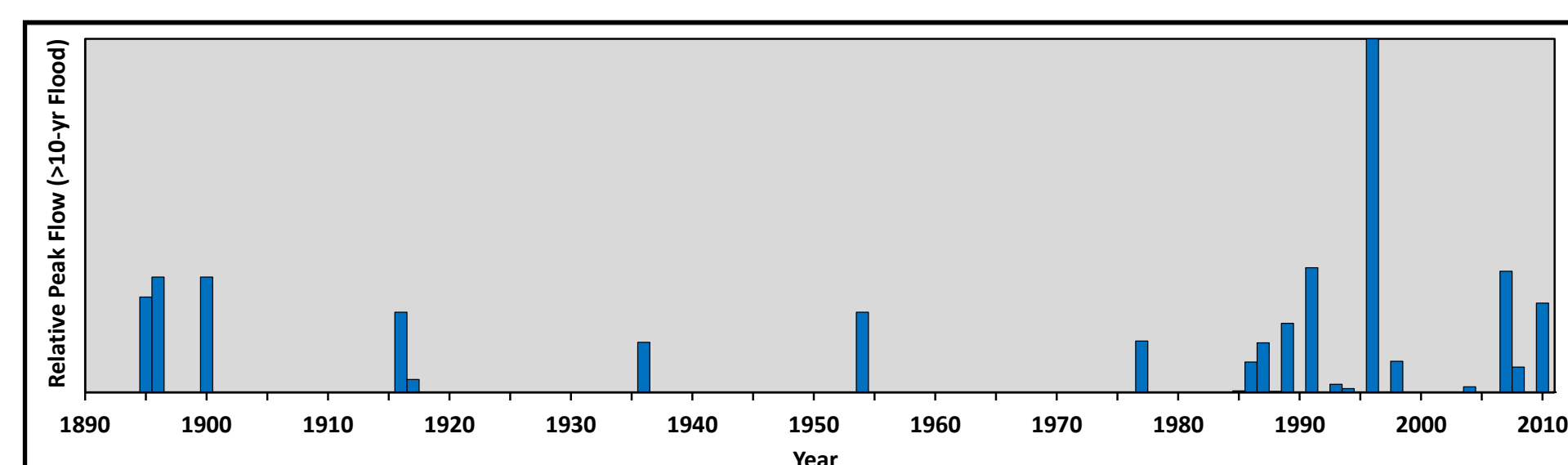


Figure 2: Occurrences and relative peak flows of ten-year or greater floods of the Presumpscot River at Westbrook.

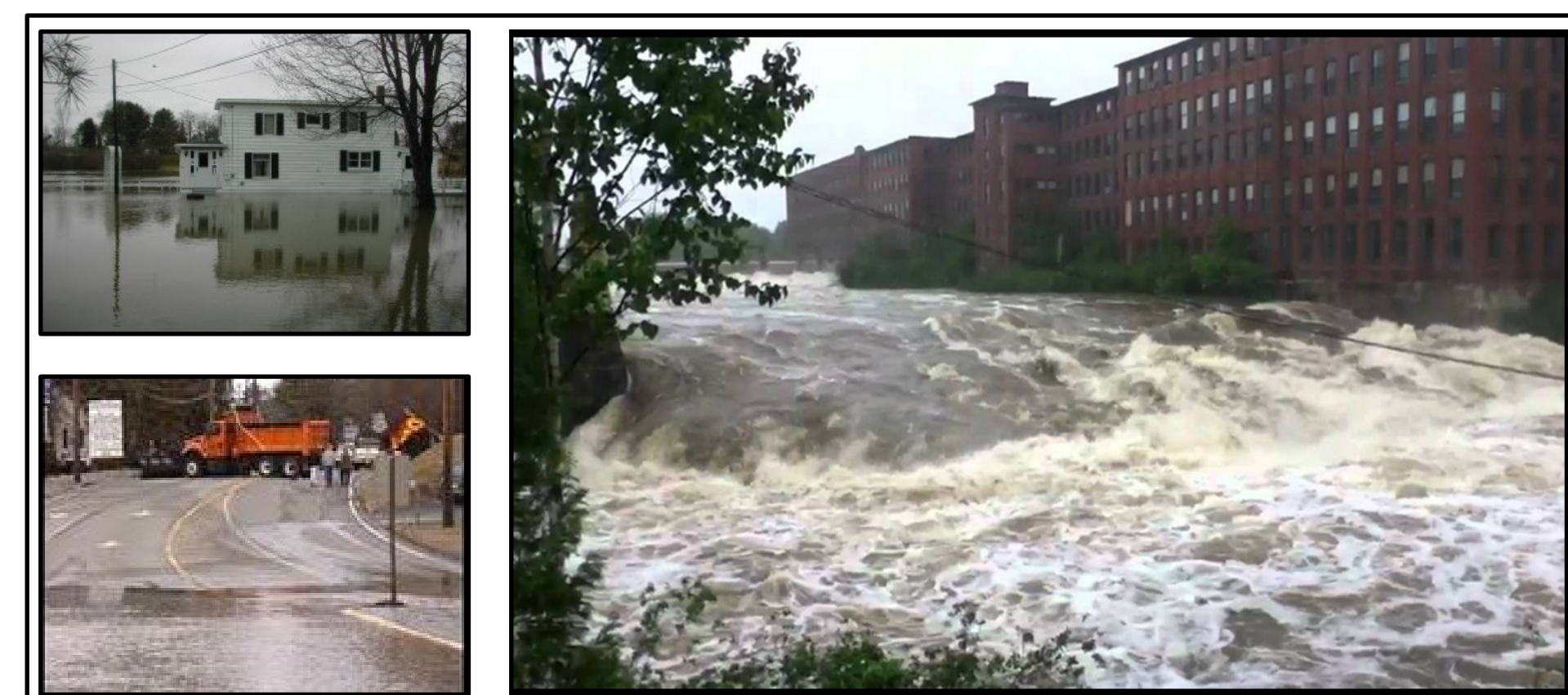


Figure 3: Flooding in Westbrook February 2010 (credit WCSH 6 News).

Digital Elevation Models (DEMs)

Most river-flow models use a DEM to generate the channel and floodplain morphology (Zhang and Montgomery, 1994). Flooding of the Presumpscot River in Westbrook was modeled to evaluate the effect of DEM resolution on flood damage estimates. Two DEMs for Westbrook were obtained from the USGS—1/3 arc-second and 1 arc-second (also referred to as 10 m and 30 m, respectively). The 10-m DEM is the highest resolution currently available for Westbrook. Location of the stream channel is significantly more accurate with the 10-m DEM, and there are also differences in the shape and extent of the 100-year floodplains (Figure 4).

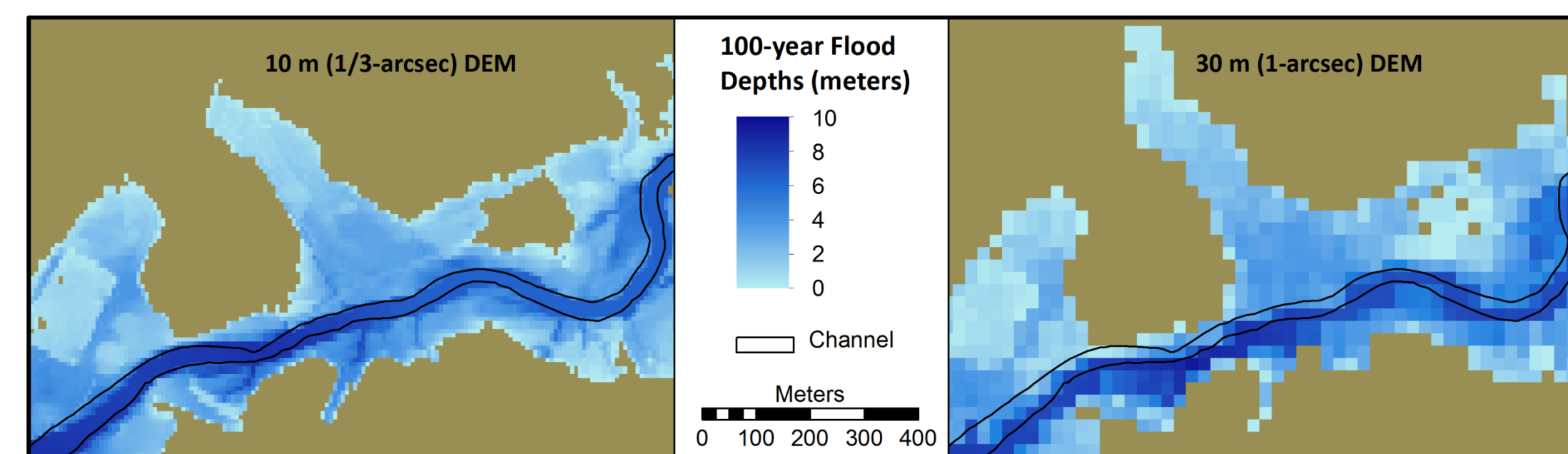


Figure 4: River channel and 100-year floodplain for a 1.5 km section of the Presumpscot River in Westbrook based on the 10-m and 30-m DEMs.

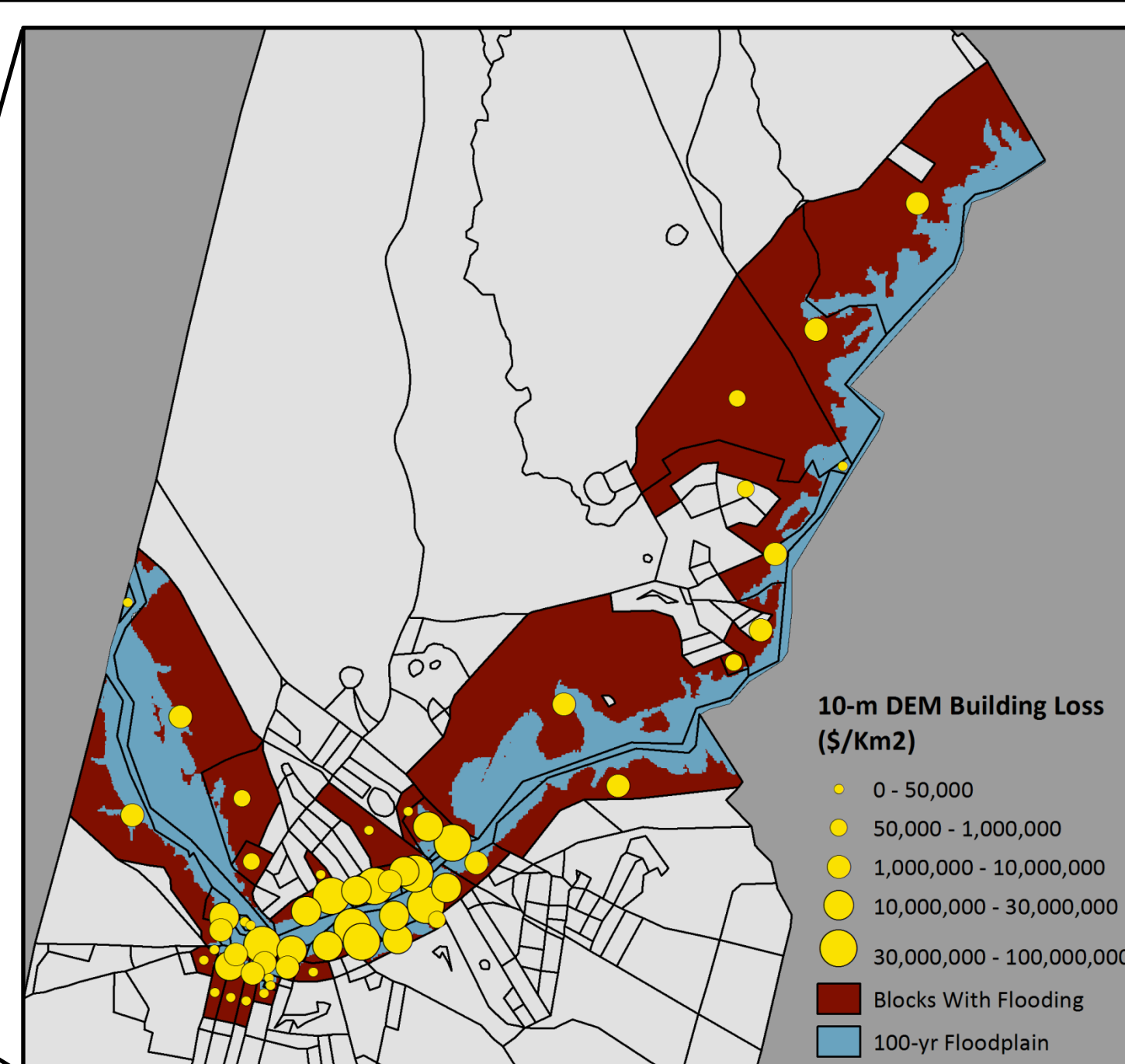


Figure 5: HAZUS 100-year flood building-related damage losses based on the 10-m DEM.

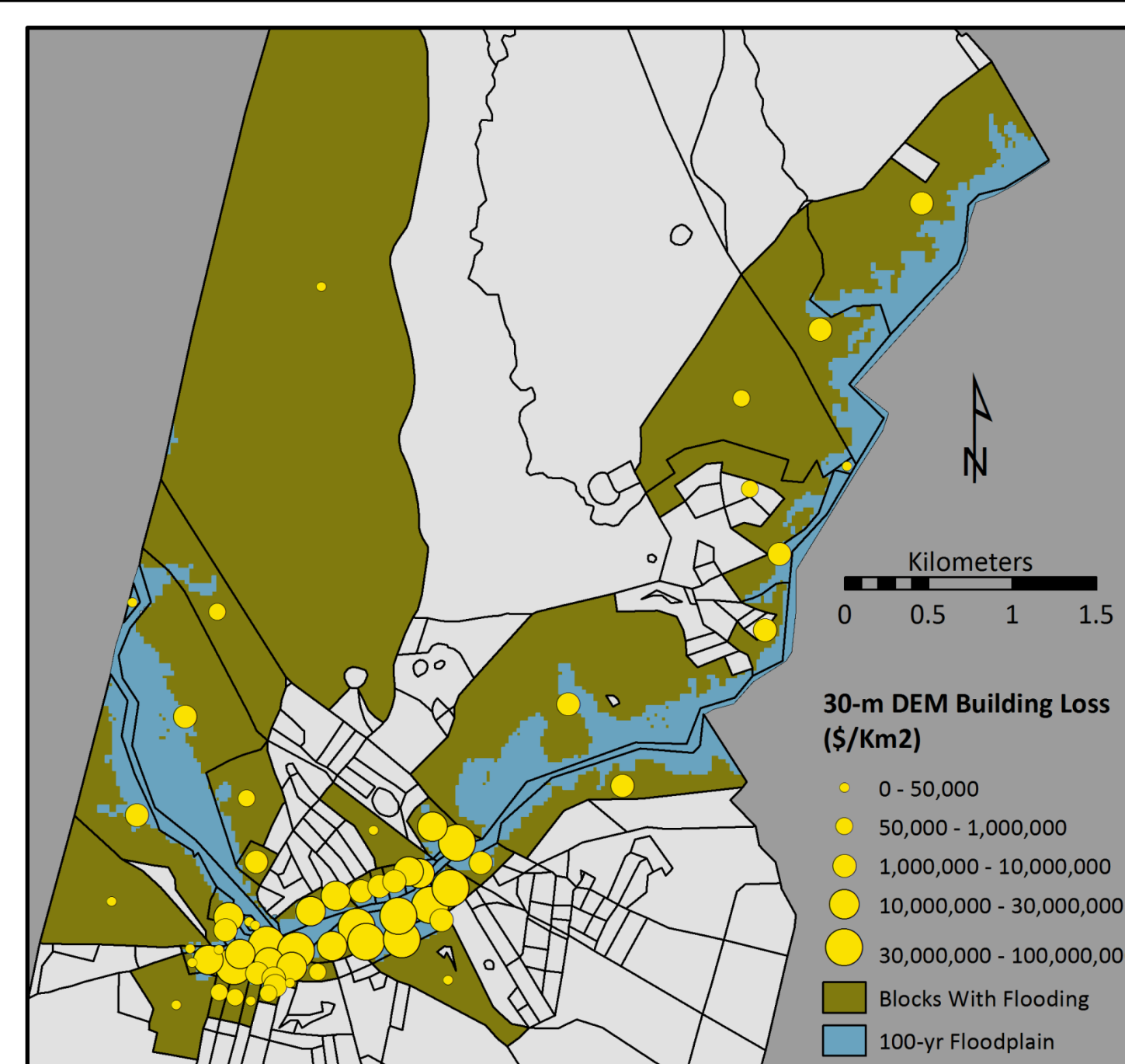


Figure 6: HAZUS 100-year flood building-related damage losses based on the 30-m DEM.

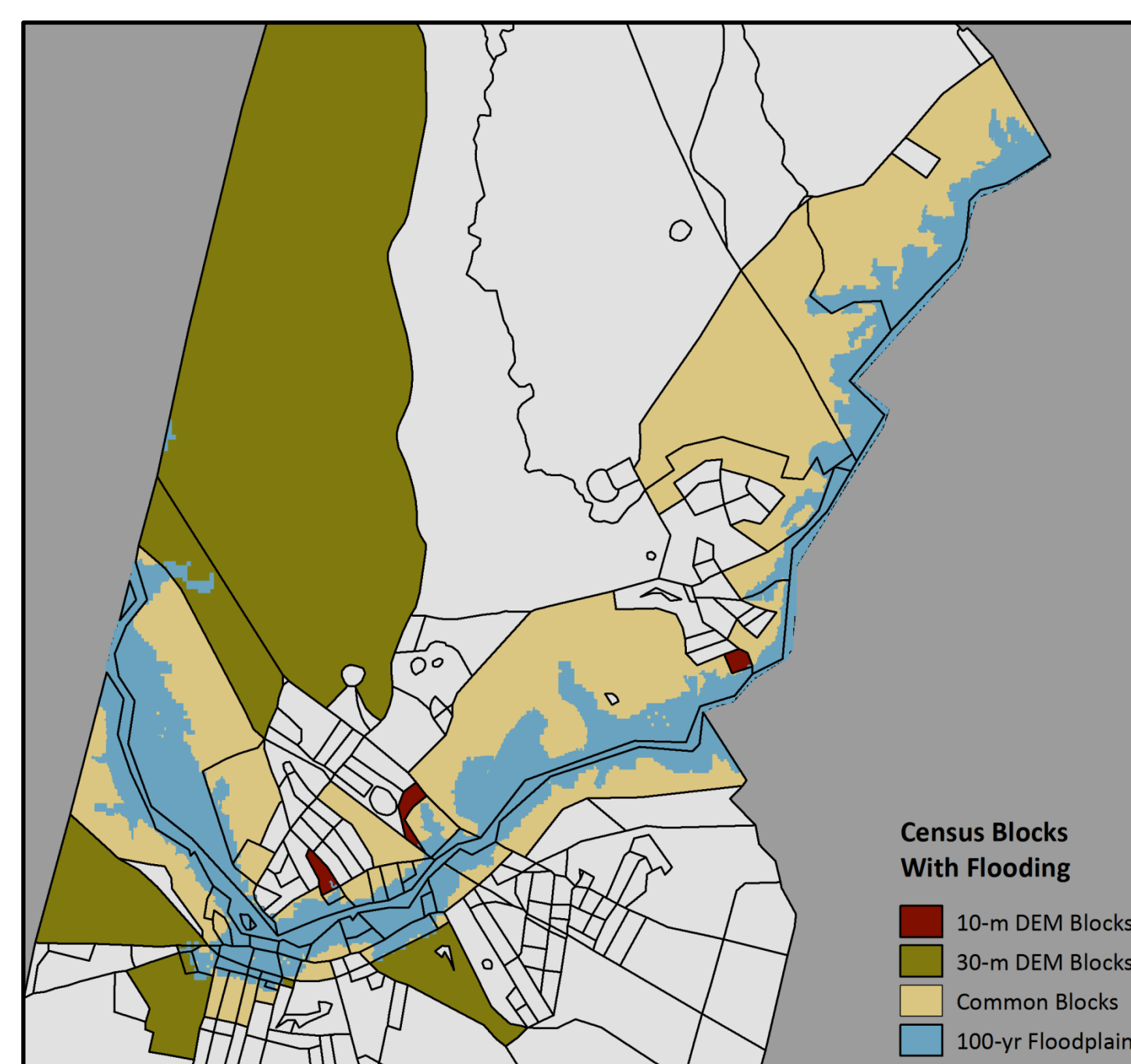


Figure 8: Difference in HAZUS 100-year flood affected census blocks based on 10-m and 30-m DEMs.

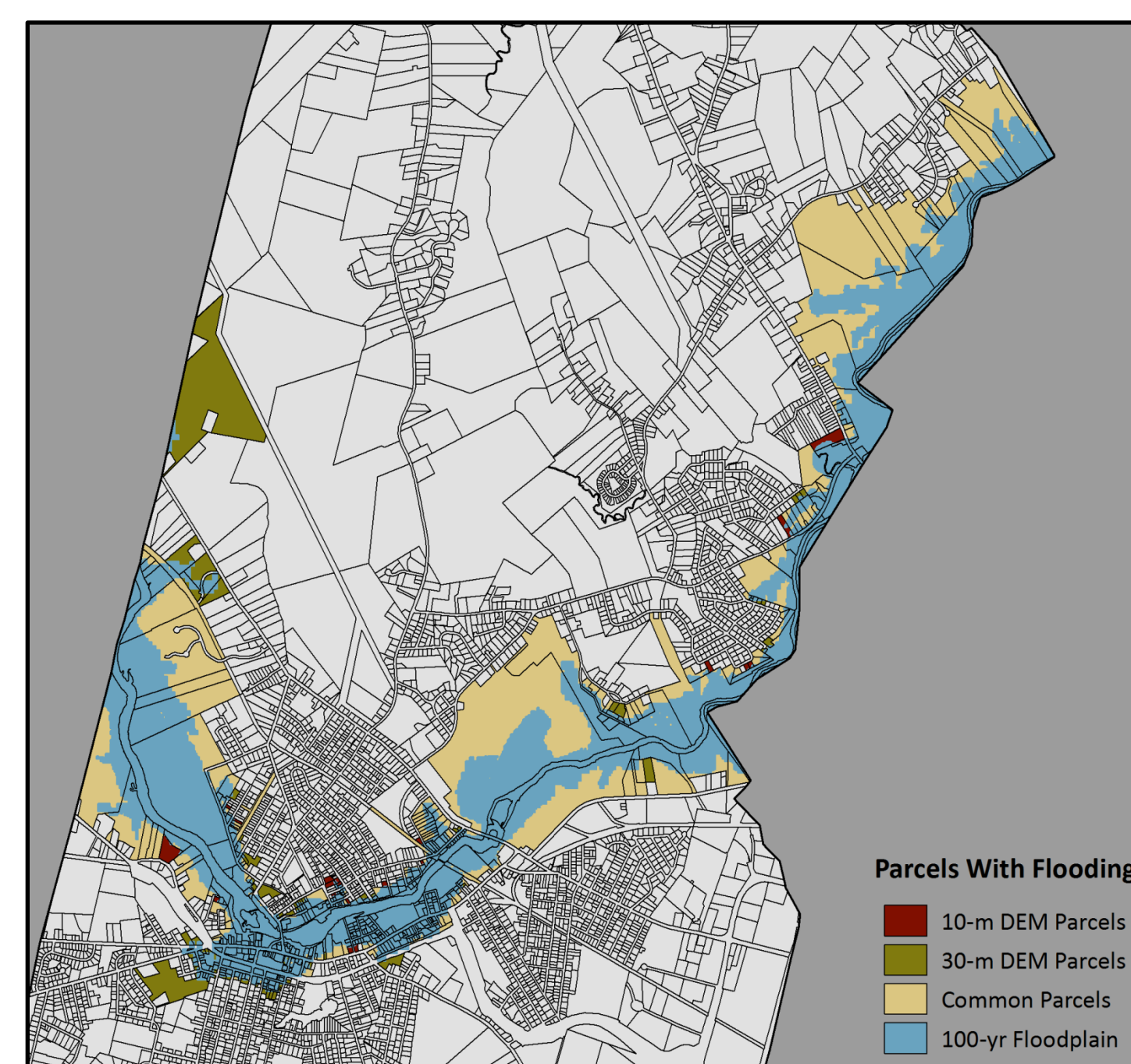


Figure 9: Difference in HAZUS 100-year flood affected parcels based on 10-m and 30-m DEMs.

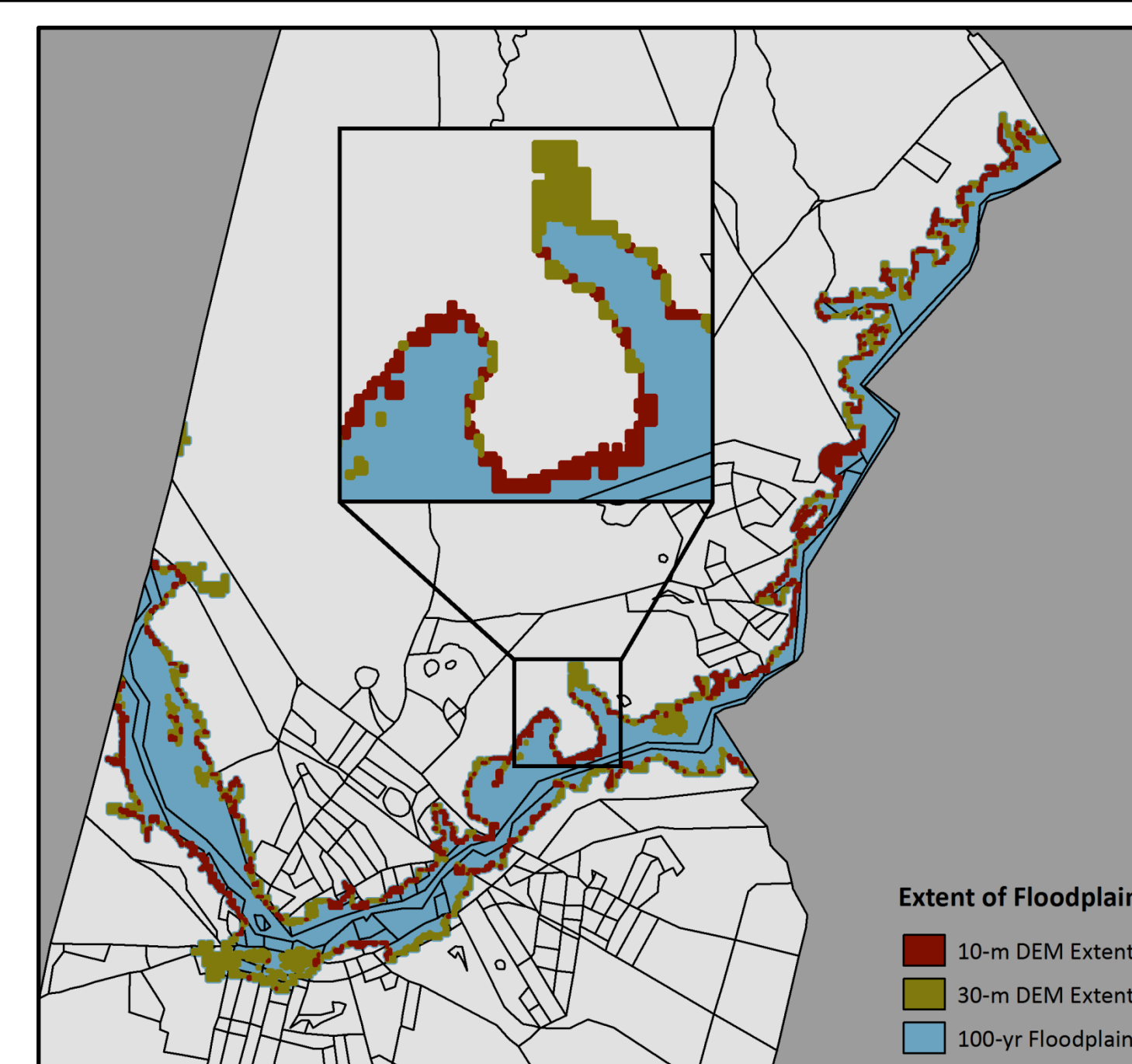


Figure 7: Difference in HAZUS 100-year floodplain extents based on 10-m and 30-m DEMs.

	10-m DEM (1/3-arcsec)	30-m DEM (1-arcsec)	Difference	Percent Difference
HAZUS RESULTS:				
Floodplain Area (km ²)	2.06	2.17	0.11	5.3 %
% Flooding of Affected Census Blocks	28.6	15.6	(13.0)	(45.5) %
Building Related Losses	\$55,578,000	\$65,168,000	\$9,590,000	17.3 %
Vehicle Losses	\$5,794,372	\$6,578,634	\$784,262	13.5 %
PARCEL DATA:				
Parcel Building Values	\$90,692,000	\$103,104,000	\$12,412,000	13.7 %
% Flooding of Affected Parcels	46.8	45.2	(1.60)	(3.4) %
Parcel Building Flood Exposure	\$42,443,856	\$46,603,008	\$4,159,152	9.8 %

Table 1: HAZUS 100-year flood damage losses and parcel-based loss estimates.

Flood Modeling With HAZUS

The Federal Emergency Management Agency (FEMA) model HAZUS-MH 2.1 was used to simulate 100-year flood damage for the Presumpscot River through Westbrook using both 10-m and 30-m DEMs. Using built-in watershed information and the DEMs, the river flood morphology and flow were modeled and the resulting damage estimates for buildings and vehicles were evaluated.

The HAZUS riverine flood model provides broad functionality (US FEMA, 2009):

- 2000 Census-derived demographics and inventories of building by occupancy and construction type, vital facilities, and infrastructure are embedded.
- Damage for each aggregation unit (census block) is a function of its structure types, depths, and velocity distributions, and its fractional inundated area.
- Damage functions and census-block inventories can be adjusted by the user.
- Locally developed parcel data can be substituted for improved estimates.

Flood Model Results

Visual inspection of the river channel in Figure 4 suggests that the HAZUS 100-year flood results based on the 10-m DEM were more accurate than the 30-m DEM results, where the floodplain area was over-estimated by 5.3 percent (Table 1). Using the default 2000 census data provided with HAZUS, building-related losses were 17.3 percent (\$9,590,000) greater than the 10-m DEM results, while vehicle losses were 13.5 percent (\$784,262) greater.

Parcel data were overlaid with the modeled floodplains using the two DEMs. Again, the 30-m DEM results over-estimated the total building value of the affected parcels by 13.7 percent (\$12,412,000). Building value adjusted for the area of parcels flooded was 9.8 percent (\$4,159,152) greater.

Only 15.6% of the 30-m DEM flood-affected census block area is within the floodplain which is 45.5 percent less than the 10-m DEM result. The parcel-level percentages are significantly greater, which suggests that HAZUS modeling on parcel-level data would be more accurate.

Discussion

Building-related damage losses for a 100-year flood based on the 10-m and 30-m DEMs are shown in Figures 5 and 6, respectively. Losses were area weighted to account for the variation of the census block areas affected. Spatial distribution of loss was similar between the models with the greatest damage clustered in the downtown area. Differences in loss estimates resulted, in part, from differences in the extent of the floodplains of the two DEMs (Figure 7). The occurrence of one floodplain exceeding the other was highly variable; however, the 30-m DEM over-estimated the overall floodplain area by 5.3 percent. Figure 8 illustrates which blocks affected by flooding were common to both results and which were unique to each of the DEMs. In the same way, Figure 9 shows which parcels were common or unique to the two floodplains. Table 1 summarizes this information as well as the percentage of affected census blocks and parcels that fell within the 10-m and 30-m floodplains.

The consistent difference between HAZUS results was an over-estimation of damage with the 30-m DEM. There are two potential causes of these differences. First, the 30-m DEM included more large census blocks with a low percentage of flooded area. In these blocks, the aggregate data for the largely unaffected portion of the block, while area weighted, were factored into the damage estimate. Second, the 30-m DEM mislocated the river channel (Figure 4) resulting in greater depths and velocities causing increased damage over census blocks along the river's edge. Kenward *et al.* (2000) and Montgomery and Foufoula-Georgiou (1993) found similar results with a 30-m DEM for small watersheds. The smaller percent difference between the two DEMs in parcel-level building exposure as compared to the block-level building losses (as well as visual inspection of Figures 8 and 9) suggests that a parcel-level analysis would produce more accurate damage estimates.

Conclusions

DEM resolution has a significant effect on damage estimates produced by the flood model HAZUS. Increasing DEM resolution from 30 m to 10 m created a more realistic floodplain and reduced building-related losses by 17.3 percent or \$9,590,000. A 3-m DEM, would likely improve the HAZUS model results and benefit the preparedness, response and recovery planning efforts in the city.

A preliminary analysis of parcel data suggests that future flood modeling for the Presumpscot River in Westbrook would benefit from a parcel-level inventory. Much of the required parcel information for Westbrook is readily available and the additional information required can be obtained.

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