HAZUS-MH Flood Model Validation

Final Report

Prepared for the National Institute of Building Sciences
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Acknowledgments

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1.0 Introduction

The objective of this study was to evaluate the accuracy of HAZUS 100-year floodplain mapping for the purpose of providing evidence that supports or opposes the use of HAZUS floodplain mapping as an acceptable 100-year floodplain mapping alternative for areas where FEMA detailed study have not been completed. The study evaluated both riverine and coastal floodplains using elevation data at multiple resolutions to determine if the increased resolution elevation data improved the accuracy of HAZUS output. HAZUS flood depth and floodplain boundary accuracy were quantified using errors relative to validation points generated from FEMA detailed study floodplain boundaries and flood elevations. Although based on a very small sample set, the results suggest that HAZUS may be a suitable source for floodplain information with smaller watersheds of at least moderate relief, especially where higher resolution elevation data is available. This conclusion is based on the relatively good accuracy in the HAZUS results with multiple elevation sources, default hydrology, and default hydraulics. Further research and validation across other regions and topographic relief should be conducted to support or counter these results.

1.1 Study Area

The study included two riverine areas and one coastal area. Two reaches were analyzed for each of the riverine areas. The first of the riverine study areas includes two relatively low relief basins of differing size in northern Harris County, TX (see figure 1). The first of these was Roan Gully (4.3 square mile drainage area) and the second being the upper section of Willow Creek (40.0 square mile drainage area). The second riverine study area is an area of moderate relief in eastern Mecklenburg County, NC (see figure 2). Basins here included Doby Creek (5.7 square mile drainage area) and the upper part of Mallard Creek (38.5 square mile drainage area). The coastal sections analyzed are from the southern shore of Long Island in Suffolk County, NY (see figure 3). These included two coastal stretches – the first, a mainland coastline in the northeast part of Long Island and the second a barrier island coastline in the southwest part of Long Island. The southwest coastline was broken into an “open” section on the ocean side of the barrier island and a “bay” section on the interior side of the barrier island.

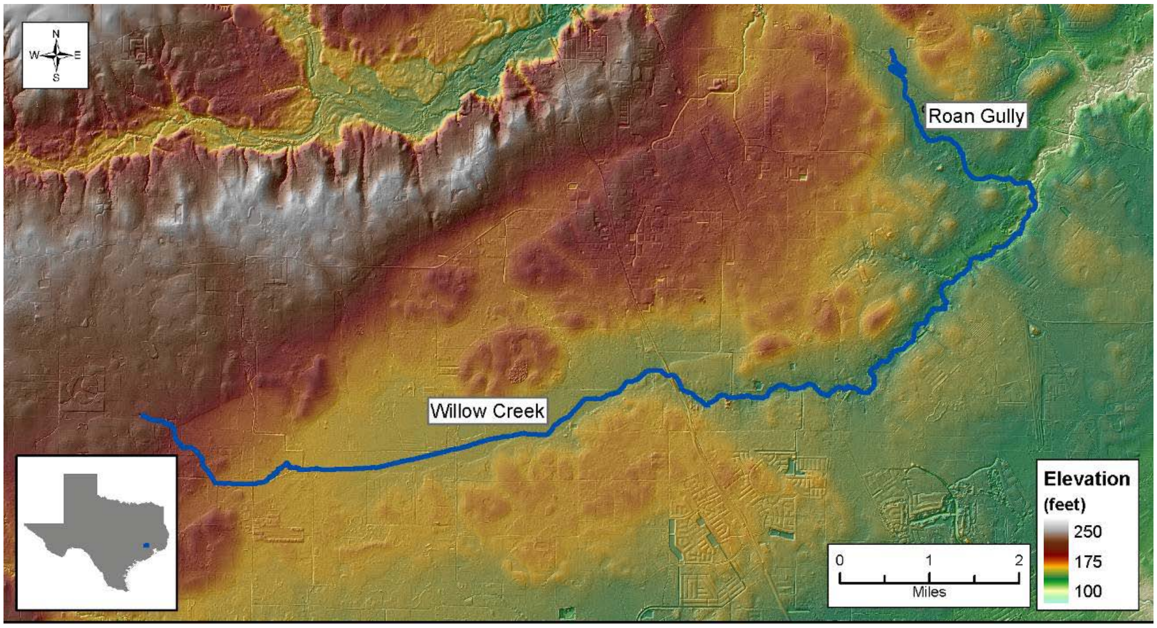


Figure 1: Roan Gully, Willow Creek, Harris County, Texas

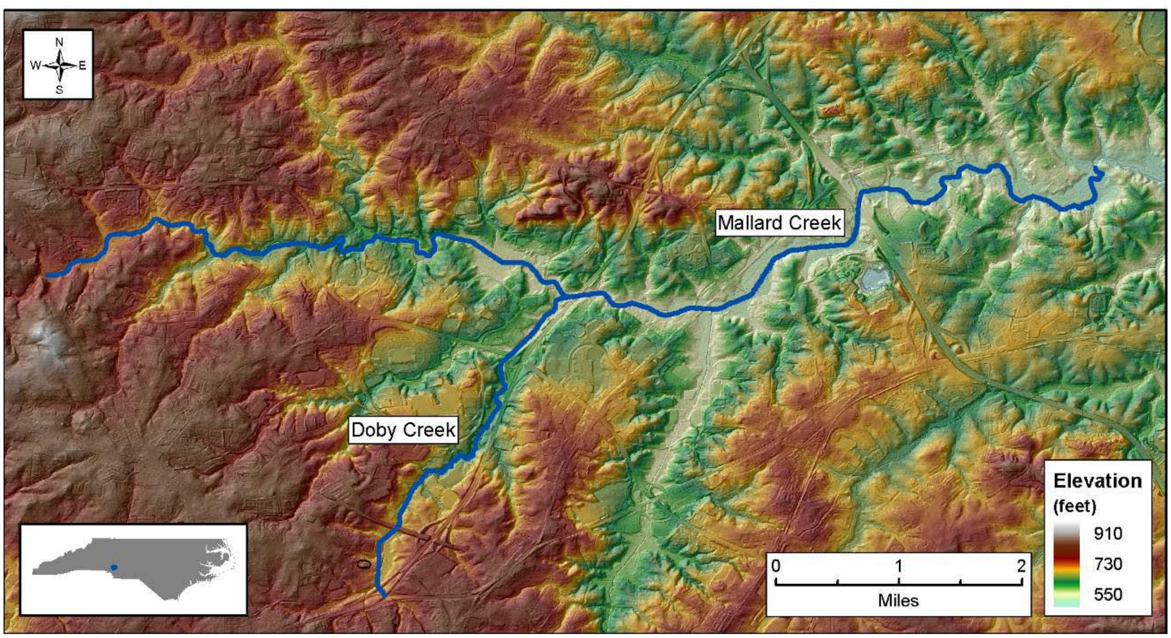


Figure 2: Doby Creek, Mallard Creek, Mecklenburg County, North Carolina

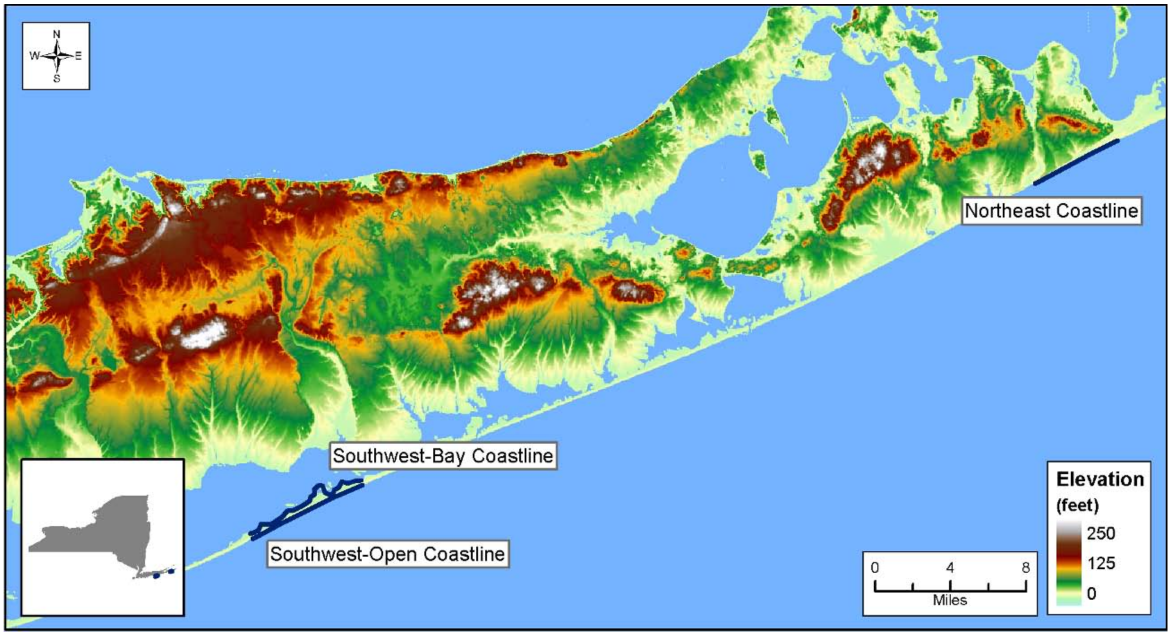


Figure 3: Northeast Coastline, Southwest-Open Coastline, Southwest-Bay Coastline, Suffolk County, NY

2.0 Methods

2.1 HAZUS-MH Process

HAZUS-MH is a GIS-based FEMA-developed model for estimating losses from floods, hurricane winds and earthquakes. Part of the flood loss estimation is a hazard analysis module that uses nationally-available databases like the USGS National Elevation Dataset and approximate modeling methods to create flood depth, flood frequency, and floodplain boundaries. This module also allows incorporation of more detailed site-specific information such as finer resolution elevation models. HAZUS-MH MR3 Patch 3 with ArcGIS 9.2, SP 6 was used for this study.

2.1.1 Elevation Data Sources

HAZUS requires elevation data in the form of a raster DEM. This is the only required data that is not packaged with HAZUS. This study included elevation data at multiple resolutions to evaluate the extent to which higher resolution elevation data would improve the accuracy of modeled floodplain boundaries and flood elevations. Elevation data sets used in this study included National Elevation Dataset (NED) 1 Arc Second DEMs (approximately 30m resolution), NED 1/3 Arc Second DEMs (10m), and locally sourced LiDAR derived DEMs (Harris County - 5m; Mecklenburg County –3m; Suffolk County –10m). Additionally, for the Harris County reaches, a high-resolution contour derived DEM was also used (5m).

2.1.2 Riverine Hydrology Sources

HAZUS computes riverine flow hydrologic properties using both included USGS gage data (when geographically available) and regression equations from USGS report WRI 94-4002 , "Nationwide Summary of USGS Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993". The regression equations are run using parameters extracted from the GIS data included with the HAZUS model such as mean annual snowfall and precipitation grids. In addition to the default HAZUS hydrology, Flood Insurance Studies (FIS) were consulted to provide alternate hydrology for determining if this would improve the accuracy of HAZUS output (see appendix 1 for HAZUS and FIS discharge values for the project study reaches). The effective dates on the FISs are 09/29/2006 for Harris County (FIS study number 48201CV001A) and 03/02/2009 for Mecklenburg County (FIS study number 37119CV00B). For the Harris County FIS there is specific mention of LiDAR data being used for the topographic base. Other FISs do not include such references.

2.1.3 Riverine Floodplain Elevation Determination and Boundary Mapping

The riverine flood hazard identification process in HAZUS is composed of the following steps, all dialogue-driven by the HAZUS program:

1. Create the region of interest by selecting either a group of census blocks, census tracts, or a county.
2. Obtain a DEM and import it into HAZUS.
3. Delineate streams using the DEM.
4. Create a case study by selecting streams and return periods to model
5. Determine default hydrology.

6. Accept default or define custom hydrology.
7. Determine floodplain boundaries and depths for 1% annual chance flood.

2.1.4 Coastal Floodplain Elevation Determination and Boundary Mapping

The coastal flood hazard identification process in HAZUS is composed of the following, similar, sequence of dialogue-driven steps:

1. Create the region of interest by selecting either a group of census blocks, census tracts, or a county.
2. Obtain a DEM and import it into HAZUS
3. Create a case study by selecting coastline
4. Define coastline type, exposure, and 100-year stillwater elevations.
5. Determine floodplain boundaries and depths for 1% annual chance flood.

Shorelines for this analysis were characterized as follows (100-year stillwater elevation depths from Suffolk County FIS (effective date 05/04/1998, study number 36103CV000):

- Northeast coastline – sandy beach, small dune; open coast; 10.3 ft 100-year stillwater elevation
- Southwest coastline-open – sandy beach, small dune; open coast; 9.3 ft 100-year stillwater elevation
- Southwest coastline-bay – sandy beach, small dune; sheltered; 5.1 ft 100-year stillwater elevation

2.1.5 Additional Floodplain Boundary Mapping

In addition to the floodplains generated in HAZUS from the varied resolution elevation sources and the two different hydrology sources (HAZUS default, FIS), two additional floodplains were generated for judging HAZUS floodplain boundary accuracy. The first of these used an additional mapping tool available in HAZUS called the Flood Information Tool or FIT. If you already have riverine cross-section or coastal flood polygons and ground elevation data, the FIT will create a surface from the user supplied data and subtracts the ground elevation to get flood boundaries and depths, thereby bypassing some of the HAZUS hydraulic processes. The second of the additional floodplains used to analyze HAZUS floodplain boundary mapping accuracy was FEMA Q3 data (unavailable for Harris County).

2.2 Analysis

For both the riverine and coastal floodplains, HAZUS floodplain boundary (horizontal) and elevation (vertical) accuracy were judged through quantification of errors at multiple validation points derived from DFIRM data, as described below. DFIRM effective dates were as follows: Harris County - 06/18/2007; Mecklenburg County - 02/04/2004; and Suffolk County (preliminary DFIRM) - 09/01/2008.

2.2.1 Riverine analysis

Riverine accuracy was analyzed using validation points generated from FEMA detailed study DFIRM data (see figure 4). For floodplain boundary assessment, validation points were generated at the left and right banks where DFIRM 100-year floodplain cross-sections intersected the DFIRM 100-year floodplain boundary. The same DFIRM cross-sections were also intersected with the HAZUS floodplain boundaries to generate a set of points for each HAZUS floodplain. Distances were calculated between the validation points and associated HAZUS points to assess HAZUS accuracy. If the HAZUS floodplain perfectly conformed to the DFIRM floodplain, the distance between the points along the same cross-section at the same bank would be 0 ft.

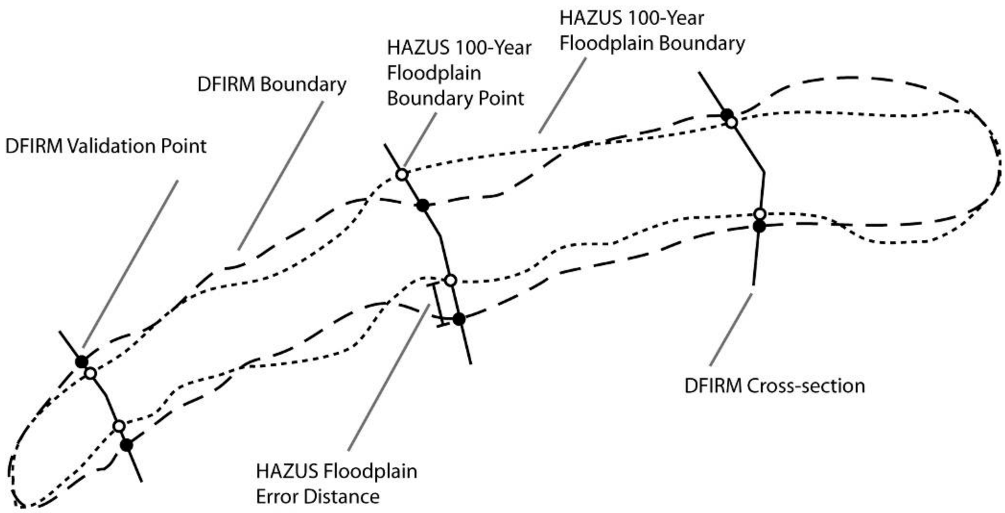


Figure 4: Riverine Floodplain Boundary Assessment Schematic

To assess HAZUS flood depth accuracy, a set of five evenly spaced points were generated along FEMA detailed study cross-sections, trimmed to the extent of the widest floodplain (see figure 5). Of these, points that intersected with all of the HAZUS floodplain boundaries were retained as validation points. These points were assigned the flood elevation of their associated cross-sections. For comparison to these, HAZUS water surface elevations (WSEs) were generated by summing flood depth grids with their associated DEMs. Vertical distances between the validation points and the HAZUS derived WSE points were quantified to compile flood elevation errors (see figure 6).

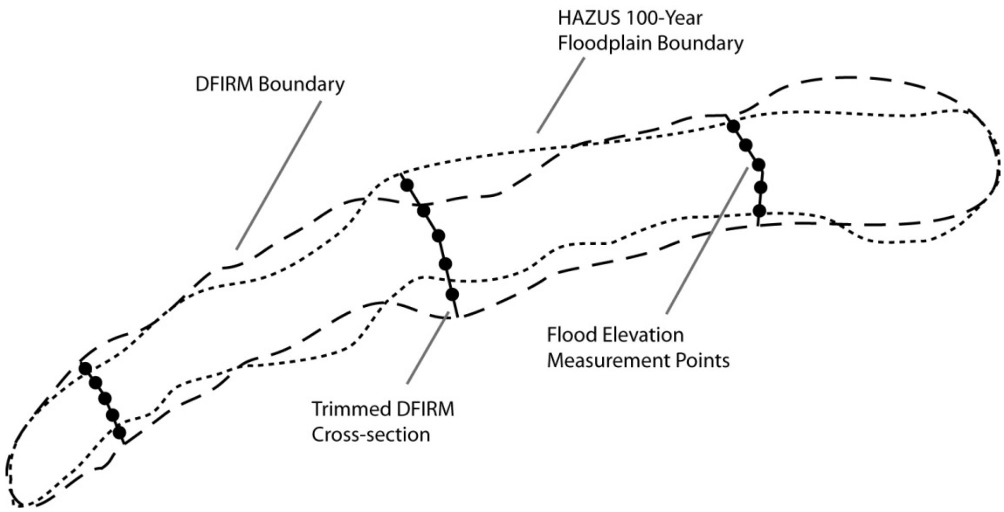


Figure 5: Riverine Flood Elevation Assessment Schematic, Part 1

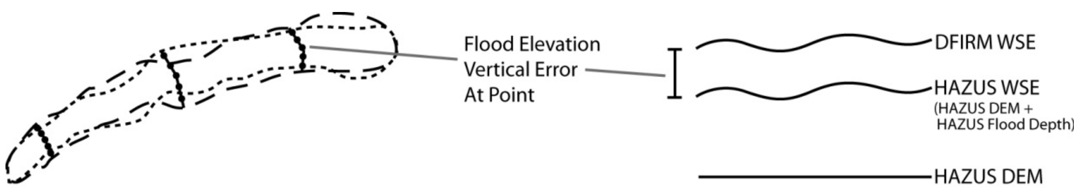


Figure 6: Riverine Flood Elevation Assessment Schematic, Part 2

2.2.2 Coastal analysis

Coastal floodplain boundary and flood elevation accuracy were also analyzed using DFIRM derived validation points. Floodplain boundary mapping validation points were generated using HAZUS transect intersections with the inland limits to the DFIRM coastal floodplain boundary. Distances were calculated to/from the validation points to where these same transects intersected the HAZUS floodplain inland boundary limits. Flood elevation accuracy was assessed through differences in elevation between the DFIRM BFEs and the HAZUS WSEs at five evenly spaced locations along the HAZUS coastline transects, which intersected all of the HAZUS flood grids. For the coastal floodplain boundary and flood elevation analysis, HAZUS transects were used to generate points, in lieu of DFIRM transects, as the DFIRM transects were too widely spaced to yield a sufficient number of validation points.

3.0 Riverine Results

3.1 Flood depths

Flood depth accuracy was quantified using elevation differences from DFIRM validation points to HAZUS flood WSEs at the same locations. Error metrics included average error (ft); median error (ft); and percent of all points within 0.5, 1.0, and 2.0 feet of associated validation points. These buffer depths were chosen as they well-represented the distribution of errors in the flood elevations. Riverine flood depth validation point errors used for this analysis, along with accompanying maps of validation cross-sections, can be found in Appendix 2.

3.1.1 Harris County

Roan Gully flood elevation errors were the lowest found among the four riverine basins. Average errors were less than 1.0 foot for all elevation-hydrology combinations (see figure 7 and table 1). When the FIS hydrology was substituted for HAZUS default hydrology, reduction in errors was only realized with the two high-resolution elevation data sources (the average errors reduced approximately 50%). Improved elevation data had little effect on accuracy, except when used with the FIS hydrology. Validation points within the +/- 1.0 foot vertical buffer were approximately 70% or greater for most runs; with the FIS hydrology and high-resolution DEMs this criteria was met at an approximately 95% success rate. All elevation-hydrology combinations had nearly 100% of validation points within the +/- 2.0 foot vertical buffer.

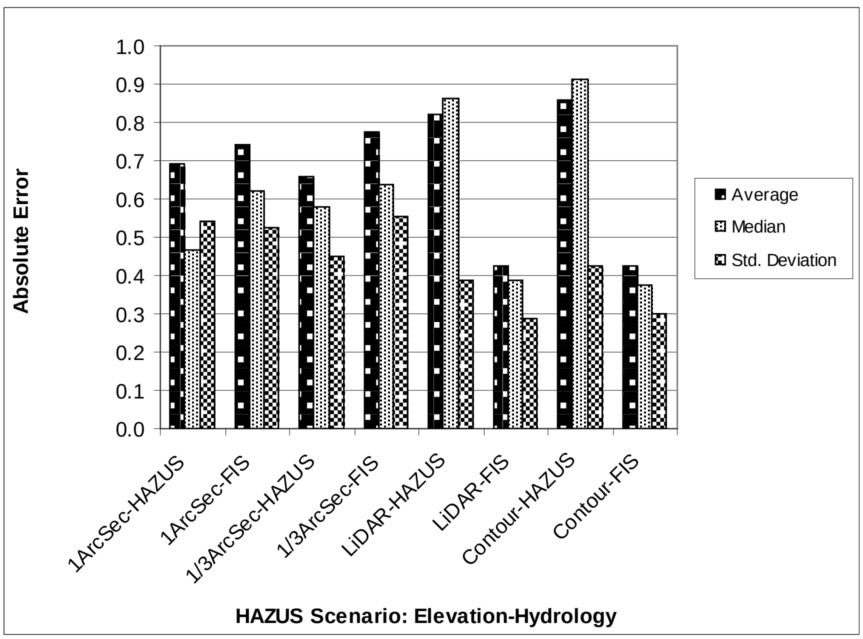


Figure 7: Roan Gully flood elevation errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR		Contour DEM	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	0.7	0.7	0.7	0.8	0.8	0.4	0.9	0.4
median error (ft)	0.5	0.6	0.6	0.6	0.9	0.4	0.9	0.4
minimum error (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
maximum error (ft)	2.4	2.2	1.8	2.2	1.6	1.1	1.8	1.4
w/in 0.5 ft (%)	52	39	46	40	21	66	20	70
w/in 1.0 ft (%)	68	70	78	66	70	95	66	95
w/in 2.0 ft (%)	99	98	100	98	100	100	100	100

Note: errors calculated as difference from 82 validation points.

Table 1: Roan Gully flood elevation errors, HAZUS mapping

Willow Creek flood elevation errors were approximately double those of Roan Creek (see figure 8 and table 2). Overall, average errors were between 1.2 to 1.8 feet for all elevation-hydrology combinations. Average errors were reduced 10 to 30% when HAZUS hydrology was replaced with the FIS hydrology. There was also some reduction in error when LiDAR or contour DEM elevation data replaced the lower resolution options. At best, 35% fell within the +/- 1.0 foot vertical buffer using HAZUS hydrology while this value reached 50% using the FIS hydrology.

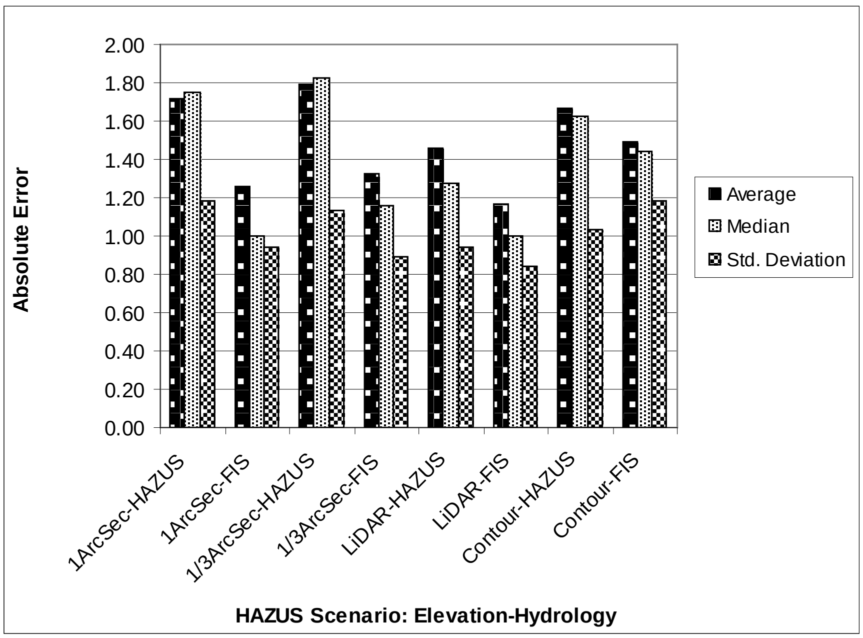


Figure 8: Willow Creek flood elevation errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR		Contour DEM	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	1.7	1.3	1.8	1.3	1.5	1.2	1.7	1.5
median error (ft)	1.8	1.0	1.8	1.2	1.3	1.0	1.6	1.4
minimum error (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
maximum error (ft)	5.4	4.1	5.1	3.6	5.2	3.8	4.2	10.7
w/in 0.5 ft (%)	20	28	17	26	16	21	15	19
w/in 1.0 ft (%)	33	50	32	41	35	50	31	37
w/in 2.0 ft (%)	63	81	59	71	74	87	62	74

Note: errors calculated as difference from 340 validation points.

Table 2: Willow Creek flood elevation errors, HAZUS mapping

3.1.2 Mecklenburg County

Flood depth errors for the Doby Creek basin were greater than realized with either of the Harris County basins (see figure 9 and table 3). Average errors varied from approximately 2.6 to 3.3 feet for all elevation-hydrology combinations and points within the +/- 1 foot vertical buffer varied from approximately 20 to 35%. FIS hydrology did not consistently reduce error values (although, with the 1/3 arc second DEM the median error was reduced by approximately 25%). Results suggest that using the LiDAR elevation data may yield greater accuracy.

Figure 9. Doby Creek flood elevation errors, HAZUS mapping

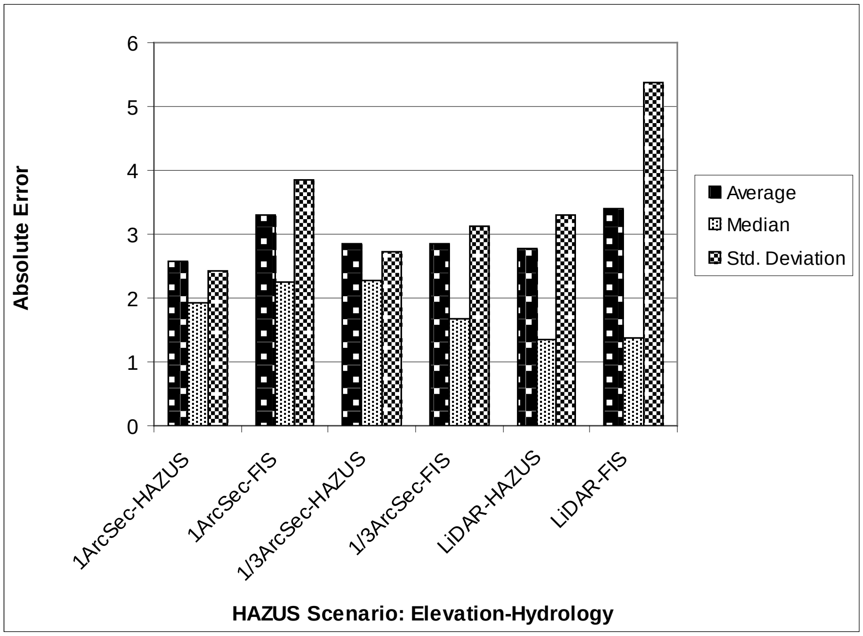


Figure 9: Doby Creek flood elevation errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	2.6	3.3	2.8	2.8	2.8	3.4
median error (ft)	1.9	2.2	2.3	1.7	1.4	1.4
minimum error (ft)	0.1	0.1	0.1	0.2	0.4	0.0
maximum error (ft)	11.6	20.9	11.9	13.1	13.8	23.2
w/in 0.5 ft (%)	14	5	5	5	8	16
w/in 1.0 ft (%)	22	21	19	35	26	29
w/in 2.0 ft (%)	61	45	47	56	68	61

Note: errors calculated as difference from 77 validation points.

Table 3: Doby Creek flood elevation errors, HAZUS mapping

Mallard Creek flood elevation errors were the highest of the other riverine basins analyzed (see figure 10 and table 4). For Mallard Creek average errors varied from approximately 3 to 4 feet and points within +/- 1 foot did not reach 25% for any case. Replacing HAZUS hydrology with FIS hydrology clearly improved accuracy with regard to both average errors and points within buffer values. Improved elevation data had little effect on results.

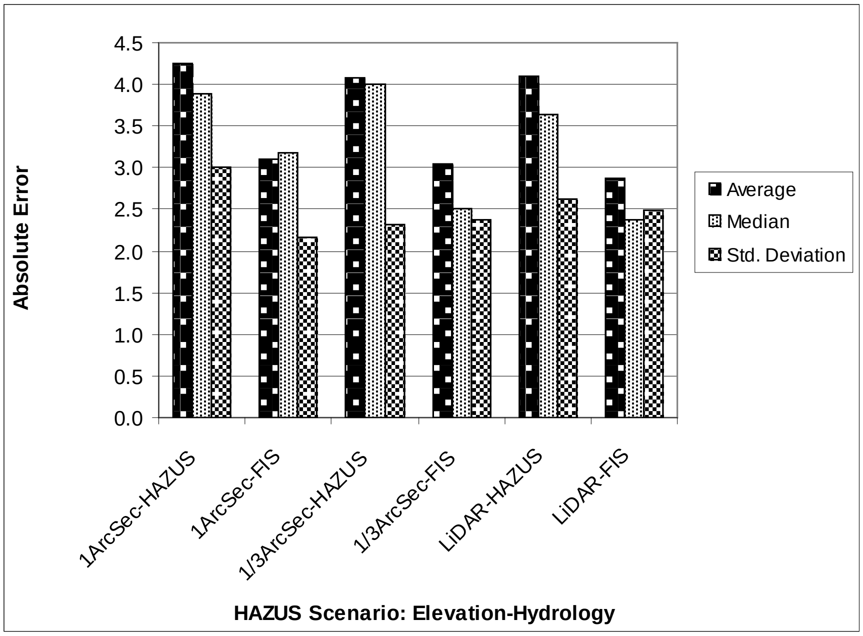


Figure 10: Mallard Creek flood elevation errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	4.3	3.1	4.1	3.0	4.1	2.9
median error (ft)	3.9	3.2	4.0	2.5	3.6	2.4
minimum error (ft)	0.0	0.0	0.2	0.0	0.1	0.0
maximum error (ft)	22.7	8.6	11.0	15.0	17.9	20.9
w/in 0.5 ft (%)	5	14	4	9	3	10
w/in 1.0 ft (%)	15	24	10	20	9	23
w/in 2.0 ft (%)	28	40	24	41	22	42

Note: errors calculated as difference from 434 validation points.

Table 4: Mallard Creek flood elevation errors, HAZUS mapping

3.2 Floodplain boundaries

Riverine floodplain boundary accuracy was assessed using horizontal distances between validation points at the edge of DFIRM floodplain boundaries to points at the edges of HAZUS floodplain boundaries. Error metrics included average error (ft); median error (ft); and percent of all points within 10, 50, and 100 feet of associated validation points. These buffer distances were chosen as they well-represented the distribution of errors in the flood boundaries. Riverine floodplain boundary validation point errors used for this analysis, along with accompanying maps of validation cross-sections, can be found in Appendix 1.

3.2.1 Harris County

HAZUS 100-year floodplains for Roan Gully had relatively large boundary errors (see figure 11 and table 5). Average errors varied from approximately 50 to 200 feet and median errors varied from approximately 20 to 150 feet. The difference between the average and median errors suggest this data included several points with large errors that skewed average values. The proportion of points within the +/- 50 foot buffer varied widely from approximately 15 to 70%. For Roan Gully the FIS hydrology generally improved accuracy. Using the higher resolution elevation sources (LiDAR or contour DEM relative to 1 arc second or 1/3 arc second DEM) generated substantial improvement in accuracy according to all measures.

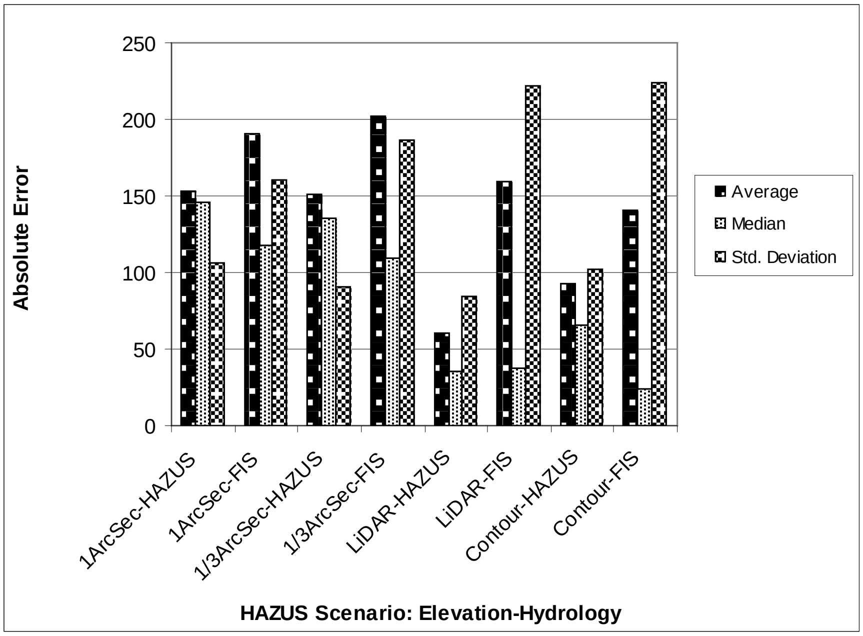


Figure 11: Roan Gully floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR		Contour DEM	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	154	190	151	202	60	160	93	141
median error (ft)	146	117	136	109	35	37	66	23
minimum error (ft)	3	10	5	4	4	1	6	0
maximum error (ft)	503	523	430	632	477	714	494	740
w/in 10 ft (%)	3	0	6	6	12	18	6	15
w/in 50 ft (%)	18	24	15	21	65	56	41	68
w/in 100 ft (%)	29	44	26	47	88	68	71	76

Note: errors calculated as difference from 34 validation points.

Table 5: Roan Gully floodplain boundary errors, HAZUS mapping

The Willow Creek 100-year floodplain boundary was the least accurate of any of the four basins (see figure 12 and table 6). Average errors varied from approximately 800 to 1100 feet and median errors from 400 to 900 feet. Points within the +/- 50 foot horizontal buffer varied from approximately 1 to 10%. As seen with the Roan Gully results, errors were reduced when either the FIS hydrology or higher resolution elevation data were used.

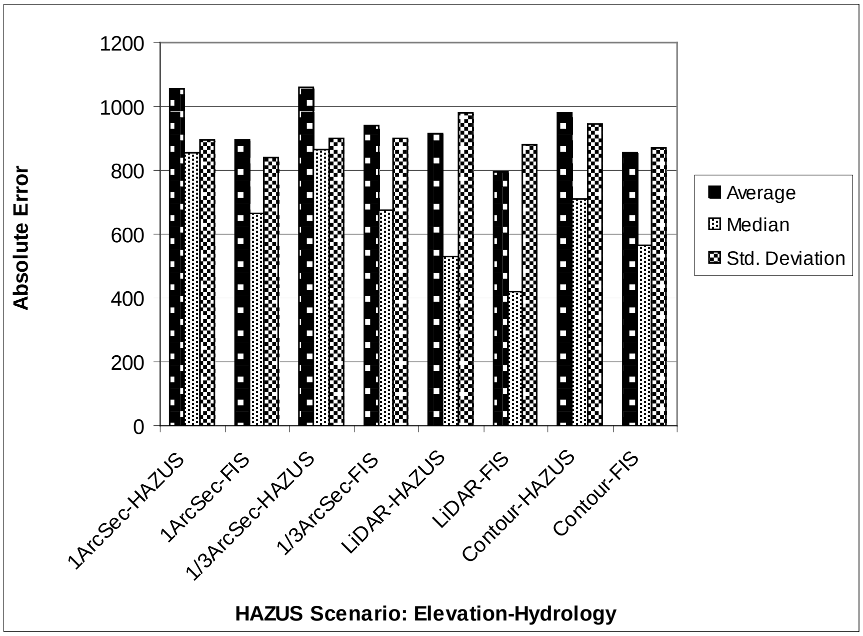


Figure 12: Willow Creek floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR		Contour DEM	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	1057	896	1062	938	917	793	980	854
median error (ft)	857	664	867	674	532	418	711	563
minimum error (ft)	3936	3668	3907	3818	4038	3843	3965	3899
maximum error (ft)	894	839	898	900	978	882	947	869
w/in 10 ft (%)	1	1	0	0	2	3	1	1
w/in 50 ft (%)	4	5	1	5	10	11	8	9
w/in 100 ft (%)	6	15	5	12	18	24	13	17

Note: errors calculated as difference from 142 validation points.

Table 6: Willow Creek floodplain boundary errors, HAZUS mapping

For the Harris County basins the HAZUS FIT with the LiDAR DEM generated more accurate floodplains compared to HAZUS default methods with the same elevation data (see table 7) – average errors were cut substantially and points within the horizontal distance buffers increased.

Roan Gully floodplain boundary errors, other data sources

Elevation	LIDAR
Hydrology	FIT
average error (ft)	29
median error (ft)	16
minimum error (ft)	0
maximum error (ft)	147
w/in 10 ft (%)	24
w/in 50 ft (%)	82
w/in 100 ft (%)	94

Willow Creek floodplain boundary errors, other data sources

Elevation	LIDAR
Hydrology	FIT
average error (ft)	40
median error (ft)	12
minimum error (ft)	0
maximum error (ft)	1041
w/in 10 ft (%)	40
w/in 50 ft (%)	82
w/in 100 ft (%)	92

Note: errors calculated as difference from 34 validation points.	Note: errors calculated as difference from 142 validation points.

Table 7: Floodplain boundary errors, other data sources

3.2.2 Mecklenburg County

Doby Creek had the lowest floodplain boundary errors of the four basins mapped (see figure 13 and table 8). Average distances from the validation points varied from approximately 25 to 55 feet. As seen with the Harris County basins, median errors were lower (approximately 10 to 45 feet) than average errors, suggesting the distribution was skewed by several points with large errors. Points within the +/- 50 foot error buffer varied from approximately 60 to 95%. Replacing the HAZUS hydrology with FIS hydrology did not generate significant improvement in results. HAZUS accuracy was improved with increases in resolution of the input elevation data. This was most apparent when replacing the 1 arc second DEM with a 1/3 arc second DEM.

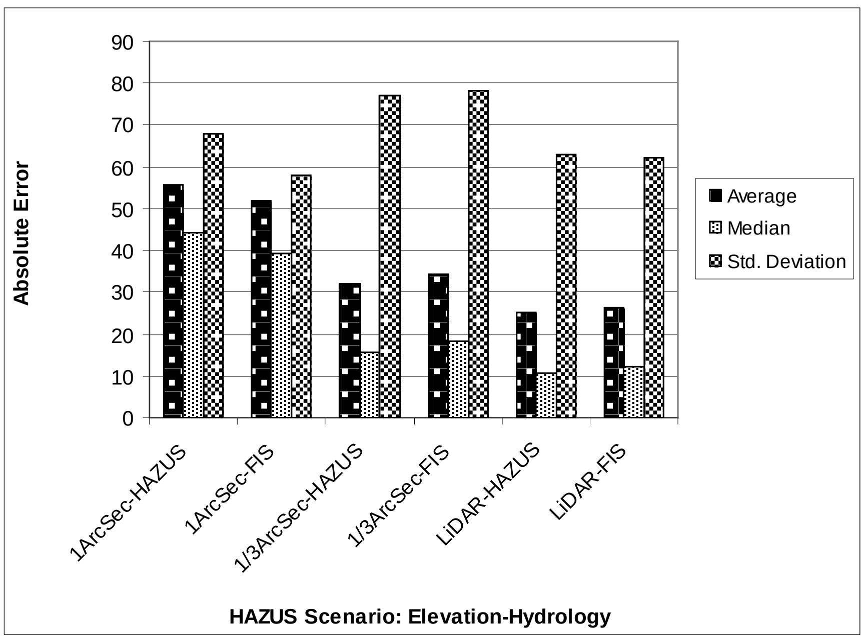


Figure 13: Doby Creek floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	56	52	32	34	25	26
median error (ft)	44	39	16	18	11	12
minimum error (ft)	1	1	0	0	0	0
maximum error (ft)	442	376	525	525	420	420
w/in 10 ft (%)	7	7	39	37	48	48
w/in 50 ft (%)	63	65	87	89	93	87
w/in 100 ft (%)	91	93	98	93	96	98

Note: errors calculated as difference from 46 validation points.

Table 8: Doby Creek floodplain boundary errors, HAZUS mapping

Mallard Creek floodplain boundary accuracy was similar to that of Doby Creek (see figure 14 and table 9). Average boundary errors were approximately 40 to 65 feet and median errors were approximately 25 to 50 feet. Points within the +/- 50 foot buffer varied from 50 to 75 feet. Replacing the HAZUS hydrology with the FIS hydrology reduced errors by approximately one-third for all but the lowest resolution elevation source. Improved elevation data also increased accuracy of the output.

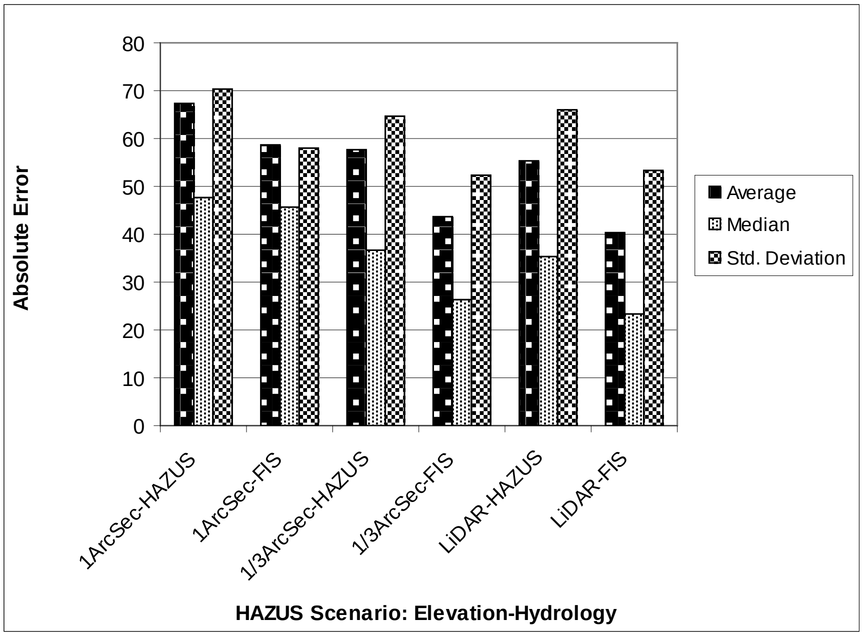


Figure 14: Mallard Creek floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second		1/3 Arc Second		LiDAR	
Hydrology	HAZUS	FIS	HAZUS	FIS	HAZUS	FIS
average error (ft)	67	59	58	44	55	40
median error (ft)	48	46	37	26	35	23
minimum error (ft)	1	0	0	1	0	0
maximum error (ft)	401	401	424	396	418	418
w/in 10 ft (%)	14	15	14	19	15	26
w/in 50 ft (%)	52	56	63	71	63	74
w/in 100 ft (%)	79	83	84	92	87	90

Note: errors calculated as difference from 180 validation points.

Table 9: Mallard Creek floodplain boundary errors, HAZUS mapping

For Doby Creek, the HAZUS FIT improved floodplain boundary accuracy over HAZUS runs with the LiDAR elevation (see table 10). Q3 boundary differences relative to the validation points were basically on par with the same accuracy seen with the lowest resolution elevation data, but were less accurate than HAZUS output with higher resolution elevation data. FIT and Q3 floodplain boundaries for Mallard Creek were very similar to those of Doby Creek in how they related to the HAZUS floodplain errors (see table 10).

Doby Creek floodplain boundary errors, other data sources

Elevation Hydrology	LIDAR FIT	N/A Q3
average error (ft)	9	55
median error (ft)	6	38
minimum error (ft)	0	1
maximum error (ft)	40	469
w/in 10 ft (%)	65	13
w/in 50 ft (%)	100	70
w/in 100 ft (%)	100	89

Note: errors calculated as difference from 46 validation points.

Mallard Creek floodplain boundary errors, other data sources

Elevation	LIDAR	N/A
Hydrology	FIT	Q3
average error (ft)	23	59
median error (ft)	11	40
minimum error (ft)	1	0
maximum error (ft)	401	401
w/in 10 ft (%)	43	12
w/in 50 ft (%)	91	58
w/in 100 ft (%)	98	80

Note: errors calculated as difference from 180 validation points.

Table 10: Floodplain boundary errors, other data sources

4.0 Coastal Results

4.1 Flood depths

Flood depth accuracy was judged using elevation differences from DFIRM validation points to HAZUS WSEs surfaces at the same locations. WSEs were generated by summing HAZUS flood depth layers with their associated DEMs. Error metrics included average error (ft); median error (ft); and percent of all points within 1, 5, and 10 feet of associated validation points. These buffer depths were chosen as they well-represented the distribution of errors in the flood elevations. Coastal flood depth validation point errors used for this analysis, along with accompanying maps of validation cross-sections, can be found in Appendix 3.

Due to the HAZUS coastal mapping process, it was not possible to analyze flood depth errors for different DEM sources. This is because WSEs for runs with different DEMs were identical (there are still differences in floodplain boundaries). This occurs because the HAZUS process first generates a flood elevation grid that is independent of a DEM, based on the 100-year stillwater elevation, and then generates a flood depth grid from the difference in the DEM elevation and the flood surface elevation. When back stepping this process to create a WSE that can be used for validation (sum of flood depth grid and associated DEM) the user will end up back at the same initial WSE that was generated by HAZUS, independent of the DEM HAZUS subsequently used to generate flood depth grids.

Flood elevation errors for the northeast coastline were the highest of the three coastline sections evaluated, with deviations from validation points averaging approximately 10 feet and no points falling within the 5 foot vertical buffer relative to the validation points (see tables 13-15). Results along the southwest barrier island coastline were relatively better. The “open” shoreline had average errors of approximately 6 feet and approximately 35% of points within the 5 foot buffer. For the southwest barrier island "bay" shoreline the average error was just above 1 foot and all of the points fell within the 5 foot buffer.

Northeast coastline flood elevation errors, HAZUS mapping

Elevation	All
average error (ft)	10.3
median error (ft)	8.7
minimum error (ft)	8.7
maximum error (ft)	12.7
standard deviation (ft)	2.0
w/in 1.0 ft (%)	0
w/in 5.0 ft (%)	0
w/in 10.0 ft (%)	59

Note: errors calculated as difference from 82 validation points.

Southwest-Open coastline flood elevation errors, HAZUS mapping

Elevation	All
average error (ft)	6.2
median error (ft)	6.7
minimum error (ft)	0.7
maximum error (ft)	11.7
standard deviation (ft)	2.7
w/in 1.0 ft (%)	5
w/in 5.0 ft (%)	35
w/in 10.0 ft (%)	93

Note: errors calculated as difference from 43 validation points.

Southwest-Bay coastline flood elevation errors, HAZUS mapping

Elevation	All
average error (ft)	1.1
median error (ft)	1.3
minimum error (ft)	0.3
maximum error (ft)	2.7
standard deviation (ft)	0.6
w/in 1.0 ft (%)	28
w/in 5.0 ft (%)	100
w/in 10.0 ft (%)	100

Note: errors calculated as difference from 78 validation points.

Table 11: Coastline flood elevation errors, HAZUS mapping

4.2 Floodplain boundaries

Coastal floodplain boundary accuracy was assessed at points generated along transects at the coastal floodplain inland most extents of the DFIRM 100-year coastal floodplain and the HAZUS 100-year coastal floodplain. Error metrics included average error (ft); median error (ft); and percent of all points within 100, 200, and 400 feet of associated DFIRM validation points. These buffer distances were chosen as they well-represented the distribution of errors in the coastal flood boundaries. Coastal floodplain boundary validation point errors used for this analysis, along with accompanying maps of validation cross-sections, can be found in Appendix 2.

Floodplain boundary errors were fairly large for most of the coastal runs (see figures 15-17 and table 12). For the Long Island northeast coastline average errors ranged from approximately 200-300 feet and there was no improvement using higher resolution elevation data. At the 200 foot horizontal buffer approximately 60% of all points met this criterion for the two lower resolution elevation data sources, while for LiDAR data slightly under 20% of points met the criteria. For the southwest barrier island "open" coastline the average errors relative to the validation points varied from approximately 300 to 400 feet, although median errors were less at 230 to 290 feet. For this section, approximately one-third of points fell within the 200 foot buffer. Increased resolution elevation data did incrementally improve floodplain boundary mapping accuracy along this coastline. Along the southwest barrier island "bay" coastline errors averaged approximately 500 to 1000 feet, with the better accuracy occurring with use of the LiDAR elevation data. For both the 1 arc second and 1/3 arc second data, approximately 5% of points well within the 200 foot error buffer, while with the LiDAR data this improved to approximately one-third of all points.

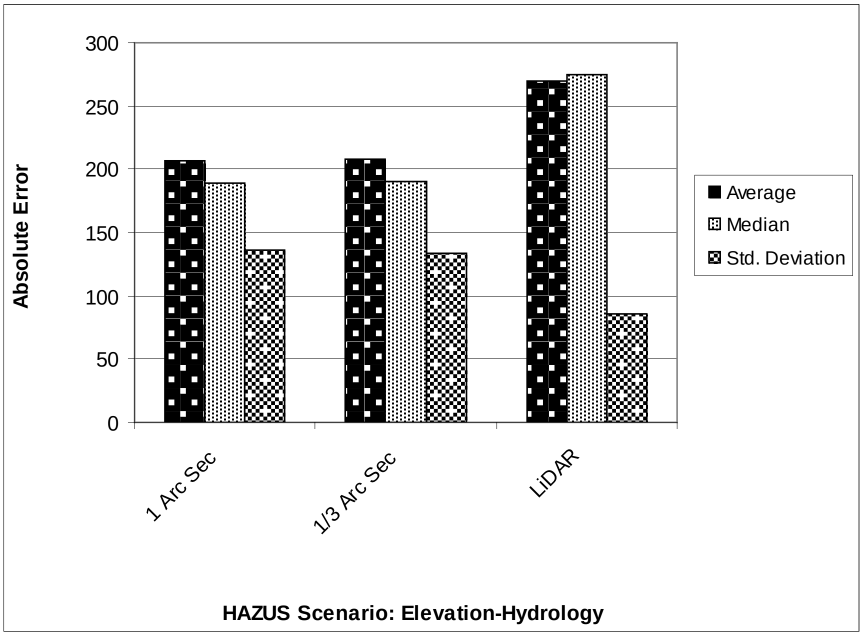


Figure 15: Northeast coastline floodplain boundary errors, HAZUS mapping

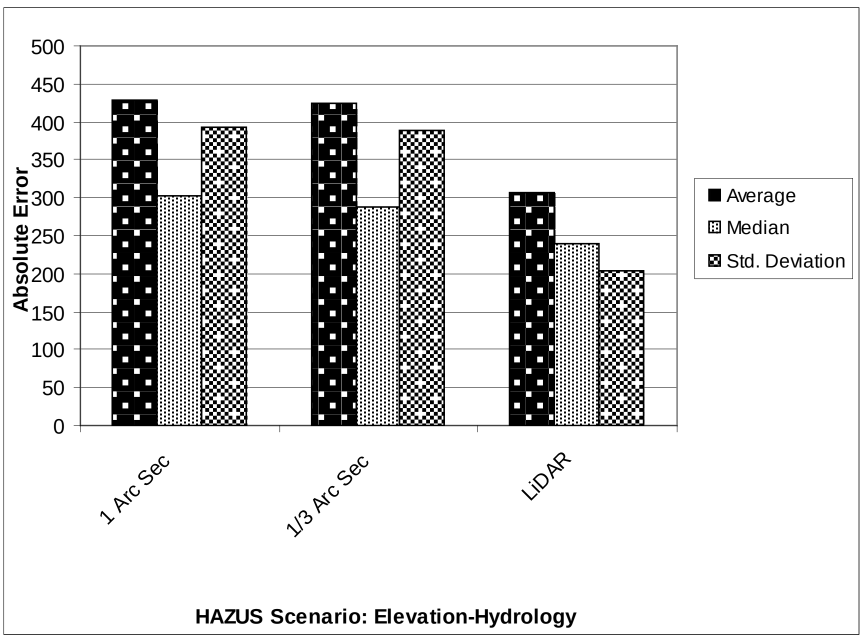


Figure 16: Southwest-Open coastline floodplain boundary errors, HAZUS mapping

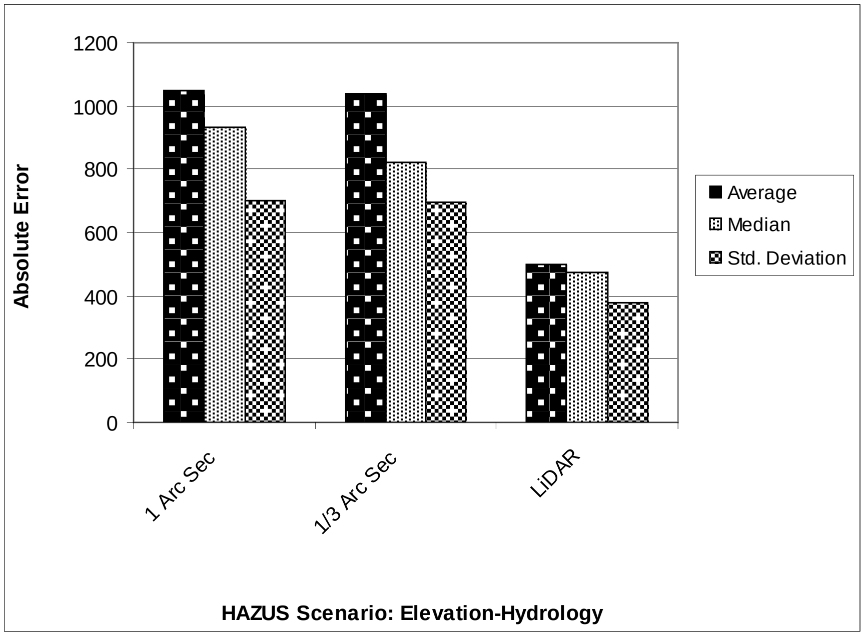


Figure 17: Southwest-Bay coastline floodplain boundary errors, HAZUS mapping

Northeast coastline floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second	1/3 Arc Second	LiDAR
average error (ft)	207	208	270
median error (ft)	189	191	275
minimum error (ft)	14	53	169
maximum error (ft)	680	697	582
w/in 100 ft (%)	10	10	0
w/in 200 ft (%)	57	57	19
w/in 400 ft (%)	95	95	95

Note: errors calculated as difference from 21 validation points.

Southwest-Open coastline floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second	1/3 Arc Second	LiDAR
average error (ft)	429	425	307
median error (ft)	302	287	240
minimum error (ft)	120	100	146
maximum error (ft)	1518	1534	826
w/in 100 ft (%)	0	0	0
w/in 200 ft (%)	32	28	36
w/in 400 ft (%)	64	72	84

Note: errors calculated as difference from 24 validation points.

Southwest-Bay coastline floodplain boundary errors, HAZUS mapping

Elevation	1 Arc Second	1/3 Arc Second	LiDAR
average error (ft)	1049	1041	502
median error (ft)	931	820	475
minimum error (ft)	132	142	39
maximum error (ft)	2795	2778	1162
w/in 100 ft (%)	0	0	22
w/in 200 ft (%)	6	6	33
w/in 400 ft (%)	17	22	44

Note: errors calculated as difference from 18 validation points.

Table 12: Coastline floodplain boundary errors, HAZUS mapping

To further evaluate floodplain mapping options compared to HAZUS default processes, both the HAZUS FIT incorporating existing DFIRM flood polygons and FEMA Q3 floodplain boundaries were compared to the DFIRM boundary and associated validation points. For the southwest barrier island, both the FIT and Q3 options showed the barrier island as nearly completely inundated (submerged from ocean to bay), indicating that errors relative to the validation points were large, but preventing quantification of this error as the floodplain had no inland edge. For the northeast coastline section errors associated with the FIT model using the LiDAR data were approximately the same as HAZUS runs with the same elevation data source (see table 13). Q3 errors were lower than seen with any of the HAZUS runs, with average errors of approximately 50 feet, 90% of points within the 100 foot buffer, and 100% of points within the 200 foot buffer.

Source	LiDAR - FIT	Q3
average error (ft)	285	49
median error (ft)	220	35
minimum error (ft)	18	3
maximum error (ft)	1822	146
w/in 100 ft (%)	5	90
w/in 200 ft (%)	48	100
w/in 400 ft (%)	90	100

Note: errors calculated as difference from 21 validation points.

Table 13: Northeast coastline floodplain boundary errors, other data sources

5.0 Conclusions

The objective of this study was to provide evidence as to whether HAZUS provided a viable option for floodplain mapping where FEMA detailed study data was unavailable.

The two riverine areas with two reaches each yielded a set of study reaches with the following divergent characteristics: small drainage, low relief (Roan Gully, Harris County, TX); moderate drainage, low relief (Willow Creek, Harris County, TX); small drainage, moderate relief (Doby Creek, Mecklenburg, NC); and moderate drainage, moderate relief (Mallard Creek, Mecklenburg, NC). HAZUS performance within these four drainage-relief combinations was mixed. Riverine flood elevation accuracy was best in the smaller basins and was improved in the larger basins when the HAZUS hydrology was replaced with hydrology from a FIS. Improved elevation data did not significantly improve performance for any of the basins. Riverine floodplain boundary accuracy was best for the moderate relief basins having greater topographic control. Accuracy was improved in all scenarios with use of higher resolution elevation data. Alternate hydrology was especially effective in improving floodplain boundary accuracy for the lower relief settings. Finally, substituting FIT data for HAZUS default hydraulics substantially improved output for the low relief basins, whereas the moderate relief basins saw only small improvements. Although based on a very small sample set, these results suggest that HAZUS may be a suitable source for floodplain information with smaller watersheds of at least moderate relief, especially where higher resolution elevation data is available. This conclusion is based on the relatively good accuracy in the HAZUS results with multiple elevation sources, default hydrology, and default hydraulics. Further research and validation across other regions and topographic relief should be conducted to support or counter these results.

The coastal floodplain analysis consisted of three shoreline types, all from the same Atlantic Ocean region. The shoreline types were a fully exposed mainland shoreline, a fully exposed barrier island shoreline, and a sheltered bay barrier island shoreline. Overall, coastal floodplain mapping results were poor. Floodplain elevation accuracy was best for the sheltered bay coastline. Floodplain boundary mapping performance was best for the open coastlines and showed improvement in most cases with higher resolution elevation data. Yet, based on the magnitude of errors, these trials suggest that HAZUS may not be an accurate alternative for mapping coastal floodplains in locations similar to these. The generally poor coastline results may be the result of some combination of (1) particular hydrographic / topographic characteristics of this area that may cause HAZUS coastal processes to perform poorly and (2) melding of AE and VE flood zones in the real world where for this trial coastal flood validation points were generated from strictly VE flood zones. The melding of AE and VE flood zones for the fully exposed mainland shoreline and fully exposed barrier island shoreline does not explain the errors as the HAZUS floodplains consistently extended inland a lesser distance than the VE flood zones. Alternatively, for the sheltered bay barrier island shoreline, melding of AE and VE flood zones in the real world could be contributing to the errors, although it is not possible to quantify the degree to which this melding is contributing to the errors. This evaluation limitation exists because the combination of AE and VE flood zones will, in general, completely inundate the barrier island from the ocean shoreline to the bay shoreline. Therefore, there is no onshore extent at which flooding ceases that allows for creation of combination AE / VE flood zone validation points.

Appendix 1: 100-Year Flood Discharge Values

HAZUS and FIS 100-Year Flood Discharge Values for the Project Study Reaches

Appendix 1, Tables 1-4. Roan Gully 100-year flood discharge by reach, HAZUS and FIS

1 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
583	802	2608
630	916	2608
662	1133	2608
664	1459	2608

1/3 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
600	735	2608
646	837	2608
674	1231	2608
677	1542	2608

LiDAR DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
651	690	2608
687	1377	2608

Contour DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
622	752	2608
659	940	2608
691	1359	2608

Appendix 1, Tables 5-8. Willow Creek 100-year flood discharge by reach, HAZUS and FIS

1 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
1084	376	1420
1113	529	1420
1115	984	1420
1112	1276	3300
1095	1637	3300
1091	2242	3300
1081	2522	3300
1085	2662	3300
1072	3004	3300
1070	3255	3300
1054	3244	3555
1052	3289	3555
1047	3362	3555
1017	3381	3555
998	3377	3555
1018	3551	3555
1024	3671	6910
1023	3904	6910
1015	4013	6910
1014	4221	6910
1010	4262	6910
1011	4320	6910
940	4708	7327
909	4760	7327
895	4918	7327

1/3 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
1128	481	1420
1130	942	1420
1131	1246	3300
1106	2196	3300
1104	2443	3300
1103	2570	3300
1093	2779	3300
1091	3290	3300
1074	3337	3555
1067	3336	3555
1041	3368	3555
1014	3401	3555
1046	3591	3555
1038	3866	6910
1039	3981	6910
1032	4242	6910
1030	4231	6910
1031	4283	6910
960	4745	7327
913	4902	7327

LiDAR DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
1071	437	1420
1120	852	1420
1122	1206	1420
1123	1517	3300
1101	2107	3300
1096	2379	3300
1084	3262	3300
1074	3293	3555
1062	3378	3555
1061	3620	3555
1049	3652	3555
1030	3731	3555
1020	4530	3555
1010	4576	3555
1011	4643	6910
1037	4953	6910
1029	5021	6910
1023	5027	6910
1024	5078	6910
983	5082	6910
956	5424	7327
938	5672	7327

Contour DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
1144	587	1420
1139	1317	3300
1125	2030	3300
1122	2461	3300
1118	2548	3300
1114	2981	3300
1105	3475	3300
1094	3564	3555
1089	3801	3555
1081	3898	3555
1076	3968	3555
1051	4723	3555
1041	4704	3555
1029	4811	3555
1025	4917	6910
1059	5134	6910
1054	5175	6910
1049	5281	6910
1048	5326	6910
1044	5420	6910
1001	5379	6910
972	5757	7327
949	5865	7327

Appendix 1, Tables 9-11. Doby Creek 100-year flood discharge by reach, HAZUS and FIS

1 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
553	318	1438
537	849	1438
516	1149	1582
503	1402	2130
489	2114	2746

1/3 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
598	354	1438
580	871	1438
556	1158	1582
525	1194	2745
521	2198	2745
504	2280	2745

LiDAR DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
588	354	1438
578	819	1438
542	1153	1582
514	2005	2745
511	2208	2745

Appendix 1, Tables 12-14. Mallard Creek 100-year flood discharge by reach, HAZUS and FIS

1 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
495	825	1307
476	1142	1676
485	1320	2263
486	1763	3321
483	2075	4195
490	3498	8162
501	3760	7961
507	4856	10343
511	4958	10343
509	5724	12823
504	5787	12823
478	5929	12763
452	6787	14768
455	6907	14768
453	7020	14717
463	7117	14717

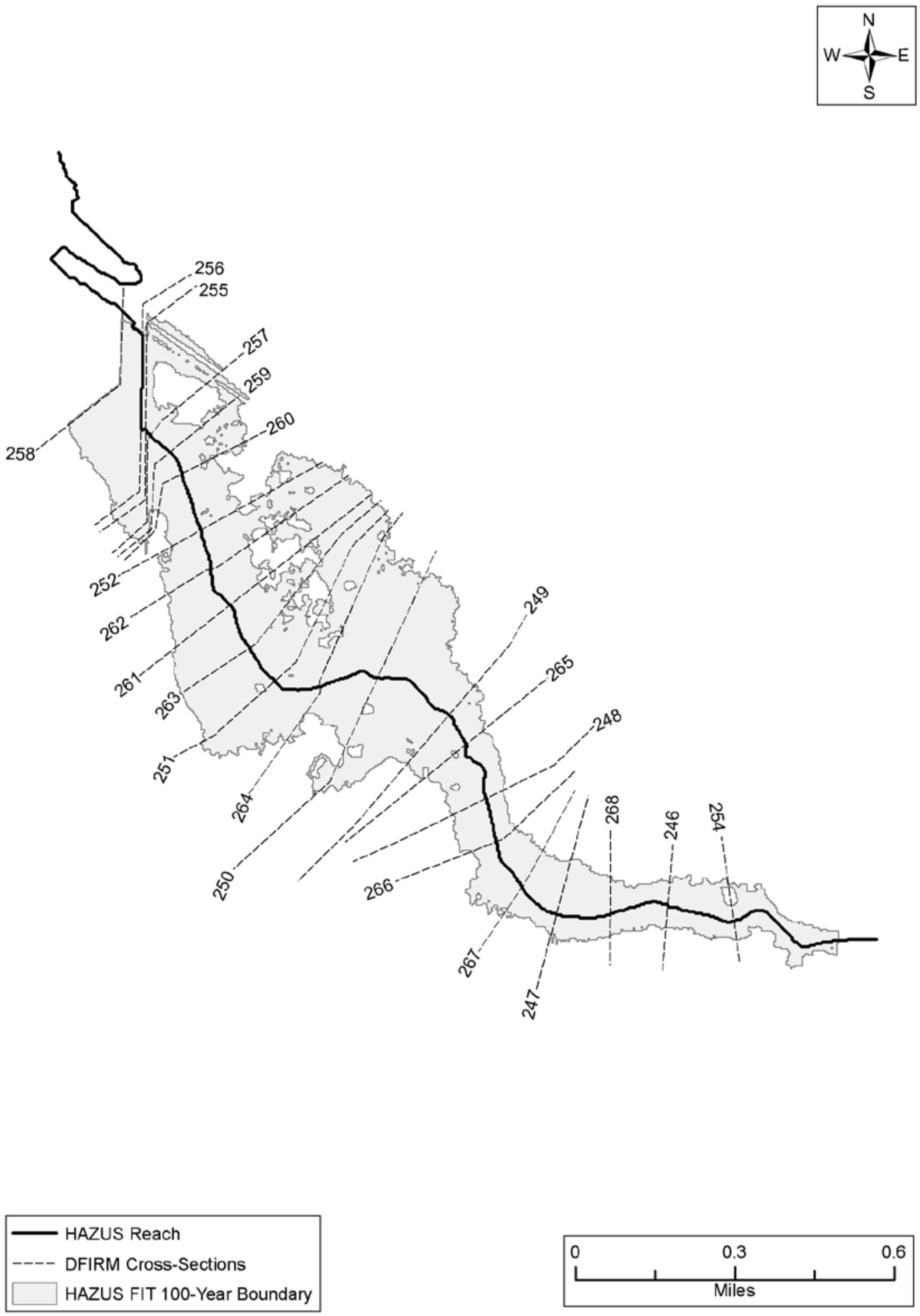
1/3 ArcSec DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
516	847	1307
493	1132	1676
504	1325	2263
505	1764	3321
501	2079	4195
506	3503	8162
513	3723	7961
526	3817	7961
529	4881	10343
535	4984	10343
531	5731	12823
524	5786	12823
497	5936	12763
498	5849	12763
474	6793	14768
472	6916	14768
469	7107	14717
476	7123	14717

LiDAR DEM		
HAZUS Reach ID	HAZUS Q (cfs)	FIS Q (cfs)
353	844	1307
338	1128	1676
345	1323	2263
346	1766	3321
342	2081	4195
347	3497	8162
360	3712	7961
364	4836	10343
362	5730	12823
359	5784	12823
348	5844	12763
340	5924	12763
322	6792	14768
321	6914	14768
318	7035	14717
325	7122	14717

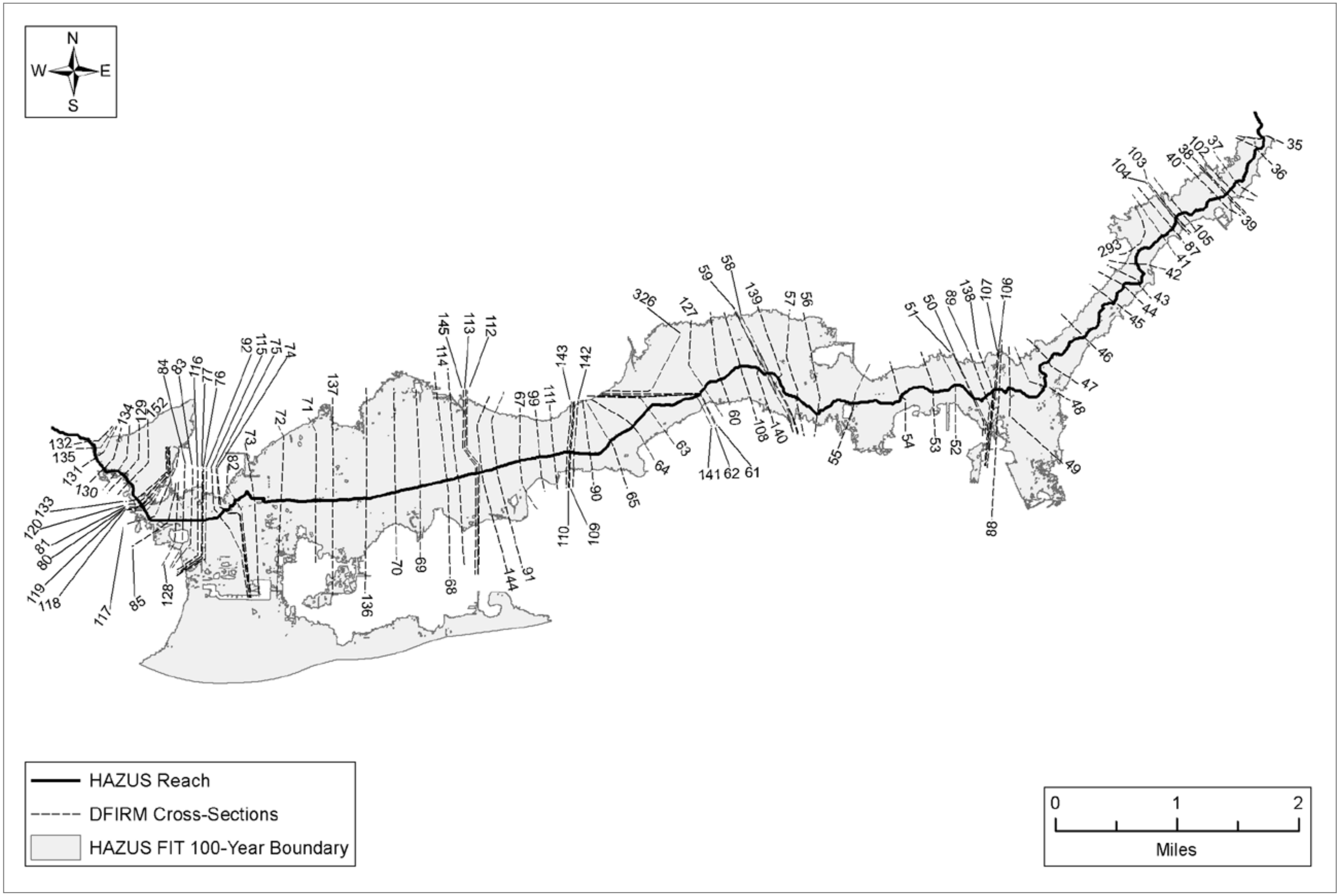
Appendix 2: Maps of Validation Cross-Sections

Riverine Flood Depth Validation Point Errors, Maps of Validation Cross-Sections

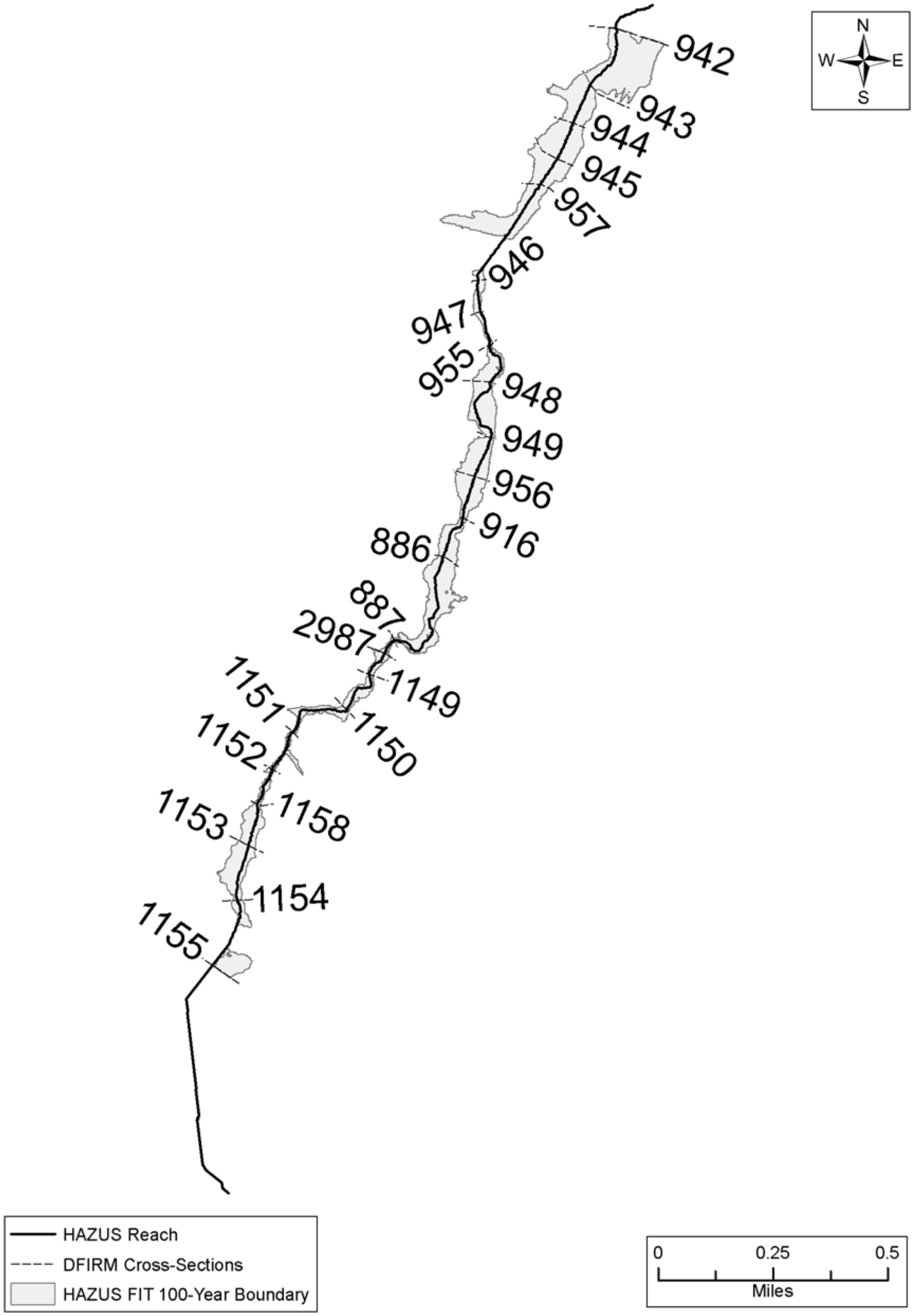
Appendix 2, Figure 1. Roan Gully Validation Cross-Sections



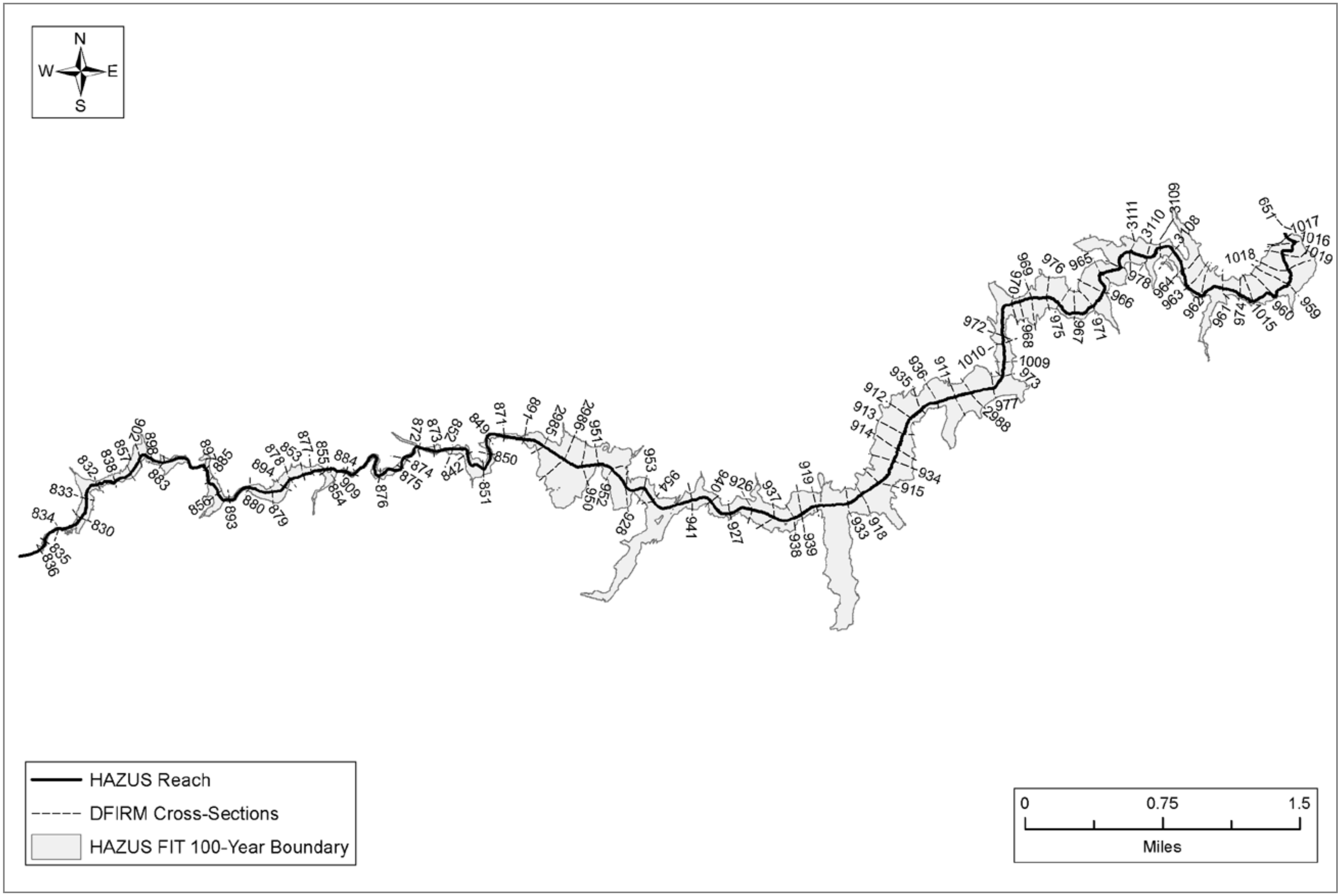
Appendix 2, Figure 2. Willow Creek Validation Cross-Sections



Appendix 2, Figure 3. Doby Creek Validation Cross-Sections



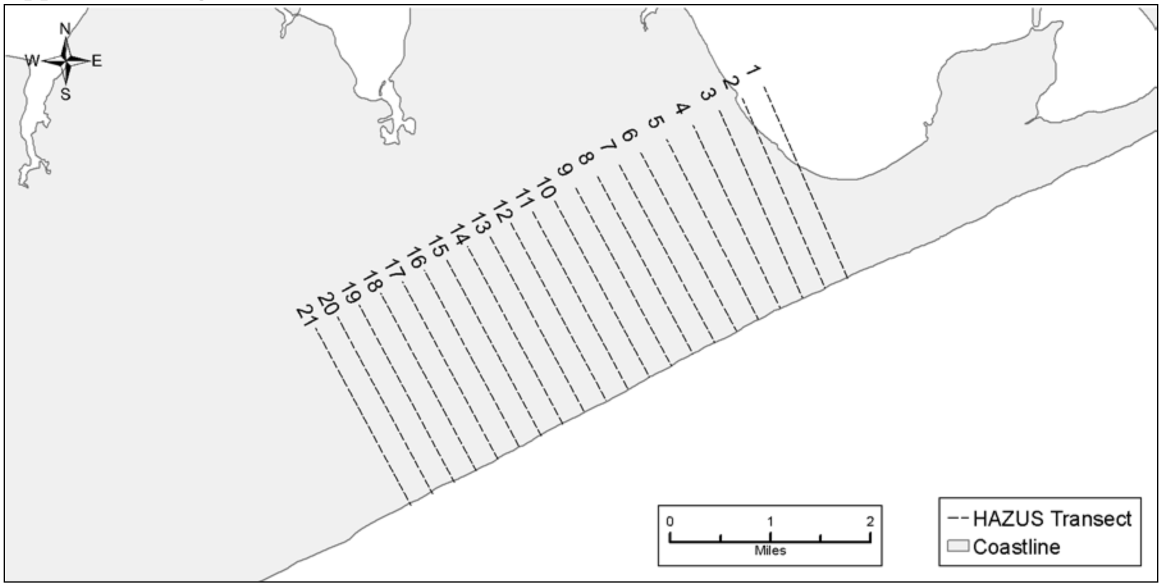
Appendix 2, Figure 4. Mallard Creek Validation Cross-Sections



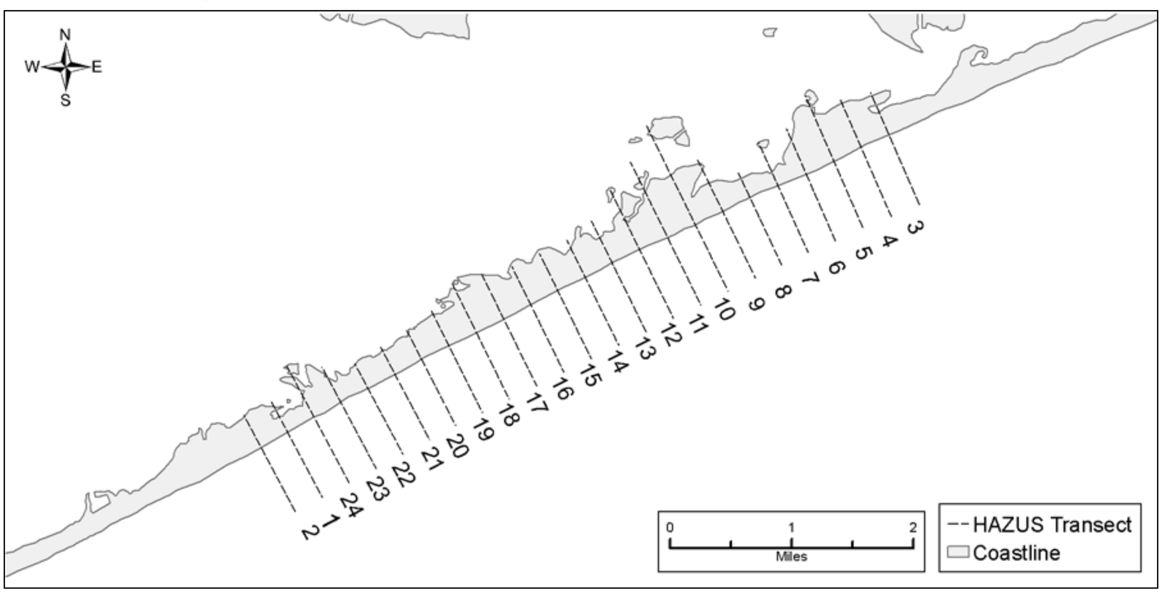
Appendix 3: Maps of Validation Transects

Coastal Flood Depth Validation Point Errors, Maps of Validation Transects

Appendix 3, Figure 1. Northeast Coastline Validation Transects



Appendix 3, Figure 2. Southwest-Open Coastline Validation Transects



Appendix 3, Figure 3. Southwest-Bay Coastline Validation Transects