

# Digital Elevation Models of Hawaii: Procedures, Data Sources, and Analysis

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Prepared for the Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act by the NOAA National Centers for Environmental Information (NCEI)

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## Summary

In September of 2021, NOAA’s National Centers for Environmental Information (NCEI) developed integrated bathymetric–topographic digital elevation models (DEMs) according to specifications developed jointly by NOAA NCEI and the United States Geological Survey (USGS) to help better define a consistent elevation mapping framework for the nation (Table 1). Overall, 133 tiled DEMs were created in the area of interest: 54 tiles were created at the highest resolution of 1/9<sup>th</sup> arc-second and 79 were created at a resolution of 1/3<sup>rd</sup> arc-second. Only 1/9<sup>th</sup> arc-second DEM tiles integrate topography and bathymetry. The DEM tiles represent best publicly-available data at the time of their creation; the intent is to update specific tiles as new source data becomes available. The utilization of a tiling scheme in developing the DEMs is intended to improve data management during source data processing as well as facilitate targeted DEM updates.

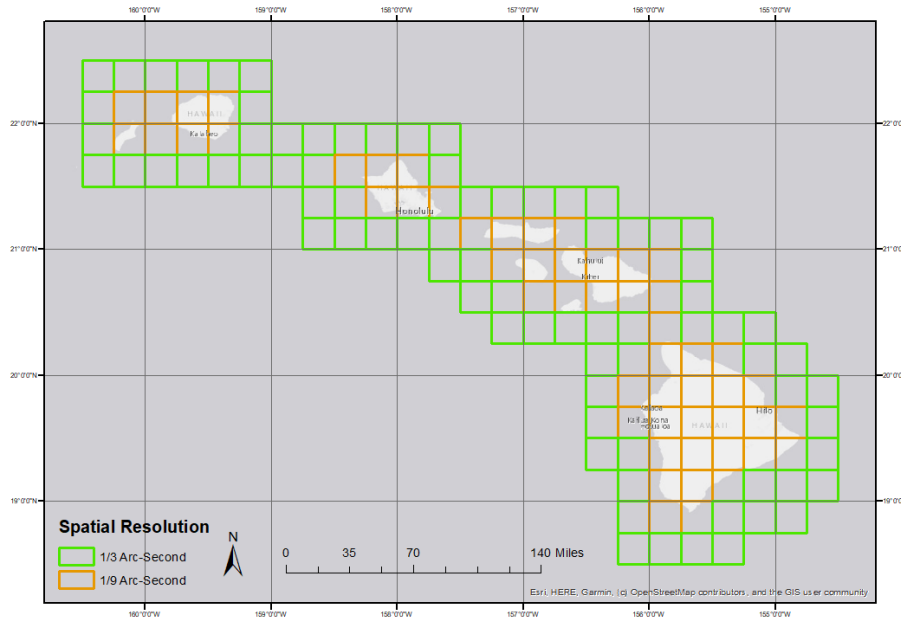
The tiled DEMs cover the State of Hawaii. The extents of these DEMs, procedures, data sources, and analysis are described below. The methodologies used by NCEI in developing DEMs are described in the NOAA National Centers for Environmental Information Topo-Bathymetric Digital Elevation Models: East Florida (Amante, 2018).

**Table 1.** Specifications for the DEM tiles.

<i>Grid Area</i>	Hawaii
Coverage Area	160.50° to 154.50° W, 18.50° to 22.50° N
Coordinate System	Geographic decimal degrees
Horizontal Datum	WGS 84
Vertical Datum	Local Mean Sea Level (LMSL)
Vertical Units	Meters
Cell Size	Variable (1/9 <sup>th</sup> or 1/3 <sup>rd</sup> Arc-Second)
Grid Format	Geotiff

## DEM Specifications

The Hawaii tiled DEMs were built to the specifications listed in Table 1. Figure 1 shows the 1/9<sup>th</sup> arc-second DEM tile boundaries in orange and the 1/3<sup>rd</sup> arc-second DEM tile boundaries in green.



**Figure 1.** Map image of the DEM tile boundaries for the Hawaii DEMs.

## Data Sources and Processing

Bathymetry data used in the generation of the Hawaii DEMs included NOAA National Ocean Service (NOS) hydrographic surveys and bathymetric attributed grids (BAGs), NOAA Office of Coast Survey (OCS) electronic navigational charts (ENCs), NOAA NCEI multibeam survey data, and U.S. Army Corps of Engineers (USACE) channel condition surveys (Table 2).

**Table 2:** Bathymetric data sources used in DEM development.

Source	Date	Data Type	Spatial Resolution	Horizontal Datum	Vertical Datum
NOAA OCS electronic navigational chart (ENC) extracted soundings	1966 - 2019	XYZ	< 10 meters to several kilometers	WGS84	Mean Lower Low Water (MLLW)
NOAA NCEI multibeam bathymetric surveys	2008 - 2016	XYZ	~1 to 10 meters	NAD83	Assumed instantaneous water level
NOAA BAG	2017	Gridded Bathymetry	< 1 meter to ~10 meters	UTM 15N	Mean Lower Low Water (MLLW)

NOAA hydrographic surveys	NOS	1934 - 2006	XYZ	< 10 meters to several kilometers	WGS84	Mean Lower Low Water (MLLW)
Moby Multibeam Grids		2016	Bathymetry DEM	varies	WGS84	LMSL
MBARI Gridded Bathymetry		2014	Bathymetry DEM	varies	WGS84	LMSL

Topographic and topographic/bathymetric data used in developing Hawaii DEMs included lidar data from the U.S. Geological Survey (USGS), USACE and NOAA; as well as gridded DEMs from USGS and NOAA (Tables 3 & 4).

**Table 3:** Topographic-Bathymetric data sources used in DEM development.

Source	Date	Data Type	Resolution	Horizontal Datum	Vertical Datum
2013 USACE NCMP Topobathy Lidar: Lanai (HI)	2013	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar: Kauai (HI)	2013	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar: Maui (HI)	2013	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar: Molokai (HI)	2013	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar: Oahu (HI)	2013	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar: Hawaii (Big Island)	2013	Lidar	< 1 meter	varies	LMSL
2007 USACE NCMP Topobathy Lidar: Hawaiian Islands	2007	Lidar	< 1 meter	varies	LMSL
2013 USACE NCMP Topobathy Lidar DEM (LMSL): Niihau, HI	1999 - 2020	DEM	< 1 meter	varies	LMSL
SHOALS topobathy	2015	Lidar	varies	WGS84	LMSL

**Table 4:** Topographic data sources used in DEM development.

Source	Date	Data Type	Resolution	Horizontal Datum	Vertical Datum
USGS National Elevation Dataset 1/3 Arc-second	2020	DEM	1/3 arc second	WGS84	LMSL
2005 NOAA Lidar: Oahu & Maui (HI)	2005	Lidar	< 1 meter	varies	Geoid12a
2003 NOAA Lidar: Oahu Coastline (HI)	2003	Lidar	< 1 meter	varies	Geoid12a
2005 HI Office of Planning Lidar: Kilauea Crater	2005	Lidar	< 1 meter	varies	Geoid12a
2013 NOAA Lidar: Oahu, HI	2013	Lidar	< 1 meter	varies	Geoid12a
2015 NOAA Lidar: Pelekane Watershed, HI	2015	Lidar	< 1 meter	varies	LMSL

With the exception of the NOAA NCEI, MOBY and MBARI multibeam bathymetric surveys, bathymetric and topographic data were transformed, when applicable, from mean lower low water (MLLW) or Geoid12a to LMSL.

Vertical datum transformations were performed using NOAA’s VDatum Software or using a constant offset (Table 5). Where more recent, higher resolution data existed, older data were edited or superseded.

**Table 5:** Constant offsets used to transform data from Geoid12a to LMSL

<b>Dataset</b>	<b>Offset (meters)</b>
2005 NOAA Lidar: Oahu & Maui (HI)	-0.633
2003 NOAA Lidar: Oahu Coastline (HI)	-0.633
2005 HI Office of Planning Lidar: Kilauea Crater	-0.474
2013 NOAA Lidar: Oahu, HI	-0.65

## DEM Development

Development of the Hawaii DEM tiles followed procedures documented in NOAA National Centers for Environmental Information Topo-Bathymetric Digital Elevation Models: East Florida (Amante, 2018). Exceptions being that gridding weights were modified as shown in Table 6. The bathymetric pre-surface derived from data sources in Tables 2 and 3 was utilized in the final DEM creation. Older, coarse, and/or inaccurate bathymetric surveys from NOAA NOS hydrographic surveys, NOAA NCEI multibeam bathymetric surveys, and NOAA OCS electronic navigational chart (ENC) extracted soundings were used in the bathymetric pre-surface generation but were not used as source datasets in the final DEM creation.

**Table 6:** Data hierarchy used to assign gridding weights.

<b>Dataset</b>	<b>Relative Gridding Weight</b>
NOAA NOS Bathymetry (bag)	1.75
NOAA NOS Bathymetry (hydro)	0.1
Bathymetric Charts (charts)	0.01
NOAA Multibeam Surveys (AHI-05-04)	0.01
NOAA Multibeam Surveys (AHI-06-05)	0.25
NOAA Multibeam Surveys (AHI-06-09)	0.25
NOAA Multibeam Surveys (FK140204)	1.4
NOAA Multibeam Surveys (FK140307)	1.4
NOAA Multibeam Surveys (FK140418)	1.4
NOAA Multibeam Surveys (FK140502)	1.4
NOAA Multibeam Surveys (FK140625)	1.4
NOAA Multibeam Surveys (FK151005)	1.5
NOAA Multibeam Surveys (FK160115)	1.6
NOAA Multibeam Surveys (FK161229)	1.7
NOAA Multibeam Surveys (FK170124)	0.01
NOAA Multibeam Surveys (FK170825)	1.7
NOAA Multibeam Surveys (FK171224)	1.8

NOAA Multibeam Surveys (FK180119)	1.8
NOAA Multibeam Surveys (FK190726)	0.15
NOAA Multibeam Surveys (FK190831)	1.9
NOAA Multibeam Surveys (FK191005)	1.9
NOAA Multibeam Surveys (FK191031)	1.9
NOAA Multibeam Surveys (HLY03DF)	0.3
NOAA Multibeam Surveys (HLY11TB)	0.1
NOAA Multibeam Surveys (HLY11TC)	1.1
NOAA Multibeam Surveys (HLY16TB)	0.25
NOAA Multibeam Surveys (HLY17TC)	1.7
NOAA Multibeam Surveys (HI-05-04)	1.25
NOAA Multibeam Surveys (HI-05-05)	0.5
NOAA Multibeam Surveys (HI-05-08)	0.5
NOAA Multibeam Surveys (HI-06-05)	0.5
NOAA Multibeam Surveys (HI-06-09)	0.5
NOAA Multibeam Surveys (HI-06-10)	0.5
NOAA Multibeam Surveys (HI-06-12)	0.5
NOAA Multibeam Surveys (HI-06-14)	0.5
NOAA Multibeam Surveys (KR2001)	0.1
NOAA Multibeam Surveys (KM0202)	0.2
NOAA Multibeam Surveys (KM0203)	0.2
NOAA Multibeam Surveys (KM0204)	0.2
NOAA Multibeam Surveys (KM0205)	0.2
NOAA Multibeam Surveys (KM0206)	0.2
NOAA Multibeam Surveys (KM0207)	0.2
NOAA Multibeam Surveys (KM0208)	0.2
NOAA Multibeam Surveys (KM0209)	0.2
NOAA Multibeam Surveys (KM0210)	0.2
NOAA Multibeam Surveys (KM0211)	0.2
NOAA Multibeam Surveys (KM0301)	0.3
NOAA Multibeam Surveys (KM0302)	0.3
NOAA Multibeam Surveys (KM0303)	0.3
NOAA Multibeam Surveys (KM0304)	0.1
NOAA Multibeam Surveys (KM0305)	0.3
NOAA Multibeam Surveys (KM0306)	0.3
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NOAA Multibeam Surveys (EW9709)	0.002
NOAA Multibeam Surveys (EW9802)	0.002
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NOAA Multibeam Surveys (EX1003)	1
NOAA Multibeam Surveys (EX1005)	1
NOAA Multibeam Surveys (EX1504L1)	1.5

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NOAA Multibeam Surveys (AMAT08RR)	0.6
NOAA Multibeam Surveys (AMAT09RR)	0.6
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NOAA Multibeam Surveys (CNTL14RR)	0.3
NOAA Multibeam Surveys (DRFT11RR)	0.2
NOAA Multibeam Surveys (DRFT12RR)	0.2
NOAA Multibeam Surveys (DRFT13RR)	0.2
NOAA Multibeam Surveys (DRFT14RR)	0.2
NOAA Multibeam Surveys (DRFT15RR)	0.2
NOAA Multibeam Surveys (DRFT16RR)	0.2
NOAA Multibeam Surveys (HNRO17RR)	0.1
NOAA Multibeam Surveys (KIWI02RR)	0.003
NOAA Multibeam Surveys (KIWI03RR)	0.003
NOAA Multibeam Surveys (KIWI04RR)	0.003
NOAA Multibeam Surveys (KIWI05RR)	0.003
NOAA Multibeam Surveys (KIWI12RR)	0.002
NOAA Multibeam Surveys (KRUS01RR)	0.4
NOAA Multibeam Surveys (KRUS02RR)	0.4
NOAA Multibeam Surveys (KRUS03RR)	0.4
NOAA Multibeam Surveys (KRUS05RR)	0.001
NOAA Multibeam Surveys (KRUS06RR)	0.1
NOAA Multibeam Surveys (LPRS04RR)	0.2
NOAA Multibeam Surveys (LPRS05RR)	0.2
NOAA Multibeam Surveys (NECR02RR)	0.01
NOAA Multibeam Surveys (NECR04RR)	0.01

NOAA Multibeam Surveys (NECR05RR)	0.01
NOAA Multibeam Surveys (RR1609)	0.25
NOAA Multibeam Surveys (RR1612)	0.01
NOAA Multibeam Surveys (RR1814)	0.01
NOAA Multibeam Surveys (RB-18-05)	1.8
NOAA Multibeam Surveys (RB-18-06)	1.8
NOAA Multibeam Surveys (RB1601)	1.6
NOAA Multibeam Surveys (SKQ201401S)	0.04
NOAA Multibeam Surveys (SKQ201402S)	0.04
NOAA Multibeam Surveys (SKQ201615S)	0.06
NOAA Multibeam Surveys (SKQ201616T)	0.06
NOAA Multibeam Surveys (SUM0105U)	0.1
NOAA Multibeam Surveys (SUM0108A)	0.1
NOAA Multibeam Surveys (SUM0108B)	0.1
NOAA Multibeam Surveys (SUM0408P)	0.4
NOAA Multibeam Surveys (YK1999)	0.001
NOAA Multibeam Surveys (YK2002)	0.001
NOAA Multibeam Surveys (TUIM02MV)	0.4
NOAA Multibeam Surveys (TUIM08MV)	0.5
NOAA Multibeam Surveys (TUIM09MV)	0.5
NOAA Multibeam Surveys (TUIM10MV)	0.5
NOAA Multibeam Surveys (TUNE03WT)	0.1
NOAA Multibeam Surveys (TUNE04WT)	0.1
NOAA Multibeam Surveys (AII8L12)	0.1
NOAA Multibeam Surveys (AVON05MV)	0.08
NOAA Multibeam Surveys (B00068)	0.08
NOAA Multibeam Surveys (B00069)	0.08
NOAA Multibeam Surveys (B00070)	0.08
NOAA Multibeam Surveys (B00071)	0.08
NOAA Multibeam Surveys (B00072)	0.08
NOAA Multibeam Surveys (B00073)	0.08
NOAA Multibeam Surveys (B00074)	0.08
NOAA Multibeam Surveys (B00075)	0.08
NOAA Multibeam Surveys (B00077)	0.08
NOAA Multibeam Surveys (B00078)	0.08
NOAA Multibeam Surveys (B00084)	0.08
NOAA Multibeam Surveys (B00086)	0.08
NOAA Multibeam Surveys (B00090)	0.08
NOAA Multibeam Surveys (B00096)	0.08
NOAA Multibeam Surveys (B00097)	0.08
NOAA Multibeam Surveys (B00098)	0.08
NOAA Multibeam Surveys (B00099)	0.08
NOAA Multibeam Surveys (B00100)	0.08
NOAA Multibeam Surveys (B00101)	0.08
NOAA Multibeam Surveys (B00296)	0.1
NOAA Multibeam Surveys (B00297)	0.1
NOAA Multibeam Surveys (B00299)	0.1
NOAA Multibeam Surveys (B00300)	0.1

NOAA Multibeam Surveys (CRGN03WT)	0.08
NOAA Multibeam Surveys (CRGN04WT)	0.08
NOAA Multibeam Surveys (CRGN05WT)	0.08
NOAA Multibeam Surveys (DI9301)	0.1
NOAA Multibeam Surveys (LAN-92)	0.1
NOAA Multibeam Surveys (LFEX01MV)	0.4
NOAA Multibeam Surveys (MGLN10MV)	0.6
NOAA Multibeam Surveys (MGLN11MV)	0.6
NOAA Multibeam Surveys (MRTN01WT)	0.08
NOAA Multibeam Surveys (PANR06MV)	0.1
NOAA Multibeam Surveys (PANR07MV)	0.1
NOAA Multibeam Surveys (PANR08MV)	0.1
NOAA Multibeam Surveys (RC2610)	0.08
Multibeam Survey (FK140613)	1.25
Moby Multibeam Grids (moby)	0.01
MBARI Gridded Bathymetry (mbari)	0.1
SHOALS topobathy (hawaii_shoals)	1
SHOALS topobathy (kauai_shoals)	1
SHOALS topobathy (lanai_shoals)	1
SHOALS topobathy (maui_shoals)	1
SHOALS topobathy (oahu_shoals)	1
National Elevation Dataset 1/3 Arc-second (ned13)	0.25
2005 NOAA Lidar: Oahu & Maui (HI) (24)	1
2003 NOAA Lidar: Oahu Coastline (HI) (25)	1
2005 HI Office of Planning Lidar: Kilauea Crater (2548)	1
2013 NOAA Lidar: Oahu, HI (3655)	1.25
2013 USACE NCMP Topobathy Lidar: Lanai (HI) (5030)	1
2013 USACE NCMP Topobathy Lidar: Kauai (HI) (5031)	2
2013 USACE NCMP Topobathy Lidar: Maui (HI) (5032)	1.25
2013 USACE NCMP Topobathy Lidar: Molokai (HI) (5033)	1.25
2013 USACE NCMP Topobathy Lidar: Oahu (HI) (5034)	1.25
2013 USACE NCMP Topobathy Lidar: Hawaii (Big Island) (5039)	1
2007 USACE NCMP Topobathy Lidar: Hawaiian Islands (517)	1
2015 NOAA Lidar: Pelekane Watershed, HI (5180)	1.75
2013 USACE NCMP Topobathy Lidar DEM (LMSL): Niihau, HI (9002)	1.25

## DEM Analysis

Once the Hawaii DEMs were generated, the DEMs were compared to the high-resolution source elevation data and high-resolution imagery. Inconsistencies were evaluated and resolved based on the most reliable data available. The largest outstanding issues with the DEM tiles are the lack of publicly-available high-resolution datasets for much of the island interiors. In such areas, older, coarser-resolution, topographic data were used from the USGS. When higher-resolution, publicly available data becomes available for these areas, these DEM tiles will be updated with more accurate, detailed elevation and depth information.

## References

C.J. Amante (2018) NOAA National Centers for Environmental Information Topo-Bathymetric Digital Elevation Models: East Florida, NOAA, pp. 6.

[https://www.ngdc.noaa.gov/mgg/dat/dems/tiled\\_tr/east\\_florida\\_tiled\\_navd88\\_2018.pdf](https://www.ngdc.noaa.gov/mgg/dat/dems/tiled_tr/east_florida_tiled_navd88_2018.pdf)