Digital Elevation Model of Orange County, California: Procedures, Data Sources, and Analysis

Prepared for the National Tsunami Hazard Mitigation Program (NTHMP) by the NOAA National Centers for Environmental Information (NCEI)
September 22, 2015
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Summary

In September of 2015, NOAA's National Centers for Environmental Information (NCEI) developed an integrated bathymetric–topographic digital elevation model (DEM) of Orange County, California for the National Tsunami Hazard Mitigation Program (NTHMP). The DEM will be used to support modeling tsunami generation, propagation, and inundation. The DEM covers Orange County, California including the communities of San Clemente, Dana Point, Laguna Beach, Newport Beach, Huntington Beach, Long Beach, Rancho Palos Verdes, and Santa Catalina Island and San Clemente Island. Extents of this DEM, procedures, data sources, and analysis are described below. The methodologies used by NCEI in developing DEM are described in the NOAA Technical Memorandum-52 for Central California and San Francisco Bay (Carignan et al., 2011).

DEM Specifications

The Orange County DEM was built to the specifications listed in Table 1. Figure 1 shows this 1/3 arc-second Orange County integrated topographic–bathymetric DEM boundary in red, the 2008 Santa Barbara, 2010 Santa Monica, 2011 Port San Luis, 2012 Monterey, and 2012 San Diego DEMs in green and the 2013 Southern California Coastal Relief Model vers.2 in blue.

Table 1. Specifications for the Orange County, California DEM.

Cell Size	1/3 arc-second
Coverage	117.45° to 118.90° W, 32.62° to 33.85° N
Coordinate System	Geographic decimal degrees
Horizontal Datum	World Geodetic System 1984 (WGS 84)
Vertical Datum	NAVD 88
Vertical Units	Meters
Grid Format	ASCII raster grid

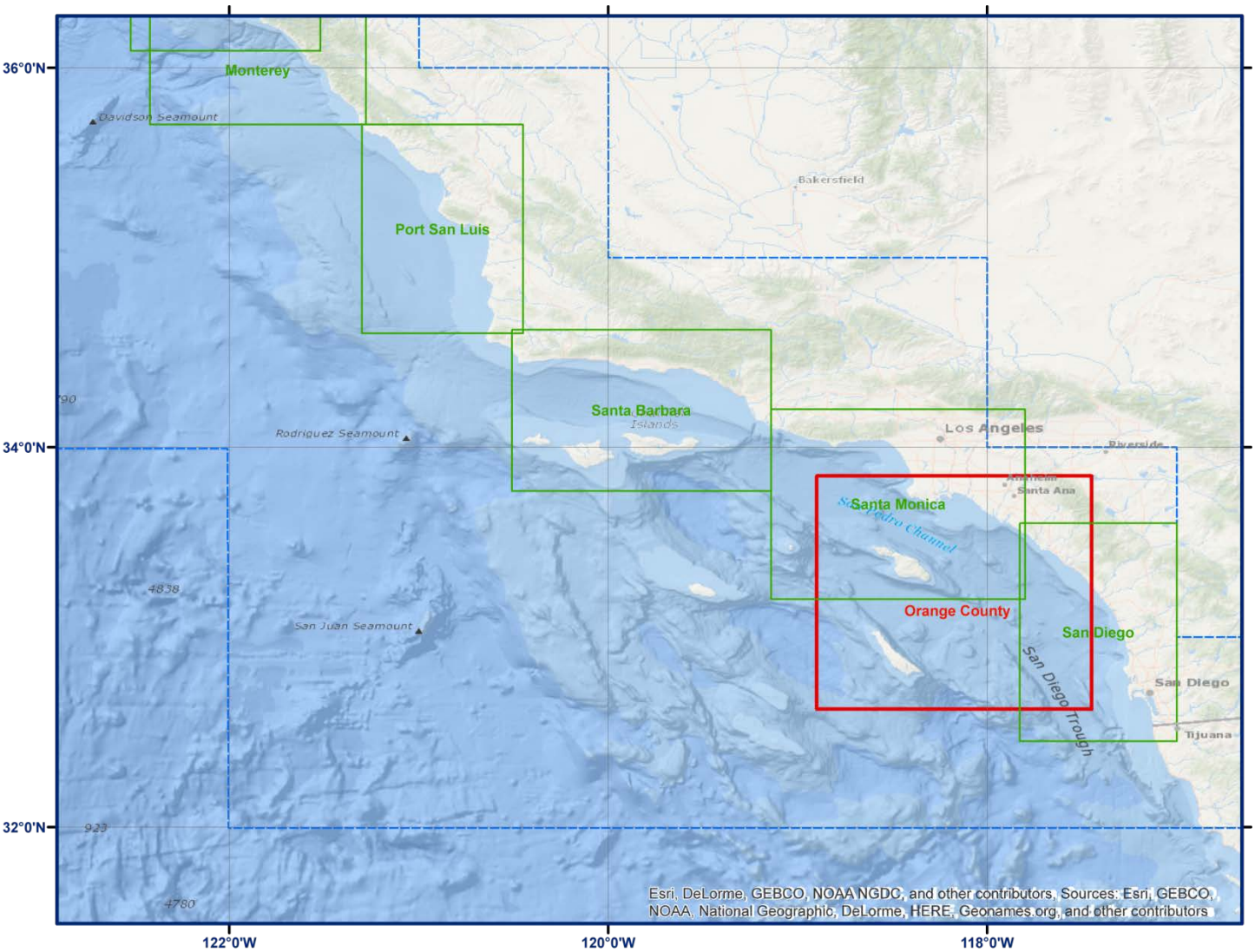

Figure 1. Map image of the boundaries for the 1/3 arc-second Orange County DEM in red and the previously developed DEMs in green.

Data Sources and Processing

Digital coastlines were extracted from NOAA's National Geodetic Survey (NGS) Continually Updated Shoreline Product (CUSP, http://shoreline.noaa.gov/data/datasheets/cusp.html). This coastline was edited to match either recently acquired high resolution lidar data or imagery available via Google Earth and ESRI's

World Imagery map service (http://www.arcgis.com/features/maps/index.html). Bathymetric and topographic data were downloaded from NOAA's Office for Coastal Management (OCM), the California State University, Monterey Bay (CSUMB) Seafloor Mapping Lab., U.S. Geological Society (USGS), and NCEI. Figure 2 shows the source and coverage of the datasets used in developing the Orange County DEM.

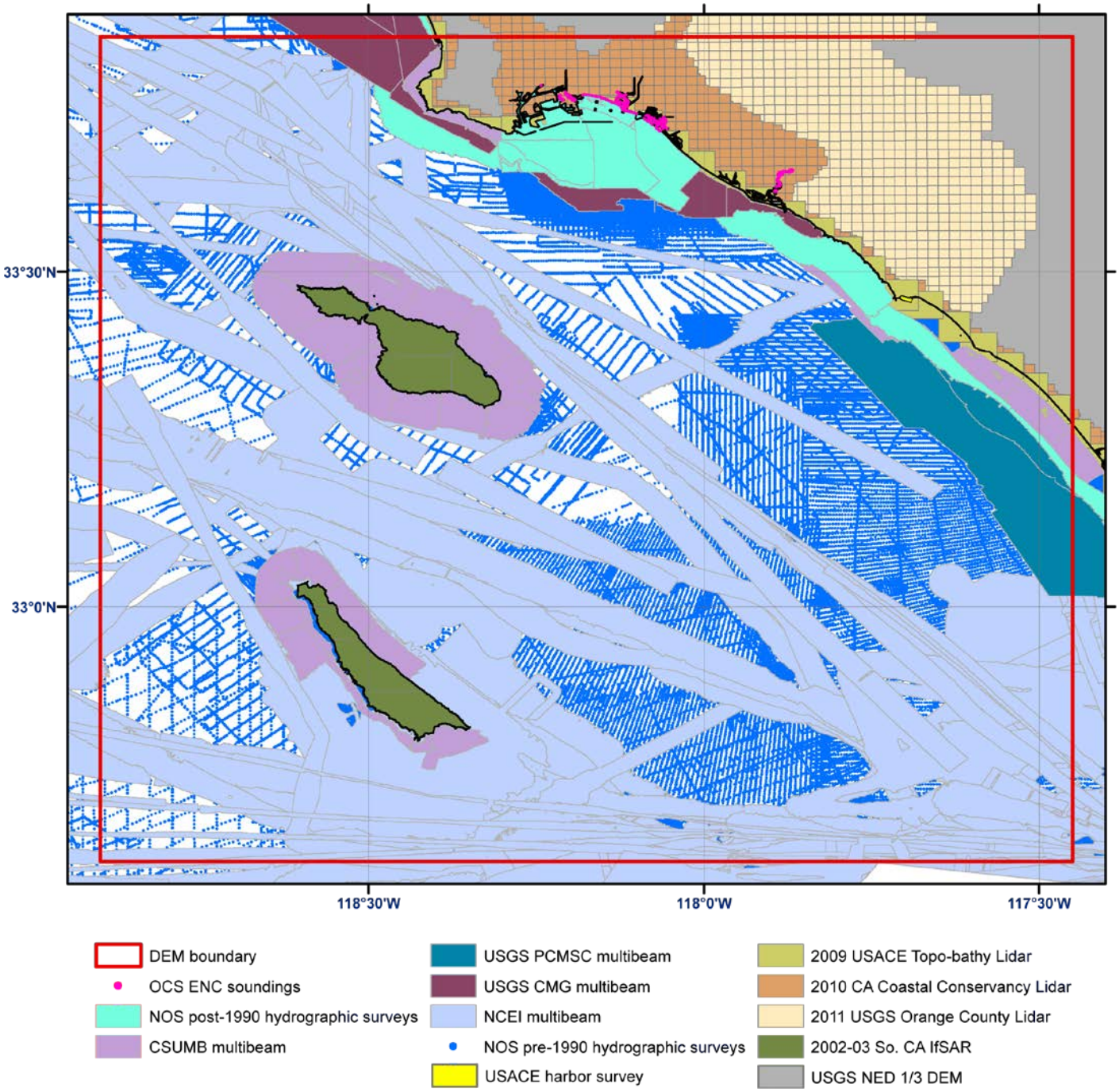

Figure 2. Source and coverage of the datasets used in compiling the Orange County DEM.

Table 2 lists the bathymetry data used in the compilation of the Orange County DEM including NOS hydrographic surveys (Appendix A) and multibeam surveys (Appendix B), CSUMB multibeam surveys, USGS multibeam surveys, and the USACE harbor survey for Dana Point.

Table 2: Bathymetric data sources used in compiling the Orange County, California DEM.

Source	*Date*	*Data Type*	*Spatial Resolution*	*Horizontal Datum*	*Vertical Datum*
NOAA NOS	1933 to 2013	Hydrographic survey soundings	< 1 meter to several kilometers	Unknown, NAD 27 geographic, NAD 83 UTM Zone 10 North, or NAD 83 UTM Zone 11 North	Mean Lower Low Water (MLLW)
USACE	2010	Hydrographic condition survey	~ 1 meter point spacing	California Lambert Zone VI (NAD 83) US foot	MLLW
CSUMB	2001 to 2014	Multibeam bathymetry	1 meter to 10 meters	NAD 83 UTM Zone 11 North or WGS 84 UTM Zone 11 North	MLLW, NAVD 88 (Geoid03), NAVD 88 (Geoid09), or NAVD 88 (Geoid12A)
USGS PCMSC	1996 to 1999	Multibeam bathymetry	4 to 8 meters	WGS 84 geographic	MLLW
USGS CMG	2010 to 2011	Multibeam bathymetry	5 to 20 meters	NAD 83 UTM Zone 11 North	NAVD 88
NCEI	1982 to 2014	Multibeam bathymetry	10 meters	NAD 83 geographic	Assumed Mean Sea Level (MSL)
OCS	2005 to 2013	ENC chart soundings	1:24,000	WGS 84 geographic	MLLW

Bathymetric data were transformed to WGS 84 geographic and NAVD 88 using GDAL and NOAA's VDatum transformation tool. Table 3 illustrates the range of vertical datums within the Orange County DEM extents. Where recent, higher resolution data exists, older data were superseded.

Table 3: Orange County, California vertical datum information. Difference in vertical datums to MLLW in meters.

	#9410396, Oceanside Harbor (8 mo.)	*#9410580, Newport Beach, Newport Bay Entrance (14 yr.)*	*#9410650, Cabrillo Beach (5 yr.)*	*#9410660, Los Angeles, Outer Harbor (19 yr.)*	*#9410738, King Harbor, Santa Monica Bay (1 mo.)*
NAVD88		0.055	0.075	0.062	
MHHW	1.630	1.649	1.671	1.674	1.622
MHW	1.405	1.424	1.446	1.449	1.397
MTL	0.839	0.852	0.866	0.868	0.842
MSL	0.832	0.845	0.860	0.861	0.833
MLW	0.274	0.279	0.286	0.287	0.287
MLLW	0	0	0	0	0

Topographic-bathymetric data (Table 4) were transformed to WGS 84 geographic using GDAL and converted to xyz format. The bathymetric data were converted to xyz format before combining with the coastline data to generate a bathymetric pre-surface at 1/3 arc-second. This bathymetric surface grid was converted to xyz format before incorporating in the final DEM.

Table 4: Topographic-Bathymetric data source used in compiling the Orange County, California DEM.

Source	*Date*	*Data Type*	*Spatial Resolution*	*Horizontal Datum*	*Vertical Datum*
2009 U.S. Army Corps of Engineers (USACE) JALBTCX Topo-bathy Lidar: CA	2009	Topographic-Bathymetric Lidar LAS	Topo 1 m, Bathy 5 m	NAD 83 geographic	NAVD 88

Topographic data used in developing the Orange County DEM are listed in Table 5. Transformations to WGS 84 geographic were done using GDAL. As all topographic data were available in NAVD 88, no vertical datum changes were necessary. All topographic data were converted to xyz format for the final gridding process. The converted xyz data files were clipped to the coastline to remove *NoData* values and returns over water. The small THUMS islands in San Pedro Harbor were only partially resolved in the lidar data. Islands Freeman and Chaffee were generated by duplicating existing lidar points from Island White.

Table 5: Topographic data sources used in compiling the Orange County, California DEM.

Source - Title	*Date*	*Data Type*	*Spatial Resolution*	*Horizontal Datum*	*Vertical Datum*
2011 USGS Lidar: Orange County (CA)	2011-2012	Topographic Lidar LAS	1 m	NAD 83 geographic	NAVD 88
2010 California Coastal Conservancy Coastal Lidar	2009-2011	Topographic Lidar LAS	1 m	NAD 83 geographic	NAVD 88
2002 - 2003 Southern California IfSAR	2002-2003	IfSAR	3 m	NAD 83 geographic	NAVD 88
USGS NED	2013	Topographic DEM	1/3 arc second	NAD 83 geographic	NAVD 88

DEM Development

Development of the Orange County DEM followed procedures documented in NOAA Technical Memorandum NGDC-52 for Central California and San Francisco Bay (Carignan et al., 2011). Exceptions being the bathymetric pre-surface was generated at 1/3 arc-second. Gridding weight was modified to Table 6.

Table 6: Data hierarchy used to assign gridding weight in MB-System.

Dataset	*Relative Gridding Weight*
2011 USGS Lidar: Orange County (CA)	1000
2010 California Coastal Conservancy Coastal Lidar	100
2002 - 2003 Southern California IfSAR	100
2009 U.S. Army Corps of Engineers (USACE) JALBTCX Topo-bathy Lidar: CA	100
Lidar derived points	100
CSUMB multibeam surveys	100
NOS hydrographic surveys (post 1990)	100
NCEI additional bathymetric points	100
USACE hydrographic survey	10
USGS multibeam surveys	1
Coastline	1
Bathymetric pre-surface	1
USGS NED	1

MHW DEM Development

The MHW Orange County DEM was generated by applying a conversion grid based on VDatum software to the NAVD 88 DEM.

DEM Analysis

The completed Orange County DEMs were compared to ENC sounding data, NGS topographic benchmarks, and high resolution imagery. Inconsistencies were evaluated and resolved based on most current or reliable data available.

Acknowledgement

Data used in this study were acquired, processed, archived, and distributed by the Seafloor Mapping Lab of California State University Monterey Bay.

Reference

Carignan, K.S., L.A. Taylor, B.W. Eakins, R.J. Caldwell, D.Z. Friday, P.R. Grothe, E. Lim (2011). Digital Elevation Models of Central California and San Francisco Bay: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-52, NOAA, pp. 49.

Dartnell, P., Conrad, J.E., Ryan, H.F., Finlayson, D.P, 2014, Bathymetry and acoustic backscatter—outer mainland shelf and slope, Gulf of Santa Catalina, southern California: U.S. Geological Survey Open-File Report 1094, 15 p., http://dx.doi.org/10.3133/ofr20141094

Gardner, James V., Dartnell, Peter, 2002, Multibeam Mapping of the Los Angeles, California Margin: U.S. Geological Survey Open-File Report 02-162, http://pubs.usgs.gov/of/2002/0162/.

VDatum Version 3.4, California – Southern California from Morro Bay south to US/Mexico border, v.1 (2014). http://vdatum.noaa.gov/welcome.html [December 2014].

Appendix A: NOS Surveys

Survey ID	*Date*	*Scale*	*Original Horizontal Datum*	*Original Vertical Datum*
H05235	1933	10000	unknown	MLLW
H05396	1933	10000	unknown	MLLW
H05397	1933	10000	unknown	MLLW
H05429	1934	5000	unknown	MLLW
H05459	1933	10000	unknown	MLLW
H05474	1933	20000	unknown	MLLW
H05475	1933	20000	unknown	MLLW
H05485	1933	10000	unknown	MLLW
H05486	1935	10000	unknown	MLLW
H05487	1934	10000	unknown	MLLW
H05523	1934	20000	unknown	MLLW
H05524	1934	20000	unknown	MLLW
H05532	1934	10000	unknown	MLLW
H05533	1934	10000	unknown	MLLW
H05534	1934	10000	unknown	MLLW
H05555	1934	20000	unknown	MLLW
H05556	1934	10000	unknown	MLLW
H05557	1935	5000	unknown	MLLW
H05558	1935	5000	unknown	MLLW
H05600	1934	20000	unknown	MLLW
H05601	1937	20000	unknown	MLLW
H05602	1934	10000	unknown	MLLW
H05603	1934	10000	unknown	MLLW
H05604	1934	10000	unknown	MLLW
H05605	1934	10000	unknown	MLLW
H05606	1934	10000	unknown	MLLW
H05645	1934	40000	unknown	MLLW
H05648	1934	10000	unknown	MLLW
H05653	1935	40000	unknown	MLLW
H05658	1934	20000	unknown	MLLW
H05758	1935	20000	unknown	MLLW
H05848	1934	40000	unknown	MLLW
H05851	1935	80000	unknown	MLLW
H06115	1935	40000	unknown	MLLW
H06116	1935	40000	unknown	MLLW
H06117	1935	40000	unknown	MLLW
H06118	1937	80000	unknown	MLLW

Survey ID	*Date*	*Scale*	*Original Horizontal Datum*	*Original Vertical Datum*
H06119	1935	120000	unknown	MLLW
H06120	1937	80000	unknown	MLLW
H06128	1936	5000	unknown	MLLW
H06159	1936	10000	unknown	MLLW
H06206	1936	40000	unknown	MLLW
H06208	1936	80000	unknown	MLLW
H06209	1936	200000	unknown	MLLW
H06259	1937	80000	unknown	MLLW
H06260	1937	80000	unknown	MLLW
H06986	1944	5000	unknown	MLLW
H08921	1968	10000	NAD 27	MLLW
H08980	1968	40000	NAD 27	MLLW
H09067	1969	80000	NAD 27	MLLW
H09068	1969	80000	NAD 27	MLLW
H09108	1970	40000	NAD 27	MLLW
H09111	1970	40000	NAD 27	MLLW
H09112	1970	40000	NAD 27	MLLW
H09113	1970	40000	NAD 27	MLLW
H09114	1970	40000	NAD 27	MLLW
H09244	1971	5000	NAD 27	MLLW
H09245	1971	5000	NAD 27	MLLW
H09246	1971	10000	NAD 27	MLLW
H09247	1974	10000	NAD 27	MLLW
H09250	1971	10000	NAD 27	MLLW
H09251	1971	10000	NAD 27	MLLW
H09252	1972	10000	NAD 27	MLLW
H09253	1972	40000	NAD 27	MLLW
H09254	1974	80000	NAD 27	MLLW
H09274	1972	5000	NAD 27	MLLW
H09275	1972	10000	NAD 27	MLLW
H09276	1972	10000	NAD 27	MLLW
H09277	1972	40000	NAD 27	MLLW
H09376	1974	20000	NAD 27	MLLW
H09377	1974	20000	NAD 27	MLLW
H09467	1974	10000	NAD 27	MLLW
H09468	1974	10000	NAD 27	MLLW
H09469	1974	10000	NAD 27	MLLW
H09470	1974	5000	NAD 27	MLLW
H09471	1977	5000	NAD 27	MLLW

Survey ID	*Date*	*Scale*	*Original Horizontal Datum*	*Original Vertical Datum*
H09476	1974	5000	NAD 27	MLLW
H09487	1975	10000	NAD 27	MLLW
H09492	1975	10000	NAD 27	MLLW
H09493	1975	10000	NAD 27	MLLW
H09494	1975	20000	NAD 27	MLLW
H09495	1975	5000	NAD 27	MLLW
H09496	1975	5000	NAD 27	MLLW
H09497	1975	5000	NAD 27	MLLW
H09498	1975	20000	NAD 27	MLLW
H09499	1975	20000	NAD 27	MLLW
H09508	1975	20000	NAD 27	MLLW
H09558	1975	10000	NAD 27	MLLW
H09559	1975	10000	NAD 27	MLLW
H09561	1975	20000	NAD 27	MLLW
H09570	1975	5000	NAD 27	MLLW
H09576	1975	20000	NAD 27	MLLW
H09580	1975	10000	NAD 27	MLLW
H09590	1977	10000	NAD 27	MLLW
H09591	1976	10000	NAD 27	MLLW
H09592	1976	5000	NAD 27	MLLW
H09662	1976	20000	NAD 27	MLLW
H09670	1978	5000	NAD 27	MLLW
H09671	1977	5000	NAD 27	MLLW
H09672	1977	5000	NAD 27	MLLW
H09673	1978	5000	NAD 27	MLLW
H09674	1977	5000	NAD 27	MLLW
H10331	1990	10000	NAD 27	MLLW
H10997	2000	5000	NAD 83 UTM 11	MLLW
H10998	2000	10000	NAD 83 UTM 11	MLLW
F00484	2002	5000	NAD 83 UTM 11	MLLW
F00507*	2006	10000	NAD 83 UTM 11	MLLW
H11471*	2005	5000	NAD 83 UTM 11	MLLW
H11878*	2008	20000	NAD 83 UTM 11	MLLW
H11879*	2008	20000	NAD 83 UTM 11	MLLW
H11880*	2008	20000	NAD 83 UTM 11	MLLW
H11881*	2008	20000	NAD 83 UTM 10	MLLW
H11882*	2008	20000	NAD 83 UTM 11	MLLW
H12617	2013	6000	NAD 83 UTM 11	MLLW
H12618	2013	6000	NAD 83 UTM 11	MLLW

Survey ID	*Date*	*Scale*	*Original Horizontal Datum*	*Original Vertical Datum*
H12619	2013	10000	NAD 83 UTM 11	MLLW
H12620	2013	10000	NAD 83 UTM 11	MLLW

* Bathymetric Attributed Grid (BAG) format

Appendix B: NCEI Multibeam surveys

Survey ID	*Date*	*Ship*	*Institution*	*Original Horizontal Datum*	*Original Vertical Datum*
AT07L09	Atlantis	2002	Woods Hole Oceanographic Institution (WHOI)	NAD 83 geographic	assumed MSL
AT11L19	Atlantis	2004	WHOI	NAD 83 geographic	assumed MSL
AT15-11	Atlantis	2006	WHOI	NAD 83 geographic	assumed MSL
AT15-53	Atlantis	2009	UNOLS R2R	NAD 83 geographic	assumed MSL
AT18-06	Atlantis	2011	UNOLS R2R	NAD 83 geographic	assumed MSL
AT18-11	Atlantis	2011	UNOLS R2R	NAD 83 geographic	assumed MSL
AT26-06	Atlantis	2013	UNOLS R2R	NAD 83 geographic	assumed MSL
AT26-07	Atlantis	2013	UNOLS R2R	NAD 83 geographic	assumed MSL
AT3L13	Atlantis	1998	WHOI	NAD 83 geographic	assumed MSL
AT3L14	Atlantis	1998	WHOI	NAD 83 geographic	assumed MSL
AT3L20	Atlantis	1998	WHOI	NAD 83 geographic	assumed MSL
AT3L6	Atlantis	1997	WHOI	NAD 83 geographic	assumed MSL
AVON01MV	Melville	1999	University of California, Scripps Institution of Oceanography (UC/SIO)	NAD 83 geographic	assumed MSL
AVON12MV	Melville	1999	UC/SIO	NAD 83 geographic	assumed MSL
BONZ02WT	Thomas Washington	1982	UC/SIO	NAD 83 geographic	assumed MSL
BONZ03WT	Thomas Washington	1982	UC/SIO	NAD 83 geographic	assumed MSL
CALF01RR	Roger Revelle	1996	UC/SIO	NAD 83 geographic	assumed MSL
CALF03RR	Roger Revelle	1996	UC/SIO	NAD 83 geographic	assumed MSL
CNTL01RR	Roger Revelle	2002	UC/SIO	NAD 83 geographic	assumed MSL
CNTL08RR	Roger Revelle	2003	UC/SIO	NAD 83 geographic	assumed MSL
CRGN01WT	Thomas Washington	1987	UC/SIO	NAD 83 geographic	assumed MSL
EX1101	Okeanos Explorer	2001	NOAA	NAD 83 geographic	assumed MSL
GLOR00MV	Melville	1992	UC/SIO	NAD 83 geographic	assumed MSL
HLY05TI	Healy	2005	UNOLS R2R	NAD 83 geographic	assumed MSL
JNUS01WT	Thomas Washington	1992	UC/SIO	NAD 83 geographic	assumed MSL
KIWI01RR	Roger Revelle	1997	UC/SIO	NAD 83 geographic	assumed MSL
KRUS06RR	Roger Revelle	2004	UC/SIO	NAD 83 geographic	assumed MSL
LFEX02MV	Melville	2004	UC/SIO	NAD 83 geographic	assumed MSL
LWAD99MV	Melville	1999	UC/SIO	NAD 83 geographic	assumed MSL
MCD0212	McDonnell	2002	US Navy	NAD 83 geographic	assumed MSL
MGL0810	Marcus G. Langseth	2008	Marine Geoscience Data System (MGDS)	NAD 83 geographic	assumed MSL

Survey ID	*Date*	*Ship*	*Institution*	*Original Horizontal Datum*	*Original Vertical Datum*
MGL1102	Marcus G. Langseth	2011	UNOLS R2R	NAD 83 geographic	assumed MSL
MGL1108	Marcus G. Langseth	2011	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1011	Melville	2010	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1216	Melville	2012	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1217	Melville	2012	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1306	Melville	2013	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1308	Melville	2013	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1313	Melville	2013	UNOLS R2R	NAD 83 geographic	assumed MSL
MV1401	Melville	2014	UNOLS R2R	NAD 83 geographic	assumed MSL
NBP0206	Nathaniel B. Palmer	2002	MGDS	NAD 83 geographic	assumed MSL
NECR01RR	Roger Revelle	2000	UC/SIO	NAD 83 geographic	assumed MSL
OXMZ01MV	Melville	1999	UC/SIO	NAD 83 geographic	assumed MSL
PPTU11WT	Thomas Washington	1986	UC/SIO	NAD 83 geographic	assumed MSL
RAPA00WT	Thomas Washington	1990	UC/SIO	NAD 83 geographic	assumed MSL
REM-01MV	Melville	1993	UC/SIO	NAD 83 geographic	assumed MSL
REVT01RR	Roger Revelle	1996	UC/SIO	NAD 83 geographic	assumed MSL
REVT02RR	Roger Revelle	1996	UC/SIO	NAD 83 geographic	assumed MSL
RSCN01MV	Melville	1997	UC/SIO	NAD 83 geographic	assumed MSL
SEAW02RR	Roger Revelle	2001	UC/SIO	NAD 83 geographic	assumed MSL
SMNT01WT	Thomas Washington	1983	UC/SIO	NAD 83 geographic	assumed MSL
TO9001WT	Thomas Washington	1990	UC/SIO	NAD 83 geographic	assumed MSL
TO9002WT	Thomas Washington	1990	UC/SIO	NAD 83 geographic	assumed MSL
TUNE01WT	Thomas Washington	1991	UC/SIO	NAD 83 geographic	assumed MSL
TUNE09WT	Thomas Washington	1992	UC/SIO	NAD 83 geographic	assumed MSL
WEST00MV	Melville	1993	UC/SIO	NAD 83 geographic	assumed MSL
WEST15MV	Melville	1995	UC/SIO	NAD 83 geographic	assumed MSL