

Digital Elevation Model of the Strait of Juan de Fuca: Procedures, Data Sources, and Analysis

Prepared for the Pacific Marine Environmental Laboratory (PMEL), NOAA Center for Tsunami Research Program by the NOAA, National Centers for Environmental Information (NCEI)

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Summary

In April of 2015, NOAA's National Centers for Environmental Information (NCEI) developed an integrated bathymetric–topographic digital elevation model (DEM) of the Strait of Juan de Fuca for the Pacific Marine Environmental Laboratory (PMEL), NOAA Center for Tsunami Research Program. The DEM will be used to support modeling tsunami generation, propagation, and inundation. The DEM covers the Strait of Juan de Fuca including the U.S. communities of Neah Bay, Sekiu, Clallam Bay, Washington and Metchosin, Sooke, and Port Renfrew on Southern Vancouver Island, British Columbia. 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 Juan de Fuca DEM was built to the specifications listed in Table 1. Figure 1 shows this 1/3 arc-second Juan de Fuca integrated topographic–bathymetric DEM boundary in red, the 2007 La Push and 2011 Port Townsend integrated topographic–bathymetric 1/3 arc-second DEMs in green and the 2013 British Columbia 3 arc-second bathymetric DEM in blue.

Table 1. Specifications for the Juan de Fuca DEM.

<i>Cell Size</i>	1/3 arc-second
<i>Coverage</i>	123.52° to 125.12° W, 48.04° to 48.72° N
<i>Coordinate System</i>	Geographic decimal degrees
<i>Horizontal Datum</i>	World Geodetic System 1984 (WGS 84)
<i>Vertical Datum</i>	NAVD 88
<i>Vertical Units</i>	Meters
<i>Grid Format</i>	ASCII raster grid

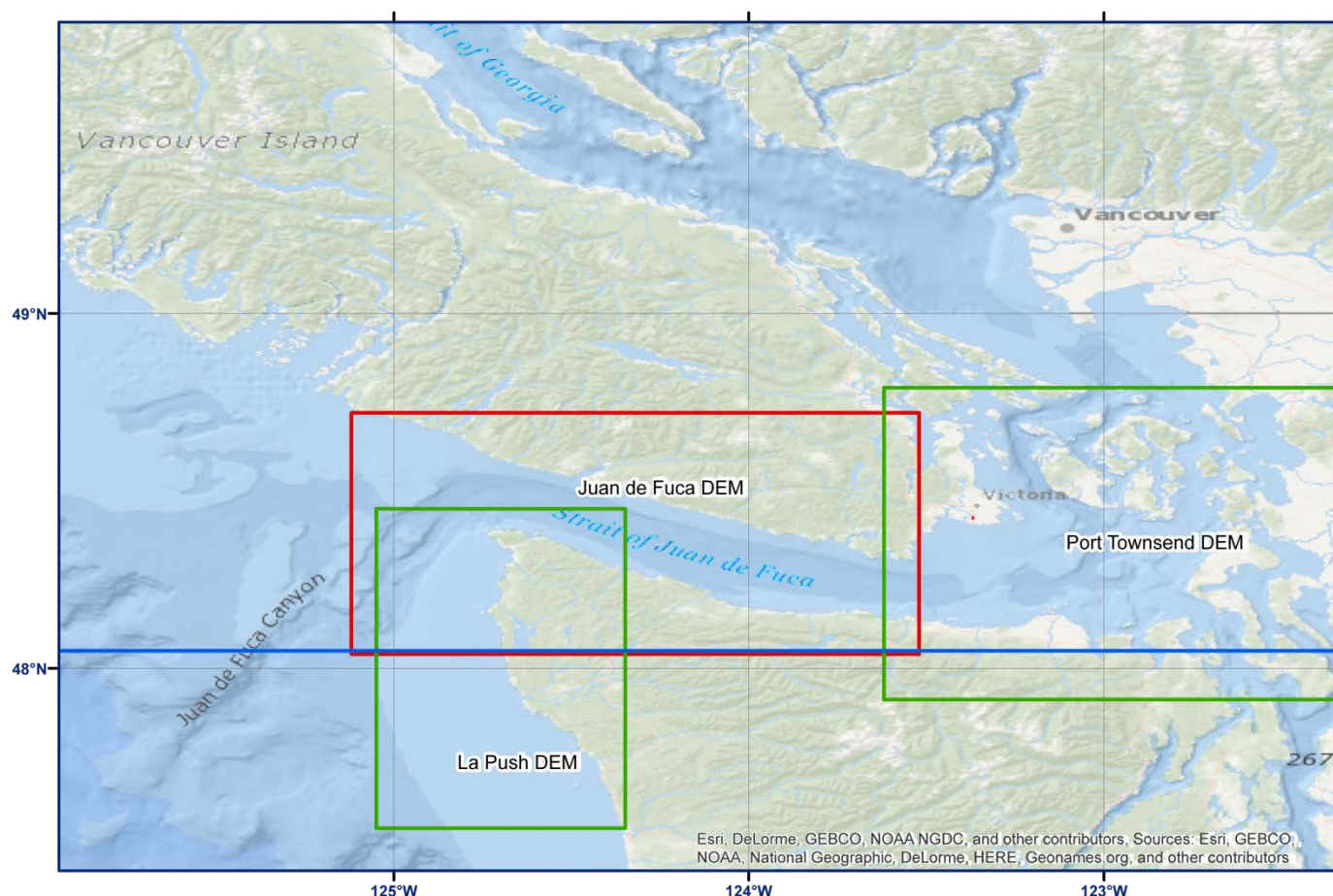


Figure 1. Map image of the boundaries for the 1/3 arc-second Juan de Fuca DEM in red and the previously developed DEMs in green and blue.

Data Sources and Processing

Digital coastlines were extracted from NOAA's Office of Coast Survey (OCS) ENC Direct to GIS online extraction service (http://nauticalcharts.noaa.gov/csdl/ctp/encdirect_new.htm). These coastlines were merged and 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/imagery.html>). Bathymetric and topographic data were downloaded from NOAA's Office for Coastal Management (OCM) and Office of Coast Survey (OCS), Olympic Coast National Marine Sanctuary (OCNMS), Puget Sound Lidar Consortium (PSLC), the Canadian Hydrographic Service (CHS), Natural Resources Canada (NRCAN), and the U.S. Geological Society (USGS), and NCEI. Figure 2 shows the source and coverage of the datasets used in developing the Juan de Fuca DEM.

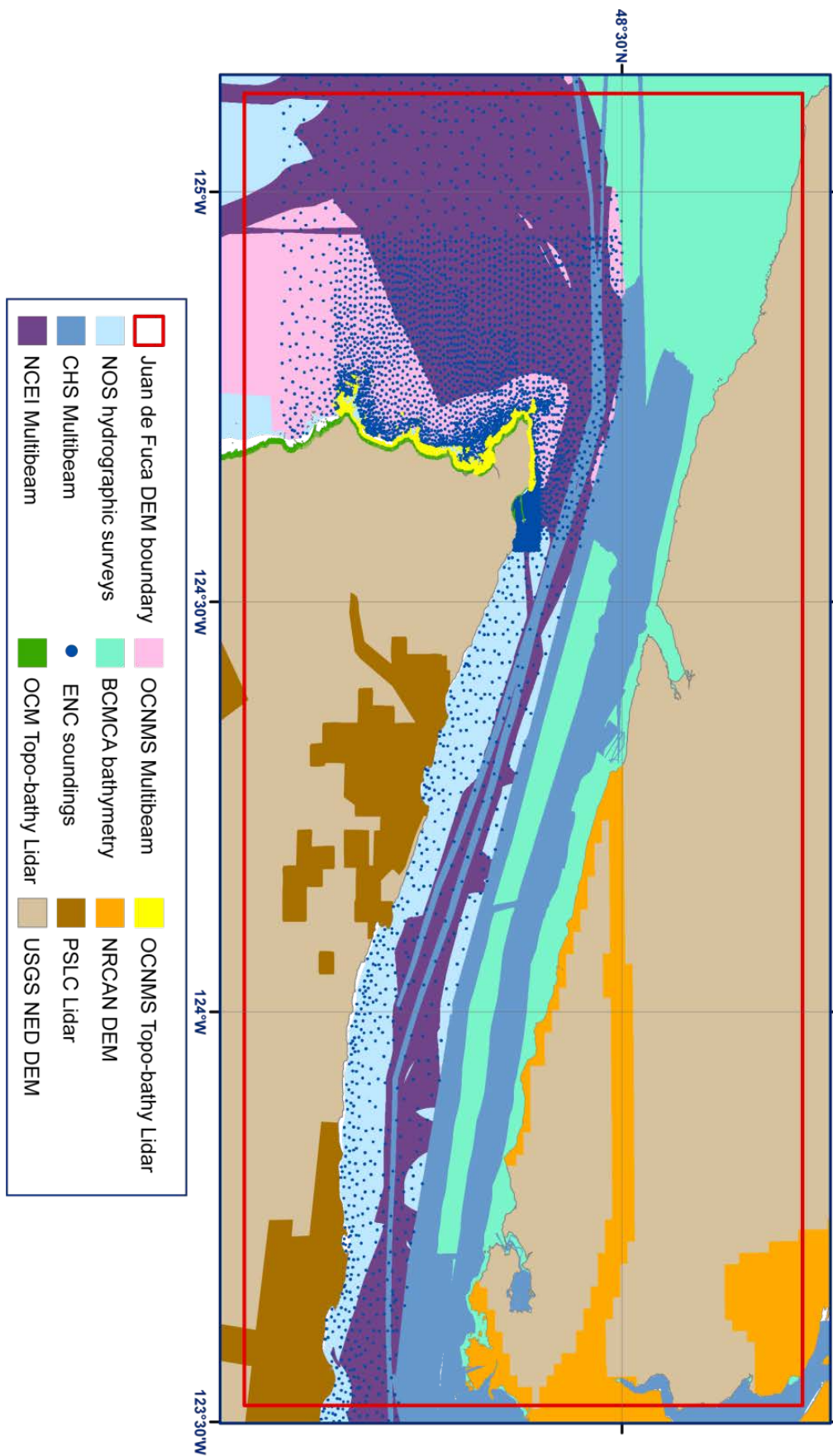


Figure 2. Source and coverage of the datasets used in compiling the Juan de Fuca DEM.

Table 2: Bathymetric data sources used in compiling the Juan de Fuca DEM.

<i>Source</i>	<i>Date</i>	<i>Data Type</i>	<i>Spatial Resolution</i>	<i>Horizontal Datum</i>	<i>Vertical Datum</i>
NOAA NOS	1891 to 2010	Hydrographic survey soundings	< 1 meter to several kilometers	Unknown, NAD 1927 Projected Modified Transverse Mercator, or NAD 1983 Projected UTM Zone 10	Mean Lower Low Water (MLLW)
CHS	1998 to 2011	Multibeam bathymetry	Gridded to 10 meters	WGS 84 geographic	Lower Low Water Large Tide (LLWLT)
NCEI	2000 to 2013	Multibeam bathymetry	10 meter grid	NAD 83 geographic	Assumed Mean Sea Level (MSL)
OCNMS	2001 to 2011	Gridded multibeam survey data	8 meter grid	NAD 83 UTM Zone 10	Assumed MSL
NOAA OCM	1997 to 2013	ENC soundings	1:20,000 to 1:300,000	WGS 84 geographic	MLLW
BCMCA	2012	Bathymetric DEM	100 meter	NAD 1983 Albers	Assumed MSL

Table 2 lists the bathymetry data used in the compilation of the Juan de Fuca DEM including NOS hydrographic surveys (Appendix A) and multibeam surveys (Appendix B). Bathymetric data were transformed to WGS 84 geographic and NAVD 88 using GDAL and NOAA's VDatum transformation tool. Outside of the VDatum tool boundaries, a constant value, -0.972 meters, was used to convert LLWLT to NAVD 88 vertical datum. The TSRI survey report for the Leech River Lidar data provided chart datum transformation values for the southern coast of Vancouver Island. The average difference between the chart datum and CGVD28 (HTv2)2010 at three Canadian tide stations, 2.062 meters, was subtracted from an approximation of the NAVD 88 difference from CGVD28, 1.09 meters (AECON, 2013). Where recent, higher resolution data exists, older data were superseded. 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 3: Topographic-Bathymetric data source used in compiling the Juan de Fuca, Washington DEM.

<i>Source</i>	<i>Date</i>	<i>Data Type</i>	<i>Spatial Resolution</i>	<i>Horizontal Datum</i>	<i>Vertical Datum</i>
OCM - 2010-11 U.S. Army Corps of Engineers (USACE) JALBTCX Topobathy Lidar:	2010-2011	Topographic-Bathymetric Lidar DEM	2 meter grid	NAD 83 geographic	NAVD 88
OCNMS	2005	Topographic-Bathymetric Lidar	4 meter grid	WGS 1984 UTM Zone 10	MLLW

Topographic-bathymetric data (Table 3) were transformed to WGS 84 geographic using GDAL. Bathymetric values were separated from topographic values and used only in the bathymetric surface.

Table 4: Topographic data sources used in compiling the Juan de Fuca, Washington DEM.

<i>Source - Title</i>	<i>Date</i>	<i>Data Type</i>	<i>Spatial Resolution</i>	<i>Horizontal Datum</i>	<i>Vertical Datum</i>
2012 Puget Sound Lidar Consortium (PSLC) Lidar: Jefferson and Clallam Counties, Washington	2012	Geographic Database (GDB)	3 feet	NAD 83 (1991 HARN) WA SP South (FIPS 4602)	NAVD 88
2005 Puget Sound Lidar Consortium (PSLC) Lidar: Olympic Peninsula Project (Clallam County)	2005	GDB	6 feet	NAD 83 (HARN) WA SP North (FIPS 4601)	NAVD 88
2001 Puget Sound Lidar Consortium (PSLC) Lidar: Clallam County	2001	GDB	6 feet	NAD 83 (1991 HARN) WA SP North (FIPS 4601)	NAVD 88
NRCAN DEM (Leech River)*	2007	Bare-earth DEM	2 meters	NAD 83 UTM Zone 10 North	LLWLT
NRCAN DEM (Saanich)*	2010	Bare-earth DEM	2 meters	NAD 83 UTM Zone 10 North	CGVD28 (HT2.0)
USGS NED		Topographic DEM	1/3 arc-second	NAD 83 geographic	NAVD 88
USGS NED		Topographic DEM	1 arc second	NAD 83 geographic	NAVD 88

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Topographic data used in developing the Juan de Fuca DEM are listed in Table 4. Transformations to WGS 84 geographic were done using GDAL. NRCAN lidar DEMs were converted to NAVD 88 using the constant values described in bathymetry data section. The converted data files were clipped to the coastline to remove NoData values or filtered to remove returns over water. A 300 meter buffer was made to smooth the area between the NED 1/3 DEM and the JALBTCX topo-bathy lidar. The buffer file was made by merging points from both the NED and OCM lidar and generating an interpolated surface replacing the NED data located

within the buffer area. A separate buffer was used to smooth the seam between the NED and PSLC lidar data. All topographic data were converted to xyz format for the final gridding process.

DEM Development

Development of the Juan de Fuca DEM followed procedures documented in NOAA Technical Memorandum NCEI-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 5.

Table 5: Data hierarchy used to assign gridding weight in MB-System.

<i>Dataset</i>	<i>Relative Gridding Weight</i>
PSLC lidar	100
NRCAN DEM (Leech River)	100
CHS multibeam	100
NOS BAG hydrographic surveys	100
OCNMS multibeam gridded data	100
NRCAN DEM (Saanich)	10
OCS ENC soundings	10
OCM - 2010-11 U.S. Army Corps of Engineers (USACE) JALBTCX Topobathy Lidar	10
Bathy surface	10
Topographic buffer file	10
OCNMS Topographic-Bathymetric Lidar	1
Coastline	1
NCEI multibeam surveys	1
USGS NED DEM	1

MHW DEM Development

The MHW Juan de Fuca DEM was developed by generating a conversion grid based on VDatum software. Control points located at 10 tide stations on Vancouver Island were used to extend VDatum coverage into non-U.S. jurisdiction. Vertical datum information for these tide stations were provided by CHS previously for the Southeast Alaska DEM (Caldwell et al., 2010). The completed conversion grid was then applied to the NAVD 88 DEM.

DEM Analysis

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

Acknowledgement

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Appendix A: NOS Surveys

<i>Survey ID</i>	<i>Date</i>	<i>Scale</i>	<i>Original Horizontal Datum</i>	<i>Original Vertical Datum</i>
H02096	1891	40,000	unknown	unknown
H02170	1893	80,000	unknown	unknown
H02869	1907	50,000	unknown	unknown
H05070	1930	20,000	unknown	MLLW
H05109	1930	20,000	unknown	MLLW
H05110	1930	40,000	unknown	MLLW
H05111	1942	40,000	unknown	MLLW
H05114	1930	120,000	unknown	MLLW
H05146	1931	20,000	unknown	MLLW
H05147	1931	40,000	unknown	MLLW
H05148	1931	40,000	unknown	MLLW
H05149	1931	40,000	unknown	MLLW
H05155	1931	20,000	unknown	MLLW
H05156	1931	20,000	unknown	MLLW
H05157	1931	40,000	unknown	MLLW
H05158	1931	20,000	unknown	MLLW
H05159	1931	40,000	unknown	MLLW
H05172	1931	120,000	unknown	MLLW
H06653	1943	40,000	unknown	MLLW
H07036	1945	5,000	unknown	MLLW
H07037	1945	10,000	unknown	MLLW
H09413	1974	80,000	NAD 1927 Projected Modified Transverse Mercator	MLLW
H09414	1974	40,000	NAD 1927 Projected Modified Transverse Mercator	MLLW
H09415	1974	40,000	NAD 1927 Projected Modified Transverse Mercator	MLLW
H09416	1974	40,000	NAD 1927 Projected Modified Transverse Mercator	MLLW
H10583	1995	10,000	NAD 1983 Projected Modified Transverse Mercator	MLLW
H11083	2003	20,000	NAD 1983 Projected UTM Zone 10	MLLW
H11086	2001	5,000	NAD 1983 Projected UTM Zone 10	MLLW
H11748	2007	10,000	NAD 1983 Projected UTM Zone 10	MLLW
H11751	2007	10,000	NAD 1983 Projected UTM Zone 10	MLLW
H12219	2010	20,000	NAD 1983 Projected UTM Zone 10	MLLW
H12220	2010	20,000	NAD 1983 Projected UTM Zone 10	MLLW
H12221	2010	20,000	NAD 1983 Projected UTM Zone 10	MLLW
H12222	2010	20,000	NAD 1983 Projected UTM Zone 10	MLLW
H12223	2010	20,000	NAD 1983 Projected UTM Zone 10	MLLW

Appendix B: NCEI Multibeam surveys

<i>Survey ID</i>	<i>Date</i>	<i>Ship</i>	<i>Institution</i>	<i>Original Horizontal Datum</i>	<i>Original Vertical Datum</i>
AT3L56	2000	Atlantis	Woods Hole Oceanographic Institution (WHOI)	NAD 1983 geographic	Assumed MSL
HEALY02	2001	Healy	WHOI	NAD 1983 geographic	Assumed MSL
HLY0101	2001	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN144	2002	Thomas G. Thompson	Marine Geoscience Data System (MGDS)	NAD 1983 geographic	Assumed MSL
TN146	2002	Thomas G. Thompson	MGDS	NAD 1983 geographic	Assumed MSL
KM0311	2003	Kilo Moana	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY0401	2004	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN172	2004	Thomas G. Thompson	MGDS	NAD 1983 geographic	Assumed MSL
AT11L31	2005	Atlantis	WHOI	NAD 1983 geographic	Assumed MSL
AT11L32	2005	Atlantis	WHOI	NAD 1983 geographic	Assumed MSL
HLY05TC	2005	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN183	2005	Thomas G. Thompson	MGDS	NAD 1983 geographic	Assumed MSL
HLY06TB	2006	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY06TD	2006	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY06TG	2006	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY06TI	2006	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY06TJ	2006	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY07TA	2007	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY07TB	2007	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY07TC	2007	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY07TD	2007	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY07TG	2007	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL

<i>Survey ID</i>	<i>Date</i>	<i>Ship</i>	<i>Institution</i>	<i>Original Horizontal Datum</i>	<i>Original Vertical Datum</i>
EX0801	2008	Okeanos Explorer	National Oceanic and Atmospheric Administration (NOAA)	NAD 1983 geographic	Assumed MSL
EX0802	2008	Okeanos Explorer	NOAA	NAD 1983 geographic	Assumed MSL
HLY08TG	2008	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
HLY09TA	2009	Healy	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN240	2009	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN247	2010	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN254	2010	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN255	2010	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN264	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN265	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN267	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN268	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN269	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN270	2011	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN279	2012	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN281	2012	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN282	2012	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN283	2012	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN290B	2013	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN290C	2013	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL
TN291	2013	Thomas G. Thompson	UNOLS R2R	NAD 1983 geographic	Assumed MSL

Appendix C: Difference in meters between tidal datums at select tide stations in the DEM region.

<i>Station ID</i>	9443090	9443361	9443826	9444090
<i>Station Name</i>	Neah Bay	Sekin, Clallam Bay	Crescent Bay	Port Angeles
MHHW	2.425	2.286	2.151	2.153
MHW	2.167	2.03	1.971	1.987
MTL	1.327	1.287	1.315	1.287
MSL	1.315	1.269	1.285	1.295
MLW	0.486	0.545	0.659	0.586
NAVD88	0.256	0.176		0.129
MLLW	0	0	0	0

<i>Station ID</i>	87C9766	97C9107	78C9501
<i>Station Name</i>	Victoria Harbour	Bannfield	Patricia Bay
Chart Datum	7.241	29.288	5.431
CGVD28(HTv2)2010	5.346	27.245	3.183
NAD83(CSRS)2010	-13.13	9.473	-15.381