NOAA Technical Report NOS CO-OPS 081

Shoreline Tidal Boundary Project

For Tulalip, WA

Photo Credit: Mark Bailey

Silver Spring, Maryland

March 2016

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) provides the National infrastructure, science, and technical expertise to collect and distribute observations and predictions of water levels and currents to ensure safe, efficient and environmentally sound maritime commerce. The Center provides the set of water level and tidal current products required to support NOS' Strategic Plan mission requirements, and to assist in providing operational oceanographic data/products required by NOAA's other Strategic Plan themes. For example, CO-OPS provides data and products required by the National Weather Service to meet its flood and tsunami warning responsibilities. The Center manages the National Water Level Observation Network (NWLON), a national network of Physical Oceanographic Real-Time Systems (PORTS®) in major U. S. harbors, and the National Current Observation Program consisting of current surveys in near shore and coastal areas utilizing bottom mounted platforms, subsurface buoys, horizontal sensors and quick response real time buoys. The Center establishes standards for the collection and processing of water level and current data; collects and documents user requirements which serve as the foundation for all resulting program activities; designs new and/or improved oceanographic observing systems; designs software to improve CO-OPS' data processing capabilities; maintains and operates oceanographic observing systems; performs operational data analysis/quality control; and produces/disseminates oceanographic products.

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Shoreline Tidal Boundary Project For Tulalip, WA

Jena Kent

March 2016

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INTRODUCTION

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) has a rich history in the application of tidal datum products and services for nautical charting and marine boundary determination. Tidal datums are primarily provided through the analysis of water level data collected at water level stations. Tidal datum elevations relative to the land are realized through the establishment of tidal bench mark networks which are used to establish marine boundaries. Typically, water level stations and their associated bench mark networks are installed in support of NOAA's hydrographic and shoreline mapping program; however, they are also installed through partnerships with local groups wishing to reestablish marine boundaries.

The legal shoreline in the United States is the Mean High Water (MHW) shoreline as delineated by NOAA on United States nautical charts based on established tidal datums. More specifically, each point on a MHW shoreline represents the horizontal position of the land-water interface at the time when the water level is at a height equal to the MHW elevation value at that point (Figure 1). These tidal datums are also critical in providing the legal definition for a variety of marine boundaries. MHW, for example, is the dividing line between many State tidelands and private uplands, and Mean Lower Low Water (MLLW) is the dividing line between Federal territorial seas and state submerged lands (CO-OPS, 2001). The marine boundary definition is supported by the fact that all tidal datums at a water level station are referenced to the land through geodetic leveling to a number of tidal bench marks, which are brass markers set into solid rock or other permanent structures, or are stainless steel rods that are driven to refusal. It is critical to update tidal datum elevations and their relationships relative to the land. These relationships can change over time if the land subsides (or rises due to glacial rebound), or if relative sea level rises due to effects such as global warming (CO-OPS, 2001).

The purpose of this report is to document the CO-OPS support of the Tulalip Tribes in establishing marine boundaries. The report documents the field work required for station installation, data collection and processing, tidal datum computation, and tidal bench mark elevation determination required to meet the needs of the Tulalip Tribes.

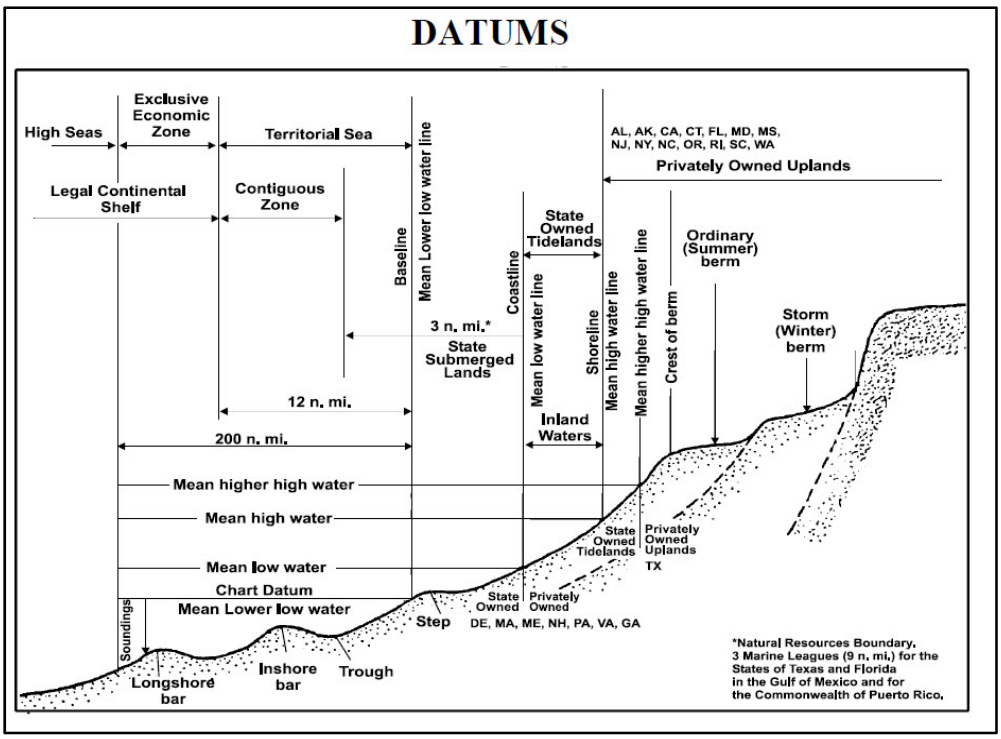

Figure 1. The principal tidal datums related to a beach profile. The intersection of the tidal datum with land determines the landward edge of a marine boundary (CO-OPS, 2001).

PROJECT INFORMATION

This project was initiated through a request from Mr. Dorrel Dickson of the Tulalip Tribes' Geographic Information Systems (GIS) group in 2011. Mr. Dickson contacted NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) and his request was received by the Coastal Oceanographic Applications and Services of Tides and Lakes (COASTAL) Program Manager regarding the need to have updated tidal datums and tidal bench mark elevations within the Tulalip Reservation in the state of Washington. The Tulalip Reservation includes all tidelands within its borders. Tidelands are defined as land that is submerged at high tide. According to tribal regulations, the tidelands are owned by the tribe versus individual members. Tidelands are reserved for the use and benefit of the Tribes (Tulalip Tribes, 2015). The shoreline on the Tulalip Reservation is where many ancestral settlements and burial sites are located and where tribal fishing, gathering, cultural activities, and recreation continue to this day.

The Tulalip Tribes' goal was to have NOAA-accepted, legally-defensible tidal datum elevations in each of their communities. In order to support this goal, updating tidal datum elevations and tidal bench marks were required, so that they would be available for homeowners (tribal and non-tribal residents) in the area to affordably hire a local surveyor to mark the limits of the homeowner's upland ownership (based on the elevation of the water level at NOAA established tidal bench marks). Prior to this project, most of the surveyors the Tulalip Tribes had contacted

were reluctant to use the only NOAA-established Tulalip Bay, WA historic tidal bench mark elevations because they feared the tidal elevations could not be transferred accurately to other locations outside of Tulalip Bay. The surveyors also were concerned about being found liable for using an unofficial tidal datum that could not be defended in court. Anticipating potential litigation over existing structures outside of the bay, the Tulalip Tribes required updated tidal bench mark elevations in each of the local communities.

The Tulalip Tribes worked in partnership with the Washington State Department of Transportation (WSDOT) to establish a tidal bench mark network along the shores of the Puget Sound within the reservation. Tidal bench marks were installed in each of the four communities, so that local surveyors would have a reliable and defendable reference point to help the community members and Tulalip Tribes establish the limits of their ownership. Prior to this project, the tidal bench marks near the reservation were established within areas influenced by rivers and did not translate reliably to the tidal shoreline areas. The Tulalip Tribes desired to update existing tidal bench mark elevations in Tulalip Bay to the current 19-year National Tidal Datum Epoch (NTDE), and increase the number of tidal bench marks to ensure all communities are near a tidal bench mark with the latest tidal datum elevations.

CO-OPS worked closely with the Tulalip Tribes to determine water level station locations and requirements needed for accurate marine boundary definition. As a result, CO-OPS installed four tertiary (three to four months) water level stations (Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point) along the coast at key locations in the Tulalip Tribes' territory (Figure 2). The four stations were successfully installed, operated, and removed using standard operating procedures and protocols.

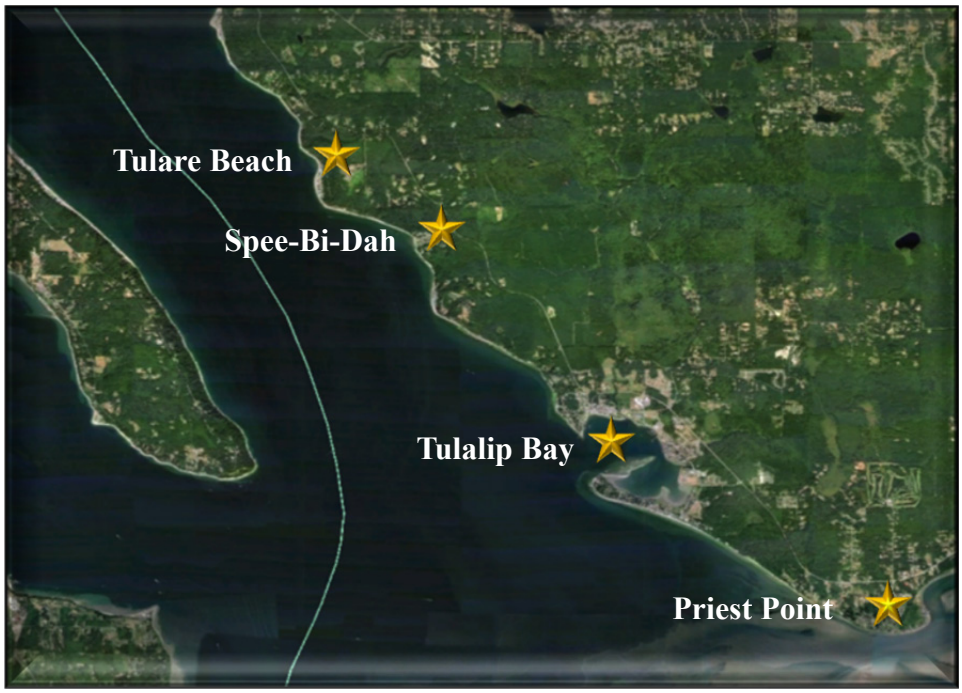

Figure 2. Map displaying locations of the Tulalip Project water level stations at Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point, WA.

Successful completion of this project has resulted in a baseline network of published tidal datums and tidal bench mark elevations for the Tulalip Tribes' coastal zone. Using this baseline network, local surveys can be carried out for demarcation of the MHW line which serves to delineate the jurisdiction of the Tulalip Tribes from local upland landowners. Data from these installations were quality controlled in real-time and subsequently analyzed and tabulated for product development. Water level data products including highs/lows, hourly heights and monthly means were used to calculate accepted tidal datums relative to the most recent NTDE using standard simultaneous comparison with the NOAA control water level station at Seattle, WA. NOAA tidal bench mark sheets were published that include tidal and orthometric datum relationships and the relationship of those datums to all tidal bench marks in each of the station's networks. Relationships between orthometric datums [North American Vertical Datum (NAVD88)] and tidal datums were also calculated and established at each location.

WATER LEVEL STATION CONFIGURATIONS

The water level stations for this project were installed and maintained by the CO-OPS Field Operations Division (FOD) in the CO-OPS Seattle, WA office. Standard water level station configurations were used consisting of a water level sensor, a data collection platform (DCP), a solar panel, a Geostationary Operational Environmental Satellite (GOES) antenna, and a local network of five tidal bench marks. At Tulare Beach, Tulalip Bay, and Spee-Bi-Dah, a digital bubbler water level sensor was used. This sensor consists of a bubbler orifice installed on the sea floor several yards offshore to capture the lowest tidal elevations, connected via secured tubing to the onshore DCP, and the tubing tied into a vented Paroscientific pressure transducer. Infrastructure existed at Priest Point to mount a standard Microwave Water Level (MWWL) sensor close to the pier and the DCP. Figure 3 shows the equipment setup including the DCP, GOES antenna, and Global Positioning System (GPS) antenna at the Tulare Beach water level station. Additional images of each water level station are found in Appendix 1.

Figure 3. Portable Data Collection Platform (DCP), flat panel GOES antenna, and GPS antenna at Tulare Beach, WA.

WATER LEVEL PROCESSING

The Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point, WA water level data were processed by CO-OPS using documented Standard Operating Procedures (SOPs). The data were collected in near real-time every six minutes through the NOAA GOES transmission pathway and underwent automated quality control checks on a daily basis while being monitored by CO-OPS' Continuous Operational Real-Time Monitoring System (CORMS). At the end of each calendar month the data were reviewed, outliers were removed, and gaps were filled where needed. Small gaps (< 2 hours) were filled using curve fits and longer gaps up to three days were filled using data from nearby stations. Once the 6-minute interval water level data were processed, other products were generated. The standard monthly water level processing outputs are verified 6-minute data, tabulated times and heights of the high and low waters, hourly heights, and monthly means. Figures 4-6 are examples of typical monthly plots and monthly tabulations for Tulare Beach. These reports are used by CO-OPS to properly pair tides to ensure the correct calculation of tidal datums (e.g. MHW). Appendix 2 contains examples of output plots for each of the water level stations. Mixed tides occur in this region, where there are two high and low tides each tidal day; however, one high is higher than the other and one low is

lower than the other, leading to inequalities in the high [Diurnal High Water Inequality (DHQ)] and low water [Diurnal Low water Inequality (DLQ)] elevations (CO-OPS, 2001). All elevations at each location are initially referenced to an arbitrary station datum that is unique to each station and is established at a lower elevation than the water is ever expected to reach.

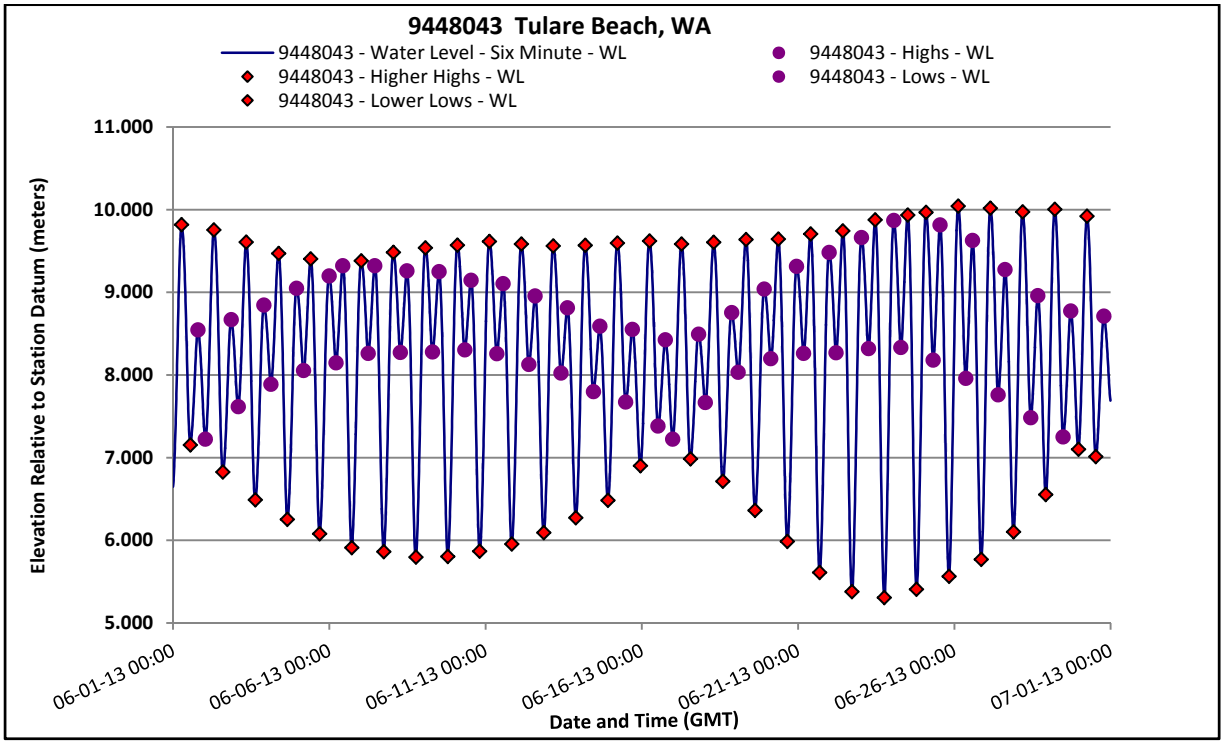

Figure 4. Tabulated high and low tides for Tulare Beach, WA for June 2013. This tabulation shows the time and height of every high and low water level in relation to station datum (STND).

Jun 24 2015 12:13 GMT HIGH/LOW WATER LEVEL DATA June, 2013
National Ocean Service (NOAA)

Station: 9448043 T.M.: 0 W
Name: Tulare Beach, Port Susan, WA Units: Meters
Type: Mixed Datum: STND
Note: > Higher-High/Lower-Low [] Inferred Tide Quality: Verified

Day	High Time	High Height	Low Time	Low Height	Day	High Time	High Height	Low Time	Low Height
1	> 6.6	9.819			16	> 5.9	9.621	12.5	7.382
	19.2	8.544	> 13.3	7.154		18.1	8.424	23.7	7.223
2	> 7.4	9.755	0.9	7.222	17	> 6.5	9.585		
	20.7	8.668	> 14.3	6.826		19.6	8.492	> 13.4	6.985
3	> 8.2	9.608	2.1	7.616	18	> 7.2	9.605	0.8	7.666
	21.8	8.845	> 15.2	6.489		21.1	8.754	> 14.2	6.714
4	> 9.1	9.470	3.2	7.887	19	> 8.0	9.639	2.0	8.032
	22.9	9.048	> 15.8	6.253		22.0	9.039	> 14.9	6.362
5	> 9.7	9.405	4.3	8.053	20	> 8.8	9.645	3.1	8.196
	23.9	9.198	> 16.6	6.079		22.9	9.313	> 15.7	5.987
6	10.4	9.321	5.2	8.147	21	> 9.6	9.707	4.3	8.261
			> 17.3	5.910		23.9	9.482	> 16.5	5.611
7	> 0.5	9.381	5.9	8.260	22	> 10.4	9.743	5.2	8.268
	11.0	9.320	> 17.9	5.862				> 17.4	5.378
8	> 1.2	9.483	6.6	8.272	23	0.7	9.661	6.1	8.319
	11.7	9.259	> 18.5	5.796		> 11.2	9.876	> 18.2	5.307
9	> 1.8	9.538	7.3	8.277	24	1.5	9.868	7.0	8.331
	12.3	9.250	> 19.0	5.804		> 12.2	9.935	> 18.9	5.407
10	> 2.4	9.570	8.1	8.303	25	> 2.2	9.968	7.8	8.179
	12.9	9.145	> 19.5	5.868		13.1	9.814	> 19.9	5.564
11	> 3.0	9.615	8.7	8.257	26	> 3.0	10.043	8.8	7.959
	13.5	9.105	> 20.1	5.955		14.0	9.626	> 20.6	5.770
12	> 3.5	9.584	9.3	8.127	27	> 3.7	10.017	9.7	7.759
	14.1	8.955	> 20.7	6.093		15.0	9.274	> 21.4	6.102
13	> 4.0	9.560	10.0	8.022	28	> 4.4	9.974	10.7	7.483
	14.9	8.811	> 21.3	6.273		16.1	8.959	> 22.2	6.554
14	> 4.6	9.568	10.9	7.797	29	> 5.1	10.005	11.6	7.250
	15.8	8.589	> 22.0	6.484		17.5	8.773	> 23.3	7.100
15	> 5.2	9.596	11.6	7.671	30	> 5.9	9.920		
	16.8	8.551	> 22.9	6.902		18.9	8.711	> 12.6	7.012

Highest Tide: 10.043 3.0 Hrs Jun 26 2013
Lowest Tide: 5.307 18.2 Hrs Jun 23 2013

Monthly Means:

MHHW	9.698					
MHW	9.380	DHQ	0.318			
MTL	8.215			GT	3.505	HWI 0.30
DTL	7.946			MN	2.331	LWI 6.48
MSL	8.217					
MLW	7.049	DLQ	0.856			
MLLW	6.193					

Station #	Sn	PC	Begin Date	End Date	In	COCTT	PID	VID	AID	Data Type
9448043	1	N1	W3	20130601 00:00	20130630 23:54	6	01000	414	281	High/Low

Figure 5. Standard tabulation output products from Tulare Beach, WA of tabulated high and low tides and monthly means for June 2013. This tabulation shows the time and height of every high and low water level in relation to station datum (STND).

Jun 24 2015 12:58 GMT — HOURLY WATER LEVEL DATA — National Ocean Service (NOAA) — June, 2013

Station: 9448043 — T.M.: 0 W
Name: Tulare Beach, Port Susan, WA — Units: Meters
Note: [] Inferred Water Level Value — Datum: STND
Quality: Verified

Hour	Jun 1	Jun 2	Jun 3	Jun 4	Jun 5	Jun 6	Jun 7	Jun 8	Jun 9	Jun 10	Jun 11	Jun 12	Jun 13	Jun 14	Jun 15	Jun 16
0	6.649	7.319	8.017	8.578	8.976	9.194	9.343	9.303	9.089	8.760	8.426	8.004	7.597	7.253	7.038	7.077
1	6.933	7.222	7.744	8.333	8.800	9.098	9.360	9.480	9.452	9.288	9.100	8.755	8.359	7.963	7.616	7.460
2	7.409	7.395	7.616	8.062	8.531	8.899	9.242	9.429	9.531	9.546	9.505	9.283	9.018	8.678	8.308	8.005
3	8.047	7.781	7.732	7.894	8.249	8.619	8.997	9.235	9.431	9.539	9.617	9.555	9.423	9.235	8.953	8.620
4	8.752	8.318	8.053	7.969	8.065	8.325	8.695	8.955	9.192	9.389	9.531	9.555	9.561	9.527	9.406	9.183
5	9.369	8.905	8.482	8.222	8.119	8.152	8.373	8.607	8.854	9.108	9.301	9.396	9.475	9.549	9.590	9.533
6	9.742	9.433	8.954	8.578	8.369	8.231	8.260	8.329	8.496	8.763	8.981	9.103	9.254	9.396	9.543	9.620
7	9.798	9.726	9.378	8.992	8.693	8.480	8.386	8.283	8.293	8.434	8.607	8.728	8.911	9.102	9.327	9.498
8	9.600	9.715	9.598	9.329	9.051	8.783	8.640	8.450	8.334	8.301	8.319	8.338	8.493	8.684	8.969	9.197
9	9.212	9.492	9.526	9.471	9.332	9.100	8.935	8.699	8.555	8.393	8.266	8.136	8.151	8.228	8.488	8.746
10	8.660	9.048	9.215	9.341	9.396	9.296	9.201	8.975	8.812	8.605	8.430	8.177	8.022	7.891	8.019	8.202
11	8.010	8.422	8.691	8.968	9.185	9.273	9.321	9.200	9.076	8.840	8.651	8.363	8.103	7.800	7.722	7.707
12	7.447	7.709	8.001	8.387	8.741	8.971	9.196	9.244	9.237	9.065	8.889	8.590	8.285	7.918	7.687	7.424
13	7.173	7.120	7.262	7.658	8.086	8.438	8.798	8.991	9.176	9.141	9.079	8.832	8.522	8.101	7.807	7.405
14	7.222	6.840	6.705	6.920	7.314	7.720	8.173	8.509	8.838	8.973	9.066	8.953	8.730	8.335	8.030	7.549
15	7.418	6.885	6.492	6.391	6.590	6.909	7.375	7.795	8.261	8.548	8.787	8.856	8.813	8.520	8.270	7.801
16	7.710	7.115	6.586	6.266	6.148	6.235	6.586	6.959	7.493	7.889	8.280	8.513	8.654	8.581	8.489	8.070
17	8.063	7.472	6.898	6.458	6.115	5.929	6.027	6.248	6.676	7.103	7.585	7.978	8.290	8.408	8.550	8.310
18	8.387	7.910	7.350	6.848	6.403	6.057	5.863	5.836	6.041	6.378	6.817	7.290	7.772	8.080	8.414	8.422
19	8.544	8.347	7.904	7.399	6.899	6.460	6.162	5.863	5.801	5.936	6.208	6.616	7.164	7.611	8.138	8.355
20	8.476	8.613	8.432	8.032	7.536	7.069	6.689	6.292	6.007	5.920	5.955	6.178	6.605	7.082	7.764	8.158
21	8.273	8.662	8.754	8.598	8.239	7.825	7.389	6.905	6.518	6.267	6.111	6.113	6.295	6.656	7.352	7.886
22	7.971	8.528	8.843	8.949	8.793	8.552	8.170	7.675	7.208	6.866	6.581	6.392	6.358	6.485	7.010	7.554
23	7.613	8.311	8.748	9.047	9.111	9.079	8.852	8.465	8.004	7.600	7.227	6.905	6.706	6.639	6.902	7.292
Mean	8.187	8.179	8.124	8.112	8.114	8.112	8.168	8.155	8.182	8.194	8.222	8.192	8.190	8.155	8.225	8.211

Hour	Jun 17	Jun 18	Jun 19	Jun 20	Jun 21	Jun 22	Jun 23	Jun 24	Jun 25	Jun 26	Jun 27	Jun 28	Jun 29	Jun 30
0	7.234	7.736	8.325	8.830	9.226	9.481	9.584	9.485	9.060	8.474	7.804	7.292	7.099	7.218
1	7.430	7.668	8.123	8.596	9.050	9.385	9.655	9.821	9.693	9.337	8.728	8.117	7.748	7.583
2	7.783	7.829	8.028	8.341	8.782	9.158	9.529	9.839	9.962	9.862	9.491	8.958	8.507	8.120
3	8.277	8.174	8.138	8.199	8.472	8.843	9.255	9.639	9.885	10.038	9.928	9.620	9.251	8.744
4	8.829	8.602	8.432	8.285	8.273	8.492	8.894	9.318	9.626	9.901	9.999	9.945	9.803	9.377
5	9.301	9.055	8.794	8.531	8.329	8.277	8.503	8.915	9.250	9.558	9.815	9.914	10.004	9.793
6	9.552	9.418	9.193	8.885	8.602	8.371	8.317	8.503	8.756	9.103	9.409	9.672	9.900	9.919
7	9.549	9.602	9.515	9.264	8.977	8.679	8.458	8.332	8.306	8.540	8.904	9.236	9.575	9.761
8	9.336	9.516	9.637	9.558	9.371	9.056	8.806	8.497	8.185	8.089	8.286	8.660	9.078	9.390
9	8.946	9.255	9.506	9.639	9.653	9.450	9.213	8.872	8.411	7.970	7.856	8.021	8.419	8.828
10	8.387	8.775	9.141	9.423	9.679	9.712	9.625	9.300	8.787	8.230	7.774	7.580	7.755	8.134
11	7.754	8.142	8.556	8.963	9.385	9.680	9.866	9.711	9.227	8.620	8.012	7.501	7.325	7.479
12	7.244	7.446	7.820	8.270	8.819	9.318	9.777	9.932	9.629	9.055	8.336	7.694	7.283	7.078
13	7.001	6.925	7.071	7.438	7.998	8.651	9.345	9.809	9.814	9.442	8.736	8.022	7.466	7.031
14	7.032	6.719	6.538	6.632	7.049	7.742	8.597	9.331	9.648	9.628	9.105	8.411	7.776	7.213
15	7.249	6.799	6.359	6.106	6.191	6.725	7.605	8.550	9.155	9.439	9.275	8.779	8.143	7.532
16	7.545	7.081	6.522	6.002	5.692	5.871	6.550	7.539	8.366	8.945	9.091	8.957	8.517	7.910
17	7.920	7.464	6.906	6.258	5.657	5.416	5.720	6.483	7.387	8.198	8.655	8.852	8.753	8.329
18	8.270	7.928	7.407	6.759	6.032	5.472	5.324	5.694	6.411	7.284	8.019	8.510	8.742	8.628
19	8.464	8.381	7.996	7.428	6.673	5.985	5.481	5.414	5.767	6.436	7.254	8.028	8.514	8.709
20	8.480	8.659	8.554	8.160	7.456	6.745	6.110	5.658	5.572	5.871	6.533	7.424	8.182	8.598
21	8.381	8.756	8.908	8.813	8.304	7.626	6.952	6.342	5.910	5.805	6.143	6.866	7.756	8.400
22	8.187	8.690	9.039	9.201	8.987	8.519	7.885	7.195	6.643	6.218	6.199	6.567	7.331	8.138
23	7.947	8.537	8.980	9.311	9.385	9.209	8.803	8.160	7.526	6.953	6.617	6.667	7.111	7.853
Mean	8.171	8.215	8.229	8.204	8.168	8.161	8.244	8.347	8.374	8.375	8.332	8.304	8.335	8.324

Maximum
Day Hr
26 3
10.038

Minimum
Day Hr
23 18
5.324

Monthly
Mean WL
8.217

Figure 6. Standard tabulation output from Tulare Beach, WA of tabulated hourly heights for June 2013. This tabulation shows the hourly heights in relation to station datum (STND).

TIDAL AND GEODETIC DATUMS

For marine applications, a vertical datum is a base elevation used as a reference to determine heights and depths (CO-OPS, 2001). A vertical datum is referred to as a tidal datum when defined by a certain phase of the tide determined by measurements from a water level station. For example, MHW is the mean elevation of all the high waters observed over the NTDE. Mean Lower Low Water (MLLW) is the mean elevation of all of the lower low waters observed each day over the NTDE and is the United States nautical chart reference datum (CO-OPS, 2001).

Accepted tidal datums were calculated for Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point, WA relative to the present 1983-2001 NTDE. A standard NOAA simultaneous comparison procedure (CO-OPS, 2003) was used with the long-term control water level station at Seattle, WA, which has been continuously operating from 1899 to present. Figure 7 shows the geographical relationship of the Tulalip water level stations and the Seattle, WA water level station. CO-OPS standard tidal datum products (Figures 8-11) include a full range of tidal and geodetic elevations including Great Diurnal Range (GT), Mean High Water (MHW), Mean Tide Level (MTL), Mean Sea Level (MSL), Mean Lower Low Water (MLLW) and North American Vertical Datum of 1988 (NAVD88). In addition, CO-OPS products also include Mean Range of Tide (MN), Diurnal High Water Inequality (DHQ), Diurnal Low Water Inequality (DLQ), Highest Astronomical Predicted Tide (HAT) and Lowest Astronomical Predicted Tide (LAT).

Figure 7. Locations of water level stations at Tulare Beach, Tulalip Bay, Spee-Bi-Dah, Priest Point, and the control station at Seattle, WA.

The tidal datums computed for the Tulalip project show similar relationships and compare very favorably with the Seattle, WA tidal datums. The great diurnal range of tide (GT) which is defined as the elevation difference between Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) is very similar at each station [varies from 3.37 meters (11.06 feet) to 3.34 meters (10.96 feet)]. The times of the tide as indicated by the High Water Interval (HWI) and Low Water Interval (LWI) are also very close in time from 0.36 to 0.42 hours for HWI and

from 6.59 to 6.88 hours for LWI. Correspondingly, differences between MHW and MLLW are also similar at each location [varies from 3.077 meters (10.09 feet) to 3.116 meters (10.22 feet)].

Orthometric elevations were also computed from select tidal bench marks for each of the water level station locations. For land-based vertical reference, a geodetic datum is a fixed reference that is developed and maintained by NOAA's National Geodetic Survey (www.ngs.noaa.gov). The North American Vertical Datum of 1988 (NAVD88) is the existing geodetic vertical reference datum for the United States and is the vertical reference for most modern topographic elevation sources such as the United States Geological Survey (USGS) National Elevation Database (NED) (NOAA, 2010). At least two of the tidal bench marks at each of the project water level stations were leveled by the WSDOT for purposes of establishing geodetic datum elevations. The leveling data were submitted to the National Geodetic Survey (NGS) along with elevation adjustments made in February 2014. As a result, NGS published elevations for the NAVD88 elevations for each of these marks in the NGS bench mark datasheets database (=http://www.ngs.noaa.gov/cgi-bin/ds2.prl?retrieval_type=by_pid&PID=DP1194). These published NGS elevations were then used to establish the CO-OPS published tidal datum relationships between NAVD88 and the tidal datums at each water level station. The resulting differences between MHW and NAVD88 were also similar at each location [varies from 2.49 meters (8.18 feet) to 2.56 meters (8.41 feet)].

Additionally, ellipsoidal elevations were computed from GPS surveys conducted at one tidal bench mark at each of the water level stations. GPS surveys consist of collecting ellipsoidal elevations by occupying each for several hours using a survey – grade static GPS receiver. GPS data were then processed with NGS Online Positioning User Service (OPUS) software (http://www.ngs.noaa.gov/OPUS) to obtain both ellipsoidal and orthometric elevations used to refine CO-OPS' published NAVD88 elevations. Ellipsoidal elevations are not currently published on CO-OPS' tidal bench mark sheet, but can be obtained upon request.

Elevations on Station Datum

Station: 9448043, Tulare Beach, Port Susan, WA
Status: Accepted (Jul 6 2015)
Units: Meters

T.M.: 120
Epoch: 1983-2001
Datum: STND

Datum	Value	Description
MHHW	9.656	Mean Higher-High Water
MHW	9.396	Mean High Water
MTL	8.255	Mean Tide Level
MSL	8.248	Mean Sea Level
DTL	7.968	Mean Diurnal Tide Level
MLW	7.115	Mean Low Water
MLLW	6.280	Mean Lower-Low Water
NAVD88	6.899	North American Vertical Datum of 1988
STND	0.000	Station Datum
GT	3.376	Great Diurnal Range
MN	2.280	Mean Range of Tide
DHQ	0.260	Mean Diurnal High Water Inequality
DLQ	0.835	Mean Diurnal Low Water Inequality
HWI	0.360	Greenwich High Water Interval (in hours)
LWI	6.580	Greenwich Low Water Interval (in hours)
Maximum		Highest Observed Water Level
Max Date & Time		Highest Observed Water Level Date and Time
Minimum		Lowest Observed Water Level
Min Date & Time		Lowest Observed Water Level Date and Time
HAT	10.329	Highest Astronomical Tide
HAT Date & Time	01/01/1983 15:06	HAT Date and Time
LAT	4.917	Lowest Astronomical Tide
LAT Date & Time	06/22/1986 18:42	LAT Date and Time

Tidal Datum Analysis Periods

06/01/2013 - 08/31/2013

Figure 8. Accepted Tidal Datum Elevations for Tulare Beach, WA, relative to station datum based on the 1983-2001 NTDE. Products include: Accepted Ranges of Tide, Maximum and Minimum Observed Water Levels, Highest and Lowest Astronomical Tides, Greenwich Time Intervals, and Orthometric Elevations.

Elevations on Station Datum

Station: 9447773, Tulalip, Tulalip Bay, WA **T.M.:** 120
Status: Accepted (Jul 6 2015) Epoch: 1983-2001
Units: Meters **Datum:** STND

Datum	Value	Description
MHHW	10.931	Mean Higher-High Water
MHW	10.676	Mean High Water
MTL	9.541	Mean Tide Level
MSL	9.534	Mean Sea Level
DTL	9.246	Mean Diurnal Tide Level
MLW	8.407	Mean Low Water
MLLW	7.560	Mean Lower-Low Water
NAVD88	8.182	North American Vertical Datum of 1988
STND	0.000	Station Datum
GT	3.371	Great Diurnal Range
MN	2.269	Mean Range of Tide
DHQ	0.256	Mean Diurnal High Water Inequality
DLQ	0.847	Mean Diurnal Low Water Inequality
HWI	0.420	Greenwich High Water Interval (in hours)
LWI	6.590	Greenwich Low Water Interval (in hours)
Maximum		Highest Observed Water Level
Max Date & Time		Highest Observed Water Level Date and Time
Minimum		Lowest Observed Water Level
Min Date & Time		Lowest Observed Water Level Date and Time
HAT	11.639	Highest Astronomical Tide
HAT Date & Time	01/01/1983 15:06	HAT Date and Time
LAT	6.203	Lowest Astronomical Tide
LAT Date & Time	06/22/1986 18:42	LAT Date and Time

Tidal Datum Analysis Periods

08/01/2013 - 11/30/2013

Figure 9. Accepted Tidal Datum Elevations for Tulalip Bay, WA, relative to station datum based on the 1983-2001 NTDE. Products include: Accepted Ranges of Tide, Maximum and Minimum Observed Water Levels, Highest and Lowest Astronomical Tides, Greenwich Time Intervals, and Orthometric Elevations.

Elevations on Station Datum

Station: 9448009, Spee-Bi-Dah, WA
T.M.: 120
Status: Accepted (Sep 30 2014)
Epoch: 1983-2001
Units: Meters
Datum: STND

Datum	Value	Description
MHHW	8.844	Mean Higher-High Water
MHW	8.582	Mean High Water
MTL	7.429	Mean Tide Level
MSL	7.424	Mean Sea Level
DTL	7.134	Mean Diurnal Tide Level
MLW	6.277	Mean Low Water
MLLW	5.423	Mean Lower-Low Water
NAVD88	6.019	North American Vertical Datum of 1988
STND	0.000	Station Datum
GT	3.421	Great Diurnal Range
MN	2.304	Mean Range of Tide
DHQ	0.263	Mean Diurnal High Water Inequality
DLQ	0.854	Mean Diurnal Low Water Inequality
HWI	0.390	Greenwich High Water Interval (in hours)
LWI	6.600	Greenwich Low Water Interval (in hours)
Maximum		Highest Observed Water Level
Max Date & Time		Highest Observed Water Level Date and Time
Minimum		Lowest Observed Water Level
Min Date & Time		Lowest Observed Water Level Date and Time
HAT	9.515	Highest Astronomical Tide
HAT Date & Time	01/01/1983 15:06	HAT Date and Time
LAT	4.083	Lowest Astronomical Tide
LAT Date & Time	06/22/1986 18:36	LAT Date and Time

Tidal Datum Analysis Periods

06/01/2014 - 08/31/2014

Figure 10. Accepted Tidal Datum Elevations for Spee-Bi-Dah, WA, relative to station datum based on the 1983-2001 NTDE. Products include: Accepted Ranges of Tide, Maximum and Minimum Observed Water Levels, Highest and Lowest Astronomical Tides, Greenwich Time Intervals, and Orthometric Elevations.

Elevations on Station Datum

Station: 9447717, Priest Point, WA
T.M.: 120
Status: Accepted (Dec 1 2014)
Epoch: 1983-2001
Units: Feet
Datum: STND

Datum	Value	Description
MHHW	29.39	Mean Higher-High Water
MHW	28.53	Mean High Water
MTL	24.83	Mean Tide Level
MSL	24.80	Mean Sea Level
DTL	23.91	Mean Diurnal Tide Level
MLW	21.12	Mean Low Water
MLLW	18.43	Mean Lower-Low Water
NAVD88	20.32	North American Vertical Datum of 1988
STND	0.00	Station Datum
GT	10.95	Great Diurnal Range
MN	7.41	Mean Range of Tide
DHQ	0.86	Mean Diurnal High Water Inequality
DLQ	2.69	Mean Diurnal Low Water Inequality
HWI	0.49	Greenwich High Water Interval (in hours)
LWI	6.88	Greenwich Low Water Interval (in hours)
Maximum		Highest Observed Water Level
Max Date & Time		Highest Observed Water Level Date and Time
Minimum		Lowest Observed Water Level
Min Date & Time		Lowest Observed Water Level Date and Time
HAT	31.45	Highest Astronomical Tide
HAT Date & Time	01/01/1983 15:18	HAT Date and Time
LAT	14.04	Lowest Astronomical Tide
LAT Date & Time	06/22/1986 18:54	LAT Date and Time

Tidal Datum Analysis Periods

07/01/2014 - 09/30/2014

Figure 11. Accepted Tidal Datum Elevations for Priest Point, WA, relative to station datum based on the 1983-2001 NTDE. Products include: Accepted Ranges of Tide, Maximum and Minimum Observed Water Levels, Highest and Lowest Astronomical Tides, Greenwich Time Intervals, and Orthometric Elevations.

TIDAL BENCH MARKS

Tidal bench marks are an essential part of collecting accurate water level observations and the development of water level products. There are a minimum of five tidal bench marks at each water level station which ensure sensor and network stability. Some of the tidal bench marks are brass discs set in the ground and some are deep rod marks, which have proven to be more dependable in areas without bedrock. The rods are stainless steel, driven to refusal to depths between 30 and 50 feet (9.14 and 15.24 meters) depending on resistance (CO-OPS, 2013). Figure 12 shows one of the deep rod marks installed for Tulare Beach, WA. Figure 13 shows a bronze tidal bench mark installed for Tulalip Bay, WA. Leveling the tidal bench marks to the sensor at the water level station and between each tidal bench mark provides a means to monitor and verify vertical stability. These measurements are crucial in determining the accuracy of the collected water level data and quality of derived water level products. As explained earlier, connections between tidal datum elevations and geodetic elevations are obtained after leveling between tidal bench marks and geodetic network tidal bench marks (CO-OPS, 2013). Figure 14 illustrates the locations of the local tidal bench mark network. Appendix 3 shows the resulting published tidal bench mark sheets for Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point, WA with a map of the tidal bench mark network for each water level station. Note, that some tidal bench mark descriptions have an NGS-assigned Permanent Identifier (PID). These are the tidal bench marks used to establish the relationship of NAVD88 to the tidal datums, and the PID provides a hotlink to the NGS datasheet.

Figure 12. Tulare Beach, WA, deep rod mark, "8043 B 2013."

Figure 13. Tulalip Bay, WA, bronze disk, "7963 B 2013."

Figure 14. Locations of deep rod marks at Tulare Beach, WA (left). Graphic courtesy of Dorrel Dickson. Locations of full tidal bench mark network (right) for Tulare Beach, WA. The large red balloon identifies the water level station location. The small red balloons identify published tidal bench marks and the blue balloon identifies an unpublished tidal bench mark.

The tidal datum section of the published tidal bench mark sheets shown in Appendix 3 provides elevations of tidal and geodetic datums referenced to MLLW as well as tidal bench mark elevations referenced to both MLLW and MHW. Both tidal and geodetic elevations are used by surveyors as the baseline for delineating MHW and are often used to ground-truth Digital Elevation Models (DEMs) and Vertical Datum (VDatum) interpolation models. VDatum is an interpolation tool developed by NOAA that allows users to estimate elevation relationships among tidal, geodetic, and ellipsoidal datums (NOS, 2012). Comparisons of datum elevations between observations and the VDatum model relative to MLLW are presented in Appendix 4. The calculated differences from the comparisons are within 0 – 5 centimeters (0 - 0.16 feet), which are within expected model uncertainties for the Tulalip area (VDatum.noaa.gov).

UNCERTAINTY

The uncertainty or error in tidal datums is heavily dependent upon the length of the observational time period (CO-OPS, 2001). The fundamental definition of tidal datums requires that they be computed relative to a specific 19-year NTDE. Tidal datums computed using shorter time periods require that equivalent 19-year tidal datums be computed through simultaneous comparsion with a long-term control station that has datums determined over a full NTDE. CO-OPS has developed a methodology (Bodnar, 2014) to estimate errors in tidal datums based on the length of the observation, the distance from the control station used, the difference in the time of tide from the control station, and the ratio of the ranges of tide with the control station. The control station used for the Tulalip project was Seattle, WA. Three consecutive months were used for each tidal datum calculation except for Tulalip Bay, WA which used four months of data. Table 1 lists the start and end months used in the tidal datum computation and the estimated errors in their computation. The errors computed for the Tulalip stations are typical for three month tertiary water level stations.

Table 1. Estimated Errors in Tidal Datums for the Tulalip Project.

Station Name/ID	Start Month	End Month	Error in Meters	Error in Feet
Tulare Beach, WA (Station ID: 9448043)	June 2013	August 2013	0.015	0.05
Tulalip Bay, WA (Station ID: 9447773)	August 2013	November 2013	0.015	0.05
Spee-Bi-Dah, WA (Station ID: 9448009)	June 2014	August 2014	0.015	0.05
Priest Point, WA (Station ID: 9447717)	July 2014	September 2014	0.015	0.05

Note: Tidal datum error estimates using the standard deviation of the estimate (in meters and feet). To estimate the 95% confidence interval of the errors, multiply the standard deviation by 1.96 meters (6.43 feet). Seattle, WA (Station ID: 9447330) was used as the control for tidal datum computation.

All leveling was conducted using second order, Class I levels, including the geodetic leveling conducted by the WSDOT. This class of leveling uses closure tolerances of 0.006 meters (0.020 feet) to ensure a high level of accuracy. Taking into account the leveling errors, the tidal datum errors (above) and the measurement errors, the tidal datum elevations of the tidal bench marks for this project are estimated to have a tidal datum elevation uncertainty of 0.021 meters (0.069 feet) [one standard deviation].

HISTORICAL TIDAL DATUM AND DATUM RECOVERY

Tulalip Bay, WA is an historic water level station that was reoccupied on four different occasions prior to 2013. Water level observations were first collected from 01/1886 - 12/1886 followed by a short term installation from 04/1935 - 06/1935. The station was then reoccupied from 06/1961 - 10/1961, and then again in 09/1963 - 10/1963. Tidal datums were calculated after each re-occupancy of the station relative to the NTDE in use at the time. Due to the short term occupancy in 1961 and 1963, the tidal datums for these two time periods were averaged. Table 2 shows an historical comparison of Tulalip Bay tidal datums relative to MLLW and the tidal ranges since 1988. The other tidal datums shown are MHHW, MHW, MTL, and MLW. The ranges of tide shown are the Great Diurnal Range (GT) and Mean Range (MN). The ranges of tide have apparently decreased slightly over the last 128 years; however, the changes in the elevations are within their relative uncertainties due to series lengths.

Table 2. Comparison of historical and present tidal datums and tidal ranges computed over various time periods at Tulalip Bay, WA. Elevations are relative to MLLW (units in meters).

	National Tidal Datum Epoch (NTDE) used for each time period			
	1983-2001	**1960-1978**	**1941-1959**	**Not used**
	Year of Observations			
	2013	**1961 & 1963**	**1935**	**1886**
Datums	**Values (m)**	**Values (m)**	**Values (m)**	**Values (m)**
MHHW	3.371	3.383	3.432	3.557
MHW	3.116	3.109	3.176	3.179
MTL	1.981	1.951	2.015	2.029
MLW	0.847	0.823	0.853	0.881
MLLW	0.000	0.000	0.000	0.000
GT	3.371	3.383	3.432	3.557
MN	2.269	2.286	2.323	2.298

Tidal Datum Analysis Periods:
Four months: 08/2013 - 11/2013
Six months: 06/1961-10/1961 and 09/1963-10/1963
Two months: 04/1935 - 06/1935
Twelve months: 01/1886 - 12/1886

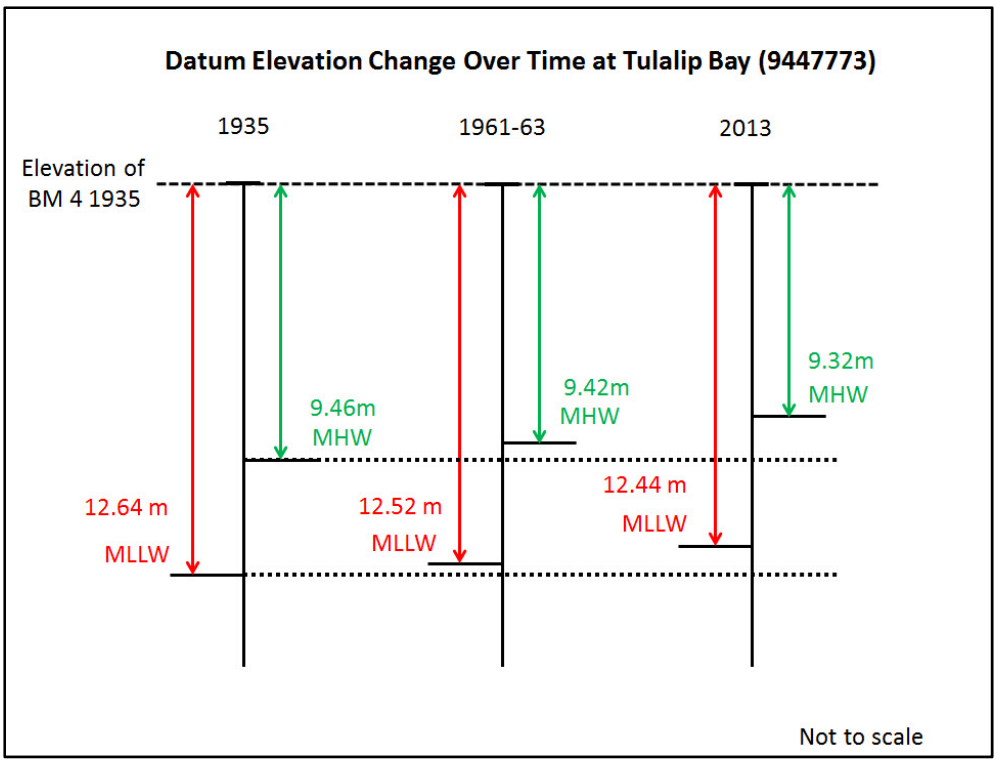

Figure 15. Tidal datum elevation changes over time relative to the elevation of tidal bench mark "4 1935" at Tulalip Bay, WA.

A tidal datum recovery at Tulalip Bay was possible because common tidal bench marks were in use since 1935. Using stable tidal bench marks allows for the comparison of tidal datum elevations relative to the land for each of the water level station occupations. Figure 15 shows the datum recovery for tidal bench mark "4 1935" at Tulalip Bay. Over time, the elevations of MHW and MLLW have risen relative to the tidal bench mark. These elevation changes correspond well to the rate of relative sea level rise at Seattle, WA of 0.198 meters/century (0.649 feet/century) (http://tidesandcurrents.noaa.gov/sltrends/sltrends.html). The range of tide has not significantly changed, as also shown in Table 2. Figure 15 effectively illustrates the increasing elevation of the sea relative to the land over time.

PREDICTED AND OBSERVED TIDAL COMPARISONS

Tidal predictions were generated for Tulare Beach, Tulalip Bay, Spee-Bi-Dah, and Priest Point, WA using the accepted sets of harmonic constants derived from a vector average of three to four individual 29-day Fourier harmonic analyses of hourly heights at each station (Parker, 2007). These accepted sets can be found in Appendix 5. Figure 16 is a three month comparison plot of observed and predicted water levels at Tulare Beach showing very good agreement between observed and predicted tides. Figure 17 shows the residual differences between observed and predicted tides for Tulare Beach with an average residual difference of 0.022 meters (0.072 feet) and a standard deviation of 0.091 meters (0.298 feet). This difference is small (<1%) compared to the great diurnal range of tide of 3.376 meters (11.076 feet). The residuals between observed and predicted tides are small for all four stations as shown in Appendix 6, and also have very similar variations over time for each station. In general, due to the strong tidal signal and the fairly deep bathymetry of Puget Sound, observed tides will usually only differ significantly from predicted tides during strong weather events such as persistent strong winds, strong storm frontal passages, coastal storms and tsunamis. Sea levels may show deviation from normal during strong El Nino years as well.

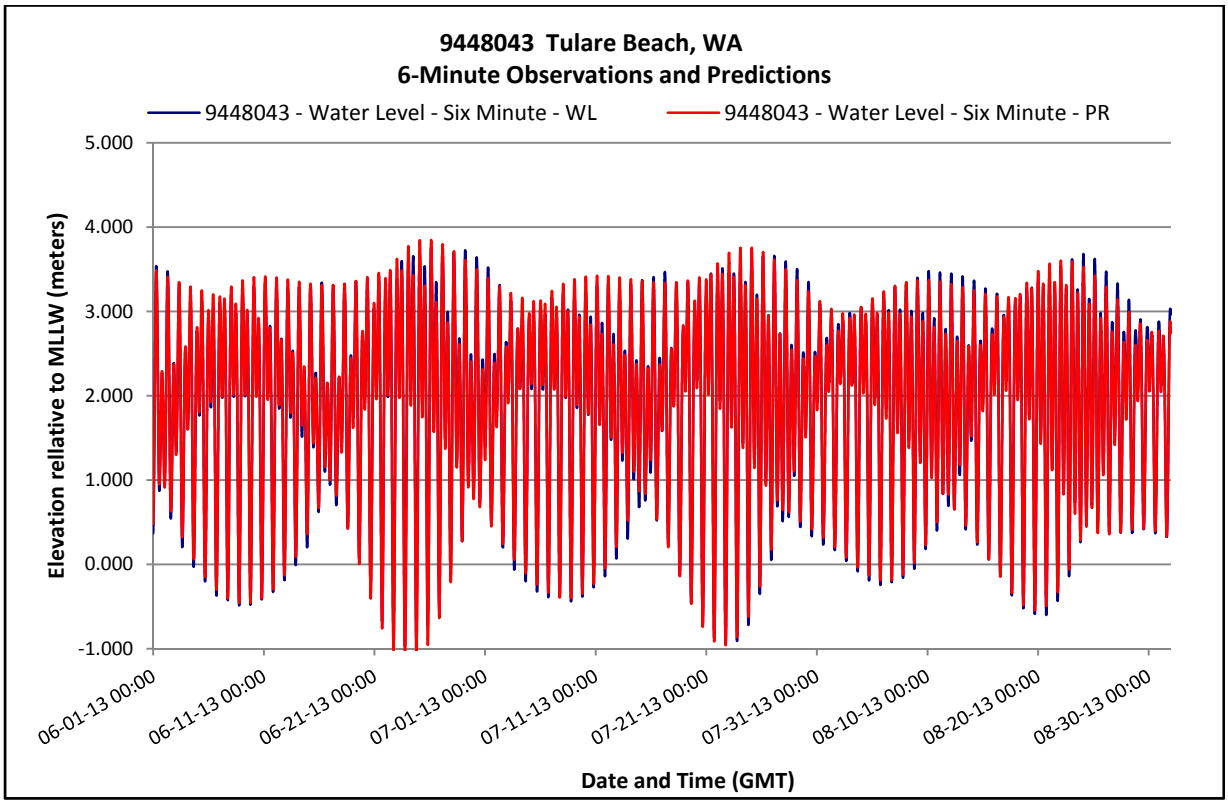

Figure 16. Tulare Beach, WA 6-minute observed (blue) and predicted (red) water levels.

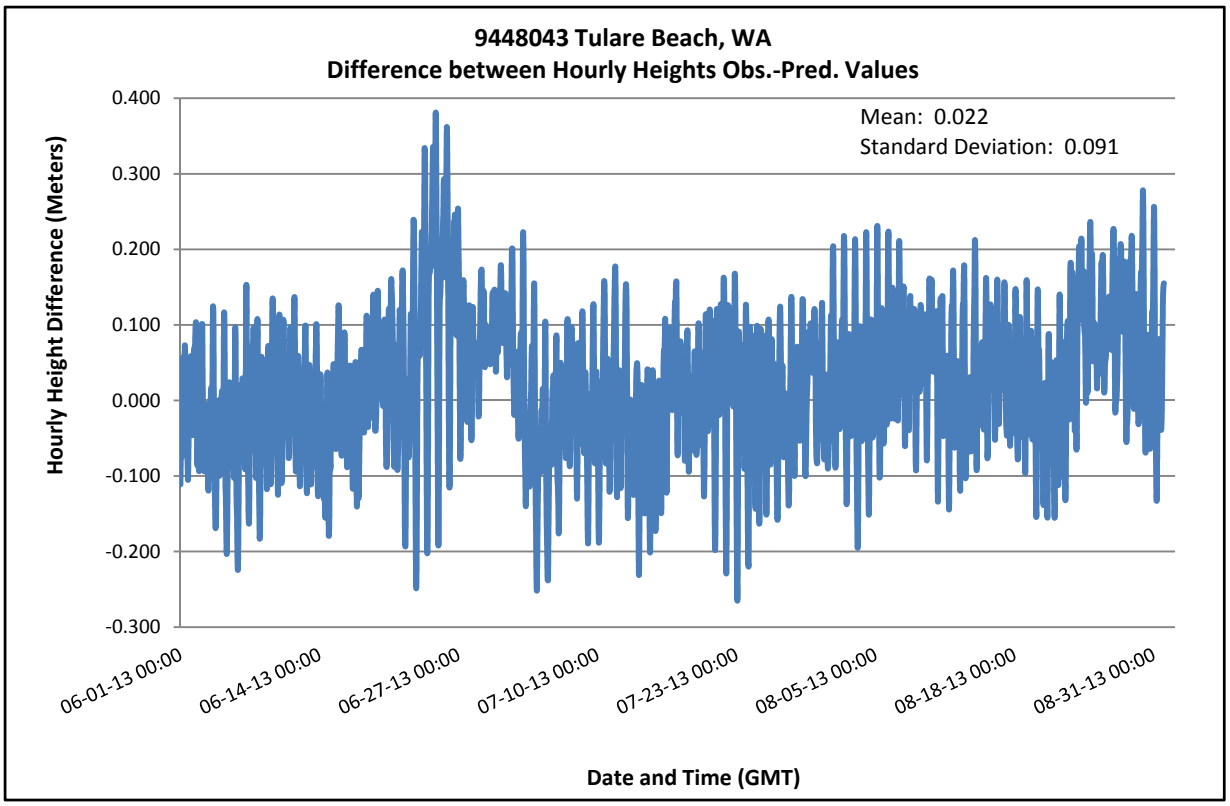

Figure 17. Residual difference of observed and predicted water levels at Tulare Beach, WA with a mean of 0.022 meters (0.072 feet) and standard deviation of 0.091 meters (0.298 feet).

As noted in Table 2, the Tulalip Bay station is an historical water level station reoccupied several times since 1886. The station had its first published tidal bench mark sheet after the 1935 occupation, and the station started to be listed in the NOAA annually published tide tables as a subordinate Table 2 station with time and height correctors applied to the Reference Station at Seattle, WA (NOS, 2014). Based on this project, tide prediction products have been updated for Tulalip Bay and new products have been added for the other newly established stations at Tulare Beach, Spee-Bi-Dah, and Priest Point (http://tidesandcurrents.noaa.gov/tide_predictions.html).

SUMMARY

In response to a request for support in resolving marine boundary issues for the Tulalip Tribes in Tulalip, WA, CO-OPS established four tertiary water level stations at strategic coastal locations within the Tulalip Tribal region. Each station, operated from three to four months, consisted of a water level station and a network of five local tidal bench marks. Standard NOAA equipment and documented standard operating procedures and methodologies were used to deliver final products for this project. Accepted tidal datums relative to the present NTDE (1983-2001) for each station were computed using simultaneous comparisons of observations with the long-term NOAA water level control station at Seattle, WA. Using leveling survey connections between the water level sensors and the local tidal bench marks, accurate tidal datum elevations were computed and published for each tidal bench mark on official NOAA Published Tidal Bench Mark Sheets. Leveling also included using NGS adjustments for publishing NAVD88 elevation relationships. These elevations are now available for use as baseline points from which coastal engineers and surveyors can conduct surveys to demarcate a MHW line along the shore and determine datum elevations for other structures and landforms. Additionally, tribal and non-tribal homeowners can now have land surveyors survey their land with confidence using new and/or updated tidal datum elevations. The Tulalip Reservation community also now has access to water level products and services that will support various coastal applications, such as habitat restoration. NOAA online tide prediction products have been added for all four stations. All verified and published products are available on the CO-OPS website (http://tidesandcurrents.noaa.gov).

ACKNOWLEDGEMENTS

The author especially recognizes the contribution of the CO-OPS Field Operations Division, Pacific Operations Branch for their work in planning, installation, and operation and maintenance of the water level stations for this project. The author gratefully acknowledges Stephen Gill (CO-OPS Chief Scientist), who provided mentoring and guidance in the analysis and interpretation of data associated with the work contained in the technical report. Special thanks to the numerous reviewers of this report. The author also would like to thank Virginia Dentler for production assistance.

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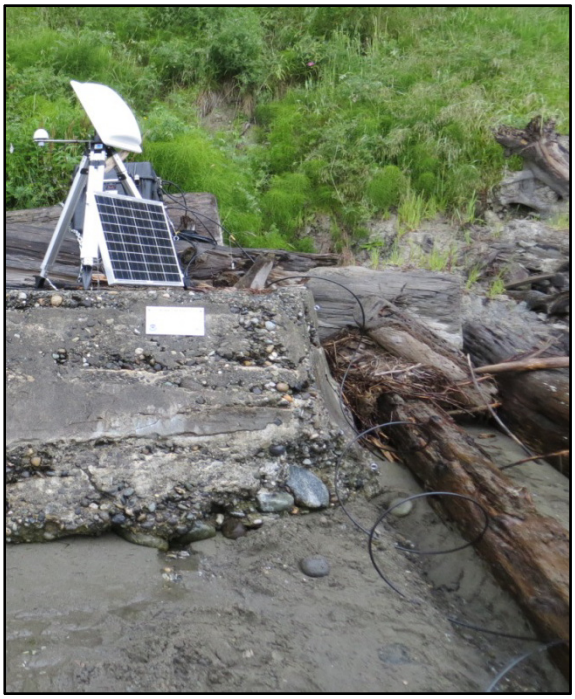
Appendix 1. Water Level Station Pictures

Tulare Beach, WA

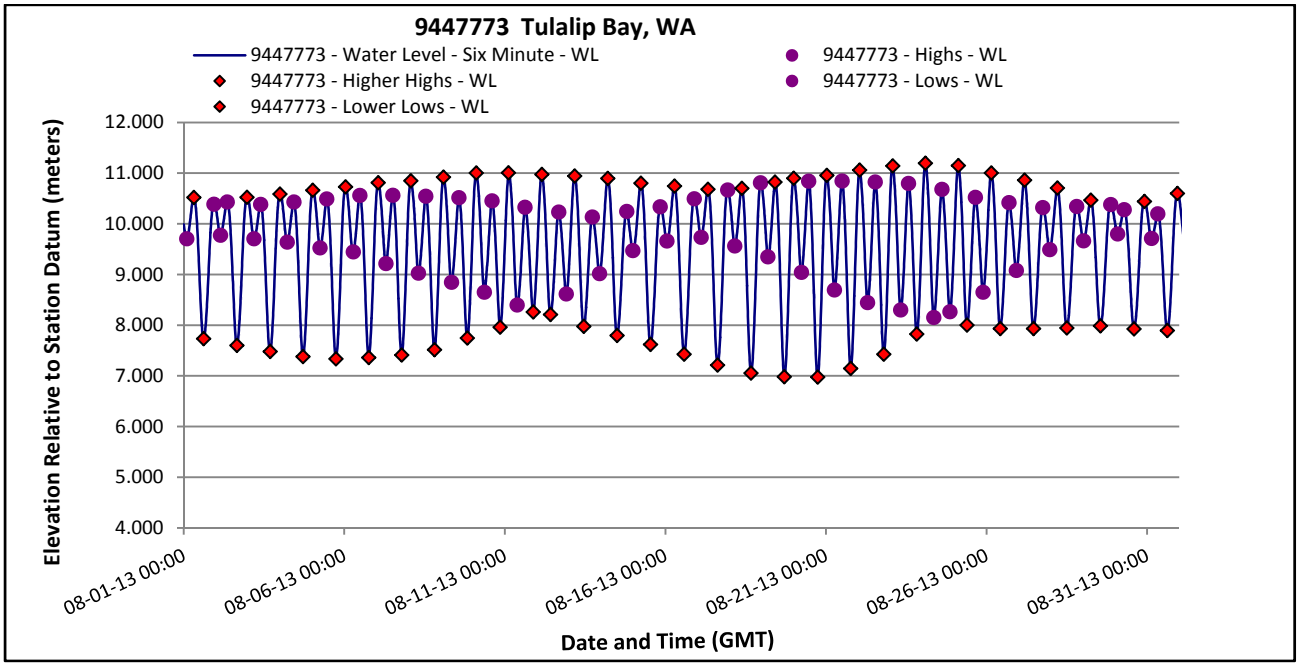
Tulalip Bay, WA



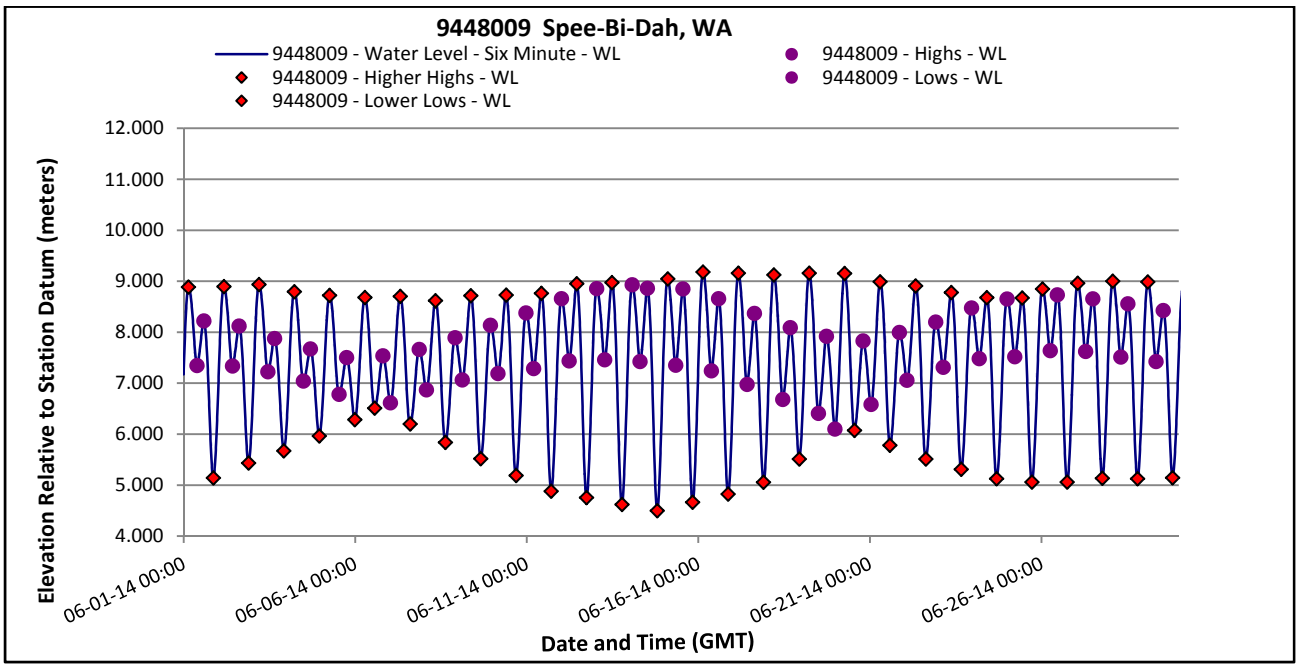
Spee-Bi-Dah, WA

Priest Point, WA

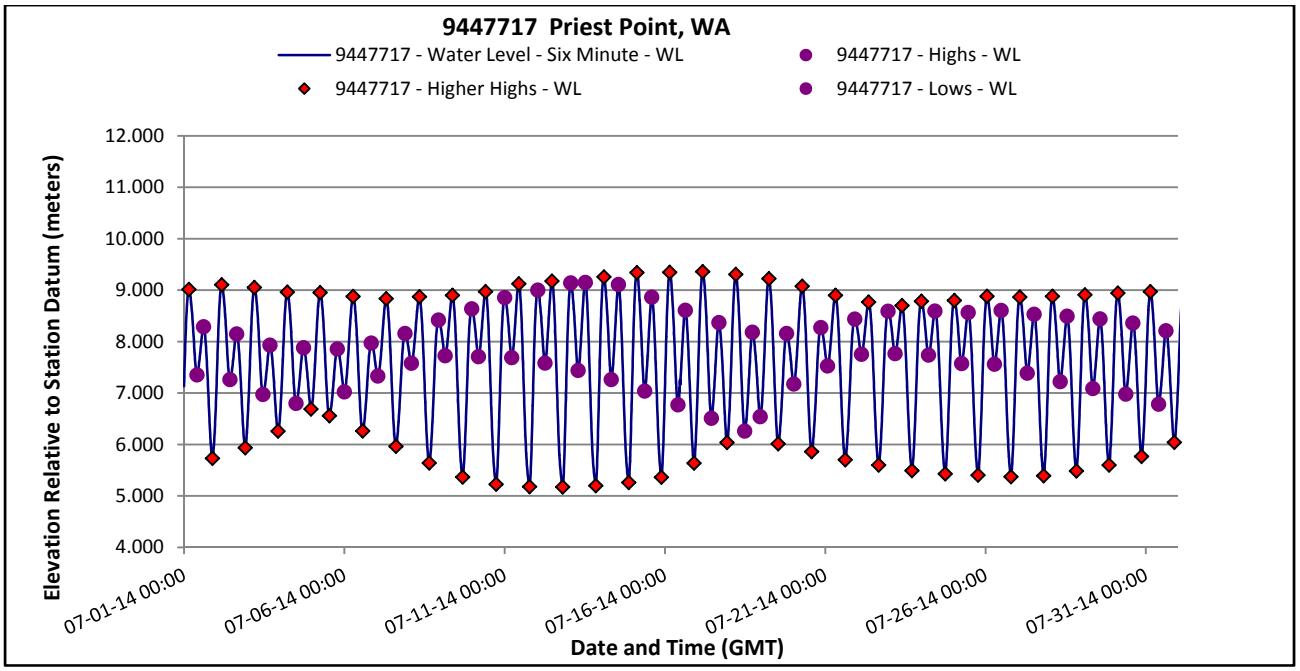
Appendix 2. Tabulated High and Low Tides



Tabulated highs and lows for Tulalip Bay, WA for August 2013. This tabulation shows the time and height of every high and low water level in relation to station datum (STND).



Tabulated highs and lows for Spee-Bi-Dah, WA for June 2014. This tabulation shows the time and height of every high and low water level in relation to station datum (STND).



Tabulated highs and lows for Priest Point, WA for July 2014. This tabulation shows the time and height of every high and low water level in relation to station datum (STND).

Appendix 3. Published Tidal Bench Mark Sheets for the Tulalip Project

Tidal bench mark sheet for Tulare Beach, WA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page

Station ID: 9448043 **PUBLICATION DATE: 07/14/2015**
Name: TULARE BEACH, PORT SUSAN WASHINGTON
NOAA Chart: 18423 **Latitude: 48° 6.4' N**
USGS Quad: TULALIP **Longitude: 122° 20.8' W**

From Seattle, take Interstate 5 North to exit 199 for Marysville. Turn left on Tulalip Road / Marine Drive and continue for 17.1 km (10.6 mi) to a left turn on 76th Ave NW / Tulare Way. Make the first right turn onto a private dirt road that is signed No Trespassing. (You are proceeding onto tribal land at this point and should have an escort from the tribe.) Continue to the end of the road atop a 33 ft (10 m) bluff above the beach. The DCP is located at the top of the bluff, chained to a large twin Douglas Fir. The tubing runs down the bluff and is trenched into the beach to the orifice location offshore.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 8043 C 2013
DESIGNATION: 944 8043 C

MONUMENTATION: Metal Rod VM#: 20735
AGENCY: National Ocean Service (NOS) PID#: DP1196
SETTING CLASSIFICATION: Stainless steel rod in sleeve

The primary bench mark is a sleeved rod set at the base of the bluff between the Tulare beach and Sunny Shores communities, located 69 m (226.4 ft) SE of the trail from the parking area to the beach, 32.17 m (105.5 ft) E of a 2 m (6.6 ft) x 1.5 m (4.9 ft) boulder on the beach just below the high water line, 10.5 m (34.4.ft) slope distance SW form a large twin Douglas fir at the top of the bluff, 1.32 m (4.3 ft) W of the toe of the bluff, and 0.25 m (0.8 ft) W of an orange fiberglass witness post. The datum point is the top of a stainless steel rod driven 15.4 m (50.5 ft) to refusal, encased in a NOS logo cap with two magnets.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9448043 **PUBLICATION DATE: 07/14/2015**
Name: TULARE BEACH, PORT SUSAN WASHINGTON
NOAA Chart: 18423 **Latitude: 48° 6.4' N**
USGS Quad: TULALIP **Longitude: 122° 20.8' W**

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 8043 A 2013
DESIGNATION: 944 8043 A

MONUMENTATION: Metal Rod VM#: 20733
AGENCY: National Ocean Service (NOS) PID#: DP1197
SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a sleeved rod set SE of the end of a private tribal road from Tulare Shores to the beach, located 11.3 m (37.1 ft) N of a blaze in a maple tree, 8.05 m (26.4 ft) SW of a blaze in a maple tree, 4.35 m (14.3 ft) NE of east edge of road and 0.22 m (0.7 ft) SW of orange fiberglass witness post. The datum point is the top of a stainless steel rod driven 25.5 m (83.5 ft) to refusal, encased in a NOS logo cap with two magnets.

BENCH MARK STAMPING: 8043 B 944
DESIGNATION: 944 8043 B

MONUMENTATION: Metal Rod VM#: 20734
AGENCY: National Ocean Service (NOS) PID:
SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a sleeved rod set at the west end of a gate between the private road to Sunny Shores and the private tribal road between the Tulare Beach community and the beach, located 7.98 m (26.2 ft) E of a blaze in a maple tree, 7.30 m (24.0 ft) NNW of a blaze in the west-most clump of maple trees, 3.78 m (12.4 ft) S of the eastern metal gate post for Sunny Shores and 0.25 m (0.8 ft) W of an orange fiberglass witness post. The datum point is the top of a stainless steel rod driven 9.7 m (31.8 ft) to refusal, encased in a NOS logo cap with two magnets.

Station ID: 9448043 **PUBLICATION DATE: 07/14/2015**
Name: TULARE BEACH, PORT SUSAN WASHINGTON
NOAA Chart: 18423 **Latitude: 48° 6.4' N**
USGS Quad: TULALIP **Longitude: 122° 20.8' W**

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 8043 D 2013
DESIGNATION: 944 8043 D

MONUMENTATION: Metal Rod VM#: 20736
AGENCY: National Ocean Service (NOS) PID#: DP1194
SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a sleeved rod set at the N corner of the intersection of Tulare Way and Tulare Way West, located 23.40 m (76.8 ft) NE of N post of gate across boat launch ramp, 5.80 m (19.0 ft) NW of the center-line of intersection and 1.95 m (6.4 ft) SW of utility pole XCWGD21 which has a metal witness sign. The datum point is the top of a stainless steel rod driven 14.2 m (46.5 ft) to refusal, encased in a NOS logo cap with two magnets.

BENCH MARK STAMPING: 8043 E 2013
DESIGNATION: 944 8043 E

MONUMENTATION: Metal Rod VM#: 20737
AGENCY: National Ocean Service (NOS) PID#: DP1195
SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a sleeved rod set at the centerline of Tulare Way West in front of address 11704, located 29.06 m (95.3 ft) north of plat monument in Tulare Way West, 23.26 m (76.3 ft) SSE of utility pole 17 and 10.34 m (33.9 ft) NE of fire hydrant. The datum point is the top of a stainless steel rod driven 15.5 m (51 ft) to refusal, encased in a cast iron OFCO cover cap marked "Street Survey Monument".

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9448043 **PUBLICATION DATE: 07/14/2015**
Name: TULARE BEACH, PORT SUSAN WASHINGTON
NOAA Chart: 18423 **Latitude: 48° 6.4' N**
USGS Quad: TULALIP **Longitude: 122° 20.8' W**

T I D A L D A T U M S

Tidal datums at TULARE BEACH, PORT SUSAN based on:

LENGTH OF SERIES: 3 MONTHS
TIME PERIOD: June 2013 - August 2013
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 9447130 SEATTLE, PUGET SOUND

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER	MHHW	=	3.376
MEAN HIGH WATER	MHW	=	3.116
MEAN TIDE LEVEL	MTL	=	1.975
MEAN SEA LEVEL	MSL	=	1.968
MEAN LOW WATER	MLW	=	0.835
North American Vertical Datum	NAVD88	=	0.619
MEAN LOWER LOW WATER	MLLW	=	0.000

North American Vertical Datum (NAVD88)

Bench Mark Elevation Information	In METERS above:	
Stamping or Designation	MLLW	MHW
8043 C 2013	3.720	0.604
8043 A 2013	17.062	13.946
8043 B 944	29.829	26.713
8043 D 2013	5.182	2.066
8043 E 2013	3.845	0.729

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9448043 PUBLICATION DATE: 07/14/2015
Name: TULARE BEACH, PORT SUSAN WASHINGTON
NOAA Chart: 18423 Latitude: 48° 6.4' N
USGS Quad: TULALIP Longitude: 122° 20.8' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88).

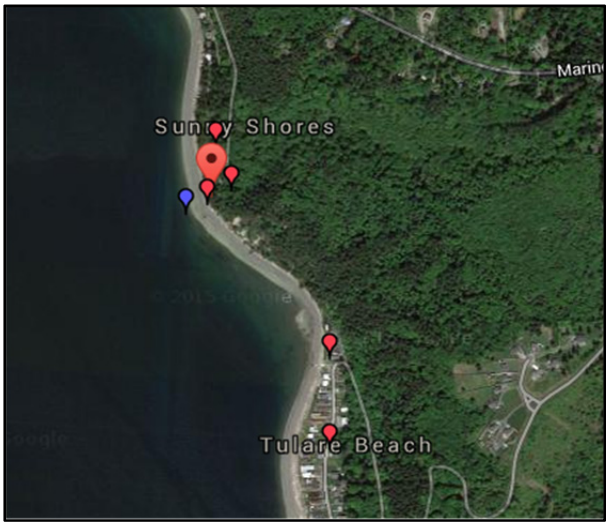
NAVD88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD88 replaces NGVD29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD88 and NGVD29 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD88 elevations. The NAVD88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD88 elevations listed for each bench mark in the NGS database.



Satellite image of the locations of Tidal bench marks for Tulare Beach, WA.

Tidal bench mark sheet for Tulalip Bay, WA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page

Station ID: 9447773 PUBLICATION DATE: 07/14/2015
Name: TULALIP, TULALIP BAY
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 3.9' N
USGS Quad: TULALIP Longitude: 122° 17.3' W

To reach from the intersection of I-90 and I-5 in Seattle, proceed north to exit 199. Turn left on Marine Drive for 5.7 mi (9.2 km) turn left on 76th place NW 0.1 mi (0.2 km) to a left on an unnamed road, 0.25 mi (0.4 km) to a right into the marina parking lot.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 4 1935
DESIGNATION: 944 7773 4

MONUMENTATION: Tidal Station disk VM#: 20811
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: DP1176
SETTING CLASSIFICATION: Dam wall for fish hatchery

The bench mark is a disk set flush in the top of concrete dam for Tulalip Fish Hatchery, 36.51 m (119.8 ft) west of a power pole, 12.5 m (41.0 ft) east of sewer manhole, 4.60 m (15.1 ft) north of the centerline of road, and 0.52 m (1.7 ft) higher than the sidewalk.

BENCH MARK STAMPING: TIDAL BM 8 1974
DESIGNATION: 944 7773 TIDAL BM 8

MONUMENTATION: Tidal Station disk VM#: 20812
AGENCY: National Ocean Service (NOS) PID#: DP1178
SETTING CLASSIFICATION: Conc wall of fish ladder

The bench mark is a disk set flush on top of the south wall of the fish ladder for the Tulalip Fish Hatchery, 8.03 m (26.3 ft) east of west end of fish ladder, 4.82 m (15.8 ft) north of a wood light pole, 1.80 m (5.9 ft) west of chain-link fence at east side of property, 0.25 m (0.8 ft) north of chain-link fence on south wall of fish ladder, and 0.65 m (2.1 ft) above ground.

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National Ocean Service

Station ID: 9447773 PUBLICATION DATE: 07/14/2015
Name: TULALIP, TULALIP BAY
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 3.9' N
USGS Quad: TULALIP Longitude: 122° 17.3' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: TIDAL BM 7 1974
DESIGNATION: 944 7773 TIDAL BM 7

MONUMENTATION: Tidal Station disk VM#: 20813
AGENCY: National Ocean Service (NOS) PID#: DP1177
SETTING CLASSIFICATION: Dam wall of fish hatchery

The bench mark is a disk set flush on top of the east dam wall for the Tulalip Fish Hatchery, 15.67 m (51.4 ft) NW of a power pole and electric meter, 12.60 m (0.7 ft) west of a wood light pole, and 3.14 m (10.3 ft) SW of SW support beam for lift platform.

BENCH MARK STAMPING: 5 1935
DESIGNATION: 944 7773 5

MONUMENTATION: Tidal Station disk VM#: 20814
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: DP1175
SETTING CLASSIFICATION: Flagpole foundation

The bench mark is a disk set flush in a concrete foundation for a now missing flagpole in the yard of an abandoned wood building with address 7615, 11.5 m (37.7 ft) east of east end of concrete dam, 7.48 m (24.5 ft) north of north edge of road, and 6.89 m (22.6 ft) NW of NW corner of building.

BENCH MARK STAMPING: 7963 A 2013
DESIGNATION: 944 7773 A

MONUMENTATION: Tidal Station disk VM#: 20815
AGENCY: National Ocean Service (NOS) PID#: DP1174
SETTING CLASSIFICATION: Concrete stairs

The bench mark is a disk set flush in the top step of a concrete stairs between the bathrooms and Tulalip Fisheries building, 3.54 m (11.6 ft) west of a power pole, 1.95 m (6.4 ft) NE of N handrail of ramp to floating dock, and 1.05 m (3.4 ft) east of SE corner of Tulalip Fisheries building.

Station ID: 9447773 PUBLICATION DATE: 07/14/2015
Name: TULALIP, TULALIP BAY
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 3.9' N
USGS Quad: TULALIP Longitude: 122° 17.3' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 7963 B 2013
DESIGNATION: 944 7773 B

MONUMENTATION: Tidal Station disk VM#: 20816
AGENCY: National Ocean Service (NOS) PID#: DP1173
SETTING CLASSIFICATION: Concrete stairs

The bench mark is a disk set flush in bottom concrete step of stairs to boat ramp from south end of parking lot, 27.15 m (89.1 ft) south of top of ramp where it meets parking lot, 3.75 m (12.3 ft) NE of centerline of ramp, and 1.95 m (6.4 ft) NW of wood power and light pole.

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National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9447773 PUBLICATION DATE: 07/14/2015
Name: TULALIP, TULALIP BAY
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 3.9' N
USGS Quad: TULALIP Longitude: 122° 17.3' W

T I D A L D A T U M S

Tidal datums at TULALIP, TULALIP BAY based on:

LENGTH OF SERIES: 4 MONTHS
TIME PERIOD: August 2013 - November 2013
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 9447130 SEATTLE, PUGET SOUND

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER	MHHW	= 3.371
MEAN HIGH WATER	MHW	= 3.116
MEAN TIDE LEVEL	MTL	= 1.981
MEAN SEA LEVEL	MSL	= 1.974
MEAN LOW WATER	MLW	= 0.847
North American Vertical Datum	NAVD88	= 0.622
MEAN LOWER LOW WATER	MLLW	= 0.000

North American Vertical Datum (NAVD88)

Bench Mark Elevation Information	In METERS above:	
Stamping or Designation	MLLW	MHW
4 1935	12.440	9.324
TIDAL BM 8 1974	6.386	3.270
TIDAL BM 7 1974	5.663	2.547
5 1935	13.254	10.138
7963 A 2013	5.702	2.586
7963 B 2013	4.554	1.438

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National Ocean Service

Station ID: 9447773 PUBLICATION DATE: 07/14/2015
Name: TULALIP, TULALIP BAY
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 3.9' N
USGS Quad: TULALIP Longitude: 122° 17.3' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88).

NAVD88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD88 replaces NGVD29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD88 and NGVD29 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

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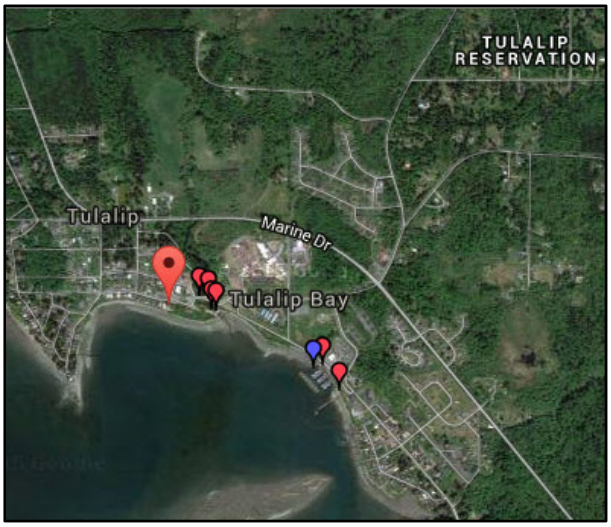


Satellite image of the locations of Tidal bench marks for Tulalip Bay, WA.

Tidal bench mark sheet for Spee-Bi-Dah, WA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page Page 1 of 5

Station ID: 9448009 PUBLICATION DATE: 11/07/2014
Name: SPEE-BI-DAH
WASHINGTON
NOAA Chart: 18423 Latitude: 48° 5.3' N
USGS Quad: TULALIP Longitude: 122° 19.3' W

From the intersection of Interstate 5 and Interstate 90 in Seattle, WA, take Interstate 5 north to exit 199 for Marysville. Turn left on Tulalip Road / Marine Drive and continue for 9.1 miles to a left turn on 108 St NW. This is the entrance road to Spee-Bi-Dah which is a gated community so you will need a contact with the community or Tulalip Tribe to open the gate. Continue on 108 St. NW which becomes Scenic Dr NW and ends at a park along the waterfront. Park at the waterfront and continue south on foot to the gauge atop a large concrete block at the approximate high water line.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 8009 B 2014
DESIGNATION: 944 8009 B

MONUMENTATION: Flange-encased Rod VM#: 21099
AGENCY: National Ocean Service PID:
SETTING CLASSIFICATION: Steel rod

THE PRIMARY BENCH MARK IS A 9/16 INCH (14 MM) STAINLESS ROD DRIVEN 31 FT (9.4 M) TO REFUSAL S OF THE INTERSECTION OF PARK WAY AND FIR DRIVE IN THE SPEE-BI-DAH COMMUNITY PARK, LOCATED 5.05 M (16.6 FT) NE OF THE W TOE OF A CONCRETE BLOCK WALL, 4.85 M (15.9 FT) S OF THE NW CORNER OF A STORAGE SHED, 1.95 M (6.4 FT) N OF A CONCRETE BLOCK WALL WITH METAL WITNESS SIGN ATTACHED.

BENCH MARK STAMPING: 8009 A 2014
DESIGNATION: 944 8009 A

MONUMENTATION: Bench Mark disk VM#: 21100
AGENCY: National Ocean Service PID#: DP1199
SETTING CLASSIFICATION: Concrete block

THE BENCH MARK IS A DISK SET IN THE TOP OF A CONCRETE BLOCK ON THE TULALIP TRIBAL BEACH S OF THE SPEE-BI-DAH COMMUNITY, LOCATED 1.9 M (6.2 FT) N OF THE S CORNER OF THE BLOCK, 1.6 M (5.2 FT) S OF N CORNER, 0.4 M (1.3 FT) E OF THE W EDGE AND 1.3 M (4.3 FT) ABOVE THE BEACH.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Page 2 of 5

Station ID: 9448009 PUBLICATION DATE: 11/07/2014
Name: SPEE-BI-DAH
WASHINGTON
NOAA Chart: 18423 Latitude: 48° 5.3' N
USGS Quad: TULALIP Longitude: 122° 19.3' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 8009 C 2014
DESIGNATION: 944 8009 C

MONUMENTATION: Flange-encased Rod VM#: 21101
AGENCY: National Ocean Service PID:
SETTING CLASSIFICATION: Steel rod

THE BENCH MARK IS A 9/16 INCH (14 MM) STAINLESS STEEL ROD DRIVEN 35.5 FT (10.8 M) TO REFUSAL AT THE E POINT OF THE SPEE-BI-DAH COMMUNITY PARK, LOCATED 3.8 M (12.5 FT) N OF THE S EDGE OF SCENIC DRIVE NW, 2.7 M (8.9 FT) S OF THE N EDGE OF PARK WAY, AND 2.7 M (8.9 FT) W OF A METAL WITNESS SIGN FASTENED TO BACK OF 'GOLF CART X-ING' SIGN.

BENCH MARK STAMPING: SBD2 2013
DESIGNATION: SBD2

MONUMENTATION: Bench Mark disk VM#: 21102
AGENCY: WA DOT PID#: DP1199
SETTING CLASSIFICATION: Aluminum rod

THE BENCHMARK IS A DISK SET ON AN ALUMINUM ALLOY ROD DRIVEN 10.7 M (35.1 FT), LOCATED 1.8 M (5.9 FT) NE FROM A FLAG POLE, 5.7 M (18.7 FT) NE FROM CENTERLINE OF SCENIC DRIVE, 6.4 M (21.0 FT) NW FROM STORM DRAIN COVER AND 12.3 M (40.4 FT) NW FROM EXTENDED CENTERLINE OF BOAT LAUNCH AND 3 CM (1.2 IN) BELOW GROUND LEVEL.

Station ID: 9448009 PUBLICATION DATE: 11/07/2014
Name: SPEE-BI-DAH
WASHINGTON
NOAA Chart: 18423 Latitude: 48° 5.3' N
USGS Quad: TULALIP Longitude: 122° 19.3' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: SBD1 2013
DESIGNATION: SBD1

MONUMENTATION: Bench Mark disk VM#: 21103
AGENCY: WA DOT PID#: DP1198
SETTING CLASSIFICATION: Aluminum rod

THE BENCHMARK IS A DISK SET ON AN ALUMINUM ALLOY ROD DRIVEN 9.2 M (30.2 FT), LOCATED 4.3 M (14.1 FT) SW FROM A POWER POLE NUMBER TM11 WITH 5 GUY WIRES AND WITNESS POST, 6.8 M (22.3 FT) SW FROM CENTERLINE OF SCENIC DRIVE, 6.3 M (20.7 FT) NW FROM EXTENDED CENTERLINE OF MAPLE STREET AND 17.1 M (56.1 FT) NW FROM STORM DRAIN COVER AND 3 CM (1.2 IN) BELOW GROUND LEVEL.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9448009 PUBLICATION DATE: 11/07/2014
Name: SPEE-BI-DAH
WASHINGTON
NOAA Chart: 18423 Latitude: 48° 5.3' N
USGS Quad: TULALIP Longitude: 122° 19.3' W

T I D A L D A T U M S

Tidal datums at SPEE-BI-DAH based on:

LENGTH OF SERIES: 3 MONTHS
TIME PERIOD: June 2014 - August 2014
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 9447130 SEATTLE, PUGET SOUND

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER	MHHW	= 3.421
MEAN HIGH WATER	MHW	= 3.159
MEAN TIDE LEVEL	MTL	= 2.006
MEAN SEA LEVEL	MSL	= 2.001
MEAN LOW WATER	MLW	= 0.854
North American Vertical Datum	NAVD88	= 0.596
MEAN LOWER LOW WATER	MLLW	= 0.000

North American Vertical Datum (NAVD88)

Bench Mark Elevation Information	In METERS above: MLLW	MHW
8009 B 2014	4.577	1.418
8009 A 2014	4.469	1.310
8009 C 2014	12.484	9.325
SBD2 2013	4.619	1.460
SBD1 2013	5.582	2.423

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9448009 PUBLICATION DATE: 11/07/2014
Name: SPEE-BI-DAH
WASHINGTON
NOAA Chart: 18423 Latitude: 48° 5.3' N
USGS Quad: TULALIP Longitude: 122° 19.3' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88).

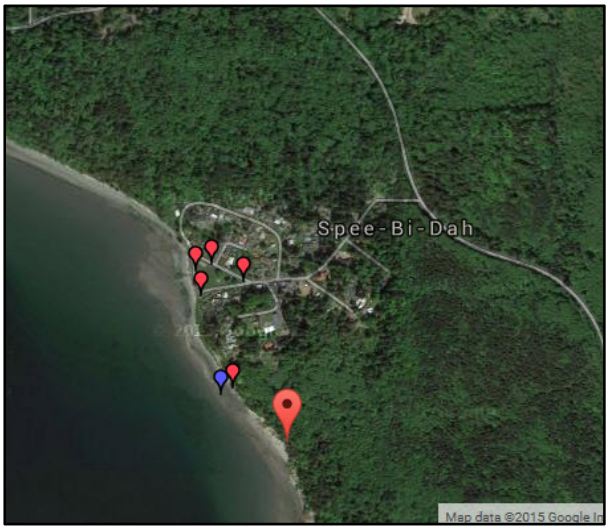
NAVD88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD88 replaces NGVD29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD88 and NGVD29 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD88 elevations. The NAVD88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD88 elevations listed for each bench mark in the NGS database.



Satellite image of the locations of Tidal bench marks for Spee-Bi-Dah, WA.

Tidal bench mark sheet for Priest Point, WA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page Page 1 of 5

Station ID: 9447717 PUBLICATION DATE: 12/11/2014
Name: PRIEST POINT
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 2.1' N
USGS Quad: MARYSVILLE Longitude: 122° 13.6' W

From the intersection of Interstate 5 and Interstate 90 in Seattle, WA, take Interstate 5 north to exit 199 for Marysville. Turn left on Tulalip Road / Marine Drive and continue for 2.7 miles to a left turn on Meridian Ave N. Continue 0.4 mi to a slight left on Priest Point Drive NE and follow another 0.6 mi to the end of the road. The tide station is located on the southern of two small piers extending from an otherwise undeveloped lot.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 7915 A 2014
DESIGNATION: 944 7717 A

MONUMENTATION: Metal Rod VM#: 21195
AGENCY: National Ocean Service (NOS) PID:
SETTING CLASSIFICATION: Stainless steel rod

The primary bench mark is a flange-encased rod located 40.90 m (134.2 ft) east of power pole 16, 5.70 m (18.7 ft) south of the NW corner of the pier, 4.40 m (14.4 ft) SSW of a wooden bulkhead, 0.30 m (1.0 ft) west of an orange fiberglass witness post. The datum point is set at an unknown depth below the ground, being the top of a stainless steel rod driven 28.7 m (94 ft) to refusal, and encased in a 5-inch NGS logo cap.

BENCH MARK STAMPING: 7915 B 2014
DESIGNATION: 944 7717 B

MONUMENTATION: Metal Rod VM#: 21196
AGENCY: National Ocean Service (NOS) PID:
SETTING CLASSIFICATION: Stainless steel rod

The bench mark is a flange-encased rod located 34.20 m (112.2 ft) south of the SW corner of the South pier, 7.65 m (25.1 ft) north of a fire hydrant, 5.50 m (18.0 ft) west of a fence. The datum point is set at an unknown depth below the ground, being the top of a stainless steel rod driven 34.7 m (114 ft) to refusal, and encased in a 5-inch NGS logo cap.

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National Oceanic and Atmospheric Administration
National Ocean Service

Page 2 of 5

Station ID: 9447717 PUBLICATION DATE: 12/11/2014
Name: PRIEST POINT
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 2.1' N
USGS Quad: MARYSVILLE Longitude: 122° 13.6' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 2013 PP1
DESIGNATION: PP1

MONUMENTATION: Metal Rod VM#: 21197
AGENCY: Washington State DOT PID#: DP1167
SETTING CLASSIFICATION: Aluminum alloy rod

The bench mark is a disk located 2.80 m (9.2 ft) SW from a 12' diameter plastic culvert pipe, 11.40 m (37.4 ft) SW from a power pole, 4.4 m (14.4 ft) NW from the approximate centerline of Priest Point Drive NE and 1.95 m (6.4 ft) NE from a power pole and witness post. The bench mark is set 16 cm (0.5 ft) below the ground, crimped to an aluminum rod driven 10.4 m (34.1 ft), and encased in a WDOT monument case.

BENCH MARK STAMPING: 2013 PP2
DESIGNATION: PP2

MONUMENTATION: Metal Rod VM#: 21198
AGENCY: Washington State DOT PID#: DP1168
SETTING CLASSIFICATION: Aluminum alloy rod

The bench mark is a disk located 6.80 m (22.3 ft) SW from the approximate centerline of Meridian Avenue North, 3.10 m (10.2 ft) NW from a witness post and a Dead End sign post, 8.90 m (29.2 ft) NW from power pole number TSA1, 2.60 m (8.5 ft) SE from a Stop sign and a witness post and 7.50 m (24.6 ft) SE from the approximate centerline of Priest Point Drive NW. The bench mark is set 16 cm (0.5 ft) below the ground, crimped to an aluminum rod driven 4.7 m (15.4 ft), and encased in a WDOT monument case.

Station ID: 9447717 PUBLICATION DATE: 12/11/2014
Name: PRIEST POINT
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 2.1' N
USGS Quad: MARYSVILLE Longitude: 122° 13.6' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 2013 PP3
DESIGNATION: PP3

MONUMENTATION: Metal Rod VM#: 21199
AGENCY: Washington State DOT PID#: DP1169
SETTING CLASSIFICATION: Aluminum alloy rod

The bench mark is a disk located 9.90 m (32.5 ft) SW from the approximate centerline of Priest Point Drive NW, 12.20 m (40.0 ft) SE of catch basin, 2.20 m (7.2 ft) NW from power pole number TC28 and a witness post and 5.80 m (19.0 ft) SE from the approximate centerline of 43rd Street NW. The bench mark is set 16 cm (0.5 ft) below the ground, crimped to an aluminum rod driven 9.5 m (31.2 ft), and encased in a WDOT monument case.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9447717 PUBLICATION DATE: 12/11/2014
Name: PRIEST POINT
WASHINGTON
NOAA Chart: 18443 Latitude: 48° 2.1' N
USGS Quad: MARYSVILLE Longitude: 122° 13.6' W

T I D A L D A T U M S

Tidal datums at PRIEST POINT based on:

LENGTH OF SERIES: 3 MONTHS
TIME PERIOD: July 2014 - September 2014
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 9447130 SEATTLE, PUGET SOUND

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER	MHHW	= 3.338
MEAN HIGH WATER	MHW	= 3.077
MEAN TIDE LEVEL	MTL	= 1.948
MEAN SEA LEVEL	MSL	= 1.939
MEAN LOW WATER	MLW	= 0.819
North American Vertical Datum	NAVD88	= 0.575
MEAN LOWER LOW WATER	MLLW	= 0.000

North American Vertical Datum (NAVD88)

Bench Mark Elevation Information	In METERS above:	
Stamping or Designation	MLLW	MHW
7915 A 2014	4.381	1.304
7915 B 2014	3.919	0.842
2013 PP1	3.980	0.903
2013 PP2	24.082	21.005
2013 PP3	27.697	24.620

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9447717 PUBLICATION DATE: 12/11/2014
Name: PRIEST POINT
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NOAA Chart: 18443 Latitude: 48° 2.1' N
USGS Quad: MARYSVILLE Longitude: 122° 13.6' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88).

NAVD88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD88 replaces NGVD29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

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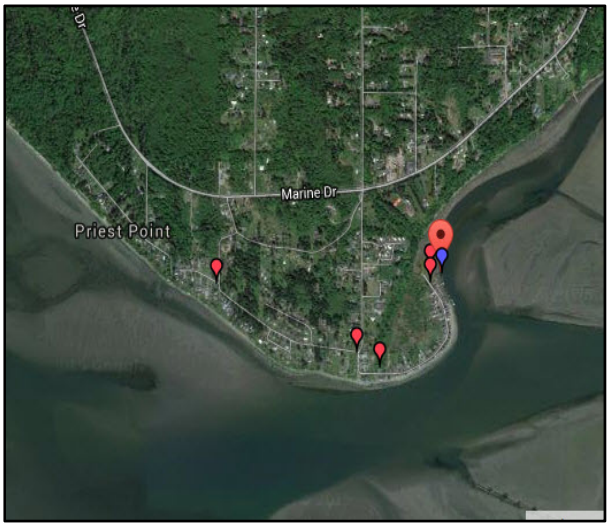

Satellite image of the locations of Tidal bench marks for Priest Point, WA.

Appendix 4. Datum Elevation Comparison between Observation and the NOAA VDatum Interpolation Model Tool. All elevations are relative to MLLW (units in meters).

	Tulare Beach, WA (Station ID: 9448043)			**Tulalip, Tulalip Bay, WA (Station ID: 9448009)**		
	Water level station observations	VDatum Interpolation	Observation – VDatum Difference	Water level station observations	VDatum Interpolation	Observation-VDatum Difference
MHHW	3.376	3.413	-0.037	3.421	3.405	0.016
MHW	3.116	3.145	-0.029	3.159	3.136	0.023
MTL	1.975	1.996	-0.003	2.006	1.989	0.017
MSL	1.968	1.996	-0.028	2.001	1.985	0.016
DTL	1.688	1.707	-0.019	1.711	1.702	0.009
MLW	0.838	0.847	0.009	0.854	0.842	0.012
NAVD88	0.619	0.637	-0.018	0.596	0.625	-0.029
MLLW	0.000	0.000	0.000	0.000	0.000	0.000

	Spee-Bi-Dah, WA (Station ID: 9447773)			**Priest Point, WA (Station ID: 9447717)**		
	Water level station observations	VDatum Interpolation	Observation-VDatum Difference	Water level station observations	VDatum Interpolation	Observation – Vdatum Difference
MHHW	3.371	3.382	-0.011	3.338	3.327	0.011
MHW	3.116	3.108	0.008	3.077	3.066	0.011
MTL	1.981	1.966	0.015	1.948	1.928	0.020
MSL	1.974	1.950	0.024	1.939	1.926	0.013
DTL	1.686	1.691	-0.006	1.669	1.663	0.006
MLW	0.847	0.822	0.025	0.819	0.809	0.010
NAVD88	0.622	0.590	0.032	0.575	0.565	0.010
MLLW	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 5. Harmonic Constants for the Tulalip Project

Tulare Beach, WA

Station Metadata

Station Id	:	9448043
Station Name	:	Tulare Beach, Port Susan
State	:	WA
Latitude	:	48.1069
Longitude	:	-122.3472
Time Zone	:	GMT
Unit	:	Feet

Center for Operational Oceanographic Products and Services

Name	--	Description
Cst#	--	Constituent Number Order in which NOS lists the constituents
Name	--	Common name used to refer to a particular constituent, subscript refers to the number of cycles per day
Amplitude	--	One-half the range of a tidal constituent
Phase	--	The phase lag of the observed tidal constituent relative to the theoretical equilibrium tide
Speed	--	The rate change in the phase of a constituent, expressed in degrees per hour. The speed is equal to 360 degrees divided by the constituent period expressed in hours

Cst#	Name	Amplitude	Phase	Speed
1	M2	3.440	9.7	28.984104
2	S2	0.840	35.5	30.000000
3	N2	0.690	344.3	28.439730
4	K1	2.600	277.3	15.041069
5	M4	0.070	184.3	57.968210
6	O1	1.550	257.4	13.943035
7	M6	0.050	325.0	86.952320
8	MK3	0.000	0.0	44.025173
9	S4	0.010	222.4	60.000000
10	MN4	0.000	0.0	57.423832
11	NU2	0.130	347.7	28.512583
12	S6	0.000	203.7	90.000000
13	MU2	0.080	344.0	27.968208
14	2N2	0.090	318.8	27.895355
15	OO1	0.070	297.2	16.139101
16	LAM2	0.020	21.6	29.455626
17	S1	0.000	0.0	15.000000
18	M1	0.110	267.5	14.496694
19	J1	0.120	287.2	15.585444
20	MM	0.000	0.0	0.544375
21	SSA	0.110	231.1	0.082137
22	SA	0.250	292.9	0.041069
23	MSF	0.000	0.0	1.015896
24	MF	0.070	140.5	1.098033
25	RHO	0.060	248.9	13.471515
26	Q1	0.300	247.6	13.398661
27	T2	0.050	34.4	29.958933
28	R2	0.010	36.5	30.041067
29	2Q1	0.040	237.8	12.854286
30	P1	0.860	275.8	14.958931
31	2SM2	0.000	0.0	31.015896
32	M3	0.000	0.0	43.476160
33	L2	0.100	35.1	29.528479
34	2MK3	0.000	0.0	42.927140
35	K2	0.230	37.6	30.082138
36	M8	0.010	211.3	115.936420
37	MS4	0.000	0.0	58.984104

Tulalip Bay, WA

Station Metadata

Station Id	:	9447773
Station Name	:	Tulalip, Tulalip Bay
State	:	WA
Latitude	:	48.065
Longitude	:	-122.2881
Time Zone	:	GMT
Unit	:	Feet

Center for Operational Oceanographic Products and Services

Name	--	**Description**
Cst#	--	Constituent Number Order in which NOS lists the constituents
Name	--	Common name used to refer to a particular constituent, subscript refers to the number of cycles per day
Amplitude	--	One-half the range of a tidal constituent
Phase	--	The phase lag of the observed tidal constituent relative to the theoretical equilibrium tide
Speed	--	The rate change in the phase of a constituent, expressed in degrees per hour. The speed is equal to 360 degrees divided by the constituent period expressed in hours

Cst#	Name	Amplitude	Phase	Speed
1	M2	3.420	10.7	28.984104
2	S2	0.830	36.2	30.000000
3	N2	0.680	341.9	28.439730
4	K1	2.710	278.3	15.041069
5	M4	0.070	185.7	57.968210
6	O1	1.480	255.4	13.943035
7	M6	0.060	324.7	86.952320
8	MK3	0.000	0.0	44.025173
9	S4	0.010	274.1	60.000000
10	MN4	0.000	0.0	57.423832
11	NU2	0.130	345.7	28.512583
12	S6	0.000	0.0	90.000000
13	MU2	0.080	345.2	27.968208
14	2N2	0.090	313.0	27.895355
15	OO1	0.060	301.1	16.139101
16	LAM2	0.020	22.5	29.455626
17	S1	0.000	0.0	15.000000
18	M1	0.100	267.0	14.496694
19	J1	0.120	289.6	15.585444
20	MM	0.000	0.0	0.544375
21	SSA	0.110	231.1	0.082137
22	SA	0.250	292.9	0.041069
23	MSF	0.000	0.0	1.015896
24	MF	0.070	140.5	1.098033
25	RHO	0.060	245.6	13.471515
26	Q1	0.290	244.1	13.398661
27	T2	0.050	35.2	29.958933
28	R2	0.010	37.2	30.041067
29	2Q1	0.040	232.8	12.854286
30	P1	0.900	276.6	14.958931
31	2SM2	0.000	0.0	31.015896
32	M3	0.000	0.0	43.476160
33	L2	0.100	39.6	29.528479
34	2MK3	0.000	0.0	42.927140
35	K2	0.230	38.3	30.082138
36	M8	0.000	190.2	115.936420
37	MS4	0.000	0.0	58.984104

Spee-Bi-Dah, WA

Station Metadata

Station Id	:	9448009
Station Name	:	Spee-Bi-Dah
State	:	WA
Latitude	:	48.0883
Longitude	:	-122.3222
Time Zone	:	GMT
Unit	:	Feet

Center for Operational Oceanographic Products and Services

Name	--	**Description**
Cst#	--	Constituent Number Order in which NOS lists the constituents
Name	--	Common name used to refer to a particular constituent, subscript refers to the number of cycles per day
Amplitude	--	One-half the range of a tidal constituent
Phase	--	The phase lag of the observed tidal constituent relative to the theoretical equilibrium tide
Speed	--	The rate change in the phase of a constituent, expressed in degrees per hour. The speed is equal to 360 degrees divided by the constituent period expressed in hours

Cst#	Name	Amplitude	Phase	Speed
1	M2	3.450	10.8	28.984104
2	S2	0.840	35.3	30.000000
3	N2	0.700	342.1	28.439730
4	K1	2.610	277.8	15.041069
5	M4	0.070	183.8	57.968210
6	O1	1.540	257.0	13.943035
7	M6	0.050	323.0	86.952320
8	MK3	0.000	0.0	44.025173
9	S4	0.020	203.4	60.000000
10	MN4	0.000	0.0	57.423832
11	NU2	0.140	346.0	28.512583
12	S6	0.000	0.0	90.000000
13	MU2	0.080	346.3	27.968208
14	2N2	0.090	313.5	27.895355
15	OO1	0.070	298.8	16.139101
16	LAM2	0.020	22.1	29.455626
17	S1	0.000	0.0	15.000000
18	M1	0.110	267.5	14.496694
19	J1	0.120	288.2	15.585444
20	MM	0.000	0.0	0.544375
21	SSA	0.110	231.1	0.082137
22	SA	0.250	292.9	0.041069
23	MSF	0.000	0.0	1.015896
24	MF	0.070	140.5	1.098033
25	RHO	0.060	248.0	13.471515
26	Q1	0.300	246.6	13.398661
27	T2	0.050	34.3	29.958933
28	R2	0.010	36.2	30.041067
29	2Q1	0.040	236.2	12.854286
30	P1	0.860	276.3	14.958931
31	2SM2	0.000	0.0	31.015896
32	M3	0.000	0.0	43.476160
33	L2	0.100	39.4	29.528479
34	2MK3	0.000	0.0	42.927140
35	K2	0.230	37.3	30.082138
36	M8	0.000	0.0	115.936420
37	MS4	0.000	0.0	58.984104

Priest Point, WA

Station Metadata

Station Id	:	9447717
Station Name	:	Priest Point
State	:	WA
Latitude	:	48.035
Longitude	:	-122.2272
Time Zone	:	GMT
Unit	:	Feet

Center for Operational Oceanographic Products and Services

Name	--	**Description**
Cst#	--	Constituent Number Order in which NOS lists the constituents
Name	--	Common name used to refer to a particular constituent, subscript refers to the number of cycles per day
Amplitude	--	One-half the range of a tidal constituent
Phase	--	The phase lag of the observed tidal constituent relative to the theoretical equilibrium tide
Speed	--	The rate change in the phase of a constituent, expressed in degrees per hour. The speed is equal to 360 degrees divided by the constituent period expressed in hours

Cst#	Name	Amplitude	Phase	Speed
1	M2	3.360	15.5	28.984104
2	S2	0.830	43.4	30.000000
3	N2	0.660	346.3	28.439730
4	K1	2.610	281.1	15.041069
5	M4	0.080	267.2	57.968210
6	O1	1.520	259.9	13.943035
7	M6	0.030	350.9	86.952320
8	MK3	0.000	0.0	44.025173
9	S4	0.020	284.5	60.000000
10	MN4	0.000	0.0	57.423832
11	NU2	0.130	350.2	28.512583
12	S6	0.000	218.1	90.000000
13	MU2	0.080	347.6	27.968208
14	2N2	0.090	317.1	27.895355
15	OO1	0.060	302.1	16.139101
16	LAM2	0.020	28.4	29.455626
17	S1	0.000	0.0	15.000000
18	M1	0.110	270.5	14.496694
19	J1	0.120	291.5	15.585444
20	MM	0.000	0.0	0.544375
21	SSA	0.110	231.1	0.082137
22	SA	0.250	292.9	0.041069
23	MSF	0.000	0.0	1.015896
24	MF	0.070	140.5	1.098033
25	RHO	0.060	250.8	13.471515
26	Q1	0.290	249.4	13.398661
27	T2	0.050	42.3	29.958933
28	R2	0.010	44.5	30.041067
29	2Q1	0.040	239.0	12.854286
30	P1	0.860	279.5	14.958931
31	2SM2	0.000	0.0	31.015896
32	M3	0.000	0.0	43.476160
33	L2	0.090	44.7	29.528479
34	2MK3	0.000	0.0	42.927140
35	K2	0.230	45.6	30.082138
36	M8	0.010	284.8	115.936420
37	MS4	0.000	0.0	58.984104

Appendix 6. Residual Differences Between Observed vs. Predicted Water Levels

Station Name/ID	Mean Relative to MLLW (meters)	Mean Relative to MLLW (feet)	Standard Deviation Relative to MLLW (meters)	Standard Deviation Relative to MLLW (feet)
Tulare Beach, WA (Station ID: 9448043)	0.022	0.072	0.091	0.298
Tulalip Bay, WA (Station ID: 9447773)	0.016	0.052	0.125	0.410
Spee-Bi-Dah, WA (Station ID: 9448009)	0.048	0.157	0.087	0.285
Priest Point, WA (Station ID: 9447717)	0.077	0.253	0.099	0.325