CHAPTER 5

Procedures for Referencing Datums on Coastal Hurricane and Shore Protection Projects

5-1. Purpose. This chapter discusses the procedures to ensure hurricane protection projects and related shoreline protection structures (i.e., HSPP) are adequately connected and modeled relative to the National Water Level Observation Network (NWLON) tidal datum and the National Spatial Reference System (NSRS) orthometric datum established by the Department of Commerce. Coastal hurricane protection and shore protection structures include levees, floodwalls, breakwaters, jetties, groins, and dikes. Beach renourishment/restoration projects are also included in this category. Most of the guidance in Chapter 4 on coastal navigation projects is directly applicable to coastal hurricane and shore protection projects. Thus, references to Chapter 4 will be made where applicable.

5-2. Reference Datums and Tide Gage Connections. Most USACE shore protection projects have been designed relative to a sea level tidal datum—typically MLW or MSL referenced to a superseded legacy NGVD29 datum. Some projects may be defined relative to MHW. The designed protection grade will include allowances for storm surge, wave runup, tidal ranges, and other modeled factors used to develop a protection elevation. Uncertainties in these reference datums must also be considered in the design of protection elevations. Construction of shore protection projects is usually performed relative to a local orthometric datum, such as NAVD88. When RTK methods are used for construction stake out and machine control grading, NAD83/GRS80 ellipsoid references are required. As stated in preceding chapters, the main objective is to establish a firm relationship between the local orthometric and tidal datums at the project site, and that these datums (and any legacy reference datums) are referenced to the current NSRS and NWLON frameworks. For the vast majority of shore protection projects, modeling protection grades to the current tidal datum and NSRS/NAVD88 reference is relatively straightforward and normally requires minimal field survey effort.

a. Reference datums. Figure 5-1 illustrates the reference datums used for various shore protection projects. Design elevations of the beach renourishment berms or crests of the shore protection structures are computed relative to local tidal datums. This LMSL datum shown in Figure 5-1 must be based on nearby tide gages that relate LMSL to the NAVD88 datum. If no gages are near the project site, then the LMSL elevation at the project site relative to NAVD88 must be estimated using established hydrodynamically generated tidal models (e.g., VDatum). On existing projects originally referenced to a legacy reference datum (NGVD29 or MLW), the relationship between these datums and NAVD88 should be established. This assumes the original construction PBMs can be recovered. Stone placement on jetties or breakwaters, or grading of berms or hurricane protection levees, normally would be performed using RTK elevation measurements.

b. Primary Project Control Point (PPCP). All shore protection projects should have at least one primary NSRS bench mark from which all construction is referenced. This PPCP shall be published in the NSRS. On large beach renourishment or hurricane protection projects, more than one primary NSRS reference bench mark may be required. All projects shall have at least

three PPCPs or LPCPs for use on construction plans. During Preconstruction Engineering and Design (PED), and prior to construction, the elevations of PPCPs and LPCPs shall have been checked internally—and regionally against other nearby NSRS points. Most coastal areas in CONUS have relatively dense NSRS network coverage (e.g., NGS level lines), from which the project can be directly referenced to this framework with minimal effort.

Figure 5-1. Reference datums on shore protection projects.

c. Tidal datum references. HSPP sites should be evaluated to verify (1) that the design/constructed sea level reference datum is current (i.e., latest tidal epoch and model) and (2) that this sea level datum can be related to the local NSRS orthometric datum (NAVD88) and the NAD83/GRS80 ellipsoid.

(1) If an active or historic NOAA tidal gage is situated in or near the HSPP area, data from that gage can be directly used to reference the project to the current tidal datum epoch. If the gage's tidal bench marks have not been connected to the NSRS orthometric datum, then GPS field surveys will be required to perform this connection. Only a small percentage of NOAA gage sites have tidal PBMs that have been connected to either NGVD29 or NAVD88. HSPP on remote coastlines may need static baseline GPS or CORS/OPUS observations to connect them to the NSRS. In general, CORS/OPUS methods described in Chapter 3 will provide sufficient accuracy to develop NAVD88 and tidal relationships on tidal bench marks at gages without published NSRS data.

(2) If there are no nearby tide gages, then the NAVD88-MSL relationship can be estimated using spatial interpolations between the nearest gages—see Appendix E. The local NAVD88-MSL relationship may also be estimated using NOAA VDatum models of the project region. If estimates are used, project documents must clearly describe the estimating procedure, uncertainties of the estimate, and potential impacts on the design (risk assessment) of the protection elevation of a control structure.

5-3. HSPP Elevation Accuracy Requirements. Table 5-1 lists general elevation accuracy requirements for HSPPs. This table should only be used as general guidance. Site dependent factors may require variations from this guidance.

Table 5-1. Survey Accuracies Common to Shore Protection Projects.

Bench Mark/Activity	Accuracy (95%)	Relative to
Primary Project Control Point (PPCP)	± 0.25 ft	Regional NSRS network
Local Project Control Points (LPCP)	± 0.02 to 0.05 ft	PPCP
Construction TBMs (hubs, nails, etc)	± 0.02 to 0.05 ft	LPCP
Construction grade stakes	± 0.1 ft	LPCP or TBMs
Levee or beach grading	± 0.5 ft	LPCP or TBMs
Offshore borrow area excavation	± 0.5 to 1 ft	PPCP
Offshore stone placement	± 0.5 to 1 ft	PPCP, LPCP, or TBMs

5-4. Shore Protection and Beach Renourishment/Restoration Projects. Shore protection projects are usually designed relative to tidal or orthometric datums, depending on local preferences. On many older projects, the relationship between orthometric and tidal datums is not firmly established. The PPCPs used to control the project should be related to the latest tidal datum and have a firm reference to the NSRS (NAVD88).

a. Control scheme for beach renourishment projects. Figure 5-2 depicts a survey control scheme that is set up for typical beach fill projects. Orthometric elevations of local LPCPs, PBMs, TBMs, grade stakes, and surveys are referenced to a PPCP that is published in the NSRS.

(1) Primary Project Control Point. Depending on the geographical scope of the project, one or more PPCPs may be needed. These PPCPs are used as RTK base stations to control grading operations (machine control), dredge borrow area surveys and excavation, setting grade stakes during beach fill operations, and controlling pre- and post-fill measurement & payment surveys. The NSRS connection will normally be performed following the same accuracy standards and field survey specifications outlined in Chapter 3—e.g., ± 0.25 ft. Checks between the PPCP and other NSRS bench marks are required prior to performing surveys.

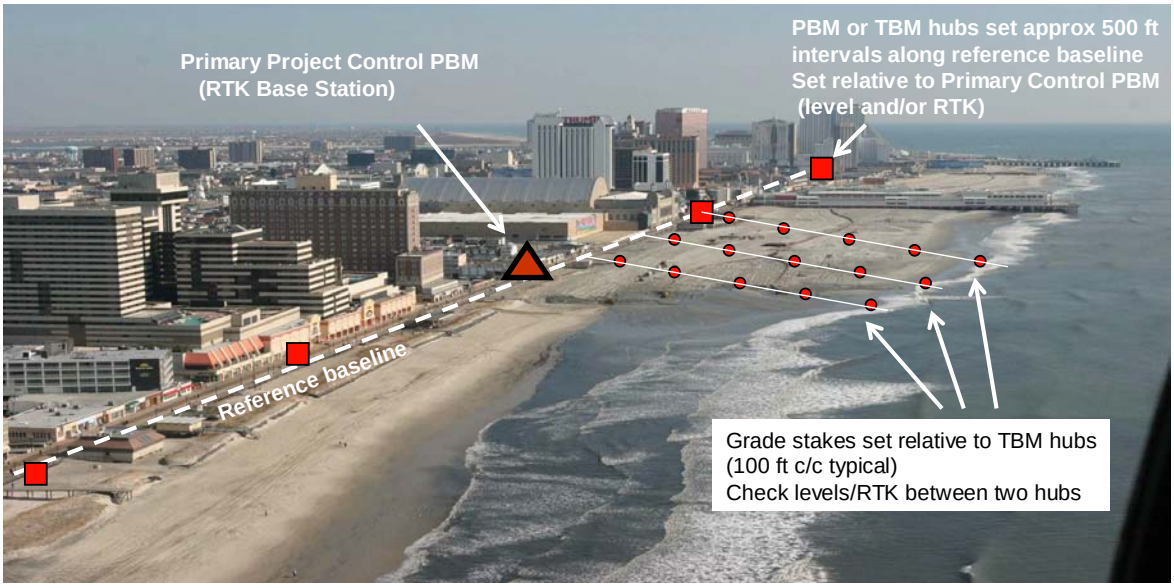

Figure 5-2. Beach renourishment project at Atlantic City, NJ. (Philadelphia District)

(2) Reference baselines. Most shoreline projects are continuously monitored by performing topographic and hydrographic surveys relative to established ranges. These ranges are referenced to a fixed baseline set back from the beach, and beach profile offsets are referenced to this baseline.

(3) Local reference PBMs. The baseline is usually referenced to local PBMs (LPCPs) set at various intervals. These LPCPs will have SPCS coordinates along with local station-offset coordinates. Vertical control on these baseline LPCPs may be referenced to legacy or local datums in order to monitor relative accretion or erosion at a measured profile. The LPCPs should be resurveyed at the beginning of a project. If the project specifications require holding legacy elevations on LPCPs, then any significant differences between these legacy elevations and the resurveyed elevations shall be clearly noted.

(4) Temporary reference or calibration hubs. In cases where no fixed LPCPs are available along the reference baseline, TBM hubs are established at various intervals. These hubs are used for controlling beach profile surveys—checking RTK calibration or for referencing level runs on individual beach profiles. Elevations on these hubs are normally surveyed by differential leveling relative to the PPCPs. Levels are run through local LPCPs and TBM hubs over the project reach. RTK elevation checks should also be made to verify site calibration and check for leveling blunders.

(5) Grade stakes. During beach fill operations, grade stakes are set from the reference LPCPs or TBMs. Either RTK, total station, or differential leveling methods are used. Elevation checks should be made to at least two fixed LPCPs or TBMs. The number of grade stakes on each profile will vary with the number of grade breaks on the project—see Figure 5-3. Grade stake elevation tolerances are normally specified as ± 0.1 ft relative to the reference LPCP or TBM. Grading tolerances are typically ± 0.5 ft.

b. Beach profile surveys. Beach fill measurement & payment surveys are normally performed at 100 ft c/c intervals. Spacing of periodic monitoring study profiles will vary between 200 ft and 1,000 ft. A design profile template is shown in Figure 5-3. Various topographic and hydrographic survey methods are used—see EM 1110-2-1003 (*Hydrographic Surveying*). These surveys are referenced to offsets from the reference baseline, or in some cases, an erosion control line, or construction setback control line. Profiles are run on established range azimuths. In Figure 5-3, the offset profile is referenced to a fixed local PBM for this section.

c. Reference datums. It is likely that older shoreline protection projects were designed and constructed relative to NGVD29 with the assumption that this datum approximated mean sea level (MSL). This NGVD29 is thus a legacy or local datum. These projects have likely been constructed and monitored relative to pre-set range monuments with a "locally "published" NGVD29 reference datum. Resurveys should document the updated relationships between the NAVD88 datum and the legacy datum. This is accomplished by comparing the updated NAVD88 elevation with the legacy NGVD29 elevations on recovered local bench marks.

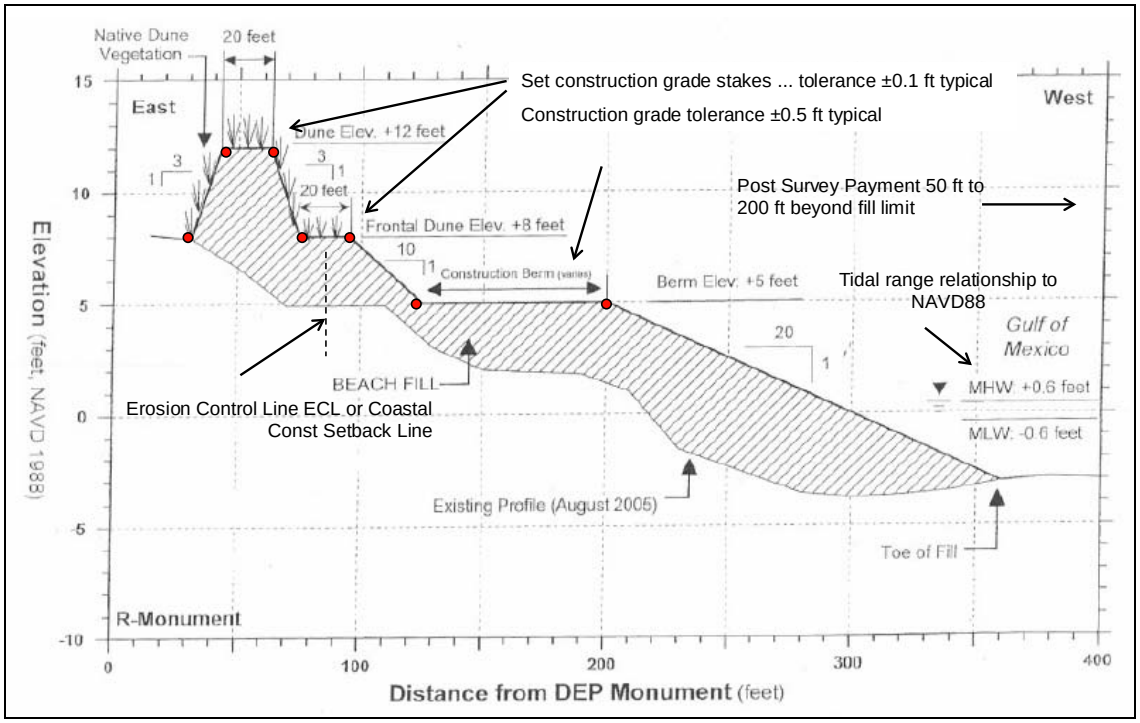

Figure 5-3. Beach profile template used for construction stake out and measurement & payment surveys.

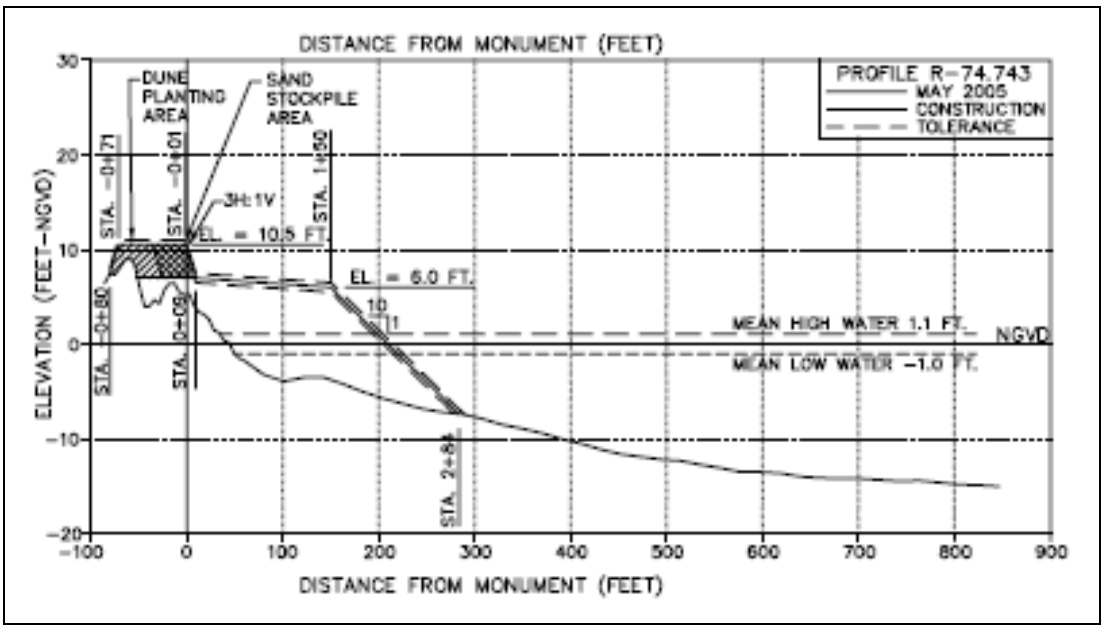

Figure 5-4. Beach profile template referenced to PBM R-74.743 on NGVD.

(1) NGVD29 datum references. In Figure 5-4, taken from construction plans, the "NGVD" elevation of the range monument "PROFILE R-74.743" was likely determined in 1974 when the range monument was set. The original or current relationship with the NSRS is probably unknown. Its "NGVD" relationship to MLW (-1.0 ft) or MHW (+1.1 ft) is likely based on the relationship at the nearest NOAA tide gage, which may be some 10 to 30 miles distant. The tidal epoch is not indicated in the drawing—a 0.25 ft to 0.5 ft tidal epoch difference may have occurred since the early 1970s. If the reference PBM and the NGVD/MSL design grade were not updated to reflect the relationship to the current tidal epoch, any new construction would be constructed 0.25 ft to 0.5 ft below the intended design elevation.

(2) Tidal datum relationships. Beach restoration projects are often distant from an established tide gage. The reference tidal datum may be estimated from nearby gages by spatial interpolation methods described in Appendix E. Such an interpolated tidal datum estimate is normally of sufficient accuracy. An interpolated tidal range between two NOAA gages would be reasonable if the tidal ranges at each gage do not vary significantly—for instance < 0.3 ft. Alternatively, if VDatum coverage exists in the area, this model may be used to estimate the relationship between MSL and the orthometric NAVD88 datum. Project documents must clearly document the source of any estimated relationships between orthometric and tidal datums.

d. Borrow area reference datums. Offshore borrow area elevations or depths should be referenced to the PPCP datum. Dredged excavation grades and borrow area surveys should be controlled by RTK or RTN measurements relative to, or calibrated from, this point. If the borrow area datum is referenced to a tidal datum (e.g., MLLW) then the relationship to the local NAVD88 datum must be documented.

e. Accuracy tolerances. Typical survey tolerances for shoreline protection projects are listed in Table 5-1.

f. Checklist. The following checklist may be used in developing control for a shoreline protection project.

(1) Is project referenced to a published NSRS control point (PPCP)?

(2) Has the PPCP elevation been checked against other published NSRS points?

(3) Are local project control points (LPCPs) firmly connected to the PPCP?

(4) Is the RTK base station situated at a PPCP or LPCP?

(5) Have beach profile reference monuments been set relative to the PPCP and LPCP?

(6) Are profile monuments correctly referenced to an established horizontal baseline?

(7) Have differential levels been run between all LPCP PBMs and range TBMs?

(8) Are leveled PBM and TBM elevations checked with RTK elevations?

(9) Is tidal datum relationship to NAVD88 established over the project site?

(10) Is the tidal datum based on current epoch?

(11) Are any legacy orthometric datums referenced to NAVD88?

g. Example application project—Fort Fisher, NC. Appendix G contains an example of a Wilmington District shore protection project that has been adequately referenced to the current NSRS orthometric datum and to the local tidal datum.

5-5. Breakwater and Jetty Construction Projects. Breakwaters and jetties constructed in tidal areas must be connected to both a local tidal design datum and NAVD88. Designed protection elevations are usually specified above MSL, although other reference tidal datums or legacy orthometric datums may be used (e.g., MLW, MHW, NGVD29). Construction and stone placement elevations will likely be referenced to NAVD88 and RTK methods used to monitor real-time placed elevations. Project control requirements to support construction and in-place surveys are the same as those required for shoreline protection projects described above.

a. Figure 5-5 depicts the control requirements for a jetty construction project. (A similar scheme would be laid out for a detached breakwater). A published PPCP needs to be established near the project site for use as an RTK base or RTN calibration. The elevation of this point is checked against nearby NSRS bench marks. Local control PBMs (LPCP) are then set inland from the jetty base. These points are surveyed relative to the PPCP using GPS or differential leveling. The LPCPs may be included in the NSRS or in the District's U-SMART database. Depending on the type of capping, access, construction requirements, etc, additional TBMs may be set in the stone along the jetty or detached breakwater.

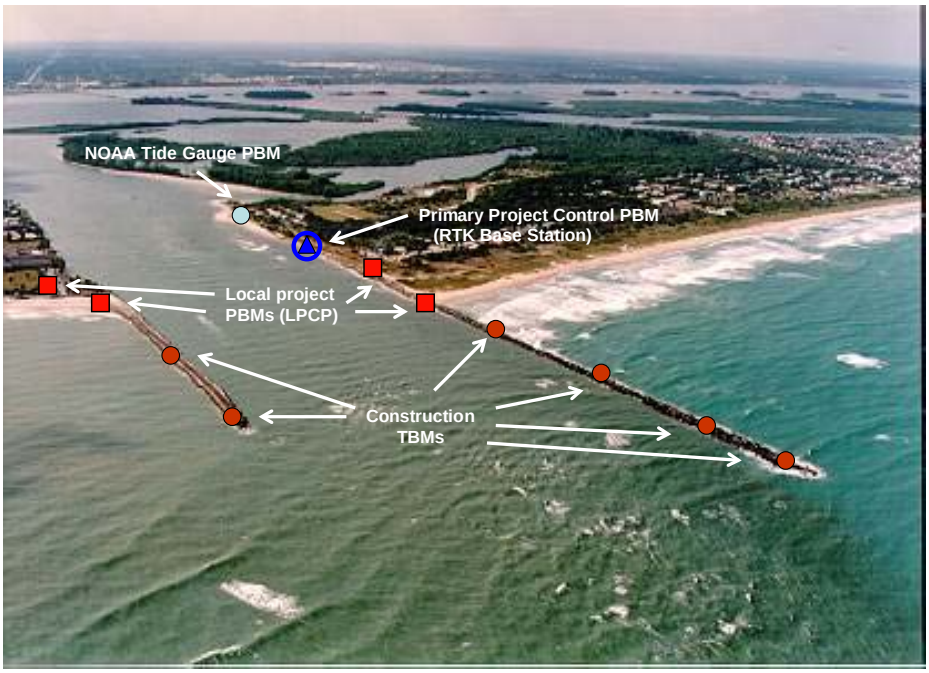

Figure 5-5. Project control requirements for jetty construction or maintenance.

b. The relationship between the orthometric and local tidal datum needs to be developed. In Figure 5-5, a NOAA gage is near the site and the connection between tidal PBMs and the PPCP can be made by GPS or differential levels. If no gage exists near the project site, then spatially interpolated or modeled (VDatum) estimates may be considered.

c. Breakwater monitoring surveys are often surveyed using a combination of subsurface multibeam hydrographic surveys and low altitude LIDAR airborne surveys. It is essential that the PPCP RTK base point for these surveys be the same point and both surveys be referenced to NAVD88 rather than tidal datums. In cases where acoustic returns are scattered by rock, lead line surveys may be required to measure voids.

5-6. Coastal Hurricane Protection Projects. Floodwalls, levees, seawalls, flood gates, pump stations, and related hurricane protection structures in coastal (tidal) areas require defined relationships between the design reference plane (normally MSL and stillwater surface elevations) and the local geodetic orthometric datum. This relationship must be established from a tidal gage at the project site or from hydrodynamically modeled spatial interpolations between tide gages. The latest geodetic, tidal datums, and tidal models established by NOAA must be used—and continually maintained and updated for epoch changes throughout the life of the project.

a. Reference tidal datum. Many hurricane protection project elevations have been designed relative to sea level datums based on interpolated or extrapolated references from gages—far and near. Depending on the type of gage, tidal range, and the distance from the gage, this interpolation or extrapolation may be valid—or sufficiently accurate—within ± 0.25 ft of the reference water level stillwater or surge design surface. Obviously, with sea level rise in many

CONUS coastal areas, the crest elevation of structures may be below that originally designed. In such cases, the original design documents should be checked to verify that allowance for sea level rise was considered in the design elevation.

b. NSRS connection. Connection to an NSRS orthometric datum need only be at the ± 0.25 ft accuracy level. This connection accuracy is usually adequate to relate protection heights to floodplain and first-floor elevations on a federally recognized reference system—e.g., NAVD88. Evaluated shore protection projects that are not on updated tidal and/or NSRS datums will require additional effort. In general, the updated sea level datum can be estimated by linear interpolation given sufficient NOAA or Corps gages exist in the region. The NSRS connection will normally be performed following the same accuracy standards and field survey specifications outlined in Chapter 3—differential leveling, static GPS baseline observations, or CORS/OPUS methods. At least one PPCP on each project shall have both a water level reference elevation and a NAVD88 elevation.

c. Example project: New Orleans to Venice Hurricane Protection Project. Figure 5-6 depicts local levee control PBMs along a portion of the Mississippi River below New Orleans to Venice, LA—West Plaquemines Levee District. Published NSRS PBMs ("N 367" and "J 370") are part of an older NGS level line that have updated time-dependent NAVD88 elevations—"NAVD88 (2004.65)."

(1) The BOOTHVILLE CORS ARP site provides real-time vertical control for GPS/OPUS observations in this region. The tidal bench mark at the Venice (Grand Pass) gage (876 0849 A TIDAL) is likewise connected to the NSRS network. These primary NSRS points provide direct PPCP control for this project area and no field surveys are required to establish additional points. Local levee control points (e.g., LPCP PIs) can be connected directly to these NSRS PPCP points using conventional survey methods, such as RTK. Levee profile elevations or cross-sections can be run directly from these PPCPs or LPCPs; however, given a Louisiana RTN covers this region, that network would be used for supplemental topographic surveys using the PPCPs for site calibration of the RTN.

(2) Since this area contains a LWRP hydraulic datum computation, this relationship between the LWRP to NAVD88 should be documented. The area also contains references to a legacy dredging datum—Mean Low Gulf (MLG). This estimated relationship must also be referenced to NAVD88.

(3) The datum relationships and uncertainties for an LPCP situated atop a levee can be tabulated as shown in Table 5-2. These relationships are based on survey observations from the NSRS network points to the LPCP. LWRP flow profile elevations are determined from interpolations between stage/discharge data at river gages that are referenced to NAVD88. The MLG datum is estimated from the Venice gage.

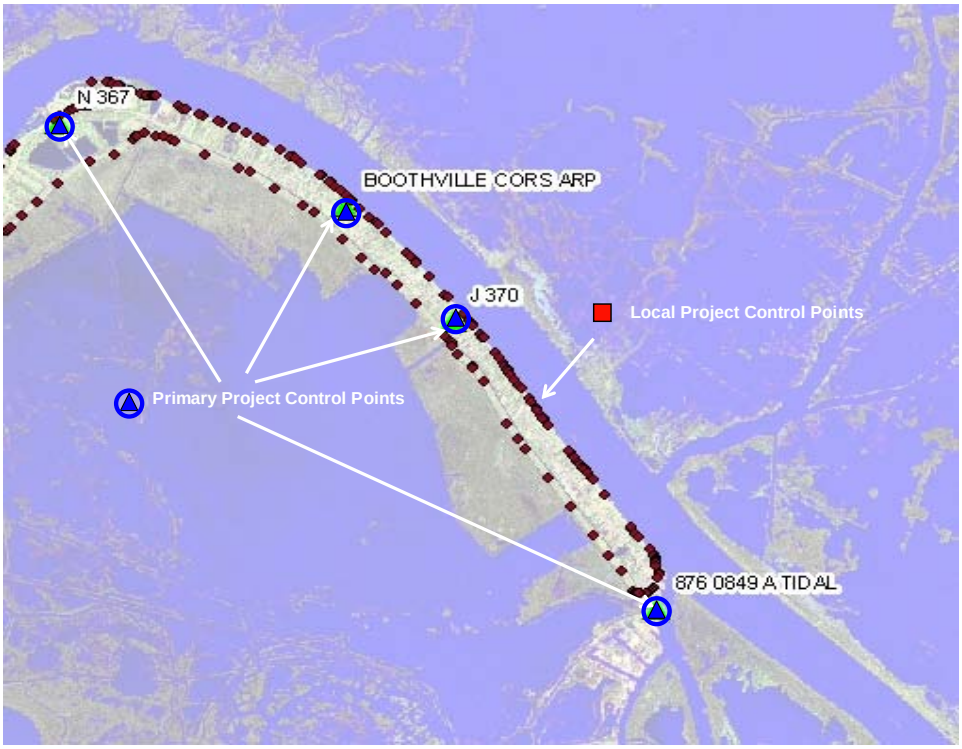

Figure 5-6. Mississippi River levee control connections with the NSRS and NOAA tide gage. Local project control points (LPCP) are connected with the PPCPs. (West Plaquemines Levee District)

Table 5-2. Elevations at a Baseline LPCP Station atop a Hurricane Protection Levee.

Datum	Elevation	Referenced From	Estimated Uncertainty	Relative to
LWRP 05	13.5 ft	River gage (interpolated)	± 0.2 ft	Profile
MSL	14.4 ft	NOAA gage 876 0849	± 0.2 ft	NWLON
LWRP 07	14.8 ft	River gage (interpolated)	± 0.2 ft	Profile
NAVD88 (2004.65)	14.93 ft	NSRS PPCP J370	± 0.05 ft	NSRS

Table 5-2 (Concluded). Elevations at a Baseline LPCP Station atop a Hurricane Protection Levee.

Datum	Elevation	Referenced From	Estimated Uncertainty	Relative to
MLLW	15.0 ft	NOAA gage 876 0849	± 0.2 ft	NWLON
NAVD88 (96)	15.0 ft	NSRS (superseded)	± 0.2 ft	NSRS
NGVD29 (98)	15.8 ft	Published NSRS	± 0.5 ft	NSRS
MLG	17.6 ft	Published NSRS (superseded NGVD29)	± 1 ft	NSRS
Ellipsoid	-64.27 ft	Geoid model	± 0.05 ft	NAD83/GRS80

d. Connection datums on miscellaneous hurricane protection structures. Elevations of floodgates, pump stations, and other structures need to be referenced to current orthometric datums and applicable legacy datums used in the original construction.

(1) Pump Station surveys. Figure 5-7 illustrates a method of determining updated elevations for a pump station. An LPCP is established near the pump station using static GPS techniques from published NSRS bench marks. A NAVD88 elevation is adjusted on the LPCP. Differential levels are run from the LPCP to a TBM or point inside the pump station that can be referenced on the as built drawings for the station—e.g., a floor elevation. An annotated photograph of the reference point is recommended, like that illustrated in Figure 5-7 for the Bayou Ducros #7 Pump Station. From this reference point, the NAVD88 invert elevations can be scaled from the as built drawings. If no as-builts are available, then invert elevations will have to be directly measured by leveling or total station—often a difficult process in confined spaces. If the pump station drawings are referenced to a local datum (e.g., New Cairo Datum (NCD) in the New Orleans area), then the NAVD88-NCD relationship is established. For example, in Figure 5-7 (Elmwood Canal Pump Station), given the first floor elevation is +15.20 ft NCD and the NAVD88 (2004.65) elevation is + 5.87 ft, the NCD-NAVD88 (2004.65) conversion factor is + 9.33 ft. Given the as built drawings show the pump invert elevation at +20.20 ft NCD, then the invert elevation is 10.87 ft NAVD88 (2004.65); computed from [20.20 ft – 9.33 ft]. If applicable, sea level datum references may also be included as an additional datum reference.

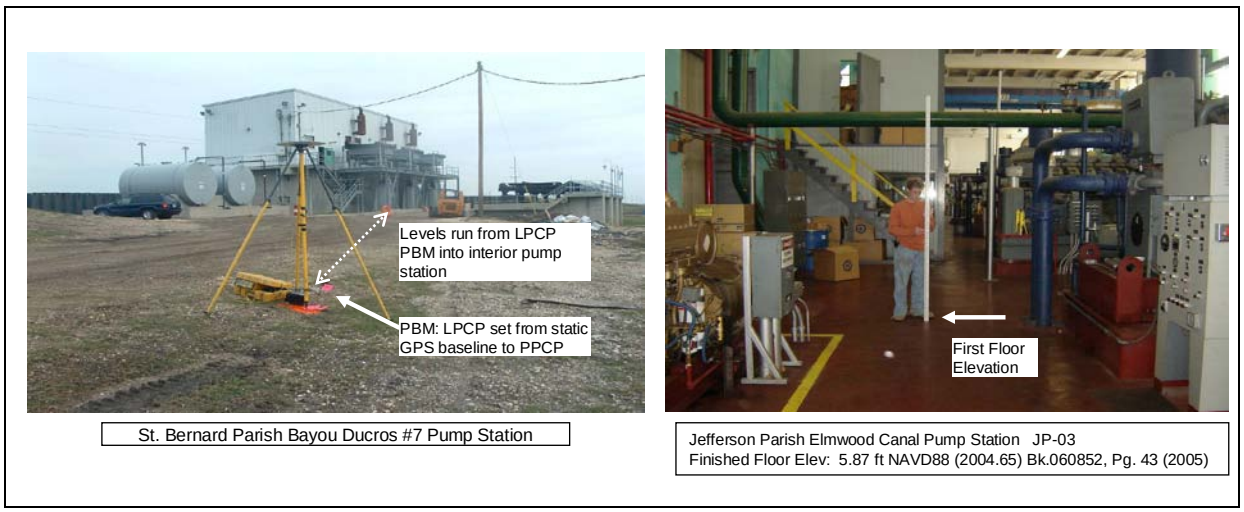

Figure 5-7. Referencing pump station elevations to NAVD88.

(2) Floodwall surveys. Figure 5-8 shows a cross-section of a hurricane protection I-wall on the New Orleans District's Inner Harbor Navigation Canal (IHNC) project. The topographic and hydrographic surveys of this section were performed relative to a local time-dependent NAVD88 datum, using RTK positioning from a NSRS PPCP. The top of wall elevation at this section shows both NAVD88 and Local Mean Sea level (LMSL) references.

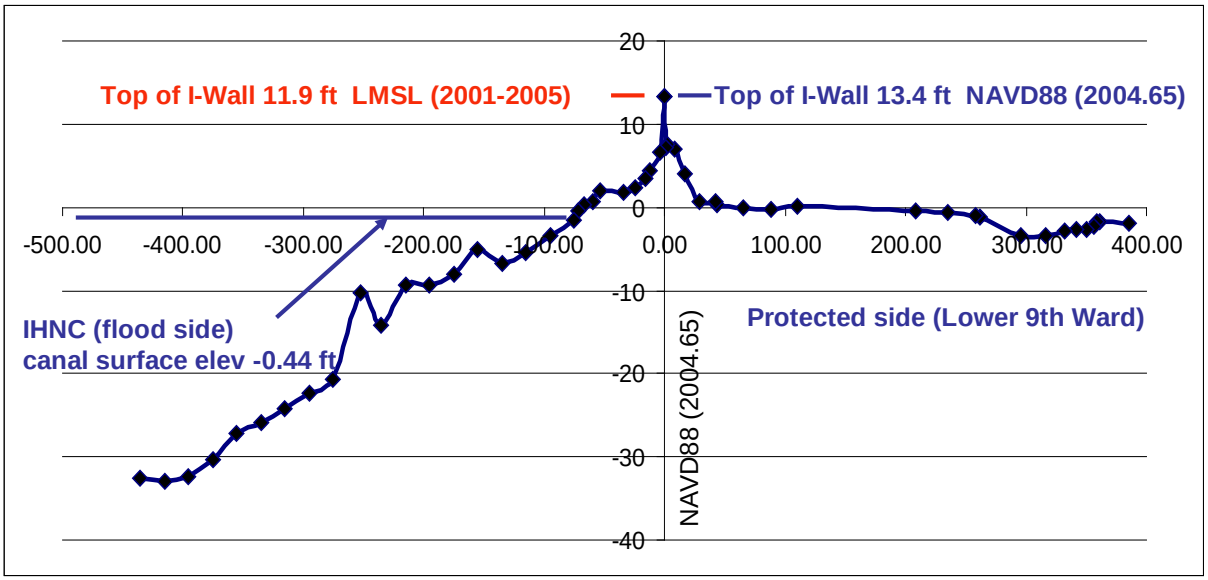

Figure 5-8. Referencing top of floodwall elevation to orthometric and sea level datums.

(3) Post hurricane high water mark (HWM) surveys. High water marks must be on a datum consistent with hydrodynamic surge models or other post-hurricane inundation studies. Therefore it is important that the reference datum used for HWMs be readily convertible to the model or study reference datum, such as LMSL. Using NAVD88 as a consistent reference is recommended, provided that the relationship between NAVD88 and LMSL can be estimated

throughout the region. Required accuracies of HWM elevations are dependent on the precision of the HWM, and the observer who estimated (marked) the HWM. Absolute field marking precisions of HWMs will range between 0.2 and 1 ft; thus, RTK survey methods are usually adequate. As shown in Figure 5-9, a TBM (stake or PK nail) is set in the vicinity of the HWM and a RTK (or fast static) elevation is placed on the TBM. Differential levels or total stations are then employed to survey the HWM on a wall or into the interior of a structure. HWM surveys, resultant elevations, and the reference datum must be clearly documented as shown in the figure.

Figure 5-9. High water mark survey procedures and datum documentation.

(4) Monitoring elevations of floodwalls and bridge restrictions. In areas subject to hurricane surge, elevations of designed or constructed structures need to be surveyed. Figure 5-10 depicts topographic surveys of a floodwall intersection with a bridge floodwall. The reference LPCP elevation on the floodwall was positioned using static or fast-static DGPS methods from the surrounding primary control network. From this LPCP point differential levels were run to obtain the elevations of the floodgate, connecting I-wall, bridge floodwall, and the bridge low chord elevation. The LPCP should be described and placed in the District's control database (e.g., U-SMART). As with all HSPP structure surveys, photographic documentation of observed elevation points is recommended. The relationship between local MSL and legacy (constructed) datums may also be noted on the photo. The reference field survey book should always be included as this book will contain additional metadata as to the survey procedures, elevation datums, source PPCPs, etc.

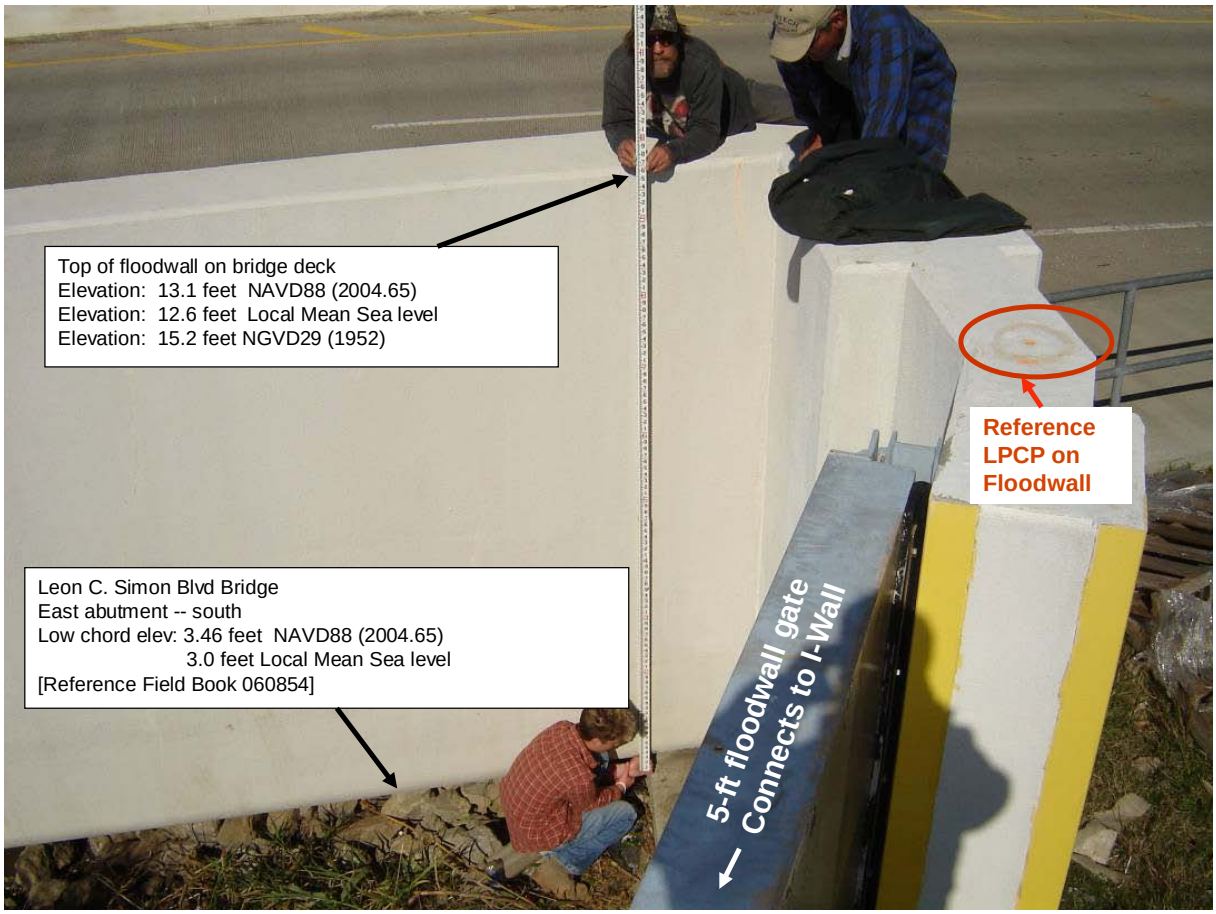

Figure 5-10. Surveying elevations of bridge chords, flood gates, and floodwalls.