CHAPTER 1

Introduction

1-1. Purpose. This manual provides technical guidance for referencing project elevation grades to nationwide vertical datums established and maintained by the U.S. Department of Commerce. It supplements ER 1110-2-8160 (*Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums*) that requires controlling elevations and local datums on USACE projects shall be properly and accurately referenced to nationwide spatial reference systems used by other Federal, state, and local agencies responsible for flood forecasting, inundation modeling, water control, flood insurance rate maps, navigation charting, and topographic mapping.

1-2. Applicability. This manual applies to all USACE commands having responsibility for the planning, engineering, design, construction, operation, maintenance, and regulation of flood risk management, coastal storm damage reduction, hurricane protection, multi-purpose water supply/control, hydropower, regulatory, ecosystem restoration, and navigation projects.

1-3. Distribution. This publication is approved for public release; distribution is unlimited.

1-4. References. Referenced USACE publications and related bibliographic information are listed in Appendix A. Where applicable, primary source material for individual chapters may be noted within that chapter.

1-5. Discussion. ER 1110-2-8160 requires that the designed, constructed, and maintained elevation grades of USACE projects shall be reliably and accurately referenced to a consistent nationwide framework, or vertical datum—i.e., the National Spatial Reference System (NSRS) or the National Water Level Observation Network (NWLON) maintained by the U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). This manual provides technical and procedural guidance for establishing the relationships for designed, constructed, or maintained project grades relative to these nationwide frameworks.

1-6. Background. In the aftermath of Hurricane Katrina in 2005, a study by the "Interagency Performance Evaluation Taskforce" (IPET 2007) found a number of project elevation and reference datum issues that had Corps-wide impact. Subsequent Corps-wide reviews revealed that flood protection and water control structure elevation grades were often referenced to uncertain or superseded terrestrial-based geodetic vertical datums instead of hydraulic/water-level referenced datums from which the structural protective elevations were designed. In some cases, long-term land subsidence, seasonal tidal fluctuations, and sea level change were not always fully compensated for in flood protection structure design or periodically monitored after construction. In addition, navigation projects in tidal regions were often defined to a vertical reference datum that was not based on the latest tidal model for the region, or were defined relative to a datum that was inconsistent with recognized national or international maritime datums. The technical variations and uncertainties between geodetic, satellite-based

(ellipsoidal), and water level datums, and their proper application on engineering and construction projects, were often misunderstood.

a. Datum uncertainty impacts. The IPET study found that inadequate or uncertain geodetic and water level datums can lead to the design and construction of deficient flood protection structures. In areas experiencing subsidence or post-glacial rebound, the relationship between the water surface and the project structures changes through time. In coastal districts, sea level change adds to the dynamic nature of this relationship. Reference datum relationships and elevation uncertainties must be factored into the overall risk analysis and design of flood protection structures and navigation project grades. The hydraulic and geodetic elevation relationships must be verified during construction, and periodically monitored after construction to account for subsidence, settlement, periodic nation-wide reference datum redefinitions and readjustments, sea level change, and other factors.

b. Relationships between hydraulic and geodetic datums. Establishing a solid relationship between hydraulic/tidal datums and geodetic datums is critical in relating measurements of wave heights and water level elevations, high-resolution hydrodynamic conditions, water elevations of hydrostatic forces and loadings at levees and floodwalls, elevations of pump station inverts, and related elevations of flood inundation models deriving drainage volumes or first-floor elevations in residential areas. This is best illustrated by the following excerpt from a report "*A National Vertical Datum Transformation Tool*" (Parker 2003).

> *"... the land-water interface depends on how water levels change in both space and time. To combine or compare coastal elevations (heights and depths) from diverse sources, they must be referenced to the same vertical datum as a common framework. Using inconsistent datums can cause artificial discontinuities that become acutely problematic when producing maps at the accuracy that is critically needed by Federal, state, and local authorities to make informed decisions."*

The relationship between the geodetic and hydraulic datums may or may not be easily defined. More often than not, the relationship is complex and requires field survey observations or extensive modeling to quantify. These relationships are especially critical on coastal hurricane protection and navigation projects where accurate hydrodynamic tidal modeling is essential in relating water level elevations to a datum that varies spatially and is time varying due to subsidence or sea level changes. Datums in other parts of the country may be subject to post-glacial rebound. Thus, there is no consistent, non-varying, vertical datum framework for many areas—periodic survey updates and continuous monitoring are required for projects experiencing vertical reference variations.

c. Flood mapping studies. The requirement for accurate vertical datums is emphasized in a National Research Council study "*Mapping the Zone—Improving Flood Map Accuracy*" (NRC 2009). This report concluded that "... the accuracy of elevation data has an enormous impact on the accuracy of flood maps. Ensuring that future flood studies are based on the most accurate and consistent foundation possible requires (1) continuation of a suite of agency elevation programs and (2) acquisition of accurate, high-resolution elevation data." The NRC study found that "... the greatest effect by far of any variant on the BFE [Base Flood Elevation] is from the

input data for land surface elevation ... [and that] the base flood elevation profile is significantly more influenced by whether the National Elevation Dataset or LIDAR terrain data are used to define land surface elevation than by any variation of methods for calculating channel hydraulics." A 2009 FEMA report to Congress "*Risk Mapping, Assessment, and Planning (Risk MAP) Multi-Year Plan: Fiscal Years 2010-2014"* (FEMA 2009) outlined that agency's plan for enhancing and maintaining the quality of flood hazard data and flood maps, with particular emphasis on expanded use of LIDAR technology to measure accurately referenced elevations in flood hazard areas.

1-7. Scope of Manual. Chapter 2 provides an overview of geodetic, hydraulic, and tidal datums used to define grades on USACE civil works projects, in both CONUS and OCONUS regions. Chapter 3 contains recommended survey procedures and accuracy standards for referencing project grades to federal frameworks. The remaining chapters (4 through 9) contain detailed guidance for referencing datums on specific types of civil works projects. The appendices to this manual contain application examples of civil works projects that have been adequately referenced to the federal datum frameworks.

1-8. General Background on the Definition and Use of Vertical Datums. Vertical datums typically represent a terrestrial or earth-based surface to which geospatial coordinates (such as heights, elevations, or depths) of project grades are referenced. The vertical datum is the base foundation for nearly all civil and military design, engineering, and construction projects in USACE—especially those civil projects that interface with water.

a. USACE vertical datums. In general, there are five types of vertical datums that are used to reference grades on USACE civil works projects.

(1) Geodetic (or Orthometric) Datums (e.g., North American Vertical Datum of 1988—NAVD88, National Geodetic Vertical Datum of 1929—NGVD29)

(2) Hydraulic Datums (e.g., Low Water Reference Planes—LWRP, IGLD, Pool stages)

(3) Tidal Datums (e.g., Mean Sea Level-MSL, Local Mean Sea Level-LMSL, Mean Lower Low Water-MLLW, Mean High Water-MHW)

(4) Local or Legacy Datums (e.g., Mean Low Gulf-MLG, Chicago City Datum, Memphis Datum, Cairo Datum, local river gage stage, US Engineer Datum-USED, COEMLW)

(5) Global Navigation Satellite System (GNSS) Earth-Centered Datums (e.g., GRS80, WSG84)

b. Multiple datums. Most USACE projects interfacing with water are referenced to at least two of the above datums. Some may require reference to all five. Increasing emphasis and eventual dependence on GNSS satellite positioning for primary construction stakeout and machine control will necessitate that all projects be eventually referenced to satellite-based datums, resulting in a minimum of three reference datums for most projects. Given these

multiple reference datums, it is critical that the relationship among the datums be firmly established, maintained, and well documented.

c. Legacy or local datums. Many USACE navigation, flood protection, and water control projects are still referenced to superseded datums, such as Mean Low Water, Mean Sea Level, NGVD29, Sea Level Datum of 1929 (SLD29), etc. Projects referenced to these superseded or legacy datums are, in effect, actually referenced to a "Local Datum." The relationship between this legacy datum, the current federal orthometric datum, and the local hydraulic reference plane is often highly uncertain. Projects referenced to legacy datums must, at minimum, be related to the current federal orthometric or tidal datum. This does not preclude the continued use of these legacy datums for navigation, flood risk management, or water control purposes; only that the relationship between the legacy datum and the current federal datum is established, documented, and maintained.

(1) Local navigation project datums. Navigation projects are usually referenced to an established low water reference plane—a tidal low water on coastal projects and a hydraulic-based reference plane on rivers, pools, lakes, and reservoirs. Tidal navigation project grades that were constructed and maintained to an older local low water datum may need to be updated for subsequent sea level or subsidence changes that have occurred since the project was authorized and/or the legacy datum was established. The current relationship between the legacy datum and the current federal tidal reference datum must be clearly indicated on all project documents.

(2) OCONUS local orthometric datums. NAVD88 or NGVD29 is not applicable to OCONUS projects in the Pacific Ocean region, the Caribbean, and in portions of Alaska where established local datums have been defined by NOAA, USACE, or another agency.

d. Project life-cycle variations in datums. The relationship within and between the reference datums listed above often may be complex given they can deviate spatially over a region, due to a variety of reasons. They may also have temporal deviations due to land subsidence or uplift, sea level changes, crustal/plate motion, project reconstruction, periodic readjustments to the datum origin, or to redefined points on the reference surface. Figure 1-1 illustrates the time-dependent datum variations that may be encountered during the life cycle of a project—in this case a hurricane protection project. It also illustrates the uncertainties and risk assessment factors associated with reference datums that must be considered in designing protection elevations over the life cycle of a project.

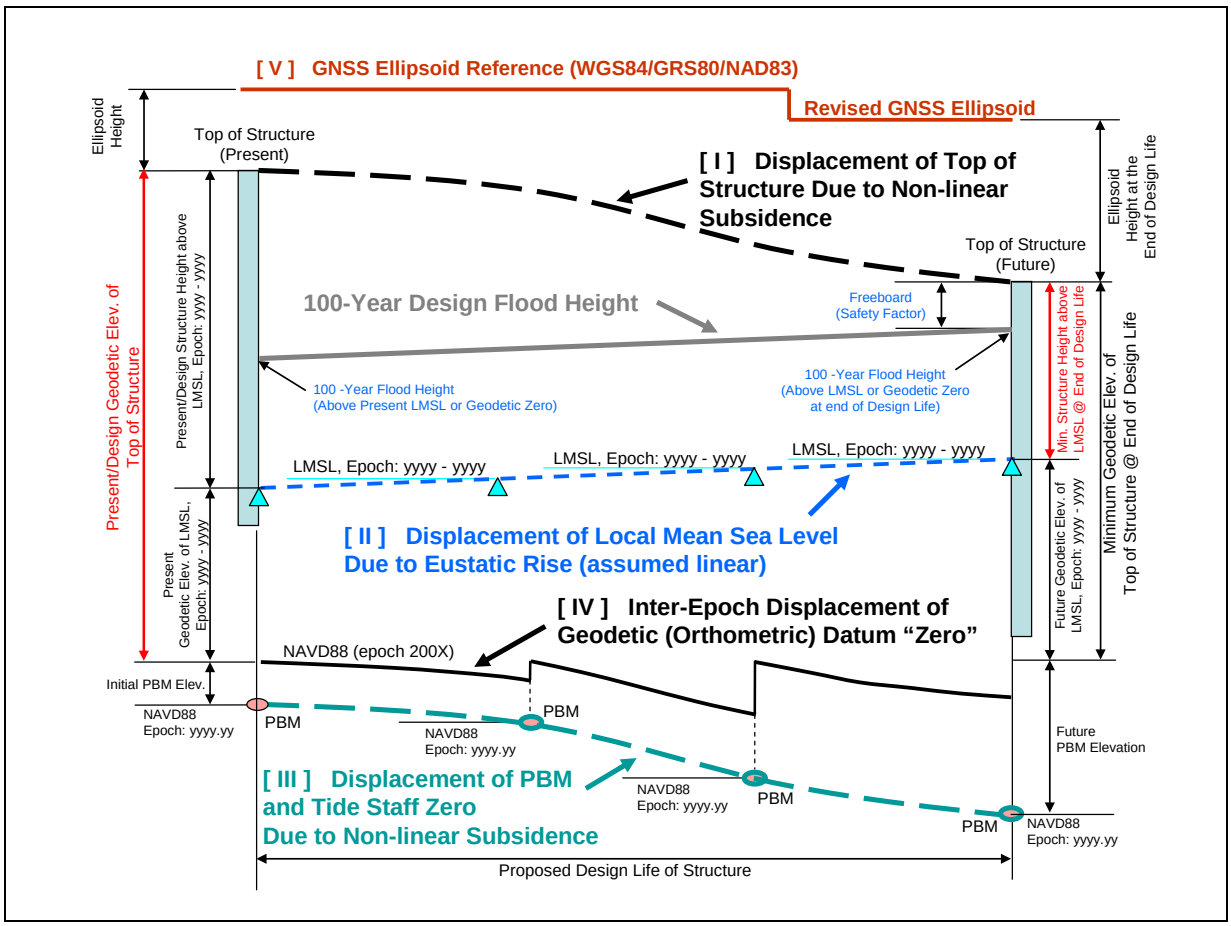

Figure 1-1. Structure design and protection height considerations and uncertainties due to vertical reference datum variations over the life cycle of a project.

(1) In Figure 1-1, the absolute protection elevation of the top of the floodwall is lessened over the project's design life cycle due to local land subsidence [I]. This subsidence is independent of any structure settlement. In addition, apparent (or local) sea level change [II] results in a change of protection, in this example, a loss due to apparent sea level rise. Concurrently, the local reference permanent bench mark(s) (PBM) used to establish constructed grades on the structure, and tide gage reference PBMs used to measure MSL, may be subsiding differently from the structure [III]. In addition, NOAA may make periodic adjustments to the geodetic reference datum [IV], the tidal MSL reference datum [II], or even redefine the datums at some point in the future. The reference ellipsoid datum [V] for satellite GNSS (e.g., GRS80 and WGS84) could also be revised at some point in the future.

(2) Of critical importance in Figure 1-1 is the relationship between the local water surface [II] and the local geodetic reference datum [IV]. This changing relationship must be monitored throughout the life cycle of a project (e.g., 50 + years). Protection elevations are referenced to the local water surface level (e.g., Local Mean Sea Level—LMSL, which in Figure 1-1 is shown rising). The current geodetic reference datum—NAVD88 [IV]—is not based on the design water surface nor is it related to the water surface—it is, in effect, an arbitrary reference system. However, this geodetic datum is used for site plan mapping during design, construction stake out

and grading, and flood plain mapping and related hydrological studies (e.g., resultant Flood Insurance Rate Maps—FIRMS). Future vertical reference datums are proposed on or after 2018 that will align with the gravity/geoid surface and may best fit to hydraulic-dynamic based surfaces.

e. Coastal and inland navigation project references. Referenced depths of navigation projects must likewise have a firmly established relationship between the water surface datum and the geodetic datum. On coastal navigation projects, the reference datum (e.g., Mean Lower Low Water) varies temporally as does Local Mean Sea Level [II] shown in Figure 1-1. It also varies spatially due to the dynamics of tidal ranges in a region, and therefore must be modeled. The modeled MLLW reference plane defines constructed and maintained dredging grades and must be continuously updated for tidal epoch, sea level, and subsidence changes as illustrated in Figure 1-1. On inland navigation projects, the reference datum is normally defined relative to hydraulic parameters (e.g., stages) at local river or pool gages. The geodetic datum is not based on the hydraulic water surface profile; therefore, the relationship between the hydraulic river stages and the geodetic datum must be developed and maintained.

f. Inland flood risk management and water control projects. Elevations of inland flood and water control structures (levees, dams, floodwalls, etc.) are designed, constructed, and maintained relative to hydrologic and hydraulic gage data in the project area. Flow profiles and other computed data from river gages may be referenced to various datums, as shown in Figure 1-2. Computed or modeled flood stage profiles may be referenced to the gage reference zero, the low water reference plane, and/or one of the geodetic datums shown in the figure. The geodetic and satellite reference datums vary spatially between the gages (i.e., they are non-parallel) and contain uncertainties that factor in to the overall uncertainty of a computed flood stage; and thus into the uncertainty and risk analysis estimates of the protection elevation of an adjacent levee, floodwall, or dam—reference ER 1105-2-101 (*Risk Analysis for Flood Damage Reduction Studies*). Figure 1-3 illustrates the elevation uncertainties on a flood protection structure resulting from propagated errors in both reference datums and survey connections. Accurate modeling of water surface profiles on a river system depends (in part) on having a consistent reference datum at the primary gages. Chapters 3 and 6 provide survey procedures and standards for connecting these various reference datums on flood risk management and water control projects. Estimated datum uncertainties are outlined in Chapter 9.

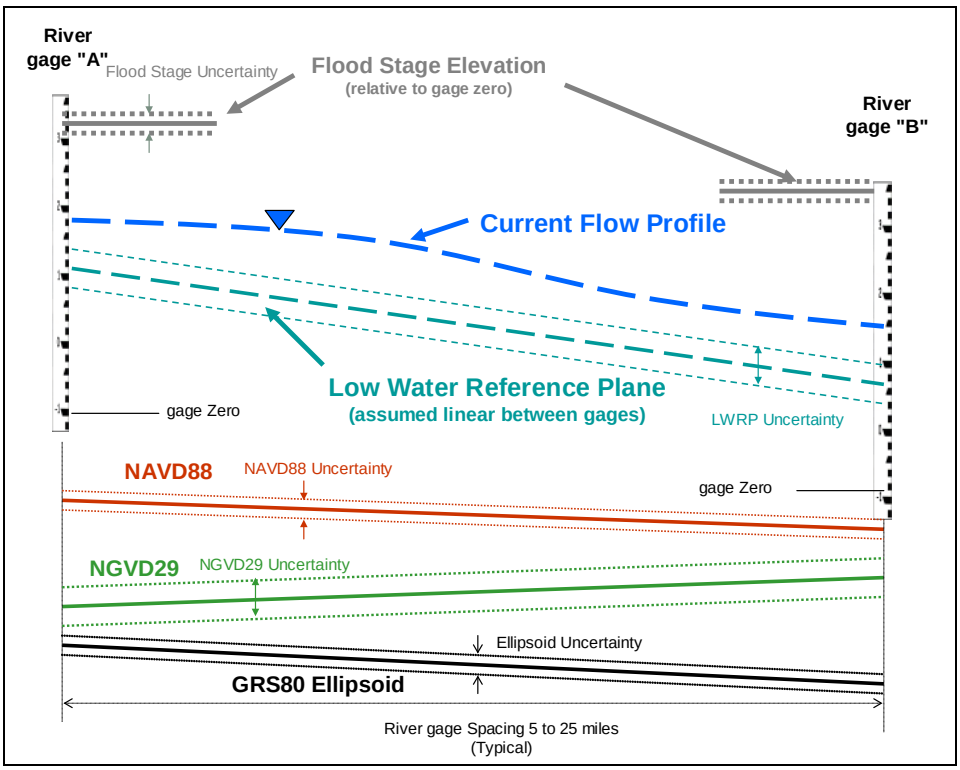

Figure 1-2. Design and protection height considerations and uncertainties due to vertical reference datum variations at gages on an inland river system. (Not to scale)

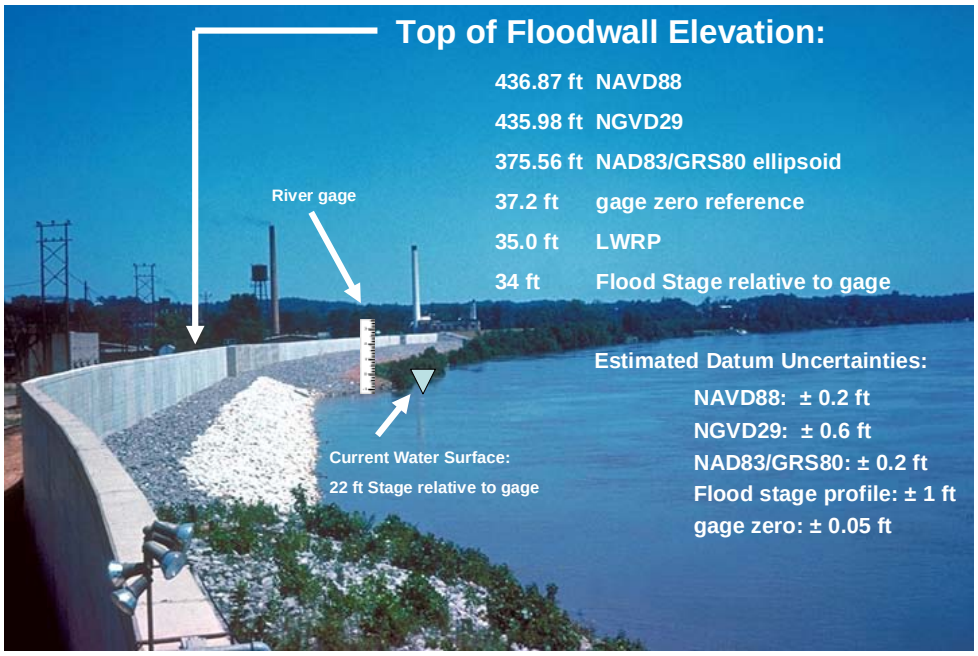

Figure 1-3. Datum and elevation uncertainties on an inland river system floodwall protection height. The reference datum uncertainties propagate to an uncertainty in the floodwall elevation. (see Chapter 9).

1-9. Federal Framework Systems for Referencing USACE Project Grades. It is important that USACE project control and elevation grades conform to the following federal framework systems and guidelines.

a. National Spatial Reference System (NSRS). The NSRS represents an independent framework system for long-term monitoring of the stability of project grades and flood protection elevations. This reference system is maintained by the NOAA National Geodetic Survey (NGS). In addition to USACE, this reference system has been adopted by most Federal agencies, including FEMA, USGS, EPA, and by most state transportation departments (DOT). The NSRS is a national reference framework that specifies latitude, longitude, height (elevation), scale, gravity, and orientation throughout CONUS and most civil works OCONUS locations. It is also the base reference for most GNSS observations. Accordingly, USACE must ensure flood risk management projects and navigation projects are referenced to this NSRS system. This insures consistency in reporting elevations or grades between agencies. In addition, incorporating Corps project control into the NSRS minimizes the need for maintaining independent databases at each District. It also ensures that Corps project control will be automatically updated when future updates to the NSRS are made. Permanent bench marks (PBM), or "*Primary Project Control Points*" (PPCP), on USACE projects shall be firmly connected to the NSRS and submitted to the NGS for inclusion in the published NSRS. Details on these procedures are explained in
Chapter 3.

b. National Water Level Observation Network (NWLON). The NWLON is composed of the continuously operating long-term primary and secondary control tide stations established by the Center for Operational Oceanographic Products and Services (CO-OPS), an agency under the NOAA National Ocean Service. This network provides the basic foundation for the determination of tidal datums for coastal and marine boundaries and for chart datums in CONUS and OCONUS regions. The National Water Level Program (NWLP), also administered by the NOAA CO-OPS, includes the NWLON and water level elevation data and bench mark elevation data from historical long-term and short-term gages operated by that agency. NOAA tidal data are referenced to a specific National Tidal Datum Epoch (NTDE). The specific 19-year NTDE period adopted by NOAA is the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., Mean Sea Level, Mean Lower Low Water, etc.) for tidal datums. A common period of observation is necessary because of periodic and apparent secular trends in sea level. Special NTDEs are adopted for local areas with extreme relative sea level change due to significant land subsidence (e.g., Louisiana) or land rebound (e.g., SE Alaska). CO-OPS computes special NTDEs based on recent 5-year modified tidal datum epochs.

c. FEMA National Flood Insurance Program (NFIP) Guidelines. FEMA has issued a number of publications dealing with flood mapping accuracy standards and related elevation datums that are needed for NFIP studies and to certify or accredit levee/floodwall systems. These certifications are referenced to Base Flood Elevations (BFE) shown on Flood Insurance Rate Maps (FIRMs). Design and constructed elevations on floodwalls, and related freeboard allowances, stillwater elevations, etc. must be consistent with the same regional vertical datums specified in NFIP regulations and guidelines—see "*Identification and Mapping of Special Hazard Areas*" (44 CFR 65) and FEMA's "*Guidelines and Specifications for Flood Hazard*

Mapping Partners" (FEMA 2003). FEMA Elevation Certificates require vertical datum designations for FIRM Base Flood Elevations and building first-floor elevations. Metadata associated with the origin of the datum (reference bench marks, FIRM, etc.) are critical in order to reliably relate FEMA BFEs to USACE floodwall protection elevations.

1-10. Implementation Actions. In accordance with ER 1110-2-8160, USACE commands need to ensure all project grade elevations or navigation depths are referenced directly or indirectly to the NSRS or NWLON framework systems described above. All newly authorized and existing projects should be evaluated to ensure that designed and constructed grades are adequately connected and referenced to the NSRS and the applicable tidal or hydraulic network. The hydraulic/tidal and geodetic vertical datum relationships must be assessed, developed and/or verified during the Feasibility and Preconstruction Engineering and Design (PED) phases, during construction, and periodically monitored after construction to account for subsidence, settlement, NOAA reference datum redefinitions and readjustments, sea level change, and other factors.

a. Critical project datum assessment items. Special attention should be made to assess the following critical issues associated with a project's vertical reference:

(1) Primary project control point bench marks. All projects shall have one or more permanent bench marks—i.e., a PPCP—that is directly connected to and published in the NOAA/NGS National Spatial Reference System (NSRS) network.

(2) Water level gage references. Permanent bench marks used to reference river, pool, reservoir, and tide gages shall be connected to and published in the NOAA National Spatial Reference System (NSRS) network.

(3) Protection grade elevations. Flood/hurricane protection structures and water control structure crest elevations shall be referenced to hydraulic flow or NWLON tidal models that are based on reliable water-level gage data that is referenced to the NSRS and reflects adjustments for sea level, settlement, or subsidence/uplift changes.

(4) Coastal navigation project grades. Coastal navigation project depths shall be defined relative to a local Mean Lower Low Water (MLLW) datum defined by the Department of Commerce; as required by Section 224 of the Water Resources Development Act of 1992 (WRDA 1992). This navigation reference datum shall be based on the latest tidal epoch. Depth measurements shall be spatially corrected based on hydrodynamic tidal models developed from and calibrated to up-to-date water-level gage data, and that field survey techniques are adequately compensating for short-term phase and slope variations in the water surface.

b. Corrective actions. Existing projects deemed deficient in any of the criteria outlined above will require corrective field survey actions. The amount of time and expense will vary considerably, depending on the geographical size of the project, risk assessments, the density and reliability of existing water level gages, and various other factors. Project engineers or managers should prepare a cost estimate in sufficient detail to allow programming the corrective action into the next budget cycle for the project. The guidance listed below synopsizes the effort required for various project conditions.

c. Geodetic control survey connections to the NSRS. At least one PPCP on every project must be geodetically connected to the NSRS. A variety of techniques for performing this connection are described in Chapter 3. In most cases, existing NSRS control in the region will suffice, and no significant field survey effort is required. In nearly all cases, PPCPs can be economically accomplished using Differential Global Positing System (DGPS) height transfer methods relative to the NSRS. Conventional differential leveling may be a more economical option, especially over short distances. PPCPs established or reestablished shall be submitted to NGS for inclusion in the NSRS.

d. Water level gage connections to the NSRS. Water level gages that are used to reference elevations of flood risk management, water control, or tidal parameters on navigation, water control, or HSPP projects must be referenced to and documented in the NSRS. A bench mark referenced to each gage shall be surveyed and placed into the NSRS and continuously maintained in that file. In some cases, this gage reference bench mark may serve as the PPCP for the entire project. Additional details are found in Chapter 4.

e. Coastal navigation project reference datums. Navigation projects in tidal areas that were not adequately updated to a current MLLW reference datum, or have outdated or unknown origin tidal modeling regimes (phase and range), or are on superseded tidal epochs, will require field efforts to update the project. This may require setting one or more short-term tidal gages to perform simultaneous comparison datum translations between an existing NWLON station and/or developing a tidal model utilizing NOAA hydrodynamic modeling techniques which can be applied to develop the MLLW datum relationship over a project reach. Minimizing tidal phase errors may require mandated utilization of GNSS differential carrier phase water surface elevation measurements in lieu of extrapolated gage elevations—i.e., Real Time Network (RTN) applications such as Real Time Kinematic (RTK), Virtual Reference Networks (VRN), or Virtual Reference Stations (VRS). Details on these methods are covered in Chapter 4.

f. Coastal navigation or Hurricane and Shore Protection Projects (HSPP) projects on non-standard or undefined tidal datums. Projects on antiquated or non-standard tidal datums must be converted or related to the MLLW datum established by NOAA used for coastal navigation and maritime charting in CONUS or OCONUS waters. This includes those projects that are still referenced to legacy datums such as Mean Low Water (MLW), Mean Gulf Level (MGL), Mean Low Gulf (MLG), Gulf Coast Low Water Datum, Old Cairo Datum 1871, Delta Survey Datum 1858, New Cairo Datum 1910, Mean Tide Level, Corps of Engineers Mean Low Water (COEMLW), U.S. Engineer Datum (USED), etc.

g. Mean Sea Level (MSL) or NGVD datums. Project control elevations or bench marks defined generically to "Mean Sea Level" or "NGVD" without any definitive source data (metadata) probably have no firmly established relationship to the current NSRS and may need to be resurveyed. "NGVD29" was once known as the "Sea Level Datum of 1929." However, neither NGVD29 nor the current NAVD88 datums are equivalent to "mean sea level." Resurveying will entail establishing a hydraulic and a NSRS geodetic reference, as applicable. Details are outlined in Chapter 3.

h. Permanent bench mark control requirements for extensive flood risk management or reservoir projects. Levee projects encompassing large geographic extents may require more than one PPCP to cover the project area. PPCPs should be added as necessary to control the project grades and features using conventional surveying methods, or preferably at a sparser density needed to accommodate GPS real-time kinematic construction survey or machine control methods. These permanent bench marks must be firmly connected to applicable hydraulic gages and regional NSRS datums as described above, and, where required, should be submitted to NGS for inclusion into the NSRS. Requirements for additional NSRS densification on large flood risk management or water control reservoir projects are covered in Chapter 6.

i. Projects subject to high subsidence rates. Projects located in high subsidence areas (e.g., portions of Louisiana, Texas, and California) may require special attention. This also applies to areas on the Northwest coast (e.g., Alaska) and other locations that may be subject to crustal uplift or glacial rebound. Vertical elevations of reference bench marks, water level gages, and protection structures must be continuously monitored for movement and loss of protection. This monitoring can be accomplished using static GPS survey methods or conventional differential leveling. In high subsidence areas, independent local vertical control networks referenced to the NSRS may be established for these purposes. These vertical networks are periodically resurveyed at intervals dependent on subsidence rates. For example, in the New Orleans, LA area, primary control PBMs on these monitoring networks are date-stamped to signify reobservation/readjustment epochs—e.g., "BM XYZ (2004.65)." Additional technical guidance for monitoring subsidence or uplift can be obtained from the USACE Army Geospatial Center (AGC) and the NGS. Details are covered in Chapter 8.

j. Ecosystem restoration projects. In aquatic ecosystem restoration projects, the appropriate vertical datum should be taken into consideration during all project phases. Restoration projects should be based on valid water level measurements, and in some cases, the current NSRS geodetic datum. Often vertical datums for restoration projects need to establish the relationship between historical and current water level and geodetic datums to ensure the ecosystem restoration success. For ecosystem restoration projects in coastal areas, see Chapter 5 for details in defining the appropriate water level datum. See Chapter 6 for details in defining the appropriate datum to be used for non-coastal ecosystem restoration projects.

k. Regulatory permitting actions. Compensatory mitigation projects or regulatory permitting activities that are referenced to tidal or non-tidal datums should be defined to an established datum based on valid water level observations, as appropriate to local, state, and federal statutory requirements. Statutory Mean High Water (MHW), High Tide Line (HTL), etc. boundary demarcations in coastal areas may, in some cases, require direct reference to NOAA NWLON gage networks. Refer to details in Chapter 7.

1-11. Periodic Reassessments of Controlling Reference Elevations. Periodic reevaluations of project reference elevations and related datums covered in this manual should be included as an integral component in the various civil works inspection programs of completed projects. The frequency that these reevaluations will be needed is a function of estimated magnitude of geophysical changes that could impact flood protection or navigation grades. Project elevations and dredging grades that are referenced to tidal datums will have to be periodically coordinated

with and/or reviewed by NOAA to ensure the latest tidal hydraulic effects are incorporated and that the project is reliably connected with the NSRS. In all cases, a complete reevaluation of the vertical datum should be conducted at each scheduled periodic inspection. Shallow-draft navigation projects may have different criteria. Any uncertainties in protection levels that are identified during the inspection will also need to be incorporated into any applicable risk/reliability models developed for the project—see EM 1110-2-1619 (*Risk Based Analysis for Flood Damage Reduction Studies*).

1-12. Metrics and Accuracy Definitions. Both English and metric units are used in this manual. Elevations, depths, and gage data for USACE civil works projects are expressed in English units, following local engineering and construction practices. Exceptions may exist on some OCONUS projects. GNSS observation data and standards are normally in metric units. NOAA geodetic data and water level gage data are published in English and/or metric units. Satellite-derived geographical or Cartesian coordinates are transformed to English units for use in local project reference and design systems, such as State Plane Coordinate System (SPCS) grids or local construction chainage-offset systems. English/metric equivalencies are noted where applicable, including the critical—and often statutory—distinction between the US Survey Foot (1,200/3,937 meters (m) exactly) and International Foot (30.48/100 m exactly) conversions. One-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) accuracy or uncertainty statistics, standards, and tolerances specified in this manual are defined at the 95% RMS confidence level. Cost estimates cited in this manual are in 2010 dollars.

1-13. Trade Name Exclusions. The citation or illustration in this manual of trade names of commercially available products, including supporting surveying equipment, instrumentation, and software, does not constitute official endorsement or approval of the use of such products.

1-14. Abbreviations and Acronyms. Abbreviations and acronyms used in this manual are listed in the Glossary.

1-15. Manual Development, Technical Assistance, and Training. Technical guidance in this manual was developed by the Army Geospatial Center (AGC) in conjunction with the U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL), the NOAA National Geodetic Survey (NGS), the NOAA Coast Survey Development Laboratory (CSDL), and the NOAA Center for Operational Oceanographic Products and Services (CO-OPS). The AGC (National Datums and Subsidence Program) may be contacted for detailed technical guidance and formal training in evaluating the adequacy of existing project reference datums and survey techniques needed to connect project control with the NSRS. Reference http://www.agc.army.mil/ndsp.

1-16. Proponency and Waivers. The HQUSACE proponent for this manual is the Engineering & Construction Community of Practice. Waivers to this guidance should be forwarded through MSC to HQUSACE (ATTN: CECW-CE).