Geodetic Vertical and Water Level Datum Assessment

Report 2

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Geodetic Vertical and Water Level Datum Summary and Scope

- *Relationship between Local Mean Sea Level (LMSL) and NAVD 88 (2004.65) current solution*
  - Final adjustments to be completed by end of March
- *Data Analysis of field survey data and ties to historical records*
  - Review and analysis of historical datums & relationships between the various datums used over the years in the southern Louisiana area.
- *Historical Evaluation of Designed and Constructed Elevations on Various Flood Control and Hurricane Protection Projects.*
  - Changes over time of the benchmarks used in the design and constriction of flood control and hurricane protection projects in the study area.
- *Field survey support to other IPET Teams*

Difference between NGVD29(1991) and NAVD88(1994/1996)

Datum Shift

All values in feet

Difference between NAVD88 (1994/1996) and NAVD88(2004.65)

Mostly due to Subsidence

Geodetic (Terrestrial) Reference Datums versus Water Level Reference Datums

- NGVD29, NAVD88, & NAVD88 (2004.65) are terrestrial based geodetic datums with no direct relationship to local water level surfaces
  - Geodetic reference datums need to be locally related to tidal LMSL or LWRP river stages using physical gage observations
  - ***NGVD29 may have had a sea level relationship in 1920s but it is not sea level today (2006)***
  - NAVD88 (2004.65) was referenced to a mean tidal water surface in Rimouski, Quebec ... not New Orleans
  - NAVD88 (2004.65) is subject to periodic readjustments by NOAA (already 2 years old)

Difference Between NGVD29 and NAVD88 (2004.65)

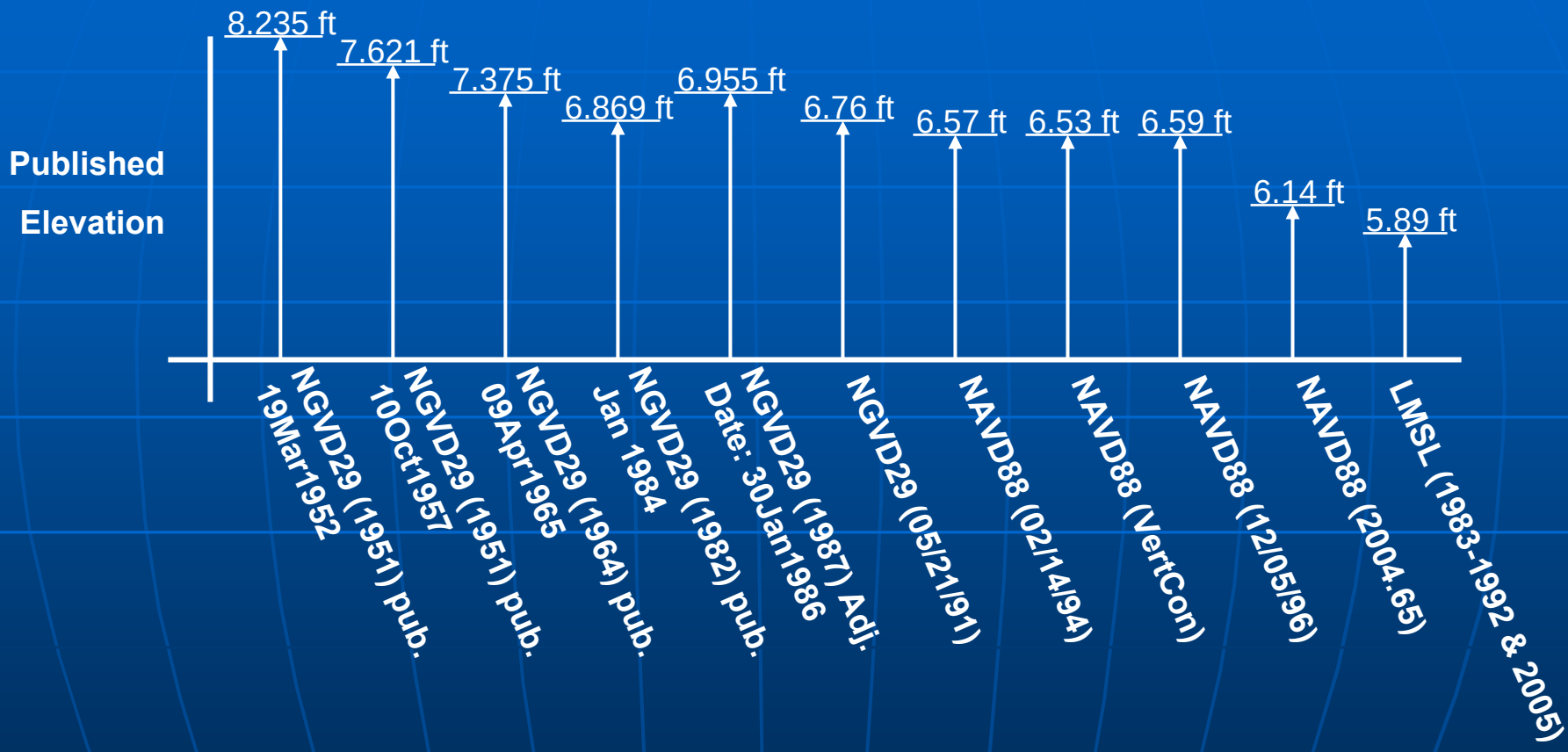
This difference is comprised of three factors.

1. *Datum Shift:* (NGVD29 to NAVD88)
2. *Error in the Old Elevation:* Due to regional subsidence, the previously published NGVD elevations were inaccurate.
3. *Subsidence:* Southern Louisiana is sinking due to many factors.

BOTTOM LINE: NGVD (or assumed MSL equivalency) cannot be used as an elevation reference … the updated NAVD88 epoch and its relationship to current LMSL must be used

Changes in the Published Heights (Elevations) for

Benchmark "ALCO 1931" (PID: BJ1342)

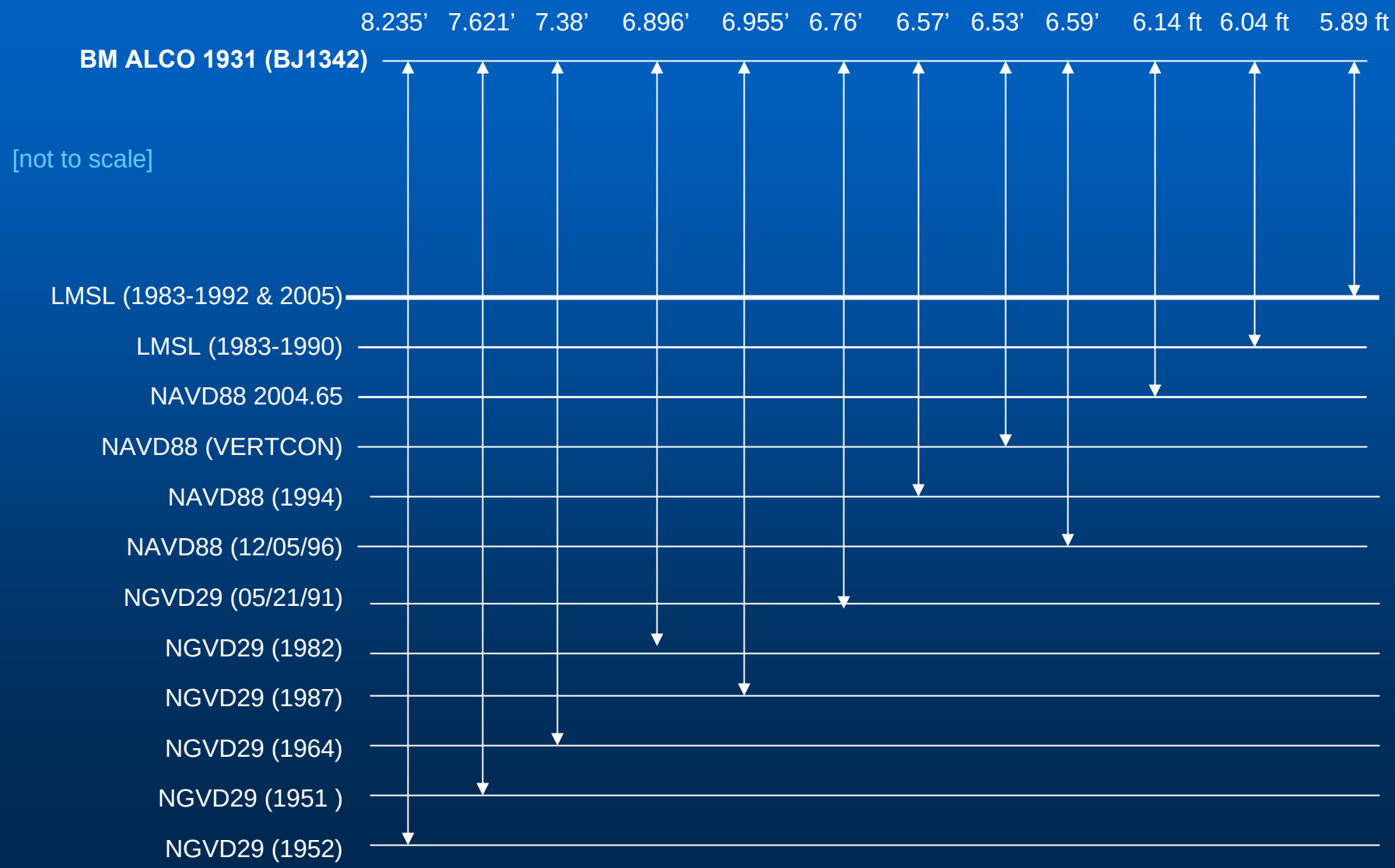


The changes in the above values point out the problem of errors in various adjustments on the datum(s) and not a direct solution to it.

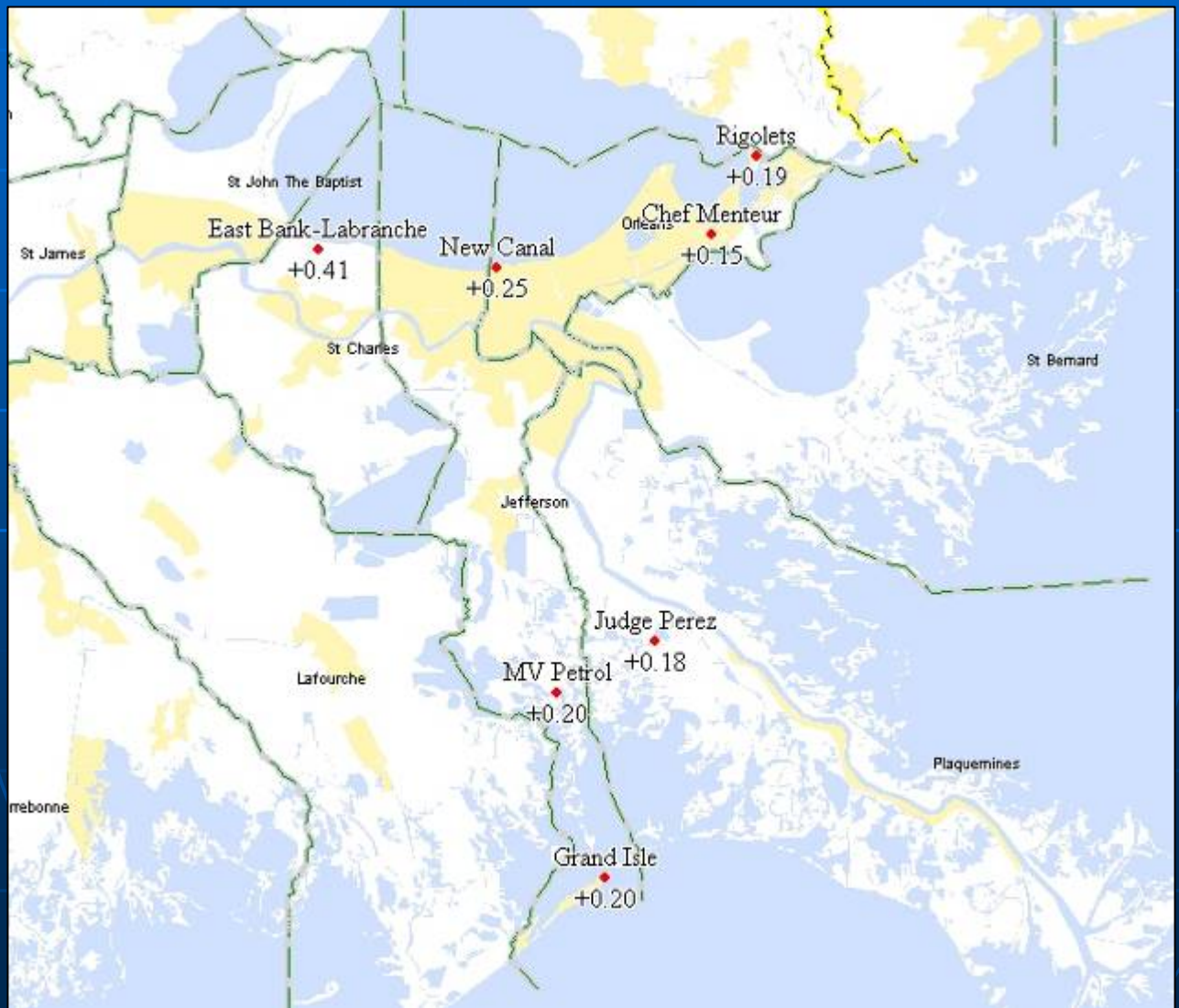
Source: NOAA (NGS and CO-OPS)

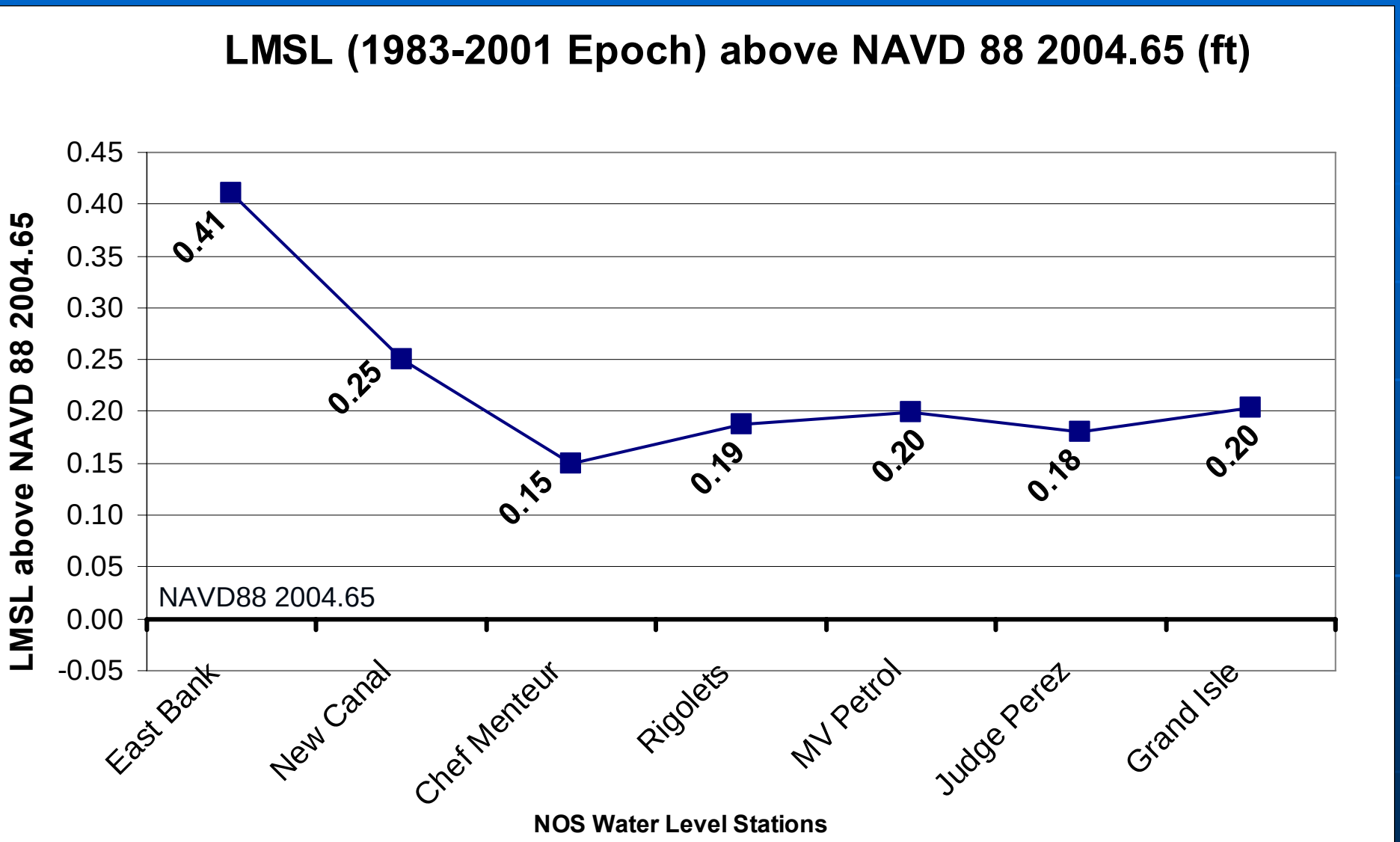
[not to scale]

17th Street Canal Floodwall Elevations
NOAA New Canal Gage & BM ALCO at Canal Entrance
Various Reference Datums (1951 to date)



Tide Stations and Values from NOAA CO-OPS Showing the height of the LMSL (1983-2001 epoch) above NAVD88 2004.65 (all values in feet)




LMSL (1983-2001 Epoch) above NAVD 88 2004.65 (ft)
LMSL above NAVD 88 2004.65
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
NAVD88 2004.65
0.41
0.25
0.15
0.19
0.20
0.18
0.20
East Bank
New Canal
Chef Menteur
Rigolets
MV Petrol
Judge Perez
Grand Isle
NOS Water Level Stations

Evaluation of Designed and Constructed Elevations on Flood Control & Hurricane Protection Structures

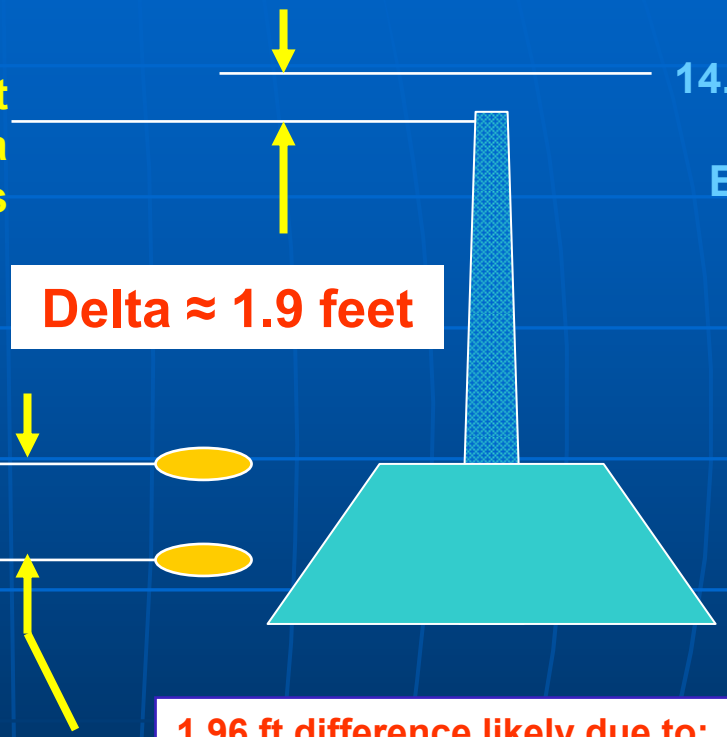
- Orleans Parish Floodwalls
  - New Orleans Lakefront Outfall Canals
  - IHNC (East Bank)
  - St Bernards & Plaquemines levees in progress
- Designed/constructed data from Design Memorandums, Plans & Specs, Contract Plans, As Builts
- Pre/Post-Katrina data from IPET, MVN, & TFG topographic surveys

17th Street Outfall Canal
East Bank Floodwall Construction

ca 1993 Floodwall Protection/Capping Project (High Level Plan)

Hammond Hwy to Veterans Blvd Sta. 8+50 to 80+00 (±) -- Typical

Existing floodwall elevations running ~12.1 ft (LMSL 1983-2001) —from 2005 post-Katrina field surveys



USACE Monument 14 used as reference for floodwall construction

1.96 ft difference likely due to:

- Uncertain BM 14 elevation … believed by MVN to be suspect/disturbed
- Uncertain BM 14 datum (1951 or ?)
- Settlement (probably < 0.3 ft)

Elevations are referenced to an estimated LMSL (1983-2001 epoch) at Lake Pontchartrain

Preliminary 5 Mar 06—subject to correction

(Not to Scale)

17th Street Outfall Canal
Design v Current Protection Elevations

Section	Elevation in feet (LMSL 1983-2001) Design	Current	Difference
WEST BANK			
Lakefront Levee to Veterans Hwy	14.0 ft	12.4 ft	1.6 ft
Veterans Hwy to I-10 Bridge	14.5 ft	13.1 ft	1.4 ft
I-10 Bridge to Southern RR	15.0 ft	13.1 ft	1.9 ft
EAST BANK			
Hammond Hwy to Veterans Hwy	14.0 ft	12.1 ft	1.9 ft
Veterans Hwy to I-10 Bridge	14.5 ft	13.2 ft	1.3 ft
I-10 Bridge to Southern RR	15.0 ft	13.3 ft	1.7 ft

LMSL (1983-2001) reference datum is estimated/provisional (March 2006)

Current elevations are levee profile averages

London Avenue Outfall Canal

Periodic Adjustments to Benchmark P 153
(Used as Reference for Floodwall Construction in 1990s)

ELEV FT	DATUM	ADJUSTMENT
12.087	NGVD29	19 Mar 52
11.476	NGVD29	1951
11.270	**NGVD29**	**09 Apr 65**
10.708	NGVD29	01 Sep 82
10.623	NGVD29	30 Jan 86
10.39	NGVD29	21 May 91
10.20	NAVD88	14 Feb 94
10.21	NAVD88	5 Dec 96
9.79	NAVD88 (2004.65)	10 Feb 06
9.66 est	LMSL (1960-1978)	pub
9.54 est	LMSL (1983-2001)	2005
TBD	LMSL (2001-2005)	(May 2006)

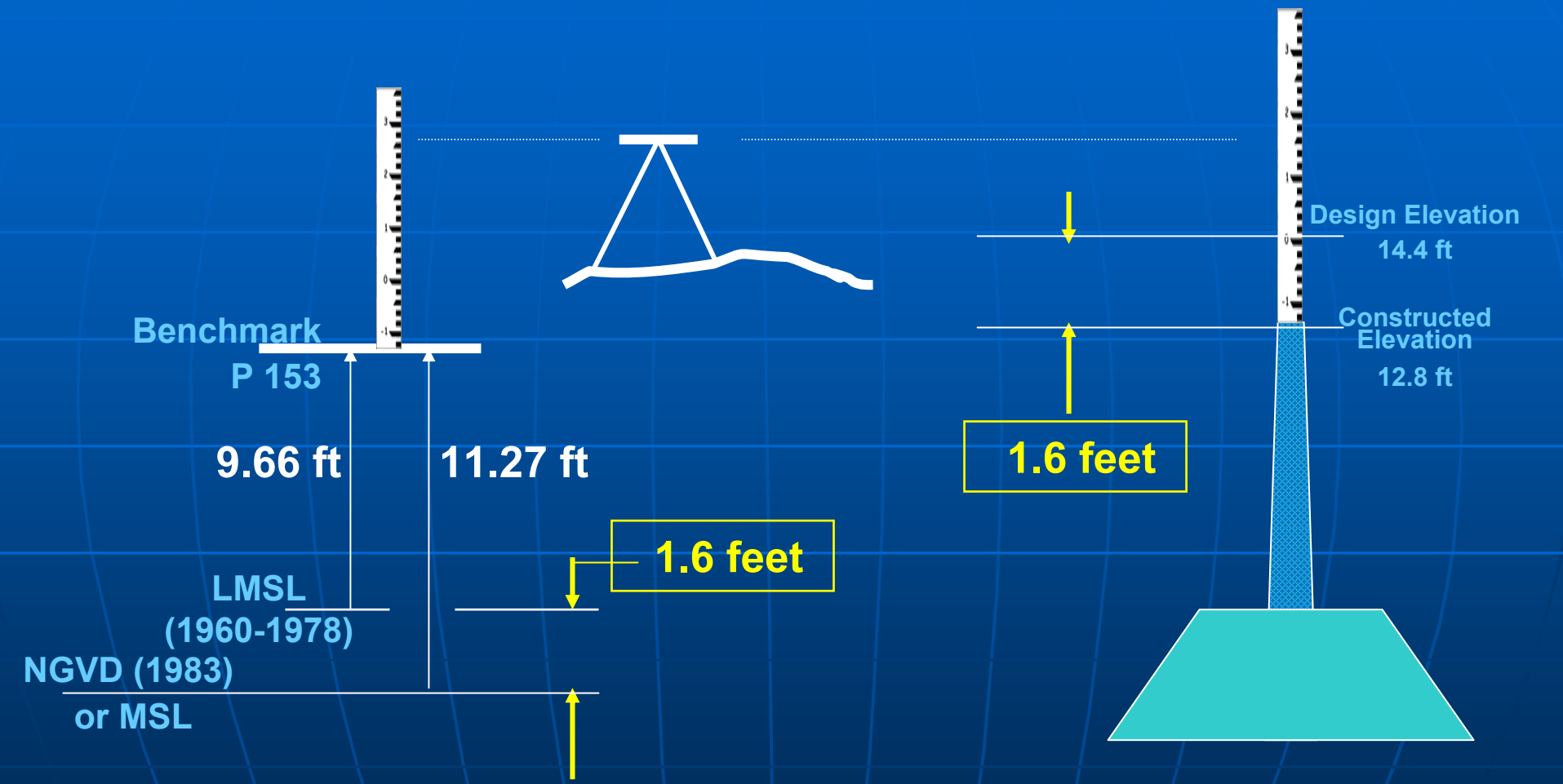
A 25 year old terrestrial datum adjustment was used in the 1990s construction ... uncertain why later adjustments were not used

Impact: approximately 1 foot (1965 to 1991 NGVD adjustments)

Floodwall construction was referenced to a terrestrial datum ... not LMSL (1960-1978)

London Avenue Outfall Canal

Design v Constructed Floodwall Elevations



(Not to Scale)

Design SPH Stillwater 11.5 ft "NGVD" @ Lake Pontchartrain
Typical Settlement Allowance 0.5 ft & Freeboard 2.0 ft

London Avenue Outfall Canal

Design v Current Protection Elevations

Section	Elevation in feet (LMSL 1983-2001) Design	Current	Difference
WEST BANK			
Leon Simon Ave to RE Lee Blvd	n/a	n/a	
RE Lee Blvd to Filmore Ave	14.4 ft	12.8 ft	1.6 ft
Filmore Ave to Mirabeau Ave	14.4 ft	12.7 ft	1.7 ft
Mirabeau Ave to Gentilly Ave	14.4 ft	12.7 ft	1.7 ft
Gentilly Ave to Pump Station 3	14.4 ft	12.7 ft	1.7 ft
EAST BANK			
Leon Simon Ave to RE Lee Blvd	14.4 ft	12.6 ft	1.8 ft
RE Lee Blvd to Filmore Ave	14.4 ft	12.6 ft	1.8 ft
Filmore Ave to Mirabeau Ave	14.4 ft	12.6 ft	1.8 ft
Mirabeau Ave to Gentilly Ave	14.4 ft	12.7 ft	1.7 ft
Gentilly Aveto Pump Station 3	14.4 ft	12.8 ft	1.6 ft

LMSL (1983-2001) reference datum is estimated/provisional (March 2006)

Orleans Avenue Outfall Canal

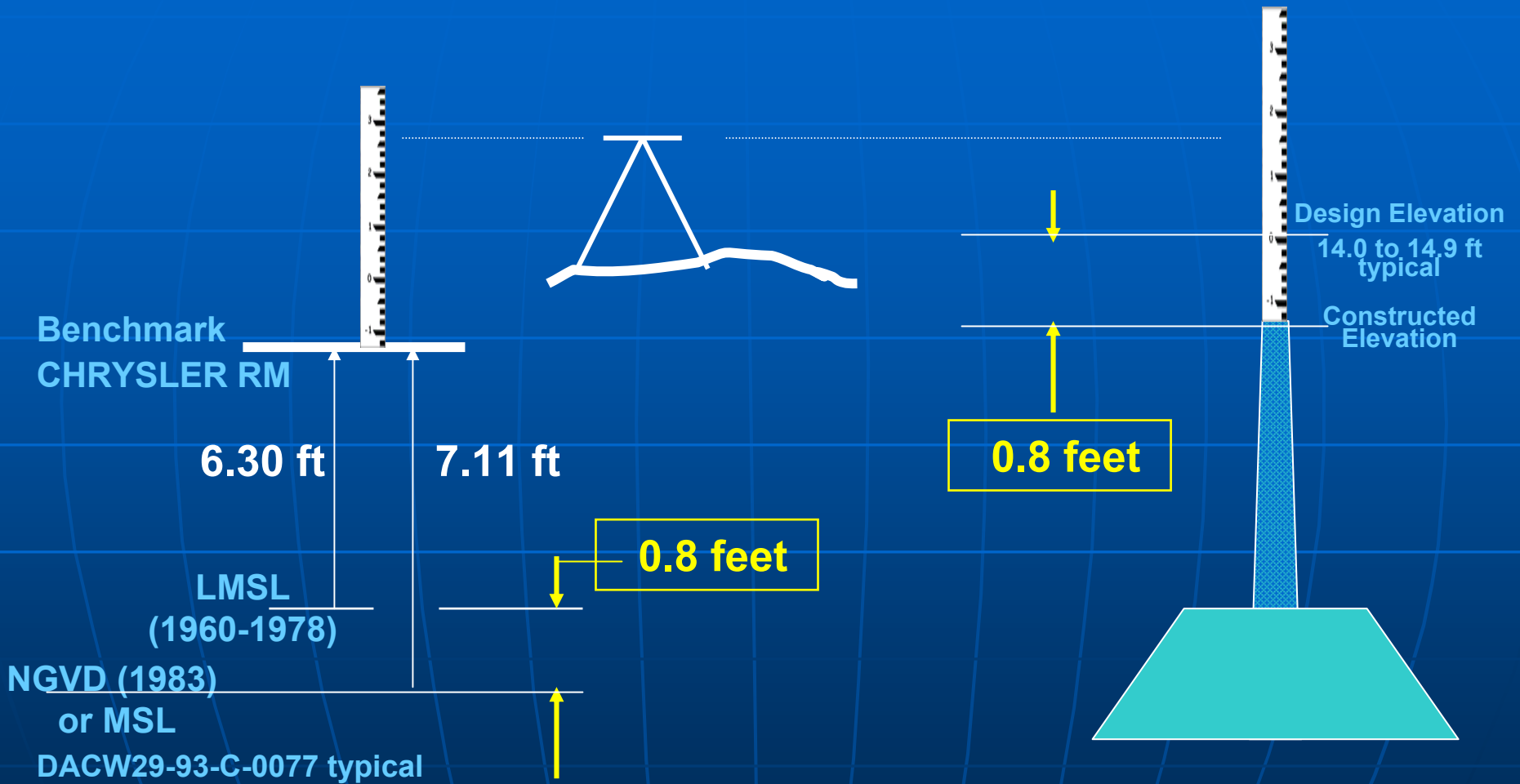
Periodic Adjustments to Benchmark CHRYSLER RM 1931 (Used as Reference for Floodwall Construction in 1990s)

ELEV FT	DATUM	ADJUSTMENT
8.533	NGVD29	19 Mar 52
7.923	NGVD29	1951
7.694	NGVD29	09 Apr 65
→ 7.108	NGVD29	01 Sep 82
7.231	NGVD29	30 Jan 86
7.03	NGVD29	21 May 91
6.83	NAVD88	14 Feb 94
6.85	NAVD88	Dec 96
6.42	NAVD88 (2004.65)	10 Feb 06
6.38	NAVD88 (2004.65)	11 Feb 06
→ 6.30 est	LMSL (1960-1978)	pub
6.13 est	LMSL (1983-2001)	2005
TBD	LMSL (2001-2005)	(May 2006)

1990s floodwall construction was referenced to a 1982 terrestrial datum ... not LMSL

Orleans Avenue Outfall Canal

Design v Constructed Floodwall Elevations



(Not to Scale)

Orleans Avenue Outfall Canal

Design v Current Protection Elevations

Section	Elevation in feet (LMSL 1983-2001) Design	Current	Difference
West Bank			
Filmore to Harrison (T)	14.0	13.2	0.8
East Bank (I-Wall)			
Filmore to Harrison	14.8	13.6	1.2
RE Lee to Filmore	14.4	13.2	1.2
Harrison to I-610 PS#7	14.9	13.6	1.3

LMSL (1983-2001) reference datum is estimated/provisional (March 2006)

IHNC East Levee Floodwall Capping (1970)

IHNC Lock to Florida Ave Sta. 0+00 to 56+20

Periodic Adjustments to Benchmark M 152

(Used as Reference for Floodwall Construction DACW29-70-B-0088 As-Built)

ELEV FT	DATUM	ADJUSTMENT
22.090	NGVD29	1951
22.697	NGVD29	19 Mar 52
21.070	NGVD29	1951/01 Sep 82
21.811	NGVD29	1963/09 Apr 65
21.811	**MSL**	**1969 Contract Plans**
21.071	NGVD29	1963/01 Sep 82
21.070	NGVD29	1982
21.148	NGVD29	1985/30 Jan 86
20.96	NGVD29	21 Jun 91
20.963	NGVD29	1995
20.76	NAVD88	14 Feb 94
20.81	NAVD88	Dec 1996
20.34	NAVD88 (2004.65)	10 Nov 05
TBD	LMSL (1983-2001)	(May 2006)
TBD	LMSL (2001-2005)	(May 2006)

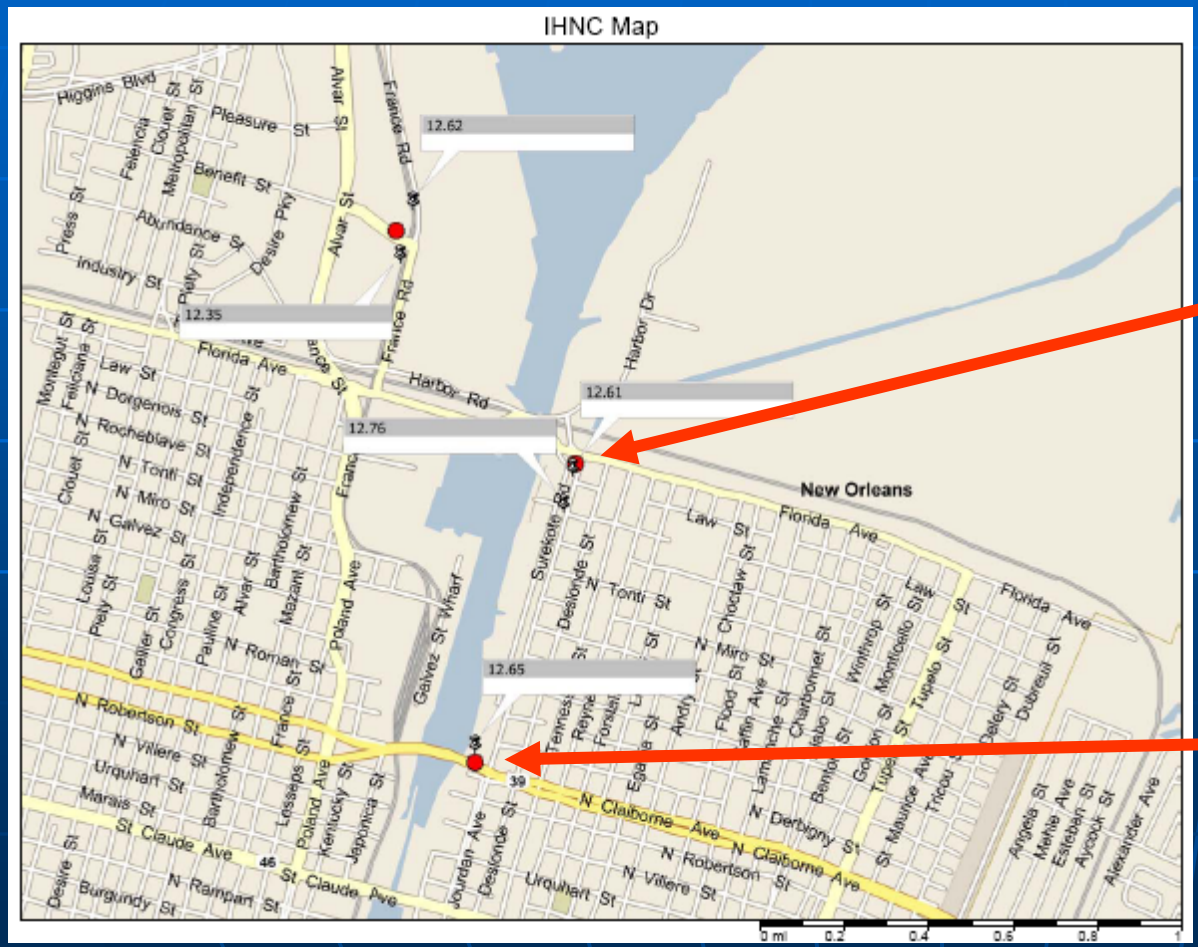
Terrestrial geodetic datum varies 2 ± feet from 1951 to date

Late 1960s floodwall design MSL elevation was referenced to the most current USC&GS terrestrial datum … ie, 1963/1965 adjustment … the relationship between this geodetic datum and LMSL not yet determined

IHNC East Levee Floodwall Capping (1970)

IHNC Lock to Florida Ave Sta. 0+00 to 56+20

Current (Pre & Post-Katrina) Floodwall Elevations
(IPET and MVN Topographic Surveys)



Designed/Constructed to 15.0 ft MSL

North of Breach

South of Florida Ave

12.3 to 12.5 ft ~LMSL (1983-2001)

South of Breach

North of Claiborne Ave

12.4 to 13.2 ft ~LMSL (1983-2001)

FINDINGS
New Orleans Lakefront Outfall Canals

- Constructed floodwall elevations in 1990s less than “MSL” design elevations
- Terrestrial geodetic datums (eg, NGVD29) used as a reference instead of water level-based datums (ie, MSL or LMSL)
  - Standard Engineering practice to use NGVD29 as the “Mean Sea Level” or “Local Mean Sea Level” value
- Subsidence or settlement from early 1990s to date does not appear significant relative to datum anomalies

Tentative Recommendations Resulting from Evaluation

- Clearly distinguish in engineering applications geodetic reference datums (ie, NAVD88) versus water level reference datums (ie, LMSL, LWRP)
  - Hydraulic design & modeling
  - Flood protection & flood inundation elevation references
  - Terrestrial mapping
  - Construction surveying & stakeout
- Establish permanent GPS and tide station network throughout region
  - Monitor subsidence and periodically update protection levels (NOAA)
- Engineering & construction surveying practices
  - Details in report

Field Survey Support to Other IPET Teams

- Commenced field surveys on 4 December 2005
- Target completion date was 31 January 2006 ... still ongoing as of mid-March 2006
- A-E Contractor: 3001, Inc. (1 to 3 survey crews in field during past 3 months)
- Responded to over 20 survey requests from other IPET Teams for basic topographic & hydrographic data needed in modeling efforts … similar to 30% Report (HWM, structure elevations, topo, hydro, etc)
- Primary field survey effort to date … 75% of funding


Questions?

For following slides are for reference purpose only

Geodetic Vertical and Water Level Datum Summary

- Entire Gulf Coast region (especially southern Louisiana)
  - Experiencing significant subsidence
  - Considerable uncertainty with regard to the precise elevations of flood protection structures and their relationship to the local water surface
  - Need consistent vertical datum and water level (local mean sea level) relationship

Difference Between NGVD29 and NAVD88 (2004.65)

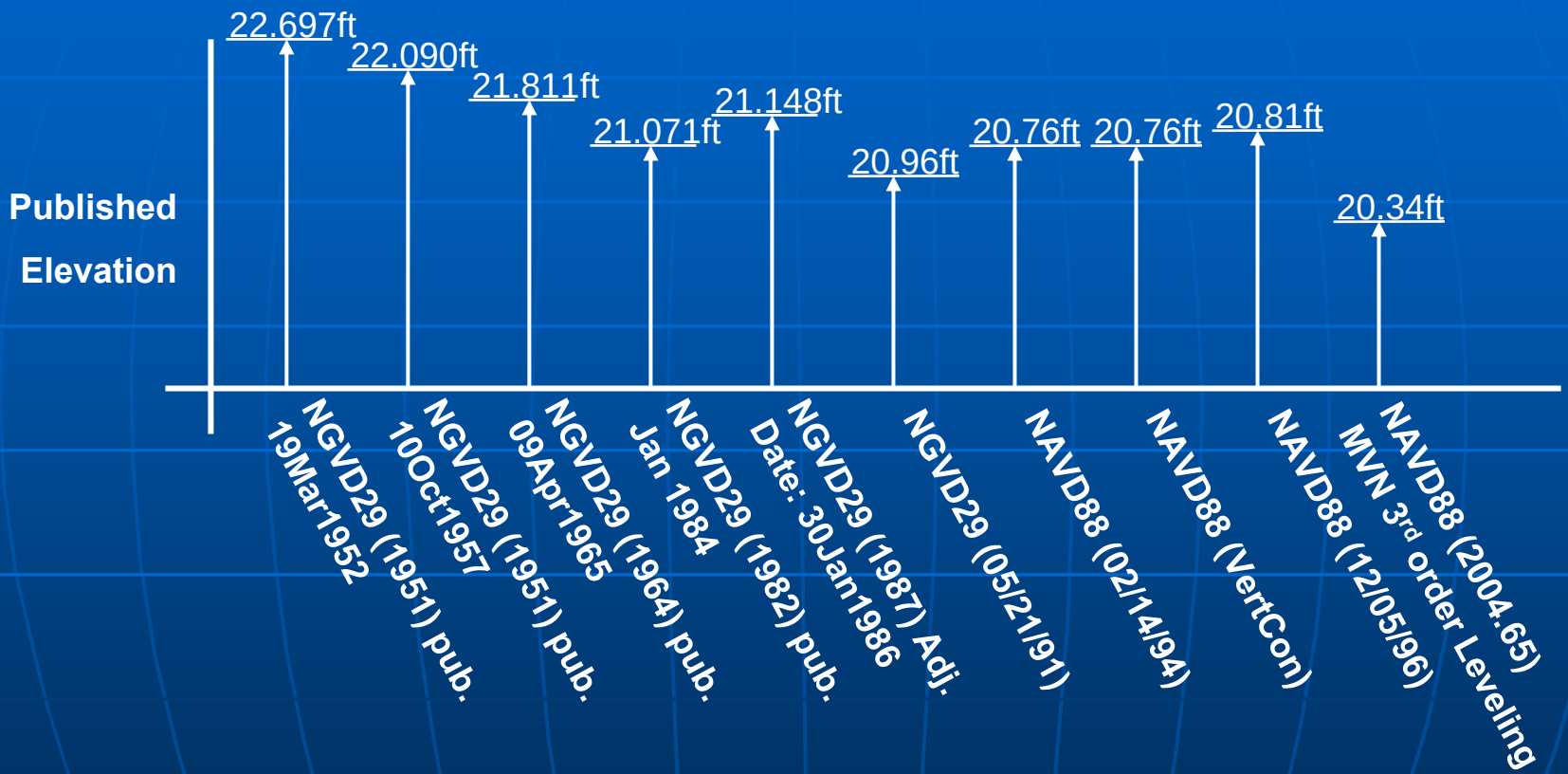
This difference is comprised of three factors.

1. *Datum Shift:* The zero reference was changed from NGVD29 to NAVD88 (2004.65). This has nothing to do with the physical elevation with respect to sea level. This is only a change in where the elevation is measured from.
2. *Error in the Old Elevation:* Due to regional subsidence, the previously published NGVD elevations were inaccurate. Because the marks held fixed were in fact subsiding, the fixed elevations were inaccurate which caused all elevations in the local network to become obsolete. This amount of error is unknown.
3. *Subsidence:* Southern Louisiana is sinking due to many factors. This process causes our vertical control to become inaccurate as the elevations change, unless monitored.

BOTTOM LINE: NGVD (or assumed MSL equivalency) cannot be used as an elevation reference … the updated NAVD88 epoch and its relationship to current LMSL must be used

Changes in the Published Heights (Elevations) for

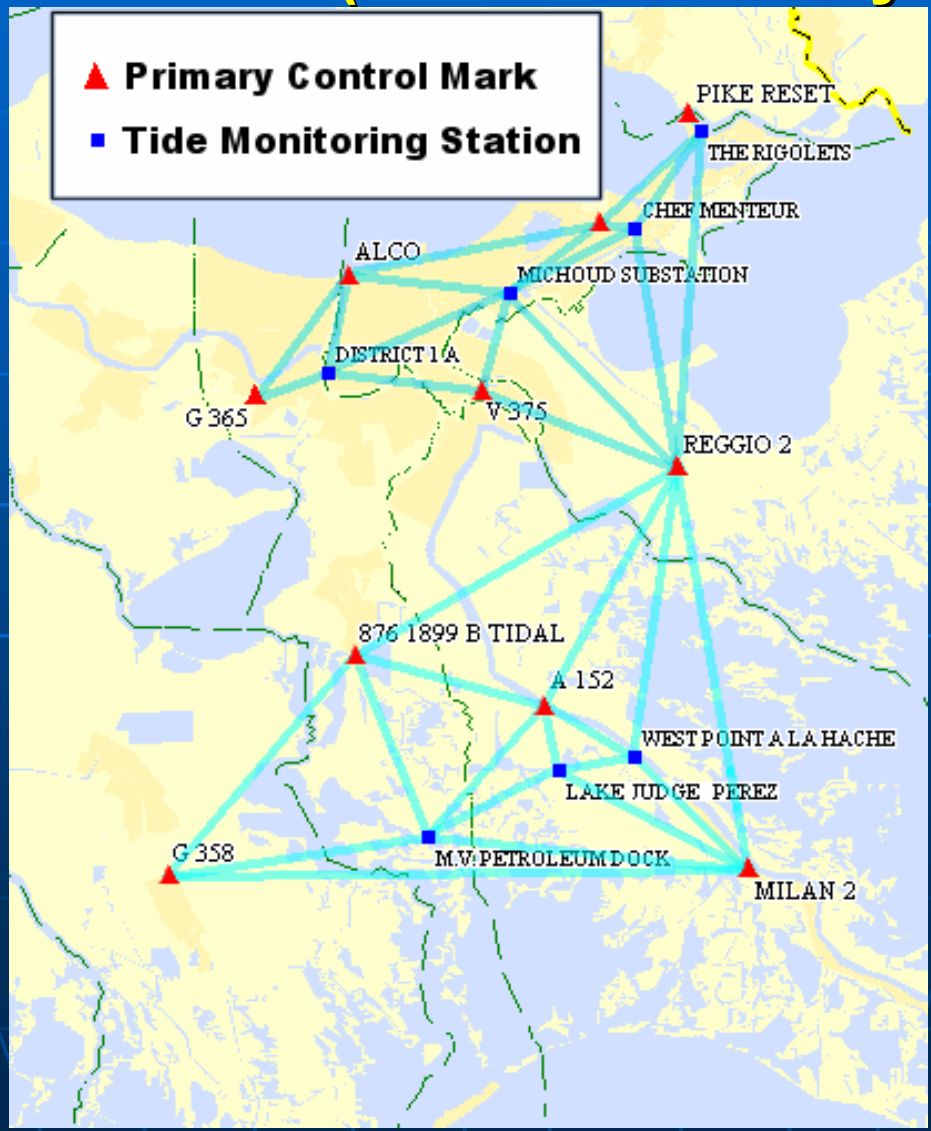
Benchmark "M 152" (PID: AU0668)



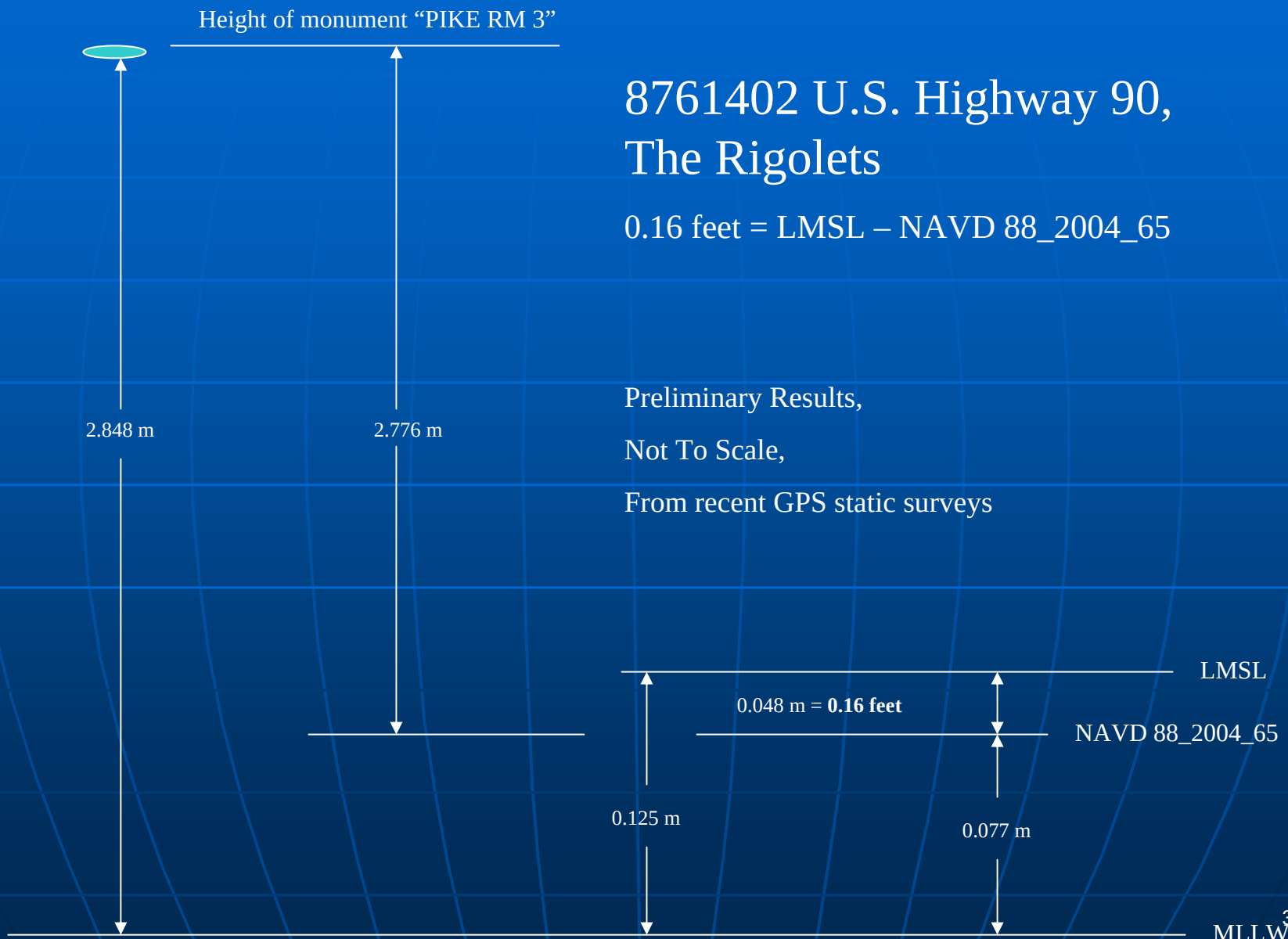
The changes in the above values point out the problem of errors in various adjustments on the datum(s) and not a direct solution to it.

Source: NOAA (NGS and NOS) and USACE-MVN [not to scale]

Static GPS Survey Connections between NAVD88 (2004.65) Benchmarks and NOAA Tidal Gage Stations (Phase 1 Surveys)



LMSL - NAVD88 2004.65 Relationship Calculation



8761402 U.S. Highway 90, The Rigolets

0.16 feet = LMSL – NAVD 88_2004_65

Preliminary Results,

Not To Scale,

From recent GPS static surveys

Geodetic Vertical and Water Level Datum Team

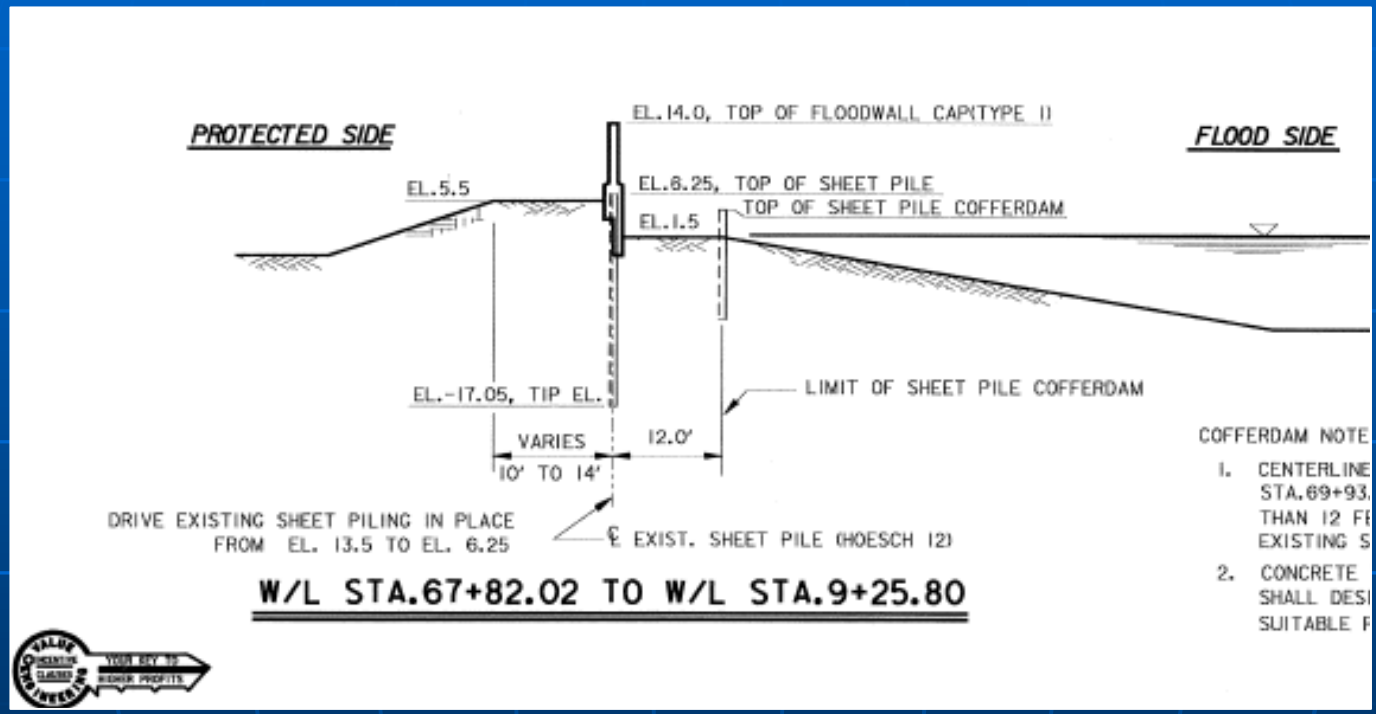
- Jim Garster, ERDC-TEC, Co-Lead
- Dave Zilkoski, NOAA-NGS, Co-Lead
- Bill Bergen, USACE-HQ, Co-Lead
- Mike Szabados, NOAA CO-OPS, Co-Lead
- Jerry Hovis, NOAA CO-OPS
- Tom Landon, NOAA CO-OPS
- Ronnie Taylor, NOAA NGS
- Brian Shannon, ERDC-TEC
- Jeff Navaille, USACE SAJ
- Mark Huber, USACE MVN
- Bob Mesko, USACE MVS

A-E Survey Contractor Support Team:
3001, Inc., New Orleans, LA—John Purpera

17th Street Outfall Canal
East Bank Floodwall Construction

ca 1991-1994 Floodwall Protection/Capping Projects (High Level Plan)

Hammond Hwy to Veterans Blvd Sta 8+50 to 80+00 (±) -- Typical



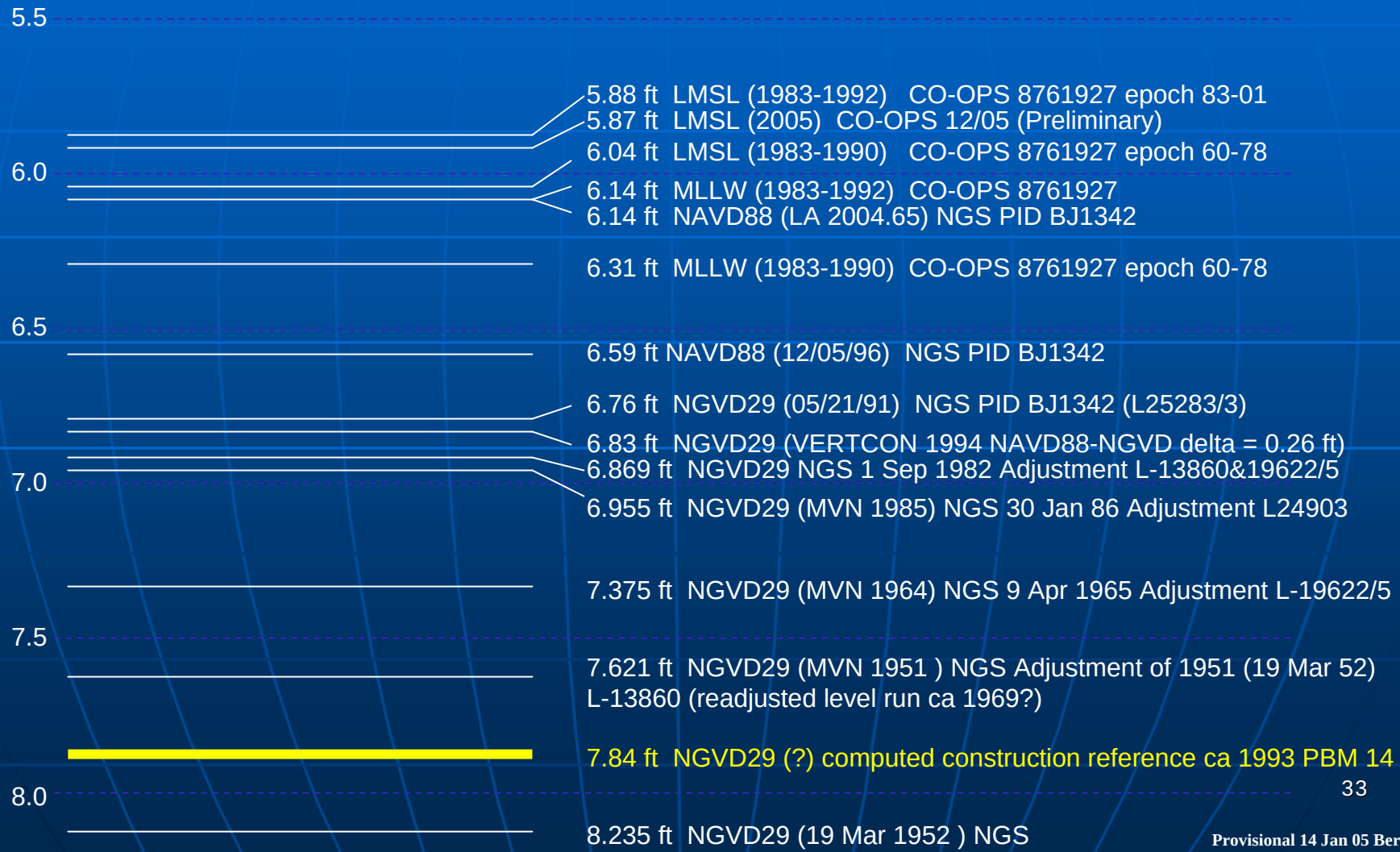
14.0 ft design elevation on MSL:

- 11.5 ft SPH Still Water Elevation from Lake Pontchartrain
- 2.0 ft Freeboard
- 0.5 ft Settlement

Assumed Lake Pontchartrain Normal Water Level = 0.0 ft MSL

Various Reference Datums at BM ALCO 1931 (17th Street Canal)
NOAA CO-OPS Gage 8761927 – New Canal
1951-2005

17th Street Outfall Canal
East & West Bank Floodwall Construction
ca 1991-1994 Floodwall Protection/Capping Projects (High Level Plan)



17th Street Canal Floodwall Elevations
East Side Levee Improvements—Floodwall Capping (1993)--Typical
Construction Reference Benchmark USCE Monument 14
Elevation "8.77 ft NGVD" – only vertical reference point in contract drawings