Appendix B: Structural Design and Analysis
(by URS Corporation)

D R A F T   R E P O R T

IN-DELTA STORAGE PROGRAM INTEGRATED FACILITIES STRUCTURAL ENGINEERING DESIGN AND ANALYSIS

Prepared for
CH2M Hill
155 Grand Avenue, Suite 1000
Oakland, CA 94612-2681

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URS

URS Corporation
500 12th Street, Suite 200
Oakland, CA 94607-4014

26814230

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1.1 PURPOSE

The Department of Water Resources (DWR) is conducting feasibility-level engineering and environmental studies under the Integrated Storage Investigations Program. As part of the project evaluations, DWR is evaluating the technical feasibility and conducting engineering investigations for the In-Delta Storage Program. Engineering investigation will aim at developing solutions to enhance project reliability through improved embankment design and consolidation of inlet and outlet structures.

1.2 SCOPE OF WORK

As part of this feasibility study, the Department requests that CH2M HILL, with its subcontractor, URS Corporation (URS) carry out the following tasks: perform structural engineering design of inlet/outlet structures, pumping stations, sheet pile walls, and structural components of the fish screens; work with DWR staff, and prepare a report on the structural feasibility of the proposed facilities. The work will be conducted in accordance with all applicable standards and guidelines contained in Standard Agreement No. 4600001841 and in coordination with Department staff.

The structural design criteria and general facility arrangements prepared by DWR staff will be used. This work will ultimately be used to complete the estimation of quantities and perform a feasibility level cost estimate as required under Task Order Number IDS-1102-1747-008.

The scope of work consists of the following tasks:

Task 1 - Structural Engineering Analysis and Design

Prepare State feasibility level structural analysis and design in sufficient detail to allow a feasibility-level cost estimate for the four proposed integrated facilities to be completed. The four integrated facilities, described in the In-Delta Storage Program's Draft Report on Engineering Investigations (DWR, 2002), as currently envisioned include: fish screens, inlet/outlet structures, pumping stations and conduits, conveyance channels, sheet pile walls and associated structural facilities. Structural design shall consider the subsurface conditions at the four proposed facility locations on Webb Tract and Bacon Island. DWR will provide information related to existing subsurface conditions. Design drawings (draft) will be provided by DWR. General arrangements and site plans will be provided. DWR staff will assist the Contractor with the completion of feasibility level design drawings.

Task 1.1 - Fish Screens

Prepare State feasibility level structural analysis and design for the structural components of the fish screen structure. These components include wing retaining walls, bridge piers, base slab, cutoffs, bridge deck/roadway, and all metalwork. Driven piles or suitable foundation is to be designed using the geotechnical laboratory information provided by DWR.

Task 1.2 - Inlet/Outlet Structures

Perform structural design for the structural components of the three gated structures at each site. These inlet/outlet structures will use vertical slide gates that will be mechanically operated. The structures will include base slab, vertical wing walls, cutoff walls, suitable foundations, and a bridge deck spanning the gated structure and connecting with the engineered embankments.

Task 1.3 - Pumping Stations and Conduit

Provide technically feasible design for structures associated with the pumping stations and conduits. The pumping stations will be housed inside a superstructure supported by suitable foundation materials. The conduits will run from the reservoir side of the integrated facility to the bypass channel and will require suitable pipe supports/collars to prevent cracking from differential settlement of the engineered embankments. Adequate foundation materials will be selected and designed for both the pumping station superstructure and the conduit such that settlement, cracking and tilting do not cause structural distress. DWR will provide details on the preferred pumping units proposed and necessary hydraulic components for the facility, including gates.

Task 1.4 - Sheet Pile Walls

Determine required depth into soil and height above ground for the sheet pile walls designed as part of the bypass channel at each site. Determine structural stability and recommend sheet pile materials suitable for each site. The sheet pile wall will be connected on the upstream end to the engineered embankment and on the downstream end to both the trash rack and the fish screen.

Task 2 - Structural Write Up For the Report on Engineering Investigations

Provide required technical report for structural analysis and design of the integrated facilities for each site. The technical report will document design basis and assumptions, procedures, results, and drawings related to the analysis of pertinent structural components and foundations for the integrated facilities.

2.1 DATA FOR SITE FACILITIES

The general integrated facility arrangements prepared by DWR will be used in feasibility-level structural design. The site vicinity is shown on Figure 1 and the four proposed facility locations on Webb Tract and Bacon Island are shown on Figure 2. Refer to Table 2-1 for Integrated Facility Elevations, and Appendix C for plans prepared by DWR.

2.2 OBJECTIVE

The structural design criteria are based on the preliminary design criteria prepared by DWR staff. The objective of structural design criteria is to establish the structural design standards for the following structures:

- Inlet/Outlet Structures
- Pumping Stations
- Conduit Supports, Collars, Apron and Equipment slabs, Cut-off Walls and Thrust Blocks
- Fish Screen Supports and Decks
- Bypass Channel Bridge Structure and Trash Rack
- Vaults
- Sheet Piling for Bypass Channels

2.3 DESIGN CODES

Reinforced concrete design shall be in accordance with the 2001 California Building Code (CBC) and American Concrete Institute ACI 318-95, Building Code Requirements for Reinforced Concrete.

2.4 DESIGN LOADS

The loads and forces in this section shall apply to all structures, structural components and structural supports designed as part of this scope of work. The load types are summarized below:

- Dead Load (D)
  - For normal weight concrete, a unit weight of 150 pcf shall be assumed.
  - For structural steel, a unit weight of 490 pcf shall be assumed.
  - Equipment, trash racks, gates, fish screens and piping weights shall be based on information provided by DWR.
- Lateral Earth Pressures (H)
  - Lateral loads from soil, at-rest, active, passive, and seismic earth pressures shall be considered. Pressure diagrams shall be developed as a function of depth for idealized soil profiles based on site-specific soil properties at individual structure locations.

- Hydrostatic Loads (F)
  - For calculating lateral loads from water and buoyancy affects, a unit weight of 62.4 pcf shall be assumed and shall be considered for applicable tide levels and operating reservoir water levels as well as the 100-year flood stage level for storm events. The corresponding elevations are provided in Table 2-2.
  - Uplift pressures shall be considered for the following dewatering scenarios:
    - Fish Screen (at least one bay at a time)
    - Transition Pool (behind the fish screen rear stoplogs)
      - Sheet pile wall will need to support hydrostatic loads when transition pool is dewatered for maintenance purposes
    - Midbay (full dewatering)
    - Reservoir (periodically emptied)
    - All gate structures will have stoplogs provided to allow dewatering
- Hydrodynamic Loads (Q)
  - Hydrodynamic loads from water developed in a seismic event, although considered, were found not to be applicable.
- Wave/Wind Action Loads (P)
  - Sheet piling shall be designed to withstand wave/wind effects as defined in the Flooding Analysis draft report (URS, 2002).
- Live Loads (L)
  - Shall include the HS20 vehicle load with impact.
  - Shall include 100 psf or 1000 pound concentrated load to account for foot traffic.
  - Shall include vibration effects resulting from operation of equipment.
- Seismic Design Criteria (E)
  - Based on the preliminary foundation design analyses presented in this report, we expect that the majority of the structures for the integrated facilities will be supported on driven pile foundations. These pile foundations will be founded in the stiffer and denser soils present beneath the near-surface clays and peat soils. Since these near-surface soils are very soft, we expect that ground motions will be transmitted to the structures primarily through the stiff pile foundations supporting the structures.
  - A smoothed horizontal acceleration response spectrum associated with a particular seismic hazard level was previously developed for the project (Seismic Analysis, URS, 2003). The selected seismic event corresponds to ground motion having a 10% probability of exceedence in 50 years (i.e., return period of about 475 years). This target spectrum represents free-field motions for the outcropping stiff soil site condition. In order to develop the ground motions that are transmitted to the structure through the pile foundations, the target spectrum was deconvolved to the deeper stiff soil layer using the

computer program SHAKE to obtain the ground motions at the pile depth of fixity. This response spectrum is shown in Figure 3.

2.5 DESIGN METHODS

2.5.1 Reinforced Concrete Design

All reinforced concrete design shall be in accordance with the ACI Strength Design Procedures and USACE EM1110-2-2104, Strength Design for Reinforced Concrete Hydraulic Structures (1992).

2.5.2 Deep Foundation Design

Deep foundation design shall be in accordance with USACE EM 1110-2-2906 (1991) and design of sheet pile foundations shall be in accordance with EM 1110-2-2504 (1994).

2.6 DESIGN CONSIDERATIONS

2.6.1 General

All designs shall provide for adequate structural dimensions in accordance with the following:

- Stability with respect to sliding, overturning and uplift (USACE EM 1110-2-2502, 1989):
  - F.S. = 3.0 for D+H, overturning
  - F.S. = 1.5 for D+H, sliding and uplift
  - F.S. = 1.0 for D+E, overturning
  - F.S. = 1.1 for D+E, sliding
- Minimize differential settlement
- Control of scour
- Prevention of piping
- Pile foundations with the following factors of safety:
  - F.S. = 3.0 for D+L+H+F+P
  - F.S. = 1.7 for D+L+H+F+E
- Drainage provision where water may accumulate (including pumping plant floor slabs, stairwells, conduits, etc.)

2.6.2 Reinforced Concrete Design

Design shall provide for the appropriate concrete thicknesses and steel reinforcement patterns for structural members to resist bending moment, thrust and shear effects imposed by reasonable loads on the structure. The following factored load combinations shall apply:

- Load Combination 1: 1.3*{1.5*D+1.7H}
- Load Combination 2: 1.4*D+1.5*E

2.7 MATERIAL STRENGTHS

Concrete

The minimum 28-day compressive strength of concrete for reinforced concrete structures shall be 4000 psi.

Reinforcing Steel

Reinforcing steel for concrete reinforcement shall conform to ASTM A615 or A706, fy=60 ksi. Plain wire for welded wire fabric shall comply with ASTM A82.

Sheet Pile Walls

Strength of sheet piling shall conform to ASTM A572, Grade 55.

Miscellaneous Steel Components

Steel components exposed to salt water and salt water sprays shall conform to ASTM A36 (as specified in U.S. Army/TM 5-809-6 Air Force AFM 88-3, Chapter 6).

2.8 MATERIAL COATINGS

All steel components shall be either stainless steel, painted with an anti-corrosion coating system, or hot-dipped galvanized.

Table 2-1
Integrated Facility Elevations*

Structural Component	Item	Description	Location: Webb Tract San Joaquin River	Location: Webb Tract False River	Location: Bacon Island Middle River	Location: Bacon Island Santa Fe Cut
Fish Screen	**Screen Dimensions**	Screen Length (vertical direction)	15	18	15	12
		Screen Width (horizontal direction)	7.5	7.5	7.5	7.5
	Elevations	Top of Screen	2.49	2.39	2.49	2.59
		Bottom of Screen (Sill) @ Screen Face	-12	-15	-12	-9
		Top of Bottom Slab @ Downstream End	-12.3	-15.3	-12.3	-9.3
		Deck (Top of Embankment)	11	11	10.2	10.4
	Overall	Total Facility Width	933	768	933	1108
		Number of Bays	54	44	54	64
		Clear Span Between Piers	20	20	20	20
Gate Structures	**Gate #1**	Sill Elevation (Top of Bottom Slab)	-12	-15	-13	-8
		Deck Elevation (Top of Embankment)	11	11	10.2	10.4
	Gate #2	Sill Elevation (Top of Bottom Slab)	-18	-18	-16	-16
		Deck Elevation (Top of Embankment)	11	11	10.2	10.4
	Gate #3	Sill Elevation (Top of Bottom Slab)	-15	-16	-12	-8
		Deck Elevation (Top of Embankment)	11	11	10.2	10.4
Midbay		Floor Elevation	-24	-24	-22	-22
Conduit	**Invert Elevations**	Reservoir Side	-12	-12	-10	-10
		Bypass Channel Side	-12	-12	-10	-10
Reservoir	**Finished Grade Elevations**	@ Gate #2 Outlet	-18	-18	-16	-16
		@ Conduit Outlet	-18	-18	-16	-16
Bypass Channel	**Finished Grade Elevations**	@ Conduit Outlet	-15	-16	-12	-8
		@ Gate #3 Outlet	-15	-16	-12	-8
		@ Connection to River Channel	-16	-17	-13	-9
		Bottom Width	30	30	40	70
	Sheet Pile Wall	Top Elevation	11	11	10.2	10.4

* from DWR design criteria.

Table 2-2
Integrated Facility Water Surface Elevations*

Item	Description	Integrated Facility Location							
		Webb Tract San Joaquin River		Webb Tract False River		Bacon Island Middle River		Bacon Island Santa Fe Cut	
		River to Reservoir	Reservoir to River	River to Reservoir	Reservoir to River	River to Reservoir	Reservoir to River	River to Reservoir	Reservoir to River
Plant Forebay & Afterbay Water Surface Elevation	Maximum	6.8	4	6.4	4	6.8	4	6.8	4
	Normal	-1		-1		-1.1		-1.1	
	Minimum	-1.7	-18	-1.5	-18	-1.7	-16	-1.7	-16

* from DWR design criteria.

This section describes the feasibility design geotechnical analyses performed for the In-Delta Storage Integrated Facilities. In these analyses, lateral earth pressures were calculated for design of the structures, structure foundation alternatives were evaluated, axial and lateral capacities for pile foundations were developed, and design analyses were performed for the sheet pile wall.

3.1 SUMMARY OF SOIL CONDITIONS

The subsurface conditions at the four integrated facility sites are similar, and consist of soft clays and peat soils overlying denser and stiffer interbedded sands and clays. Several soil borings were performed at Bacon Island and Webb Tract and laboratory testing data were considered to evaluate soil conditions. However, cone penetration tests (CPTs) recently performed by the Bureau of Reclamation were in the closest proximity to the four integrated facility sites and, therefore, the results of these CPT investigations were used to characterize the stratigraphy and strength profile with depth at the I/O structure sites. The results of previous investigations including the CPT logs are contained in the Borrow Area Geotechnical Report (URS, 2003). The soil conditions at the four integrated facility sites are summarized below:

- Webb Tract:
  - San Joaquin River Integrated Facility (northern facility) (CPTs WSC-11, -13, and –15): approximately 40 feet of soft soils overlying stiffer and denser clays and sands.
  - False River Integrated Facility (southern facility) (CPTs WSC-16, -17, and –18): approximately 20 feet to 25 feet of soft soils overlying stiffer and denser clays and sands.
- Bacon Island:
  - Middle River Integrated Facility (northern facility) (CPTs BSC-1 and –2): approximately 20 feet of soft soils overlying stiffer and denser clays and sands.
  - Santa Fe Cut Integrated Facility (southern facility) (CPTs BSC-12 and –13): approximately 25 feet to 30 feet of soft soils overlying stiffer and denser clays and sands.

3.2 LATERAL EARTH PRESSURES

It is anticipated that the integrated facility structures will be founded in new fill material placed for the embankment construction. Computation of earth pressures in new fill are based on the soil properties presented in the Embankment Design Analysis (URS, 2002). The earth pressures in Table 3-1 are expressed as equivalent fluid weights, and are presented for unsaturated (above groundwater level) and saturated (below groundwater level) conditions. The seismic loads presented in Table 3-1 are based on the design peak horizontal ground acceleration shown on Figure 3.

Table 3-1
Lateral Earth Pressures and Seismic Loads for New Fill Materials

Case	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)	Active Case (pcf)	Passive Case (pcf)	At-Rest Case (pcf)	Seismic Loads (2) (lbs/ft)
Unsaturated	110	30	0	37	330	55	11 H^2
Saturated (1)	120	30	0	82	173	91	12 H^2

Notes:
1) Active and at-rest equivalent fluid pressures for saturated case include hydrostatic pressure of 62.4 pcf
2) For seismic loads, H is the height of the wall in ft, expressed in lbs/ft of wall, and acts at a height of 0.6 H above the base of the wall.

3.3 AXIAL PILE CAPACITY

Due to the magnitude of the loads imposed by the structures, and the very soft near-surface soils, the structures will need to be pile-supported. Precast prestressed concrete piles are recommended as they are frequently used in marine applications, have good load-carrying capacity, can be installed efficiently, and are relatively economical. For preliminary design purposes, a 14-inch square precast prestressed pile was selected, which has an allowable capacity of 45 tons.

The cone penetration test results at each of the four integrated facility sites were interpreted using the LCPC method of Bustamante and Gianeselli (1982) to obtain pile capacity versus depth diagrams. Contributions from both skin friction and end-bearing were included in the capacity calculations. These diagrams are presented in Figures 4 through 7. Following the recommendations presented by the USACE in Design of Pile Foundations (1991) for “usual” loading conditions, a factor of safety of 3.0 on working loads was applied. A factor of safety of 1.7 is recommended for “extreme” loading conditions, i.e., seismic case. In accordance with USACE (1991), the use of pile load tests or a pile driving analyzer would reduce the required factors of safety.

Given a factor of safety of 3.0 and a working load of 45 tons, the capacity versus depth diagrams were evaluated to determine the depth at which an ultimate capacity of 135 tons could be achieved. The ultimate capacity was attained at the following pile tip elevations:

- Webb Tract, San Joaquin River Integrated Facility (northern facility): -65 feet
- Webb Tract, False River Integrated Facility (southern facility): -50 feet
- Bacon Island, Middle River Integrated Facility (northern facility): -70 feet
- Bacon Island, Santa Fe Cut Integrated Facility (southern facility): -65 feet.

Uplift capacity is calculated as 70 percent of downward capacity to account for deduction of end-bearing capacity. The analyses take into account downdrag forces acting on the piles to account for consolidation of the new fill.

3.4 LATERAL PILE CAPACITY

The lateral capacity of the 14-inch square precast piles was computed using the program LPILE (Ensoft, Inc., 2000). A soil profile representing the average of the four integrated facility sites was modeled. LPILE options for fixed head conditions, nonlinear EI, and prestress forces were included in the analyses. The average pile tip elevation of –65 was modeled. Three pile head elevations at –11, –16, and –21 feet were considered to represent the range of pile head elevations that will be used for the integrated facility structures.

Pile head load-deflection curves were developed for these three cases, and are presented in Figure 8. It is expected that piles will be arranged in groups at spacings of 3 to 5 pile diameters on center. To account for group effects in the soft soils, a group reduction factor of 0.9 is used for lateral capacity calculations. Group effects should be refined during final design with pile group analyses. Further design may also consider the use of batter piles to resist lateral loads.

3.5 SHEET PILE WALL

The cantilever sheet pile wall that forms the bypass channel was analyzed. Average soil conditions consisting of soft clay/peat to elevation –30 feet, underlain by stiff clays and dense sands were modeled. The top of the sheet pile wall was modeled at elevation +11, water in the bypass channel at elevation +7, and the scenario of the pool dewatered to the sill elevation at the respective structures (ranging from – 8 to –15 feet). The lateral pressures due to the 15 feet to 22 feet of head differential induce bending moments were estimated to be in the range of approximately 291 kip-feet/foot to 520 kip-feet/foot. In the absence of tieback anchors, these high bending moments will be resisted by a combination H-pile/sheet-pile wall.

In accordance with standard sheet pile design practice, the sheet pile tip elevations calculated for equilibrium have been increased by 30 percent. The computation of section modulus is based on specifying Grade 55 steel, and applying a factor of safety of 1.5. For feasibility design, sheet pile sections offered by Skyline Steel/Arbed as part of their HZ Steel Wall System were selected. Table 3-2 presents the sheet pile wall maximum bending moments, tip elevations, required section modulus, and HZ section. Further design analyses will be needed to verify that estimated deflections are tolerable.

Table 3-2
Summary of Sheet Pile Analysis Results

Structure	Recommended Sheet Pile Wall Tip Elevation (ft)	Maximum Bending Moment (k-ft/ft)	Section Modulus (in^3/ft)	Recommended Section (HZ Wall System)
Webb Tract San Joaquin River	-59	429	140.4	HZ 975A – 14/AZ13
Webb Tract False River	-62	520	170.2	HZ 975D – 14/AZ13
Bacon Island Middle River	-60	461	150.9	HZ 975B – 14/AZ13
Bacon Island Santa Fe Cut	-54	291	95.2	HZ 775B – 12/AZ18

Corrosion protection/cathodic protection would be required for the sheet pile wall.

This section describes the feasibility-level design of the structural elements of the In-Delta Storage Integrated Facilities. These analyses applied the load combinations, factors of safety and design methodology defined in the Design Criteria (Section 3) for this project, and determined the structural requirements for the structural elements of the Integrated Facilities as shown on the DWR drawings in Appendix C. The design approaches used in these analyses are presented in the sections that follow.

4.1 BOX CULVERT STRUCTURES

Recognizing the similarities between the fish screen supports and decks, the bypass channel bridge structure and trash rack, and the inlet/outlet (I/O) structures, a reinforced concrete box culvert section was determined to be most appropriate. Refer to Appendix C for details.

A 2-D finite element model SAP 2000 (Computers and Structures, Inc., 2003) of the structure was used for the analysis. The structures were designed to carry HS-20 live loads, dead loads from trash racks, screens and gates as well as lateral pressures from soil and water, including seismic loads where appropriate, as described in Section 2. For the fish screen structure, self-weight and operating loads from the cleaning unit equipment were also accounted for in the analysis. The results of the analysis are shown in Table 4-1. Thickness requirements for the concrete members as well as main reinforcement requirements are provided. For the purposes of preparing a feasibility-level cost estimate, minimum reinforcing may be assumed for the other reinforcement.

4.2 RETAINING WALLS

Cantilevered reinforced concrete retaining walls were designed for use at the ends of the I/O structures, along the approaches to the bypass channel bridge structure, and at the outlet structures for the conduits. A range of wall heights was analyzed where the top of footing elevation was assumed to be two feet below the top of the adjacent apron, as shown in Appendix C. The walls were designed to resist lateral pressures from soil and water, including seismic effects, as described in Section 2. The results of the analysis are shown in Table 4-1. Thickness requirements for concrete members as well as main reinforcement requirements are provided for various wall heights. For the purposes of preparing a feasibility-level cost estimate, minimum reinforcing may be assumed for the other reinforcement.

4.3 PUMP STATION

A feasibility-level design for the pump station was performed. Where required, the SAP 2000 finite element model of the structure was used for the analysis. Exterior walls were designed to resist lateral pressures from soil and water, including seismic effects, as described in Section 2. Significant equipment loads necessitated the use of reinforced concrete beam floor systems. The results of the analysis are shown in Table 4-1. Locations of the various elements described in Table 4-1 are shown in Appendix C.

Member sizes and main reinforcement requirements are provided for various elements. For the purposes of preparing a feasibility-level cost estimate, minimum reinforcing may be assumed for the other reinforcement.

4.4 VAULT STRUCTURES

Feasibility-level designs were prepared for the vault structures that house mechanical equipment near the gates for the I/O structures and for the vault structures that house the butterfly valves in the conduit pipes. Approximate member sizes and main reinforcement requirements are provided for various elements. For the purposes of preparing a feasibility-level cost estimate, minimum reinforcing may be assumed for other reinforcement. Pile requirements are also provided in Table 4-1. Additional details are presented in Appendix C.

4.5 OTHER STRUCTURES AND PILE REQUIREMENTS

Feasibility-level designs for conduit supports, pipe collars, equipment slabs, apron slabs, cut-off walls and thrust blocks were performed and structural requirements for these elements are provided in Table 4-1.

Pile requirements are shown in Table 4-1. Except for the retaining walls, a lateral displacement of 1-inch was assumed at the pile heads. A 1½-inch lateral displacement for the retaining walls was assumed. The pile heads were assumed to be fixed against rotation at the bottom of the structures.

Table 4-1. Summary of Structural Design Analysis Results

BOX CULVERT STRUCTURES						
Element	**Thickness (ft)**	**Main Reinf. Ratio**	**No. Piles**			
Roof slab	1.5	0.007	9piles per 500 sq. ft.			
Exterior wall	2.0	0.011				
Interior wall	2.0	0.007				
Foundation slab	3.0	0.003				
RETAINING WALL STRUCTURES						
Wall Height	**Thickness (ft)**	**Base of Wall (1H:15V batter)**	**Footing**		**No. Piles**	**Spacing**
		Main Reinf. Ratio	**Width (ft)**	**Thickness (ft)**	**per Row**	**btwn Rows**
6' to 15'	1.7	0.003	10	2.5	2	5'-0"
16' to 27'	2.0	0.016	30	3	6	4'-0"
28' to 37'	3.0	0.013	41	3	8	4'-0"
PUMPING PLANT						
Location	**Element**	**Dimensions (in)**	**Main Reinf. Ratio**	**No. Piles**		
Upper Level	Beam "A"	30 x 36	0.018	100 piles total		
	Beam "B"	18 x 24	0.018			
	Floor Slab	7	0.009			
	Wall Thickness	12	0.009			
Middle Level	Beam "C"	18 x 24	0.018			
	Floor Slab	7	0.009			
	Wall Thickness	18	0.011			
	Columns	36 x 36	0.03			
	Invert Slab Thick.	18	0.005			
Lower Level	Wall Thickness	24	0.009			
	Columns	36 x 36	0.03			
	Invert Slab Thick.	24	0.005			
VAULT STRUCTURES						
Wall Height (ft)	**Thickness at Base of Wall (ft)**	**Base of Wall (1H:15V batter)**	**Invert Slab**		**No. Piles**	
		Main Reinf. Ratio	**Thickness (ft)**	**Reinf. Ratio**	**per 100 sf**	
9	1.7	0.003	2.5	0.008	4	
28	3	0.011	3	0.011	4	

OTHER STRUCTURES					
Element	**Material**	**Volume**	**Location**	**Pile Supports**	**Reinf. Ratio**
Pipe Supports (not buried)	Concrete	3cy/ea	Place support each side of valve and under valve and every 20 feet along pipe	Not required	.0018
Collars (Buried Pipe Supports)	Concrete	3cy /ea	Place one collar support every 15 feet	2 piles/ each collar	.005
Apron Slabs and Cut-off Walls	Concrete	1.25 ft. thick	As shown on DWR drawings.	Not required	.003, each way, each face
Equipment Slabs	Concrete	2.0 ft. thick	As shown on DWR drawings.	4 piles/ 100 sq. ft.	.005, each way, each face
Thrust Blocks	Concrete	20cy/ea	Place at each bend	Not required	Not required

The objective of this study is to perform a sufficiently detailed feasibility level structural analysis and design of the four proposed integrated facilities to allow for preparation of a feasibility-level cost estimate. This report presents the results of URS' feasibility structural engineering design of the In-Delta Storage Integrated Facility inlet/outlet structures, pumping stations, sheet pile walls, bypass channel bridge structure, and structural components of the fish screens. The structural design criteria and general facility arrangements prepared by DWR were used in this work.

The subsurface conditions at the four integrated facility sites are similar, and consist of soft clays and peat soils overlying denser and stiffer interbedded sands and clays. Due to the magnitude of the loads imposed by the structures, and the very soft near-surface soils, the structures will need to be supported by precast prestressed concrete piles. For preliminary design purposes, a 14-inch square precast prestressed pile was selected, which has an allowable capacity of 45 tons. Curves showing axial capacity versus depth of pile and lateral load versus deflection are presented.

Cantilever sheet pile walls that form the bypass channel were evaluated. The sheet pile wall design accounts for the scenario of the pool dewatered to the sill elevation at the respective structures (ranging from –8 feet to –15 feet). Calculated high bending moments, due to lateral pressures from 15 feet to 22 feet of head differential, required a combination H-pile/sheet-pile wall.

Feasibility-level design structural analyses were performed and applied the load combinations, factors of safety and design methodology defined in the design criteria for this project. Due to the similarities between the fish screen supports and decks, the bypass channel bridge structure and trash rack, and the inlet/outlet structures, a reinforced concrete box culvert section was utilized. Cantilevered reinforced concrete retaining walls were designed for use at the ends of the inlet/outlet structures, along the approaches to the bypass channel bridge structure and trash rack, and at the outlet structures for the conduits. Feasibility designs were also performed for the pump station, vault structures, conduit supports, collars, and thrust blocks. Flexible conduit connections will be needed in areas where movement can occur.

Further studies may indicate the desirability to use larger piles than the 14-inch piles evaluated for this study. Larger piles would decrease the number of piles required and they would have a higher lateral capacity, thus providing for economy. Further design may also consider the use of batter piles to resist lateral loads. The design presented in this study includes cast-in-place concrete elements. Further studies may indicate that pre-cast concrete construction for such elements as the box culvert and the bridge to the fish screen structure may be more economical.

The results of the structural analyses are summarized in Table 4-1. Drawings of the structures were prepared by DWR and are presented in Appendix C.

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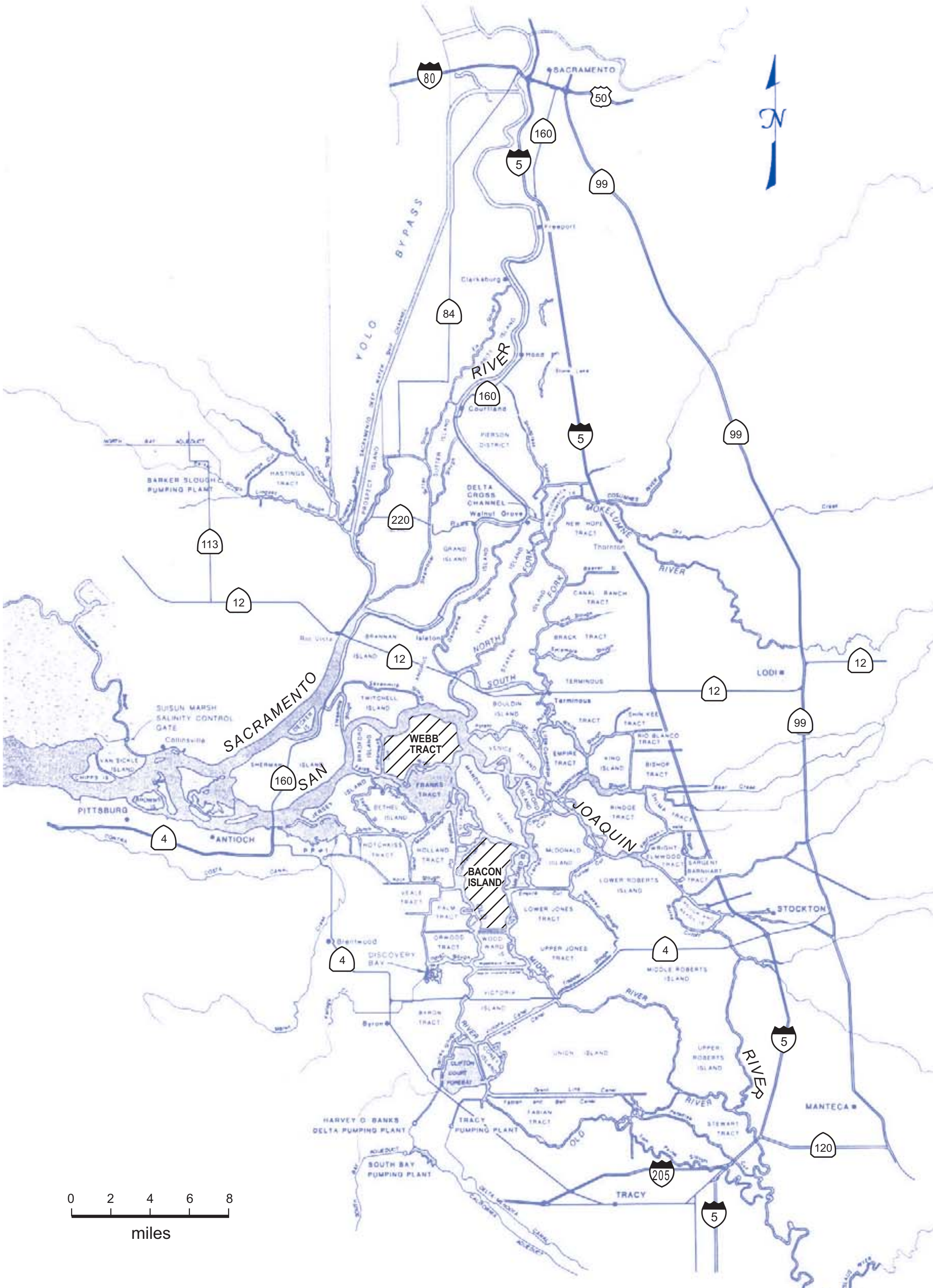

Source: Department of Water Resources,
Sacramento-San Joaquin Delta Atlas

URS	Project No. 26814230 STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES	SITE VICINITY	FIGURE 1

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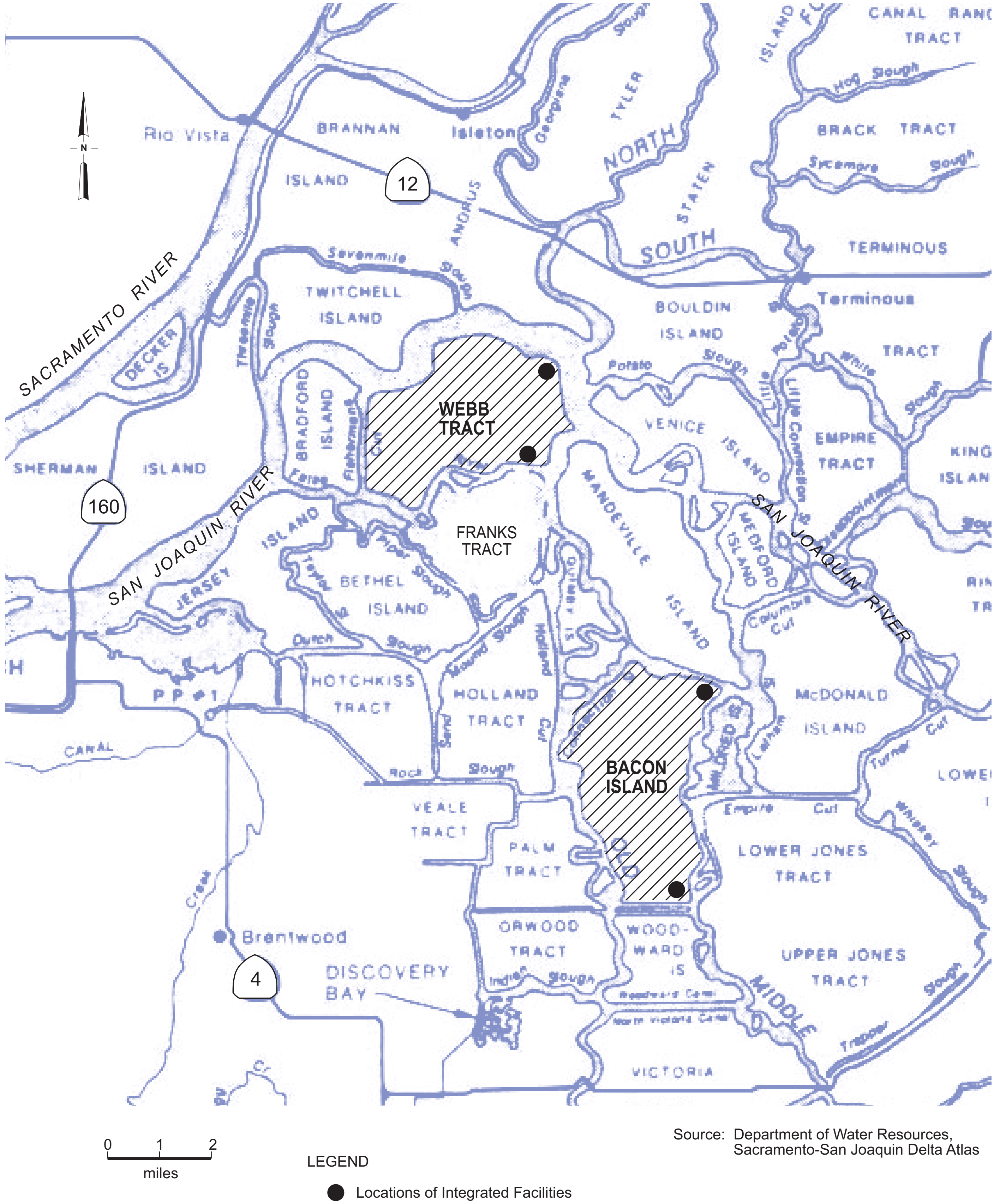

Source: Department of Water Resources, Sacramento-San Joaquin Delta Atlas

URS	Project No. 26814230 STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES	LOCATIONS OF INTEGRATED FACILITIES	FIGURE 2

26814230.01200/033103/gos

Figure 3 - In-Delta Storage Program Stiff Soil Response Spectrum at Pile Depth of Fixity

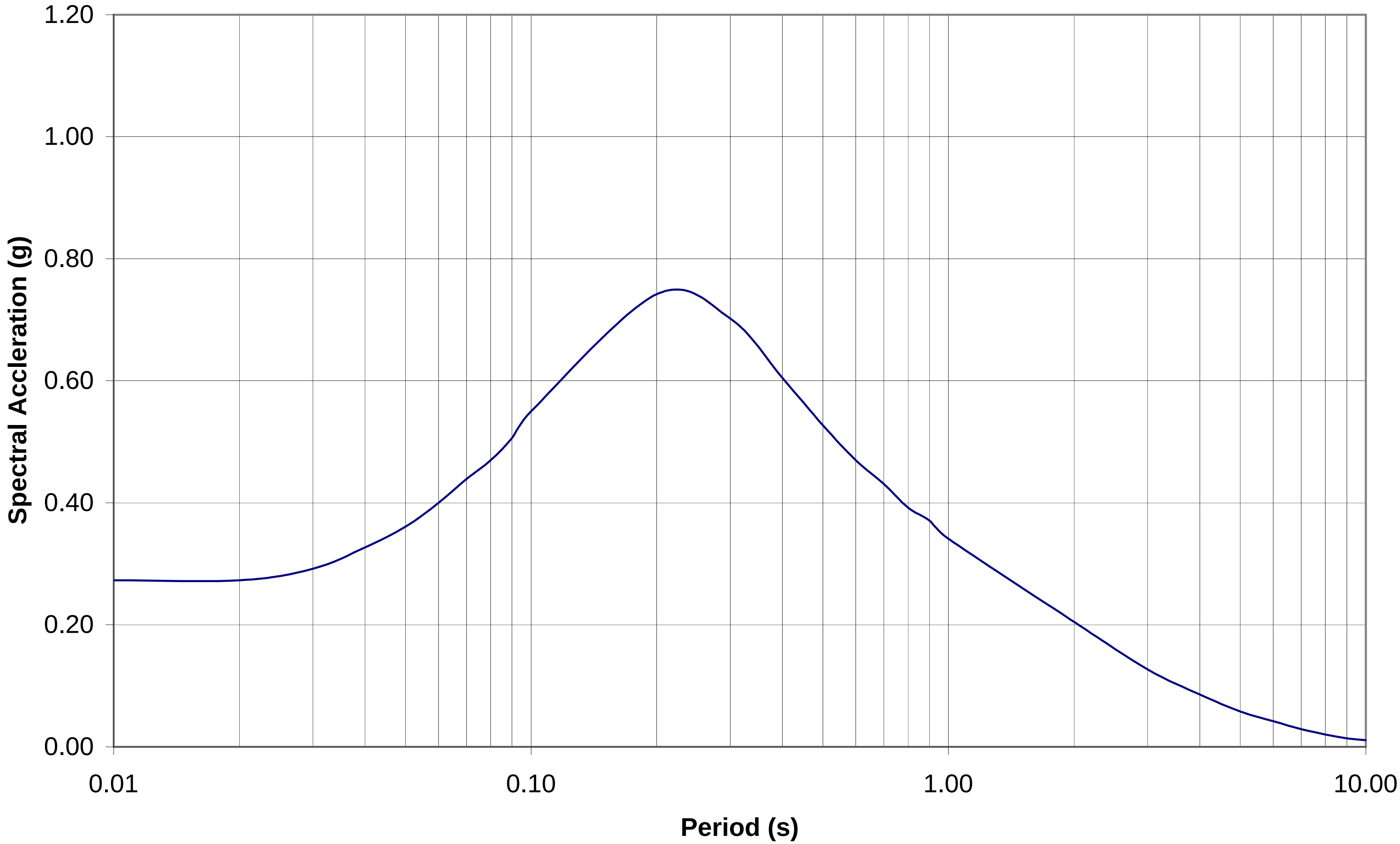

Figure 4 - Pile Capacity Webb Tract North

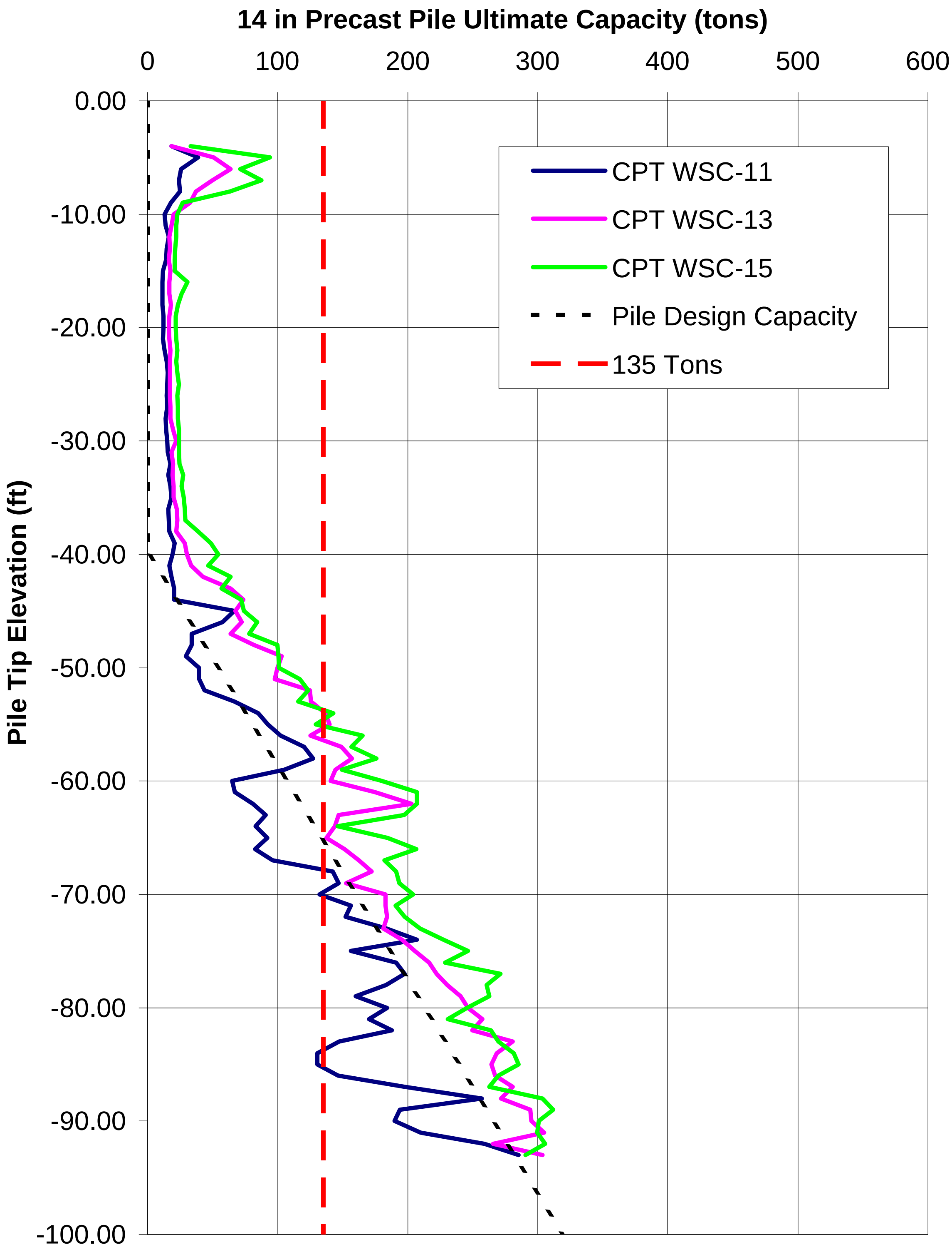

Figure 5 - Pile Capacity Webb Tract South

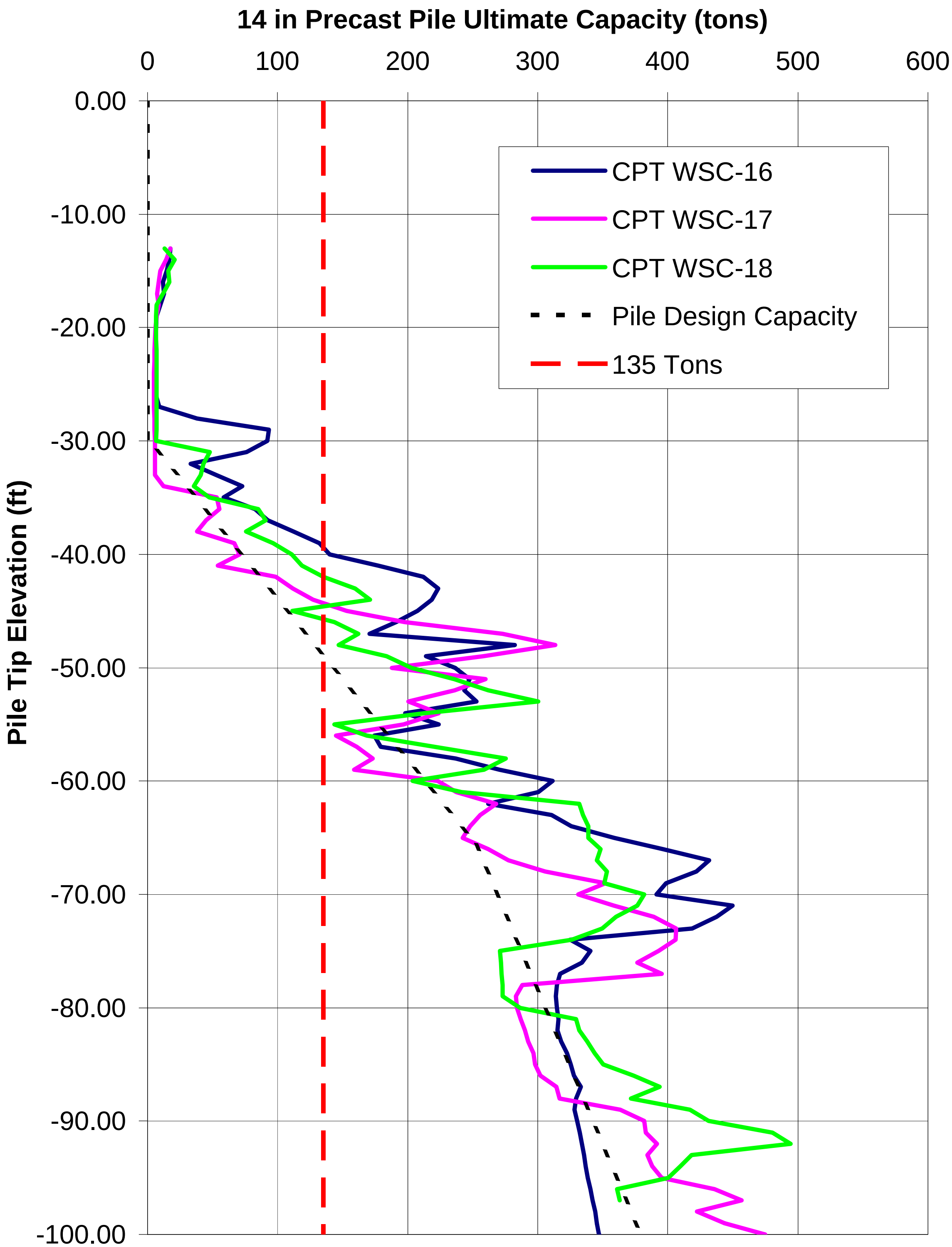

Figure 6 - Pile Capacity Bacon Island North

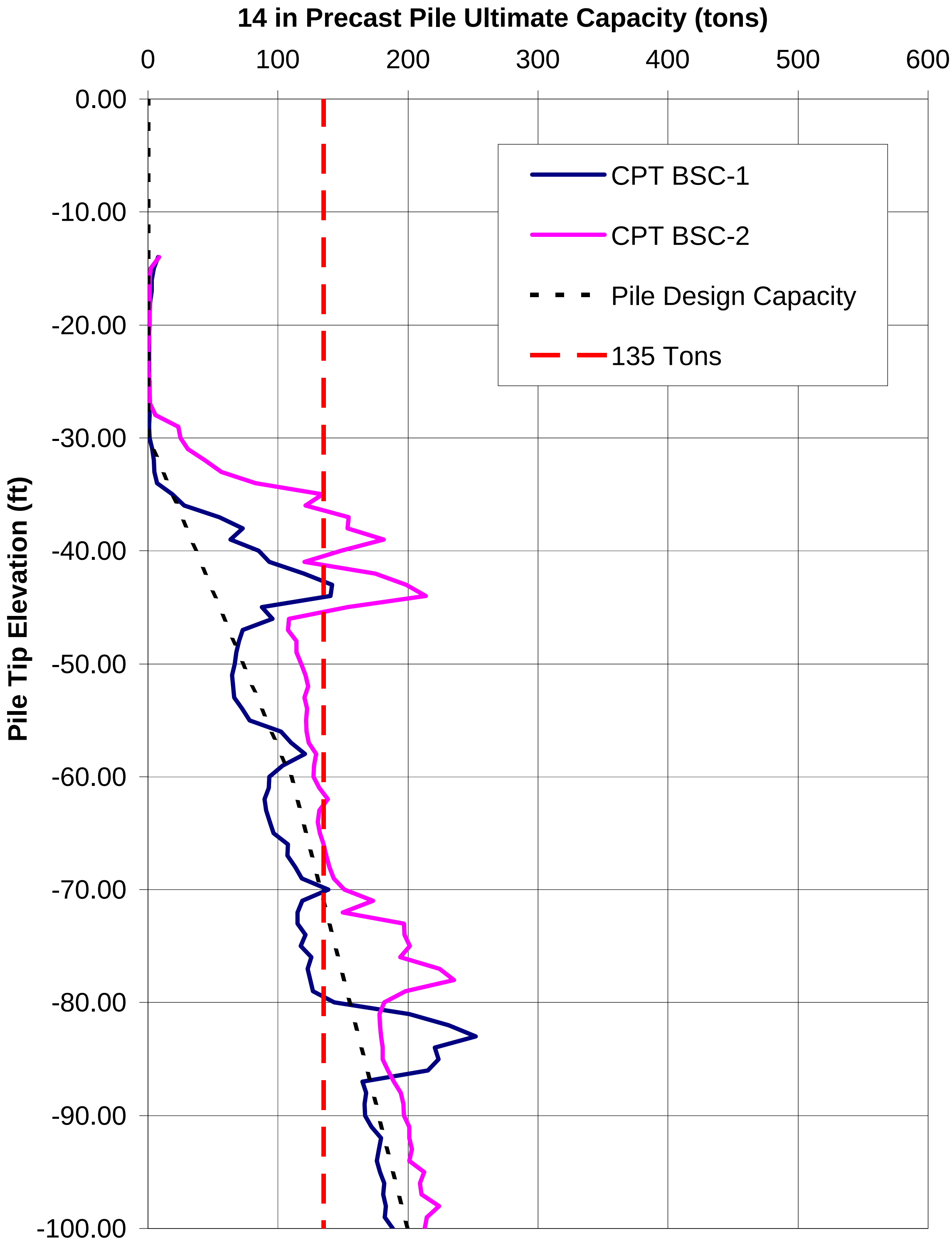

Figure 7 - Pile Capacity Bacon Island South

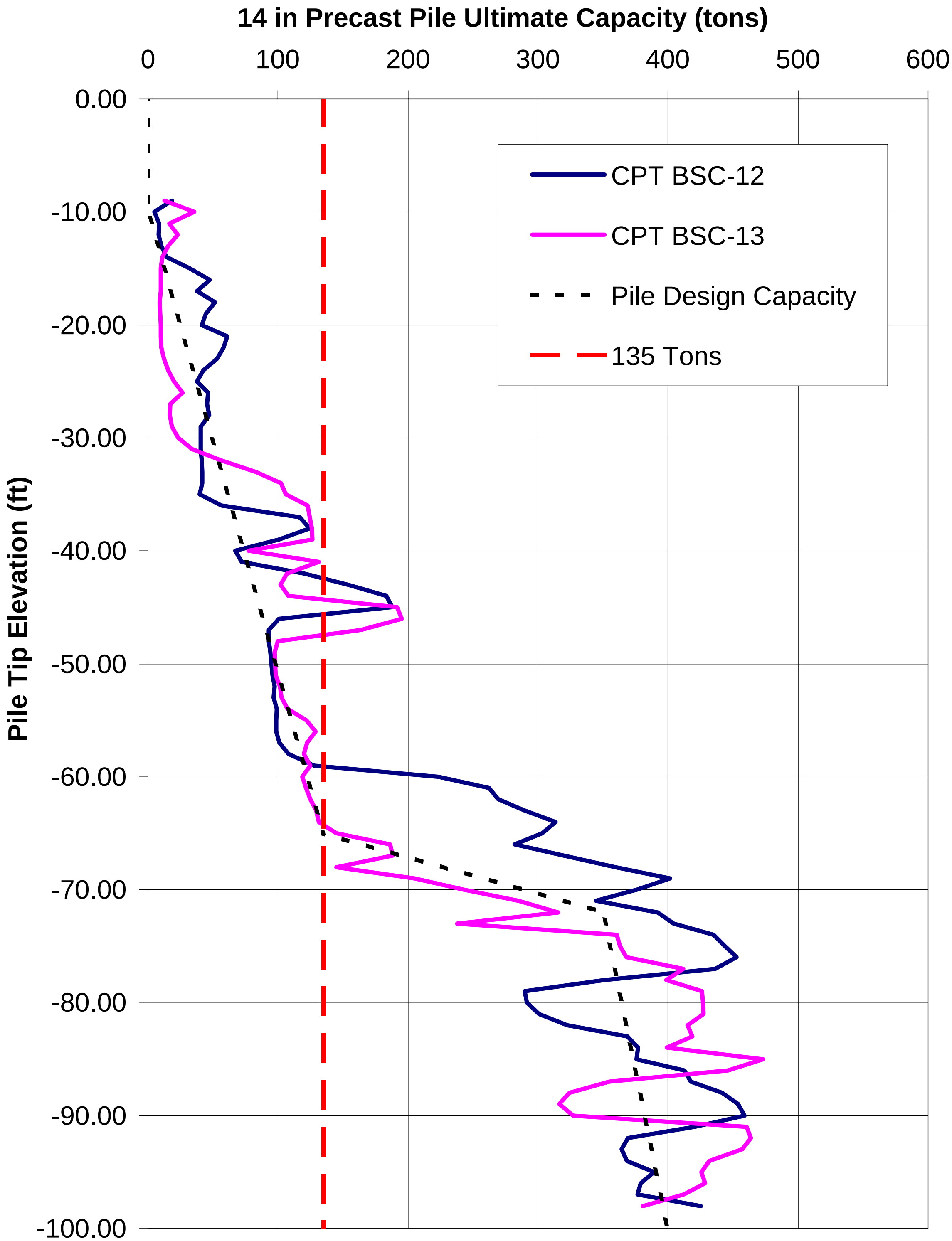

Figure 8 - 14-inch Precast Pile Lateral Load Versus Pile Head Displacement