WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

DESIGN MEMORANDUM NO. 7

NAVIGATION LOCKS AND FACILITIES

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

APRIL 1973

25

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

11 April 1973

SUBJECT: Charles River Dam, Charles River Basin, Massachusetts, DM No. 7, Navigation Locks and Facilities

HQDA (DAEN-CWE-B)
WASH DC 20314

1. In accordance with ER 1110-2-1150, there is submitted for review and approval DM No. 7, Navigation Locks and Facilities, for the Charles River Dam Project.

2. This DM is a resubmission of DM No. 7 previously submitted by NEDED-E letter dated 20 March 1972 with consideration given to comments contained in DAEN-CWE-B 1st Indorsement thereon. Specific reply to 1st Indorsement comments is contained in NEDED-E 2nd Indorsement dated 30 March 1973.

FOR THE DIVISION ENGINEER:

Incl (10 cys)
as

JOHN Wm. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM
CHARLES RIVER BASIN
MASSACHUSETTS

Design Memoranda Index

No.	Title	Anticipated Submission Date	Date Submitted	Date Approved
1	Hydrology and Tidal Hydraulics		21 May 71	2 Aug 71
2	General Design, Site Geology and Relocations		14 Feb 72	13 Mar 72
3	Concrete Materials		19 Feb 71	29 Mar 71
4	Embankments and Foundations		22 Feb 72	15 Mar 72
5	Pumping Station	May 73		
6	Vehicular Viaduct		28 Feb 72	15 Mar 72
7	Navigation Locks and Facilities		11 Apr 73	
8	Cofferdams		8 June 72	25 July 72

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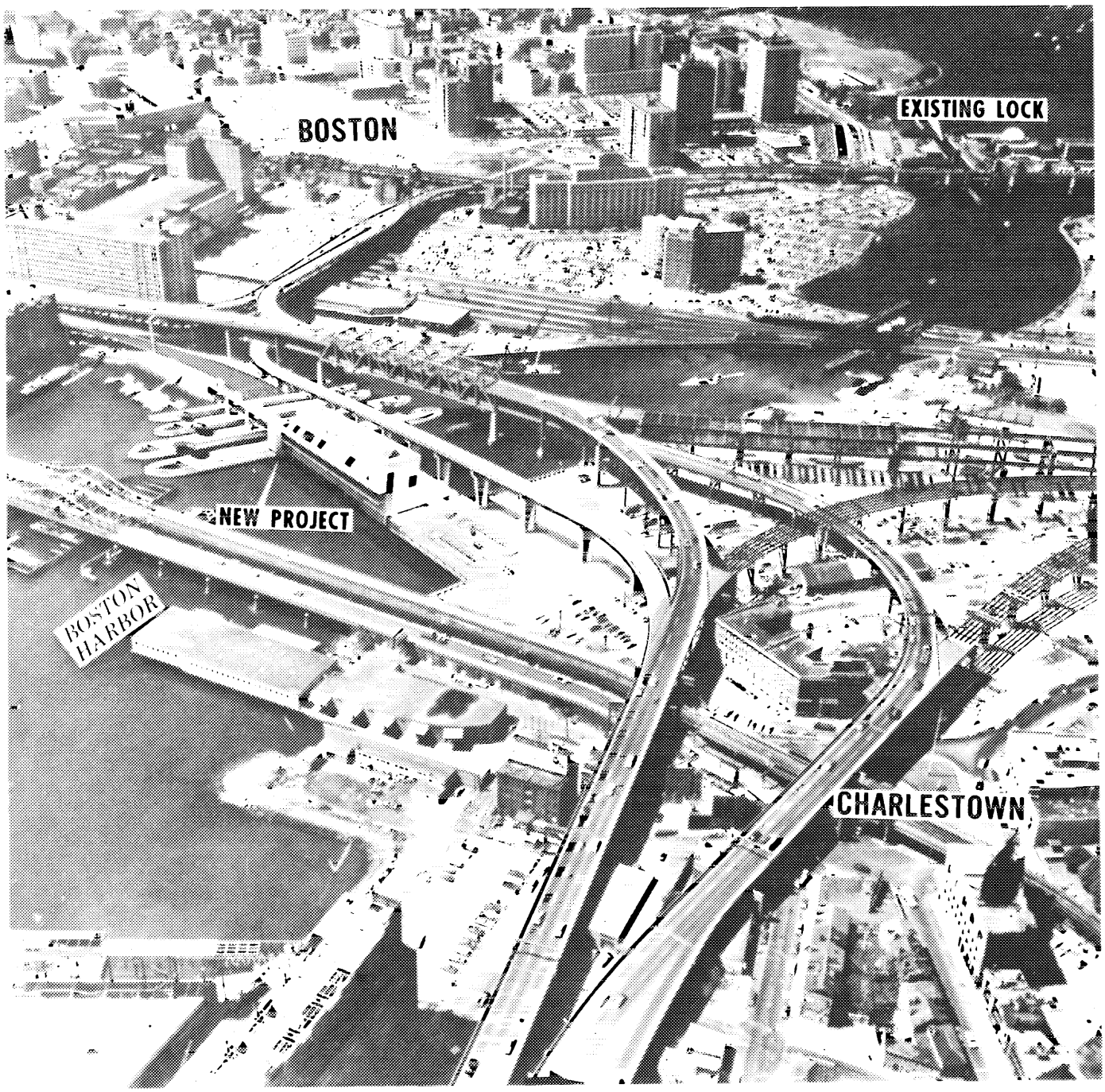

CHARLES RIVER DAM PROJECT

WATER RESOURCES DEVELOPMENT PROJECT
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CHARLES RIVER BASIN, MASSACHUSETTS
DESIGN MEMORANDUM NO. 7
NAVIGATION LOCKS AND FACILITIES

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WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
CHARLES RIVER BASIN, MASSACHUSETTS
NAVIGATION LOCKS AND FACILITIES

PERTINENT DATA

Purpose	Flood Control, navigation, and highway transporation.
Location	
State	Massachusetts
County	Suffolk
City	Boston
River	On the Charles River 2,250 feet downstream of the present Charles River Dam.
Surface Area	
Datum Relationship	M.D.C. Base is 105.65 feet below mean sea level (M.S.L.), U.S.C. & G.S. Datum of 1929 (105.65 M.D.C. = 0.00 M.S.L., U.S.C. & G.S. (1929))

Tides, Boston Harbor (Elevations, feet M.D.C. Base)	
Highest tide of record, April 14, 1851	115.7 (116.6 adjusted to 1970)
Mean high water	110.2
Mean low water (M.L.W.)	100.8
Highest tide, modern record, Dec. 29, 1959	115.0

Upstream Pool	
Normal Basin	108.0 feet, M.D.C. Base
Downstream Pool	Tidal, elevation varies

Lock Features

Feature	Large Lock	Small Locks
Number of locks	One	Two
Purpose	Commercial shipping, supplement recreational	Recreational boating only
Length	300 feet	200 feet
Width	40 feet	25 feet

Feature	Large Locks	Small Locks
Lift	2.4 feet @ Mean Sea Level -2.2 feet @ Mean High Water 7.2 feet @ Mean Low Water	
Lock Gates Tide End	Sector 2 Sections ea. 31' x 24' rad.	Sector 4 sections ea. 23' x 13.5' rad.
Basin End	2 sections ea. 26' x 24' rad.	4 sections ea. 17' x 13.5' rad.
Water Depth Above Tide Sill	14.8 ft. @ mean low water	6.8 ft. @ mean low water
Basin Sill	17.0 ft. @ normal pool elevation	8.0 ft. @ normal pool elevation
Chamber Floor	16.8 ft. @ MLW	8.8 ft. @ MLW
Filling and Emptying Culverts	Two @ 6' x 7' each	Two @ 4' x 4' each
Discharge per Culvert	408 cfs @ 8 ft. head	190 cfs @ 8ft. head
Velocity in Culvert	9.7 fps @ 8ft. head	11.9 fps @ 8ft. head
Operation	6.0' x 7.0' Slide Gates	48" ø Butterfly Valves
Wall Ports	52 - 10" ø per culvert	46 - 8" ø per culvert
Recreational Boat Capacity	70 - 75 Boats per hr.	35 - 40 Boats per hr.

B. INTRODUCTION

1. GENERAL - The proposed Charles River Dam will be located in the city of Boston, approximately 0.7 mile upstream from the confluence of the Charles and Mystic Rivers at Boston Inner Harbor and 0.4 mile downstream from the existing Charles River Dam, see Plate 7-1. The plan proposed herein consists of three navigation locks to replace the single lock at the existing Charles River Dam. As shown on Plate 7-2, there will be two small boat locks each 200 feet by 25 feet wide, and one commercial lock measuring 300 feet by 40 feet. The depth of water over the large lock tide sill at mean low water is 14.8 feet, at mean sea level 19.6 feet, and at mean high tide the depth is 24.2 feet. At the basin sill the normal depth of water will be 17 feet. The clear width of the small locks, 22 feet, will enable two average sized pleasure craft to lock side-by-side with allowance for a floating mooring system along each wall. The length of the small locks was evaluated on the basis of capacity. When required by demand, all three navigation locks could be used for passing pleasure boats. The capacity of such an operation would be between 150 and 160 boats per hour in the demand direction. The average draft, for pleasure boats, is 2-1/2 feet and the maximum is 5 feet. At mean low water the depth of water over the tide sill will be 6.8 feet, 11.6 feet at mean sea level, and at mean high tide there will be a 16.2-foot depth of water at the sill. At the normal pool level the basin sill will have a depth of water of 8 feet. To effect the safe and expeditious passage of boats at peak demand, it is proposed to utilize electric traffic and audio controls at the lock entrances. These controls as well as lock filling, emptying and lock gate operations will be monitored from the Control Stations, as subsequently discussed.

C. HYDRAULIC DESIGN

2. LOCK FILLING AND EMPTYING SYSTEM

a. General. - Filling the lock chambers would be by circular wall ports along the length of each lock wall, as shown on Plates 7-3, 7-4 and 7-5. The ports stub from the base of continuous, rectangular sidewall culverts (see Plates 7-6 and 7-7) which are fed from three rectangular openings in the endwalls at each end of each lock. Flow through the culverts serving the small boat locks is regulated by butterfly valves rotating on vertical shafts. The flow through the culverts for the large lock is controlled by a slide gate. There is one valve or slide gate at each end of the culvert located between the endwall intakes and the chamber ports. Because of the variation in the tide elevation above and below the fixed level of the upstream pool, each component of the filling system must also function efficiently as part of an emptying system.

b. Lock Chamber Filling and Emptying. - Filling and emptying the lock chamber will be by means of gravity discharge through the lock wall culverts from the higher body of water.

c. Unwatering the locks for maintenance and inspection purposes is accomplished by pumping through a wetwell until the lock floor is drained. The wetwell sump elevation is low enough to empty, by gravity, both the small and the large lock chambers as well as the floor zone between the lock bulkhead and the sector gate sills. Unwatering of the pump station forebay and discharge chambers will also be accomplished through this unwatering system. Pumping operations for the navigation locks are described in Paragraph 4. Pumping operations for the pump station are discussed in Design Memorandum No. 5, "Pumping Station".

3. HYDRAULIC CALCULATIONS

a. General. - Sidewall culverts were sized after inspecting several geometric configurations and arrangements. Analysis of culvert characteristics was based on an 8-foot initial static head between the chamber and the adjacent water body. This head is equivalent to a tidewater elevation of 100.0 feet M.D.C. (mean low water is elevation 100.8 feet M.D.C.) and a normal fixed pool elevation of 108.0 feet M.D.C. Correspondingly the 8-foot lift could also be experienced when the pool has been prelowered as discussed in Design Memorandum No. 1 to elevation 106.5 feet M.D.C. and the tidewater reaches a high of 114.5 feet M.D.C. (mean high water is elevation 110.2 feet M.D.C.). The latter case, as it depends on an exceptionally high tide coincident with a prelowered basin, is a remote possibility but nonetheless applicable to the selected culvert design.

b. Losses. - Resistance to flow in the culverts has been calculated as culvert velocity head losses. The head losses were tabulated as the summation of losses in two zones. The first zone begins at the culvert intakes in the lock endwall and extends to the first of the series of wall ports which comprise the culvert "manifold". The region between the first and last ports is considered the second zone. Resistance to flow, because of the symmetrical culvert design, is taken as equal (for a given static head) for either filling or emptying the lock chamber.

Zone one velocity head loss coefficients, "K" values were computed for:

	K	
	4' x 4'	6' x 7'
1) Outer rim	.072	.030
2) Bar rack	.159	.200
3) Entrance	.125	.130
4) Intake bends (2)	.200	.200
5) Entrance region contraction	.200	.060
6) Culvert bend (2)	.800	.800
7) Stop log slots (2)	.060	.060
8) Butterfly valve	.430	
9) Butterfly valve chamber	.200	
10) Slide gate		.010
11) Sloped invert section, and Friction in culvert	.010	.260
	K = 2.146	K = 1.750

Head loss coefficients for zone two, the manifold section, were computed for:

1) Friction loss in culvert,
2) Eddy losses, and
3) Head loss in the outlet pipes. Assuming a linear reduction in velocity from the beginning of the manifold to the end, the friction loss reduces to:

$$h_f = \frac{fL_m}{3D} \times \frac{V^2_{cul}}{2g}$$

Where h_f = friction head losses
f = friction factor
L_m = Length of manifold
V_{cul} = Average velocity in the culvert
D = 4 x Hydraulic radius = $\frac{2(W \times H)}{(W + H)}$
W = width of culvert
H = height of culvert

Eddy losses in the manifold were assumed as equal to twice the friction loss. The sum of the friction and eddy losses in the manifold then becomes:

$$h_{man.} = \frac{f\ Lm}{D} \times \frac{V^2_{cul}}{2g}$$

Head loss in the chamber ports is calculated on the principle of equalization of resistance to flow via alternate routes, i.e., the head loss through the first port must be equal to the sum of the head loss through the length of the manifold to any other port and the loss through that port. From continuity the average velocity through the ports, expressed in terms of culvert velocity through the first port to the velocity through the last port, can be ascertained. Expressed in terms of culvert velocity a "K" factor is found for the ports emptying into the chamber. The total energy loss during a lock filling or emptying is then a function of the summation of the velocity head losses, K, for zones one and two, i.e., $H_{LT} = (K_1 + K_2) \times \frac{V^2_{cul}}{2g}$, where the H_{LT} is the total head loss from pool of lock chamber and K_1 and K_2 are the head loss factors computed as stated above. Similarly for any available head H, the discharge can be expressed as a function of the velocity by substituting the area of the culvert into the above equation, or $H = KQ^2$ where "K" is a constant for a particular culvert and is equal to $K_1 + K_2$.

For any given culvert and manifold system a Head versus Discharge curve can be plotted, which for the fully open valve position yields the discharge for any instantaneous static head. To determine the discharge, rate of rise in the chamber and lock filling or emptying times for any given culvert, a hydraulic analysis during valve opening is necessary. Determination of the above culvert characteristics was made in accordance with the method outlined in EM 1110-2-1604. First the overtravel "d" for each trial culvert size is calculated using the formula stated in EM 1110-2-1604. The overtravel is a result of the momentum of the decelerating mass of water that is present from the time the filling gate is fully opened until the water surface crests in the chamber. This additional head added to the system is accounted for in the rate of rise and lock filling times.

c. Filling Curves. - Minimum valve opening times, t_v, were arrived at for both the large and small locks after considering rate of rise in the chamber, turbulence in the lower approaches and reasonable mechanical limitations on valve components. For comparative analysis a design lift of 8 feet, for the reasons previously stated, was used for each trial culvert. Culvert characteristics were then tabulated for the two stages of operation: (1) during valve opening and (2) valve fully opened, in the same manner as Table A1 in Appendix A of EM 1110-2-1604. Filling curves were plotted from the tabular data, see Plates Nos. 7-8 and 7-9. The overall filling time "T" is approximated from the formula expressed in EM 1110-2-1604, $T = m \left(\frac{H}{2g}\right)^{1/2}$. If "m", a constant, is taken at the stated average value of 840 and the design lift of 8 feet is used for the variable H, the overall filling time would be 296 seconds. Design valve opening times of 18 and 22 seconds were used for the small lock and large lock valves respectively. Knowing the respective lock areas, overall culvert sizes that would satisfy the total filling times worked out to approximately 40 square feet for the large lock and 12 square feet for each small lock culvert. Further hydraulic and structural investigation revealed that the small lock culvert sizes could be increased to approximately 20 square feet each to lessen the filling time and improve the lockage capacity. Whereas it would be desirable to also increase the culvert area in the large lock, specific structural limitations preclude a continuous void appreciably in excess of 40 square feet. The trial culvert sizes were 4' x 4' and 4'6" x 4'6" for the small lock and 6'6" x 5' and 6' x 7' for the large lock. The resulting characteristics for each trial are presented in Table 1.

TABLE 1

TRIAL CULVERT DATA

Trial Culvert Feature	Small Lock 4'x4'	Small Lock 4'-6"x4'-6"	Large Lock 6'-6"x5'	Large Lock 6'x7'
Area per Culvert (sq.ft.)	16	20.25	32.5	42
Dischg. Coeff. "C"	.52	.485	.486	.429
Overtravel, "d" (ft)	0.24	0.27	0.25	0.25
Max. dischr., Q max. (cfs)	368	436	676	770
Max. Culvert Velocity V_{cul} (fps)	11.5	10.8	10.4	9.2
Max. Rate of Rise (fpm)	4.26	5.00	3.38	3.82
Valve oper. time t_v (sec)	18	18	21	21
Total Filling Time* T (min)	3.75	3.2	4.7	4.2

Based on lift of 8 feet
*Measured to overtravel peak

The 4' x 4' culvert was selected for the small locks because of its favorable maximum rate of rise, filling time and also modular (4' x 8' panel) construction feature. The culvert size selected for the large lock was the 6' x 7'. In addition to the favorable filling and emptying features, the 6-foot width enables the culvert and the 6' x 8' gallery above to have the same vertical formwork planes. The positioning of the ports, facing each other rather than offset, was a result of analytical studies. EM 1110-2-1604 states that this arrangement is satisfactory for low lift operations.

4. WETWELL PUMPING

a. General. - As described above, the pumping capability has been provided primarily for unwatering the navigation locks and the forebay and discharge chambers of the pump station for maintenance and inspection of purposes. However, the capacity provided is somewhat greater than actually required for this purpose. The additional pumping capacity has been provided at the request of the sponsoring agency (MDC) to allow for lowering the navigation locks during the time the tide is higher than the basin by pumping the lock water to tide. This is the operation procedure followed by the sponsoring agency on the nearby Amelia Earhart Locks with the consideration that salt water intrusion is being minimized. Both the large and the small locks have two integrated emptying arrangements leading to the wetwell.

b. Small Lock Lowering. - Below each small lock chamber floor there is a 3' x 3' culvert at right angles to the main axis of the lock chamber. The culverts transition to a 36-inch diameter butterfly valve which opens to the wetwell chamber, see Plates Nos. 7-6 and 7-10. When the butterfly valve is opened, flow passes through the lock chamber sidewall ports into the main filling and emptying culverts and then into the wetwell culvert through a vertical opening at the point where the transverse culvert passes under the main culverts. This method is adequate to lower the chamber water surface to the equalization level at a rate suitable for locking. For total unwatering, this process can be continued until the level in the lock chamber reaches the elevation of the sidewall ports. The remaining 2.5-foot depth below the elevation of the ports is drained by means of scuppers in the chamber floor directly over, and draining into, the transverse culvert. The wetwell acts as a reservoir for the pumps to work under head in pumping to the tide.

c. Large Lock Lowering is accomplished in much the same manner as the small locks. A 3'-6" x 4'-6" transverse culvert is immediately below small lock No. 2 chamber floor connects the wetwell to the large lock filling and emptying culvert in the southerly wall of the large lock. Both culverts are at the same invert elevation. The

remaining 2.5' depth of water below the elevation of the sidewall ports drains to a sump in the chamber floor. A 12-inch diameter conduit leads from this low point to the sump of the wetwell. A self-priming pump in the lock pump room discharges this volume to complete the unwatering process.

d. Wetwell Pump Selection. - System curves and pump curves were plotted for:

(1) A 20" piping and pump system, and
(2) A 24" piping and pump system.

As recommended in EM 1110-2-3105 two pumps rather than one large unit are designed for the required discharge. For a tide at elevation 112 feet M.D.C. base and the wetwell elevation 90, the differential head would be 22 feet. As the wetwell continues to fill to a maximum elevation of 107 (one foot below the equalization level of 108) the differential head would reduce to 5 feet. Entering manufacturers (Goulds Pumps) pump performance curves with the total head requirements indicated that a pump of 60 hp would deliver 7,400 gpm at greater than 87% efficiency for the higher head requirements while delivering close to 9,000 gpm at less efficiency for the lower head level. Further pump and wetwell storage capacity analysis indicated that the 24-inch system offered only a negligible average discharge increase and hence the 20-inch system was chosen.

e. Wetwell Culvert Selection. - Pump room equipment placement dictates the elevation in the wetwell at which pumping should commence. The pumps selected are of the mixed flow type, starting automatically when the wetwell level reaches elevation 90 feet M.D.C. base. Assuming a level in the lock chamber at tide elevation 112 M.D.C., the culvert was analyzed for flow characteristics at a 22-foot differential head (112.0 - 90.0). Velocity head losses were computed for both 3' x 3' and 36" diameter small lock wetwell culvert and for a 4' x 4' and a 48" diameter large lock wetwell conduit. A head/discharge curve was plotted for each conduit and from this it was determined that the circular conduits produced unfavorable velocities at the design head; hence the rectangular conduits were chosen.

With the culvert characteristics known, the additional information obtained from the pump performance curves enabled a tabular compilation of discharge and water surface changes that occur after the wetwell filling valves are opened. The results of this data are shown in graphic form in Plate No. 7-11. It was assumed that pumping would begin 20 seconds after the wetwell valves were opened and the butterfly valves require 20 seconds to fully open. This method is similar to the lock filling analysis presented in EM 1110-2-1604.

f. Lock Unwatering. - The main wetwell pumps are designed for a 28-foot shut-off head. When it is desired to unwater a lock or to otherwise empty the wetwell, the main pumps can be operated to lower the level as far as elevation 89.0 feet, M.D.C. From this point on a 6-inch self-priming centrifugal type sewage pump intaking at the wetwell sump (elevation 79.0 feet M.D.C.) completes the unwatering. The design calls for a pump to deliver 800 gpm at a 33-foot head, a shut-off head of 59 feet and a 15 hp motor.

D. ARCHITECTURAL TREATMENT

5. GENERAL

The locks and their appurtenances will be simple and functional presenting a pleasing appearance by their structural mass and relationship to the other elements of the project. The lock wall finish will be Class A.

An elevated Walkway-Control Station structure will span the locks, linking the Pumping Station with the Boston shore. It will be supported on cast-in-place concrete piers which also house access stairs to the lock structure. The elevated structure will be structural steel of Warren Truss design, with window wall of duranodic finish aluminum; insulated, tinted, heat-strengthened glass; and insulated porcelain enamel soffit and facia panels.

Poured-in-place concrete will have an architectural finish coordinated with the mass concrete of the lock structure and pre-cast panels of the Pumping Station.

E. STRUCTURAL DESIGN

6. GENERAL

This section of the design memorandum presents the design criteria, basic data and assumptions used in the structural design of the navigation locks.

Plates showing the navigation lock layout, typical sections, details and stability diagrams have been included in this memorandum. Appendix A includes complete stability calculations and typical design calculations of the major structural components.

7. DESIGN CRITERIA

a. General. - The design conforms to the Corps of Engineers criteria. Accepted engineering practice has been employed in cases where Corps criteria is not available.

b. Concrete. - The allowable working stresses in accordance with EM 1110-1-2101 have been used throughout the structure. Concrete with an ultimate compressive strength of 3,000 psi has been used. Nonstructural lean concrete fill of 2,000 psi is used as fill under small locks to replace unsuitable foundation materials. Interior mass concrete at 2,000 psi will be used in all areas approximately 5 feet from exposed concrete surfaces.

c. Reinforcement.

(1) Grade and Working Stresses. - All reinforcement in the structures is designed for a working stress of 20,000 psi in flexural tension. The reinforcement specified is ASTM A615 (Billet Steel), Grade 40.

(2) Minimum Cover for Main Reinforcement. - Requirements for minimum cover conform to EM 1110-2-2103.

Interior Slabs	1"
Interior Beams	1-1/2"
Exterior Slabs	2"
Walls Exposed to Water	4"
Base Mat	6"

(3) Splices. - Splices in the main reinforcement at point of maximum moment have been avoided in the design. In accordance with EM 1110-2-2103, the lengths of splices and staggering of splices will be indicated on the contract drawings.

d. Structural Steel. - Structural steel conforms to ASTM A36. The allowable working stresses conform to those specified in the Engineering Manual EM 1110-1-2101.

e. Increase in Normal Working Stresses. - Normal allowable working stresses have been increased 33-1/3 percent where wind loads govern. The 33-1/3 percent increase in stresses will also be used where earthquake loads govern.

f. Expansion, Construction and Contraction Joints. - The navigation lock monolith will be separated by a watertight expansion joint from the pumping station structure. Transverse construction joints will be provided in the lock walls at intervals not exceeding 45 feet. Also horizontal construction joints limiting the heights of pours to approximately 6 feet will be provided in the lock walls. Contraction joints will be provided at strategic locations of walls to reduce concrete shrinkage stresses. In addition, the base slabs of all locks will have full length longitudinal construction joints to reduce differential settlements during construction and to minimize shrinkage stresses in the thick slabs.

8. BASIC DATE AND ASSUMPTIONS

a. Controlling Elevations (M.D.C. Base).

Bottom of large lock base slab	El. 78.00
Bottom of small lock No. 1 base slab	El. 87.00
Bottom of small lock No. 2 base slab	El. 84.00 to 87.00 (slope)
Invert of large lock	El. 84.00
Invert of both small locks	El. 92.00
Large lock sill, basin end	El. 91.00
Large lock sill, tide end	El. 86.00
Small lock sill, basin end	El. 100.00
Small lock sill, tide end	El. 94.00
Top of lock walls	El. 118.00
Floor of walkway and control stations	El. 139.00
Roof of walkway and control stations	El. 149.50

The following extreme water levels have been used in the design:

	Basin End	Tide End
High Water	El. 112	El. 116
Low Water	El. 106	El. 98

The design of locks for the dewatered maintenance condition was based upon a high water elevation of 114.

b. Design Loads.

Design Loads - The following unit weights for materials have been used:

Concrete	150 pounds per cubic foot (pcf)
Steel	490 pounds per cubic foot
Earth	125 pounds per cubic foot

Live Loads - The following live loads have been used:

Water (salt)	64 pcf
Roof (walkway)	30 psf
Floor (walkway)	100 psf
Monorail	4 tons

c. Water Pressure. - Full hydrostatic water pressure has been assumed acting over the entire area of the base. During construction, while cofferdam is in place, hydrostatic uplift has been neglected. An adequate factor of safety against uplift is provided for all loading conditions investigated.

d. Earth Pressure. Lateral earth pressure against the structure has been determined in accordance with EM 1110-2-2502. "At rest" pressures have been used for the design of small lock No. 1 land wall. For soil properties refer to Design Memorandum No. 4.

e. Earthquake Forces. - The effect of Zone 3 earthquake (0.1g) on the structure has been investigated in accordance with applicable Engineering Manuals.

f. Ice Pressure. - The basin is subject to freezing depending upon the severity of the winter and the relatively constant basin elevation. The Metropolitan District Commission lets an annual contract for ice breaking in order to maintain an open channel for commercial traffic. This open channel allows for sufficient expansion of the ice. However, an ice pressure analysis has been made assuming 8 inches of ice and using criteria in EM 1110-2-2602 and EM 1110-1-2101. This analysis indicated ice pressure has no effect on the design. Therefore, ice pressure on the structure is considered negligible and has been disregarded in the design of structures.

g. Wind Pressure. - A horizontal wind pressure of 35 pounds per square foot has been used in the design.

h. Frost Protection. - The base of the lock structure may be subject to frost action during construction. Proper measures will be provided to guard against this condition until the height of fill is at least 4 feet above the bottom of the base.

i. Wave Pressure. - Due to the secluded harbor location of the proposed structure, wave pressure is not considered critical and has not been included in the design. Refer to Design Memorandum No. 1, "Hydrology and Tidal Hydraulics".

j. Location of Resultant. - The resultant falls within the middle third of the base for all loading conditions investigated.

k. Resistance to Sliding.- The following minimum factors of safety against sliding have been provided, assuming a friction value of 0.5 and no cohesion.

Condition	Sliding Safety Factor
Normal without earthquake	4.0
Normal with earthquake	2.7
Extreme maintenance without earthquake	2.7
Extreme maintenance with earthquake	2.7

l. Allowable Foundation Bearing Pressure. Allowable foundation bearing pressure is 4 tons per square foot as discussed in detail in Design Memorandum No. 4.

9. PREPARATION OF CALCULATIONS

A program developed for an IBM-1130 computer for a beam on elastic foundation has been utilized for structural analysis of the lock monolith. The stress program has been used for frame and truss design.

Soil bearing pressure calculations have been programmed on an Olivetti Underwood Programmer 101, electronic desk computer.

All other calculations for the Design Memorandum have been done manually.

10. DESIGN OF LOCK FACILITIES

a. Access Walkway.- The walkway which spans the three locks utilizes a diagonal steel truss framing system with 6" x 6" structural square tubing. The walkway is supported by two intermediate concrete bents with concrete stair towers located at each end of the walkway. The stair towers and the intermediate bents are reinforced cast-in-place concrete. Lock operation control stations are located in the walkway and are centered over each lock. Framing around the control stations is vertical, providing for unobstructed access to the control consoles. See Plate 7-12 for plan and elevation.

b. Navigation Lock Monolith. - The lock monolith, which is separated by an expansion joint from the pumping station, consists of three navigation locks.

The base mats in the lock chamber are 6'-0" thick for the large lock, 5'-0" thick for small lock No. 1 and taper from 5'-0" to 8'-0" for small lock No. 2. The mats increase in thickness in the area of the gate recesses. The lock walls vary in thickness from 22'-0" to 37'-6" to accommodate sector type gates and various galleries and culverts. The lock walls will also support a proposed viaduct. (See Design Memorandum No. 6).

The lock construction conforms to the "dry-dock" type with the foundation mat and walls designed to act integrally. The base mat has been analyzed as a beam on elastic foundation using the finite element method.

The locks have been analyzed for dead loads, horizontal and vertical hydrostatic loads, earthquake and hydrodynamic loads. To reduce differential settlements occurring instantly due to elastic strain upon land application, a construction sequence is required where the lock walls are constructed independently and allowed to settle before the structural connection is made by a final concrete placement of the lock base slabs. The above is accomplished by means of the longitudinal construction joints as shown in Section on Plates 7-6 and 7-7.

Reinforcement has been designed for all conditions of moment, shear, uplift and axial loads. For reinforcement placement in the lock structure refer to Plates 7-6 and 7-7.

c. Lock Gates.- Each lock has two sector type gates, consisting of structural steel members covered with a curved steel skin plate. Typical configuration of the proposed gates is shown on Plate 7-13. The design includes earthquake loads and the allowable stresses are in accordance with EM 1110-1-2101.

11. STABILITY ANALYSIS

a. Loading Conditions. - The navigation lock structure has been investigated for the following conditions of loading.

Case Ia. Stage I construction condition with large lock under construction in the cofferdam. Dead load of the large lock only, no hydrostatic loads.

Case Ib. Stage II construction condition with small locks under construction in cofferdam but large lock in operation. Dead load of total structure with hydrostatic load on the large lock only.

Case IIa. Normal operating condition of large lock only (small locks not built). High water at el. 112 basin side and low water at el. 98 tide side. Dead load of large lock and full horizontal and vertical hydrostatic pressures.

Case IIb. Normal operating condition of all locks. High water at el. 116 on tide side and low water at el. 106 on basin side. Full dead load and full horizontal and vertical hydrostatic pressures.

Case IIIa. Extreme maintenance condition with large lock dewatered and small locks operating. Otherwise same as Case IIb.

Case IIIb. Extreme maintenance condition with small lock dewatered and large lock operating. Otherwise same as Case IIb.

Case IVa. Earthquake during Stage II construction. Same as Case Ib, except earthquake and hydrodynamic loads added.

Case IVb. Earthquake during normal operation. Same as Case IIb, except earthquake and hydrodynamic loads added.

b. Critical Conditions. - Stability calculations indicate that maximum bearing pressure on the base is 1.6 tons per square foot (Case Ia - construction condition without uplift). For normal operating conditions the maximum bearing pressure is 0.8 tons per square foot (Case IIb). The minimum base pressure of 0.2 tons per square foot occurs for Case IIIa. The resultant falls within the middle third of the base of all conditions. The minimum factor of safety for uplift was calculated to be 1.41 for Case IIIa. The minimum factor of safety for sliding (Case IIa) has been calculated to be 5.2 without earthquake and 1.8 for Case IVb with eqrthquake during normal operating condition. Loading conditions and stability diagrams are shown on Plate 7-14 and the summary of stability results are shown on Plate 7-15.

F. FOUNDATIONS

12. LARGE AND SMALL NAVIGATION LOCKS

a. Characteristics of Foundation Soils. - The subsurface investigation and characteristics of foundation soils have been discussed in Design Memorandum No. 4. At the location of the boat locks the subsurface conditions consist of a 5 to 15 foot thick surface layer of soft river bottom black organic silt. Underlying the organic silt is a 5 to 10 foot thick layer of loose to medium dense silty sand. This layer is, in turn, underlain by a 20 to 40 foot thick continuous deposit of dense to very dense till. This deposit consists of a heterogeneous mixture of sand, gravel and clayey silt with occasional cobbles and boulders. The till overlies the gray argillite bedrock formation.

b. Type of Foundations. - The major portion of the large lock and a minor portion of the small locks will bear directly on the dense till stratum. At those locations where the organic silt or silty sand is encountered at the founding elevation it will be excavated down to the level of the till and replaced with lean concrete. The maximum thickness of approximately 20 feet of lean concrete will occur under small lock No. 1. The extent and thickness of the concrete fill are shown on Plates 7-16 and 7-17.

c. Foundation Treatment. - The surface of the till may become very soft due to water, frost, traffic and expansion. This softening results in loss of bearing capacity. In order to ensure against the developing of such a condition during construction, it will be required that the final 2 feet of excavation be made immediately prior to the placement of a working mud slab. The mud slab will consist of a 6-inch thick layer of lean concrete. The structural concrete will then be built over this mud slab.

d. Bearing Capacity. - The foundation has been designed for a maximum allowable bearing capacity of 4 TSF. The maximum computed bearing pressure is less than 2 TSF.

e. Scour Protection. - The scour protection was designed in accordance with the Corps of Engineers Manual EM 1110-2-1602. Because of economy and local availability, the material selected for this protection consists generally of 5 to 300 pound stones. At those locations where the flow velocities exceed 7 fps the stone weights will be 50 to 500 pounds. The maximum average flow velocities for the design flood conditions and the required stone sizes are in Table 2.

TABLE 2

STONE PROTECTION DATA

	Location	Flow Velocity in fpm	Req'd Stone Size in lbs.
1.	Upstream of J.F. Expressway Pier	1.9	0.05
2.	Upstream of Large Boat Lock	4.0	0.70
3.	Downstream between Draw Pier and Pier No. 6 of the Charlestown Bridge	7.3	25.00
4.	Downstream between Charlestown Bridge Piers No. 6 through 9	2.8	0.10
5.	Downstream of 8' x 10' Sluices	6.3	12.00

As shown on Plates 7-16 and 7-17, a 2-foot thick layer of the stone protection will be dumped on a 1-foot minimum gravel bedding where placement will be on dry areas and on a 3-foot gravel layer where placement will be on submerged areas. This protection will extend 40 feet beyond the concrete structures on both the upstream and downstream sides of all the lock structures, except on the downstream side of the large lock. At this location the stone protection will extend 260 feet beyond the concrete structure and will consist of 50 to 500 pound stones on a 1-foot gravel bedding where placement will be on dry areas and on a 3-foot thick gravel layer where placement will be on areas submerged under water. This exception is necessitated by the relatively high discharge velocities at this location. Beyond the stone protection, the maximum computed flow velocities are less than 3 feet per second. Stone protection will not be provided beyond these limits except at the locations of the existing John Fitzgerald Expressway bridge piers and the Charlestown bridge piers. These bridges are located upstream and downstream of the locks, respectively. At these piers the protection against the eddy current scour will consist of a 2-foot thick layer of 5 to 300 pound dumped stone. This layer will extend 8 feet beyond the perimeters of the pier footings (or pile caps).

13. FENDER PIERS AND TRAINING STRUCTURES - The major portion of these structures will be founded on treated timber piles. However, at those locations where it is not possible to achieve adequate penetration into the bearing stratum to provide sufficient lateral restraint, steel H-piles will be used. The inadequate penetration results from the hard driving conditions in the till stratum which, because of its dense and strong nature, will offer excessive resistance. The steel H-piles will be provided with cast steel pile points and coal tar epoxy coating to withstand hard driving conditions and corrosive action, respectively.

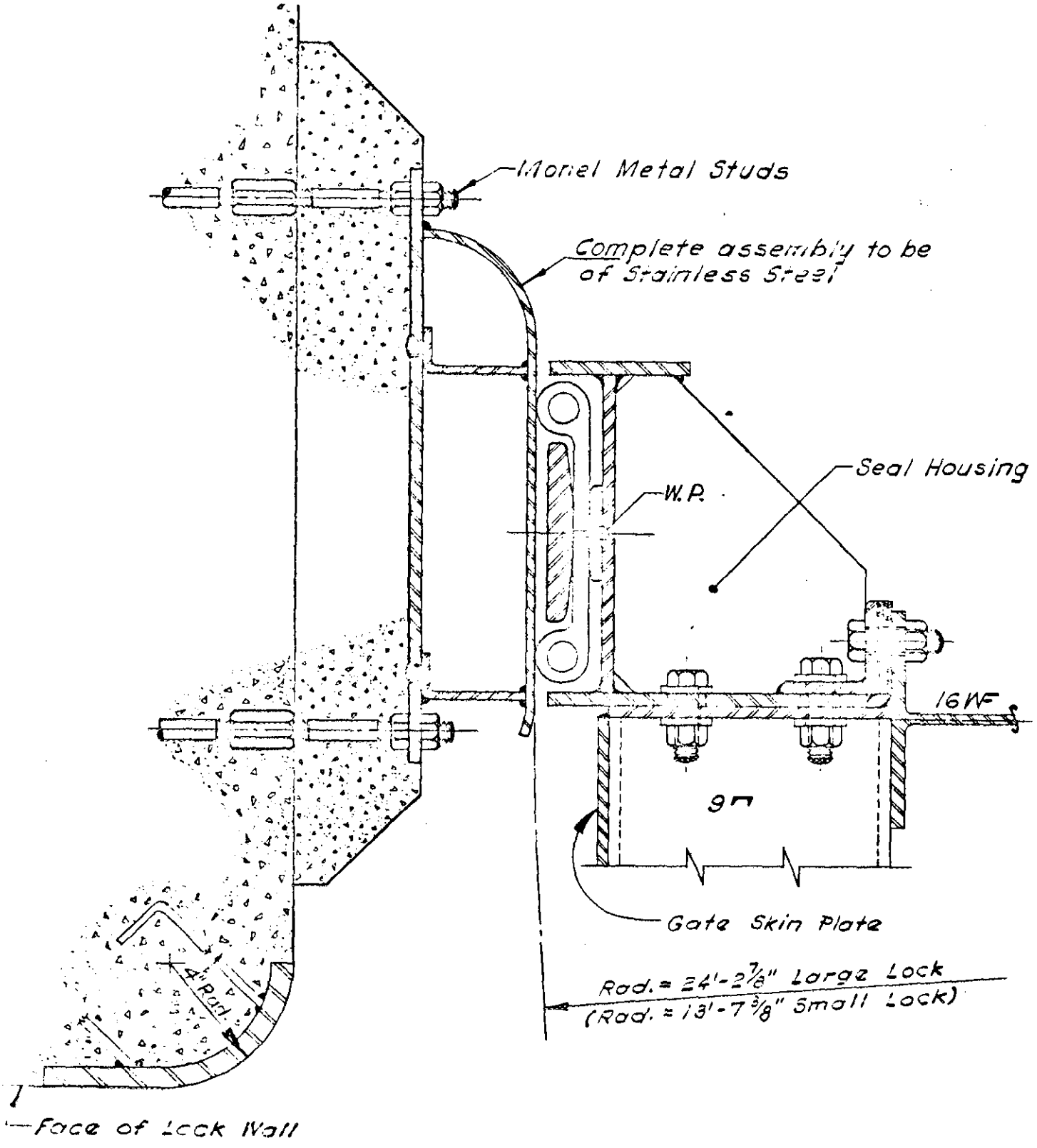
G. LOCK OPERATIONS

14. MECHANICAL OPERATION - The mechanical operation of the sector gates and the culvert and wetwell valves is by an oil hydraulic system. As illustrated on Plate 7-18 the sector gates are closed by a hydraulic cylinder moving a rack that in turn rotates a pinion sector. An arm attached to the pinion is hinged to a strut that is pinned to the gate framework. The axial force imparted to the strut forces the gate leaf to rotate into the closed position. The angle of gate rotation for full closure is 63 degrees and 26 minutes. The gate leafs reach the closed position with approximately 4 inches of travel remaining in the rack. The final movement of the rack compresses springs in the strut which hold the gates closed against an allowance for minor slippage in the hydraulic system. During movement of the gates the springs also serve as a cushion to the mechanical system in the event of obstruction jamming. Opening the gates is the exact reverse of closing them. Hydraulic pressure applied in the opposite direction retracts the rack into the cylinder. Hydraulic cylinders for valve and sector gate operation are designed for 2,000 psi working pressure. The working line pressure is 1,000 psi.

15. BASIS OF DESIGN - The basis of design for the gate operating machinery is to provide a gate operating torque sufficient to overcome the seal friction force (Appendix C) developed at maximum operating conditions. The seal friction force results from a water level of 116 on one side and 106 on the other. For this condition, the torque required at the gate pivot is 346 ft. kips. with an oil pressure of 1,100 psi (hydraulic system relief pressure) in the cylinder, the total torque produced at the gate pivot is 605 ft. kips. assuming no loss for machine efficiency (machinery friction). The force required to overcome gate bearing friction and the dynamic forces resulting from sluicing are quite small in proportion to the force required to overcome seal friction. The forces resulting from reverse head condition are discussed subsequently.

16. REVERSE HEAD OPERATION

a. General. - The problems associated with sector gates designed for reverse head (higher head on the concave side of the gate than on the convex side) have been analyzed and resolved in a manner similar to the design of the nearby Mystic River Locks sector gates. The problem is essentially one of providing side seals capable of water tight closure in either direction; the head reversal occurring with each tide cycle. Figure 1 illustrates the typical side seal used in the design. The differential force across the gate framing resulting from reverse flow through the miter is quite small



SIDE SEAL DETAIL

4 2 0 4

SCALE IN INCHES

FIG. 1

compared to the force available. The greatest force for reverse head for the large lock under the maximum operating condition produces a hydrostatic closing force on the side seal assembly of 2.7 kips. or a torque of 65 ft. kips. at the gate pivot. This is also small compared to the torque capability of the machinery.

b. Experience of Mystic River Dam. - Similar in design and operating conditions, the existing Mystic River Dam lock gates have successfully operated under reverse head conditions. Both basin and tide end gates (which face in opposite directions) have been used for flood sluicing and there has been no perceptible difference in operation of the gate, either opening or closing.

On one occasion, with the large lock dewatered, and with a reverse head of high tide against the tide end gate, an unsuccessful attempt was made to open the gate. Not unexpected the reverse head, approximately 27 feet, was more than twice the design maximum operating head. However, the gate subsequently opened when the reverse head was reduced by lock filling to about 20 feet.

17. LOCK BULKHEAD PLACING AND STORING - The proposed plan for lock bulkhead placement is to barge either the large or small lock bulkhead members from the existing Mystic River Locks and Dam. The bulkhead recesses in the proposed large lock have been designed to accommodate the bulkhead of the wider Mystic River large lock (40 feet vs. 45 feet). No modification in the recesses was required for the small locks as both sites use the same lock width. Actual placement of the bulkhead sections could be done by either a rubber-tired crane operating from the deck area or a crane operating off the barge. EM 1110-2-2602 states that bulkheads should be stored as close as possible to the lock chambers. The additional cost for bulkheads, storage provisions and handling apparatus is not justified since emergency closures can be made at the proposed lock by mechanically closing either of the sector gates.

H. LOCK FACILITIES

18. PERSONNEL FACILITIES - Personnel facilities are provided in the southeast corner of the pump station on both the engine room floor and mezzanine levels. Located within designated areas are the lockmasters office, personnel room, toilet, locker and shower facilities. Access to the personnel area can be gained either directly from the lock wall or from overhead via the walkway and lock control stations.

19. SHOP AND STORAGE AREAS - General storage areas are provided in two locations. Both areas are on the gallery level, one level below the deck. The larger area, approximately 1,700 square feet is adjacent to the lock pumping wetwell and is shown on Plate 7-19. The second below deck storage room is located between the large lock and the small lock off the gallery leading to the basin end of the locks, see Plate 7-20. This area is separated from the equipment room by a 6 inch thick concrete block wall. There is approximately 960 square feet of floor space in this area. It is expected that these two areas will serve as storage for culvert stoplogs, surplus pipe and material storage, and possibly separate trade sheds for electrical, plumbing and carpentry crafts.

A third below deck storage room, also Plate 7-20, is provided in the large lock monolith, basin end. This area, consisting of two chambers connected by a passageway, could serve as an isolated storage room for volatile liquids. The chamber floors are 2 feet below the adjoining gallery floor to prevent accident spillage from entering the galleries. Hollow metal doors lead from the gallery to each chamber. A precast concrete lift off slab in the roof of the chamber provides the necessary receiving hatch on the deck level. A truck driven adjacent to the pump station at the Charlestown approach will unload at the opened hatch. A similar twin-chamber arrangement at the downstream end of the same monolith will be the transformer vault and is shown on Plate 7-21. The transformer will be ventilated by ductwork to a nearby deck opening.

20. EQUIPMENT ROOM - Heating, ventilating, hydraulic pressure, electrical control, compressed air, and sewage ejector equipment are all located in the wall between the large lock and small lock No. 2. The area is centrally located and readily accessible from either crossover as well as the intermediate stair tower supporting the overhead walkway. A lift off hatch and a removable deck slab facilitate entry and removal of supplies and equipment.

21. CONTROL STATIONS - Elevation of the Control Stations was determined by vertical clearance of el. 136.5 feet to underside of monorail spanning the locks and sight line obstructions generated by the Charlestown Bridge and neighboring elevated highways. Location of the control consoles was determined by line of sight studies undertaken to determine maximum visibility up and down stream as well as into the locks. Size of console modules is the minimum required for maintenance and operation of the consoles. Access to the Control Stations is by staircases from all lock structures and by the enclosed walkway from Pumping Station.

I. NAVIGATION LOCK APPURTENANCES

22. LOCK HANDLING FEATURES - A number of features have been designed for the lock to assist in safe and efficient handling to locking craft.

a. Floating Mooring Bits similar in design to those shown in EM 1110-2-2602 will be at 22-foot centers on each small lock and 40-foot centers on the large lock.

b. Breasting Floats will be fastened to the floating mooring bits of the small locks to permit small craft to dock against a floating system. The breasting floats will have a continuous rubber bumper and have two tie-up cleats per 20-foot section. Construction will be of timber, with urathane foam fill for buoyancy and concrete base for ballast.

c. Handrails of aluminum tubing are placed around all sector gate recesses as shown on Plates 7-22 through 7-24 at the projecting ends of the large lock, along the large lock where it borders the pumping station intakes and discharge, at the open end of each small lock between fender walkways, and along the exterior of small lock No. 1 except for the access road opening. In accordance with EM 1110-2-2602 water side faces of lock walls shall have either guardrails or parapets for their entire length.

d. Appurtenances, see Plates 7-22 through 7-24, in the form of deck cleats, removable mooring bits, electric traffic control signals, navigation lights, lock chamber ladders and tile gages in the lock walls are in accordance with the requirements of the "Miscellaneous Provisions" section of EM 1110-2-2602.

e. Timber Fenders are of the guard wall type and will be of long leaf yellow pine construction including pilings. The tide end of the large lock will have long timber guide walls to direct commercial vessels through the pier structures of the Charlestown Bridge. Navigation turning movements prevent a similar long wall arrangement at the upstream end of the large lock. In lieu of a wall, wooden dolphins are set alongside the shipping channel to secure moored commercial craft. The guard walls are faced with solid timber sheeting down to an elevation determined from data on the stratification of salt and fresh water, which is discussed in further detail in Design Memorandum No. 1.

f. De-icing of the approach channels and the sector gate recesses on the upstream (non-tidal) end of the locks is accomplished by air bubbles in the vicinity of the face of the walls. Experience at the Mystic River facility has shown that de-icing is not required at the tide end of the locks. The air is piped from the compressor unit in the equipment room.

g. Trash and Ice Grating consisting of 4" x 1/2" bars at 6-inch centers framed into the exposed face of each sector gate structure will limit debris entering the recess. Radial timbers at 3-foot vertical centers will serve as bumpers when boats pass the recessed gate leafs.

23. EQUIPMENT AND MATERIALS HANDLING - A 4-ton overhead hoist, supported under the elevated walkway, has been provided for cross lock transport of materials and equipment. Transport along the lock walls is handled by a 10-ton capacity mobile crane. This crane is capable of moving and installing heavy equipment and materials including the bulkheads for the navigation gates. Movement of the mobile crane across the locks is accomplished by a portable aluminum bridge which will be installed as needed by the mobile crane. In addition to the above, cross lock movement of personnel and light materials can be accomplished by use of the walkways on the navigation gates (closed position) or in the gallery crossovers. Hook eyes to suspend portable hoists are included at points of vertical transfer of materials and equipment.

24. PROTECTIVE COATINGS - A corrosion study of the navigation lock gates at the existing Mystic River Dam was made after six years of service. This study, made to determine the effectiveness of the corrosion control used in a similar corrosive environment as the Charles River Project, is included as Appendix B to this memorandum. The study indicated that protective coatings alone were not sufficient; therefore the corrosion protection at Charles River will consist of a combination of protective coatings of coal tar epoxy, zinc rich primers and cathodic protection.

25. INSTRUMENTATION - Tide, fixed pool and lock chamber levels will be transmitted to the Pumping Station pneumatically. The 100 psig instrument air supply system components include a moisture trap, automatic drain, inlet filter, dryer and pressure regulation. The 20 psig level transmitting components are a purge rotometer, differential regulator, moisture separator with automatic trap and, for the lock chambers, an electric pressure sensing unit. Provision will be made in the Pumping Station "Instrumentation" for future remote salinity and watershed tributary level measurements. Salt water intrusion and runoff data will be transmitted via leased telephone lines. The instrument air system will be cross connected to the compressed air service system filters and dryers as a back-up to the instrument system.

J. HEATING AND VENTILATION

26. CENTRAL FRESH AIR - A central summer-winter ventilation system located in the Pumping Station will provide supply air requirements to the general gallery areas, and exhaust requirements will be satisfied by exhaust fans located at the extremities of the lock spaces. Units and fans for general gallery-crossover ventilation will be thermostatically controlled and electrically interlocked as required. Transformers needs will be satisfied by thermostatically controlled exhaust fans. All heating requirements in the galleries and crossovers will be met with electric unit heaters and baseboard radiation where space requirements dictate. The equipment room will be provided with a heat dissipation ventilation system, suitable moisture control provision, electric unit heaters, and thermostatic control of system components.

27. HOT WATER UNIT HEATER - A hot water unit heater shall provide heat, as required, for the lock pump room.

K. ELECTRICAL DESIGN

28. GENERAL - The design of the electrical installation for servicing the locks includes provisions for power, exterior and interior lighting, control systems, traffic signal system, electric heating, ventilation, communication, telephone, lighting protection, grounding, and temporary power and light service.

29. POWER SUPPLY AND DISTRIBUTION - The plan for incoming power for the project, including emergency power and power distribution throughout the lock facilities, is discussed in detail in Design Memorandum No. 5.

30. LOCK CONTROL CONSOLES - In general, the following control, recording and/or communication equipment will be installed and wired complete and ready for operation:

a. Control Consoles. - Two control consoles located in each control station in the elevated walkway.

b. Outdoor Control Stations. - Six outdoor control stations located as shown on Plates 7-22, 7-23, and 7-24.

c. Paging and Reply Systems & Interior Telephone System. - Combination paging and reply system and interior telephones system located in each control station in the walkway.

d. Level Recording Programmer and Printer. - One accurate level recording programmer and printer located in pumping station.

e. Interconnected Control Cabinet. - One control cabinet located in Lockmaster's office and interconnected switching located in console.

f. Recording Console. - Recording console located in pumping station.

31. LOCK OPERATION CONTROL - In general, the following control systems will be installed and wired complete and ready for operation:

a. Fender and/or Navigation Lights. The fender and/or navigation lights shall be controlled separately by switches at the control consoles in the walkway control stations.

b. Culvert Valve Control System. - Culvert and wetwell solenoids, including limit switches for control and wetwell valve circuits with indicating lights in the elevated walkway provide a complete Culvert Valve Control System.

c. Lock Sector Gate Control Systems. - Lock sector gate control systems will include control relays in the Control Center, push button stations and indicating lights in the Control Stations and Control Towers and wiring for sector gate solenoids including limit switches for control of sector gate valve circuits with indicating lights at the valve solenoids.

d. Automatic Lock Pump Control System. - Automatic lock pump control system will be provided with H.O.A. switches and pilot lights on the starter covers so that hand operation is possible. The control stations and control tower consoles will have pilot light indicating when pumps are running.

e. Hydraulic Oil Pump Controls. - Hydraulic oil pump controls will include relays in the control center, and push buttom stations and indicating lights at the control stations and in the control tower consoles.

f. Traffic Signal Systems. - A complete and independent visual Traffic Signal System will be furnished for each end of each lock.

g. Communication Systems. - Communication systems consisting of interior automatic dial telephone system and combined voice paging and reply system will be furnished to provide instant two-way voice communication between control and remote locations.

32. LIGHTING - Complete lighting systems will be provided for the Walkway and Control Stations, Lock Pumping Station, Galleries, Lock Lighting, Navigation Lighting and Gatelights. The lighting distribution system and the controls will utilize 480Y/277 volt and 208Y/120 volt, 3 phase, 4 wire service.

33. TELEPHONE - Complete empty conduit and/or raceway system will be provided including outlet junction and terminal boxes as required by the telephone company.

L. INSTRUMENTATION OF STRUCTURES

34. GENERAL - The instrumentation proposed for the project structures will be in accordance with ER 1110-2-100 and EM 1110-2-4300. The plan location of instrumentation and applicable details are shown on Plate 7-25.

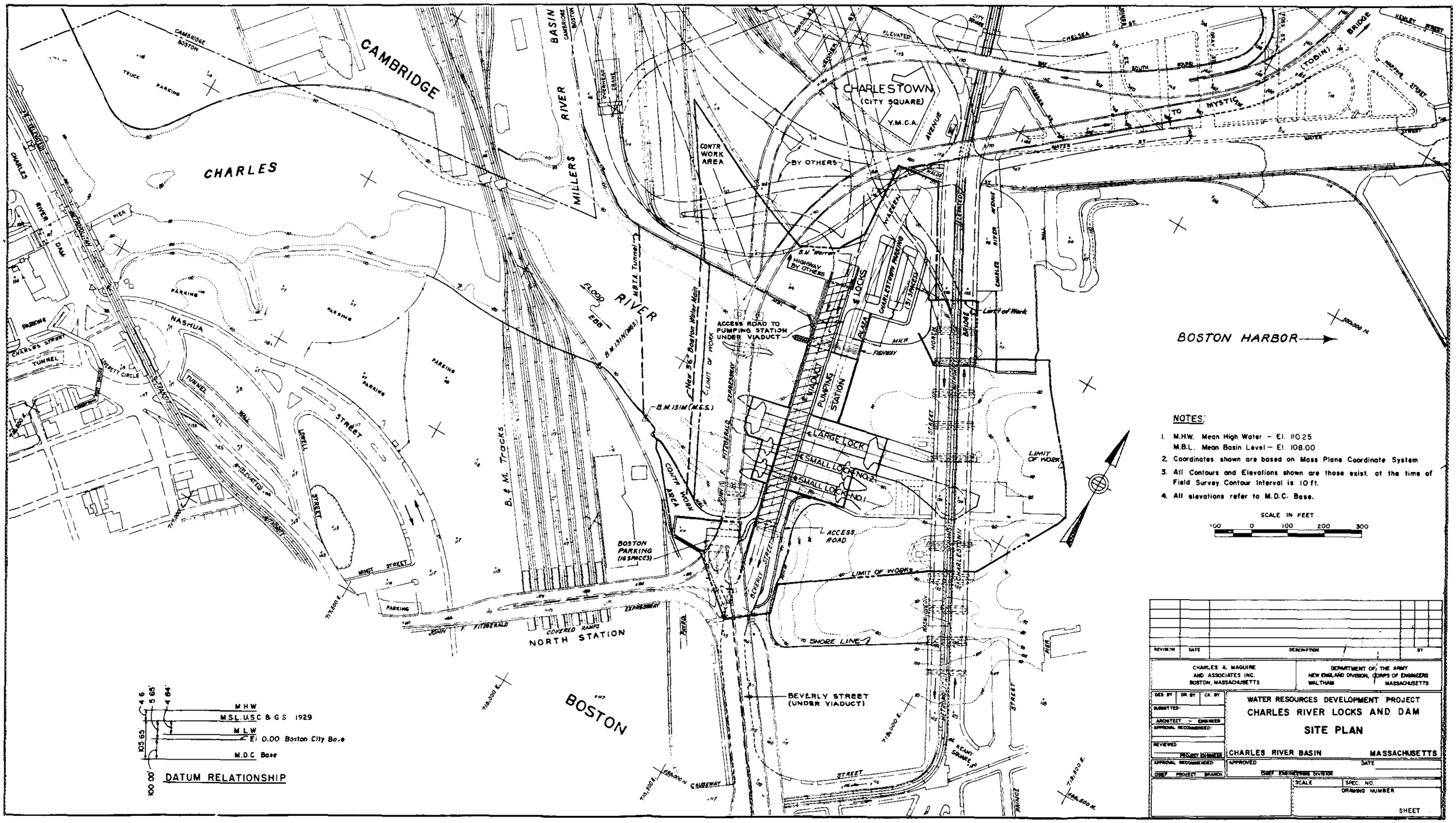
35. PLAN OF INSTRUMENTATION.

a. Uplift Cells - A total of 18 pore pressure transducer (Pneumatic Diaphragm type) are provided to monitor variations of uplift particularly during inspection periods. The cells will be located in the till subgrade at the bottom of the base slab or at the bottom of the lean concrete fill where it occurs. Permanent facilities for making readings will be provided in the storage areas between small locks No. 1 and 2 and between small lock No. 2 and the large lock to read those instruments located in the locks monolith. A third reading station will be provided on the engine room floor near the center of the west wall in the pump station to read those instruments located at the bottom of the pump station monolith.

b. Settlement Monuments. - A total of 24 bronze marker inserts are to be provided. Fifteen of the inserts will be embedded at the top of the locks at elevation 118 feet, MDC base, three in the pump station floor along the east wall at elevation 122.16 and six on the top of the pump station forebay deck at elevation 118.61. The monument will allow precise levels to be made and will also allow for alignment surveys to be taken.

c. Settlement Platforms. - Settlement platforms will be installed between baseline stations 46+00 and 53+60 prior to the construction of earth fill for the viaduct ramp at the Boston side. It is expected that several inches of settlement will occur in this reach due to the existence of the organic silt zone beneath the present fill. These platforms will be of the simple type consisting of a horizontal plate with an extendable vertical rod (threaded pipe). Settlement readings of these platforms during and after construction of the earth fill will be used to dictate the time of starting construction of the paved road surface as discussed in the Design Memorandum No. 4.

36. READING SCHEDULE - The uplift cells and the settlement monuments will be read initially prior to flooding and removal of the cofferdam, and annually after the project structures are in operation. Initial readings of the settlement platforms will be made after construction of the embankment. Readings will be taken biweekly for the first two months and monthly after the second month for approximately 6 to 8 months at which time the anticipated settlement of the embankment will be essentially completed.



NOTES:

1. M.H.W. Mean High Water – El. 110.25
   M.B.L. Mean Basin Level – El. 108.00
2. Coordinates shown are based on Mass Plane Coordinate System
3. All Contours and Elevations shown are those exist. at the time of Field Survey. Contour Interval is 10 ft.
4. All elevations refer to M.D.C. Base.

SCALE IN FEET
100 0 100 200 300

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE AND ASSOCIATES INC. BOSTON, MASSACHUSETTS

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION, CORPS OF ENGINEERS WALTHAM MASSACHUSETTS

DES. BY | DR. BY | CK. BY

SUBMITTED: ARCHITECT – ENGINEER

APPROVAL RECOMMENDED:

REVIEWED: PROJECT ENGINEER

APPROVAL RECOMMENDED: CHIEF PROJECT BRANCH

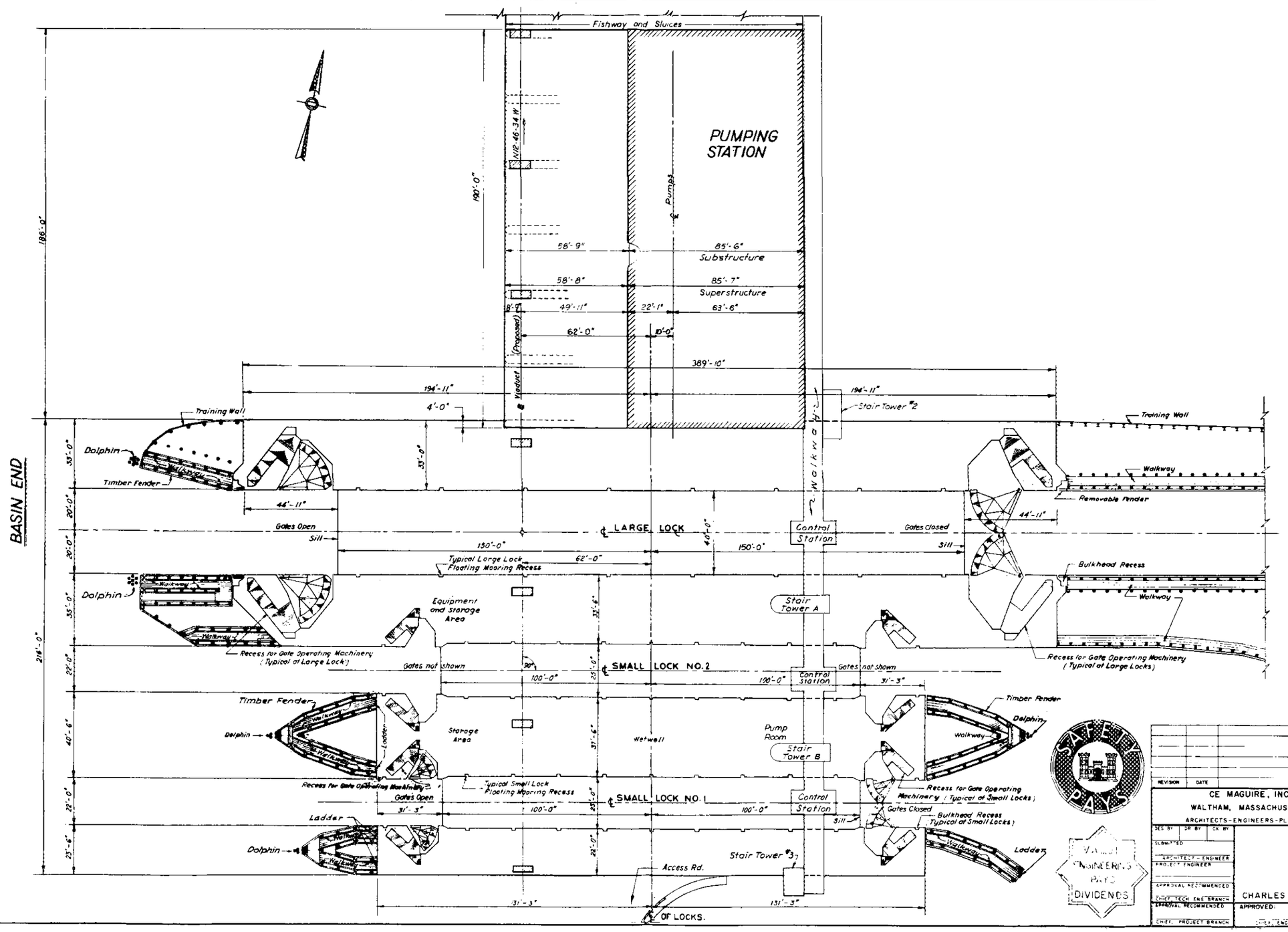
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
SITE PLAN

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE
CHIEF ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 7-1



REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES. BY | DR. BY | CK. BY
SUBMITTED:
ARCHITECT-ENGINEER
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED:
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

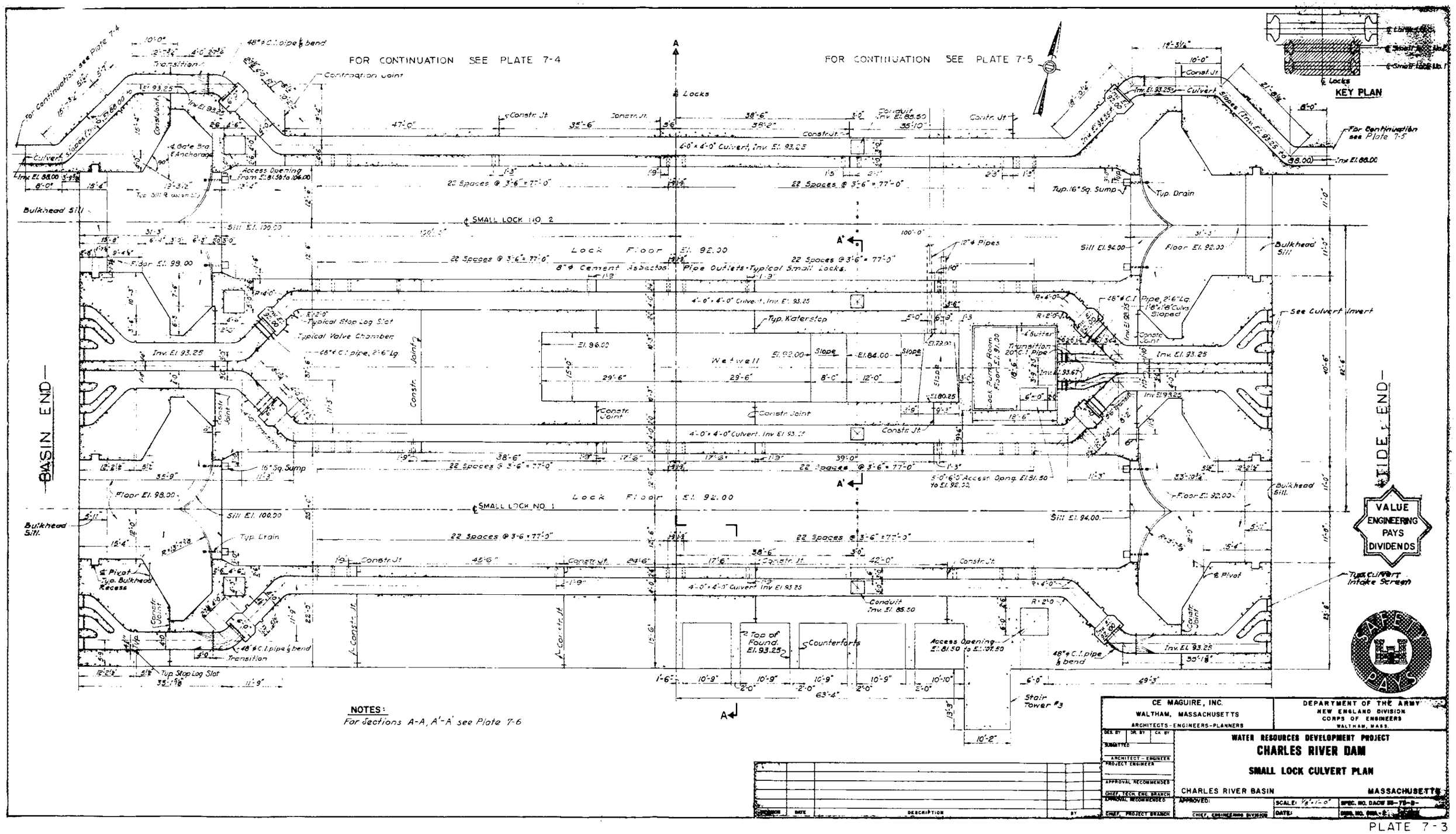
GENERAL STRUCTURAL PLAN

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE:
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CHA-2
SHEET

PLATE 7-2

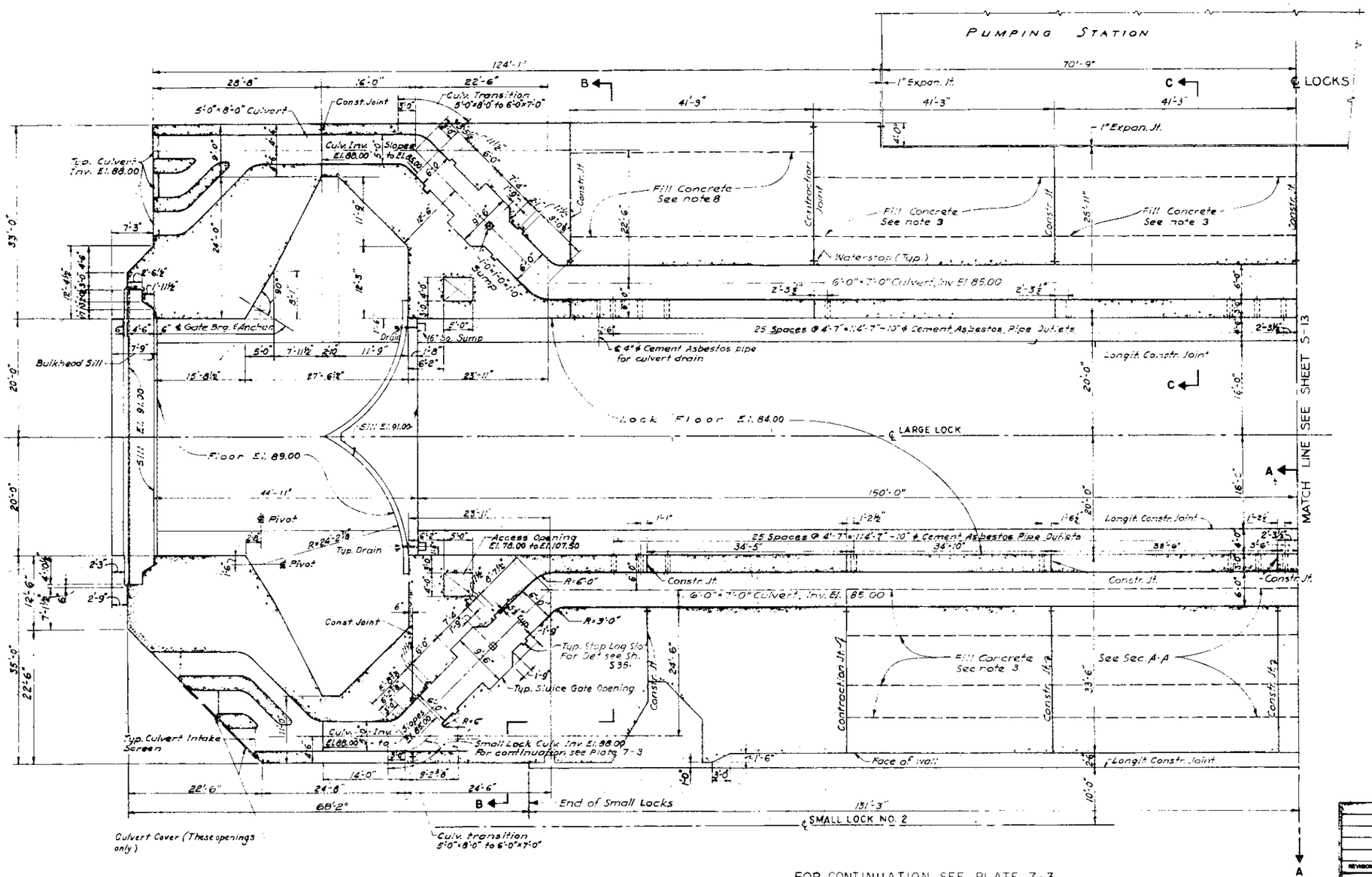


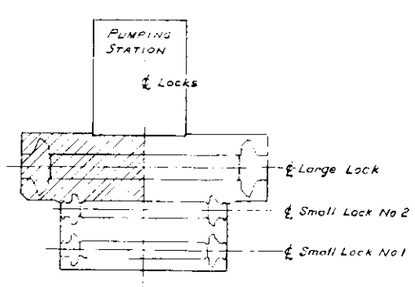
NOTES:

For Sections A-A, A'-A' see Plate 7-6

CE MAGUIRE, INC. WALTHAM, MASSACHUSETTS ARCHITECTS-ENGINEERS-PLANNERS		DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	
DES. BY / DR. BY / CK. BY / SUBMITTED / ARCHITECT-ENGINEER / PROJECT ENGINEER / APPROVAL RECOMMENDED / CHIEF, TECH. ENG. BRANCH / APPROVAL RECOMMENDED / CHIEF, PROJECT BRANCH		WATER RESOURCES DEVELOPMENT PROJECT **CHARLES RIVER DAM** **SMALL LOCK CULVERT PLAN**	
		CHARLES RIVER BASIN	MASSACHUSETTS
		APPROVED: / CHIEF, ENGINEERING DIVISION	SCALE: 1/8"=1'-0" / DATE: / SPEC. NO. DACW 33-78-B- / DWG. NO.

REVISION	DATE	DESCRIPTION	BY





KEY PLAN

NOTES:

1. For Section A-A see Plate 7-6
2. For Sections B-B & C-C see Plate 7-7
3. Fill concrete to be placed monolithically with structural concrete.

FOR CONTINUATION SEE PLATE 7-3

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

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PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ERG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

LARGE LOCK CULVERT PLAN

SHEET 1

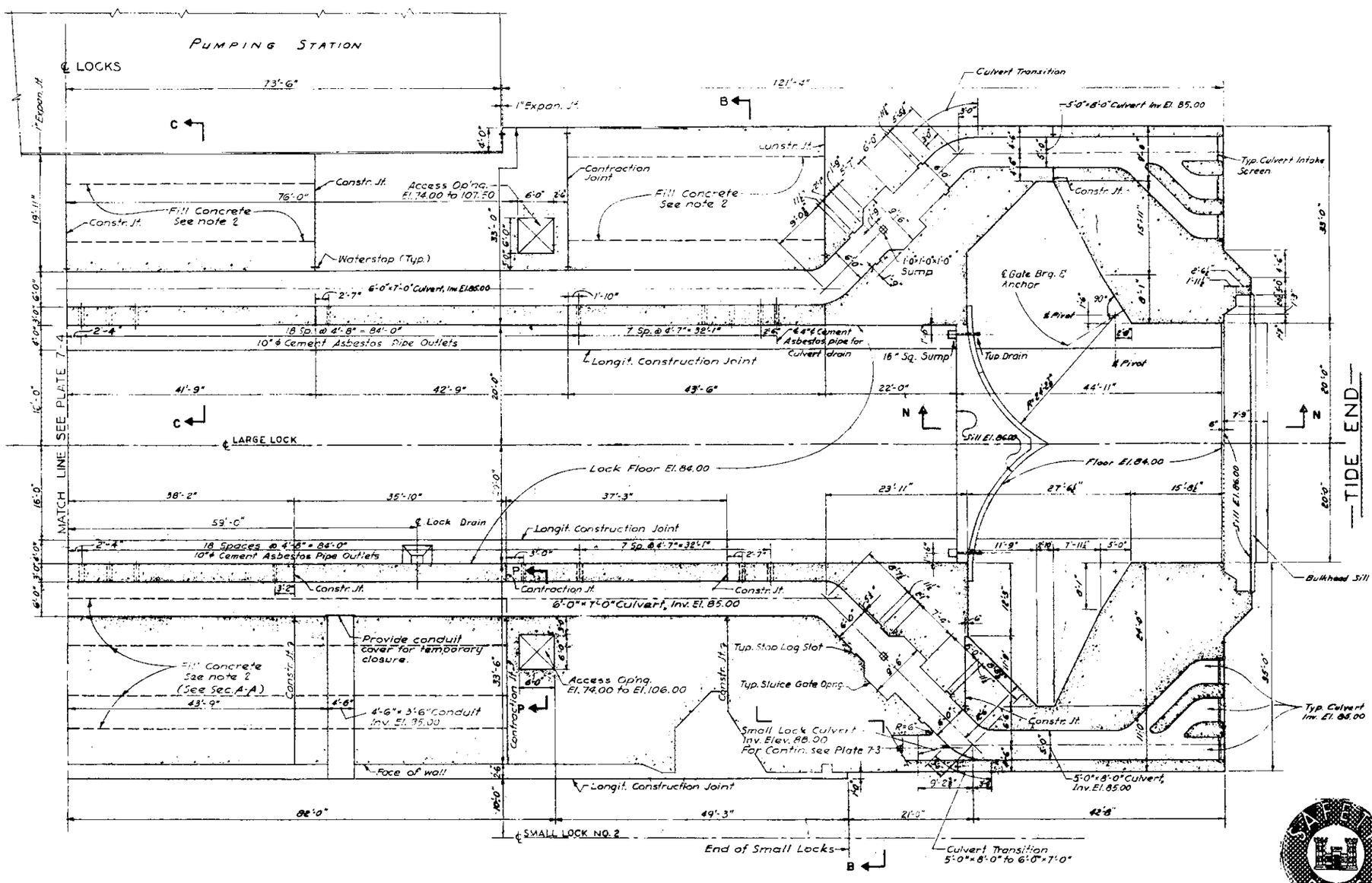
CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

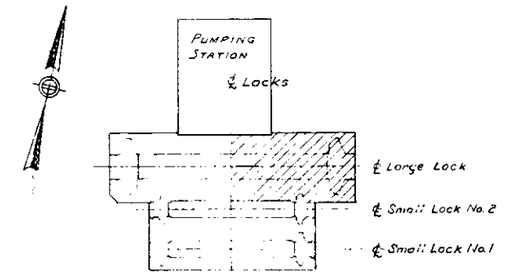
SCALE: 1/8"=1'-0"
DATE:
SPEC. NO. DACW 33-78-B-
DWG. NO. CHA-8 | SHEET

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS



FOR CONTINUATION SEE PLATE 7-3



KEY PLAN

NOTES:

1. For Sections B-B & C-C see Plate 7-7
2. Fill concrete to be placed monolithically with structural concrete.

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

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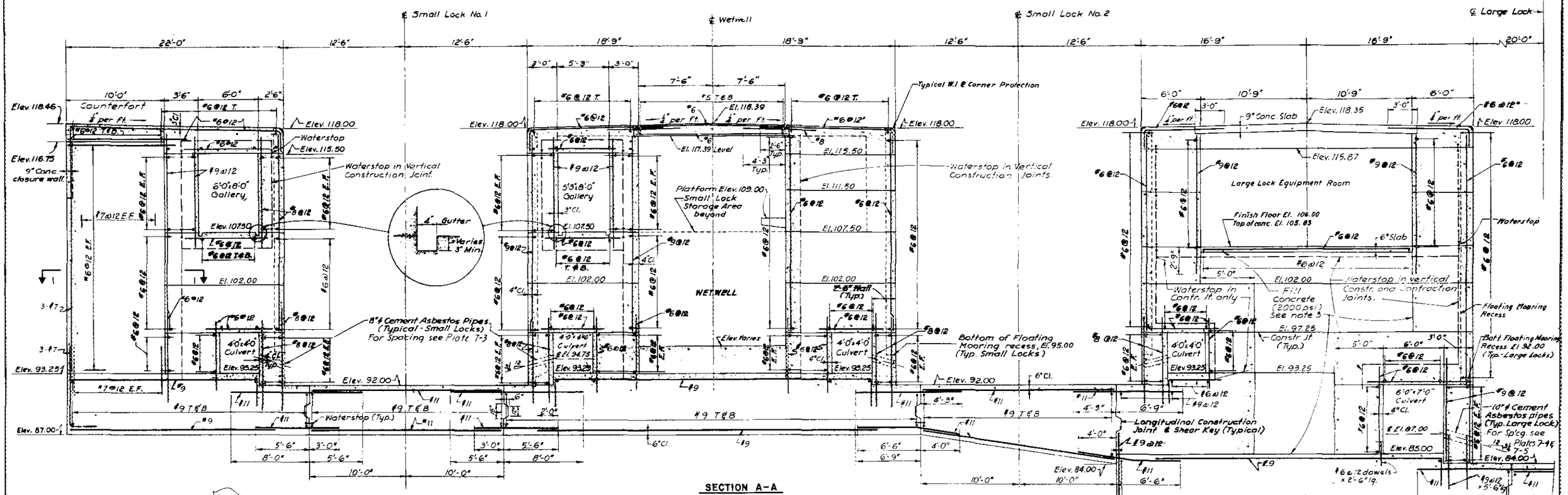
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
LARGE LOCK CULVERT PLAN
SHEET 2

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE: 1/8" = 1'-0" | SPEC. NO. DACW 33-73-B-
DATE: | DWG. NO. CNA-2 | SHEET



NOTES:

1. For location of Section A-A see Plates 7-3, 7-4, 7-19, 7-20, 7-22, & 7-23
2. For location of Section A'-A' see Plates 7-3, 7-19 & 7-22
3. Fill Concrete to be placed monolithically with structural concrete.

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED
ARCHITECT-ENGINEER
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

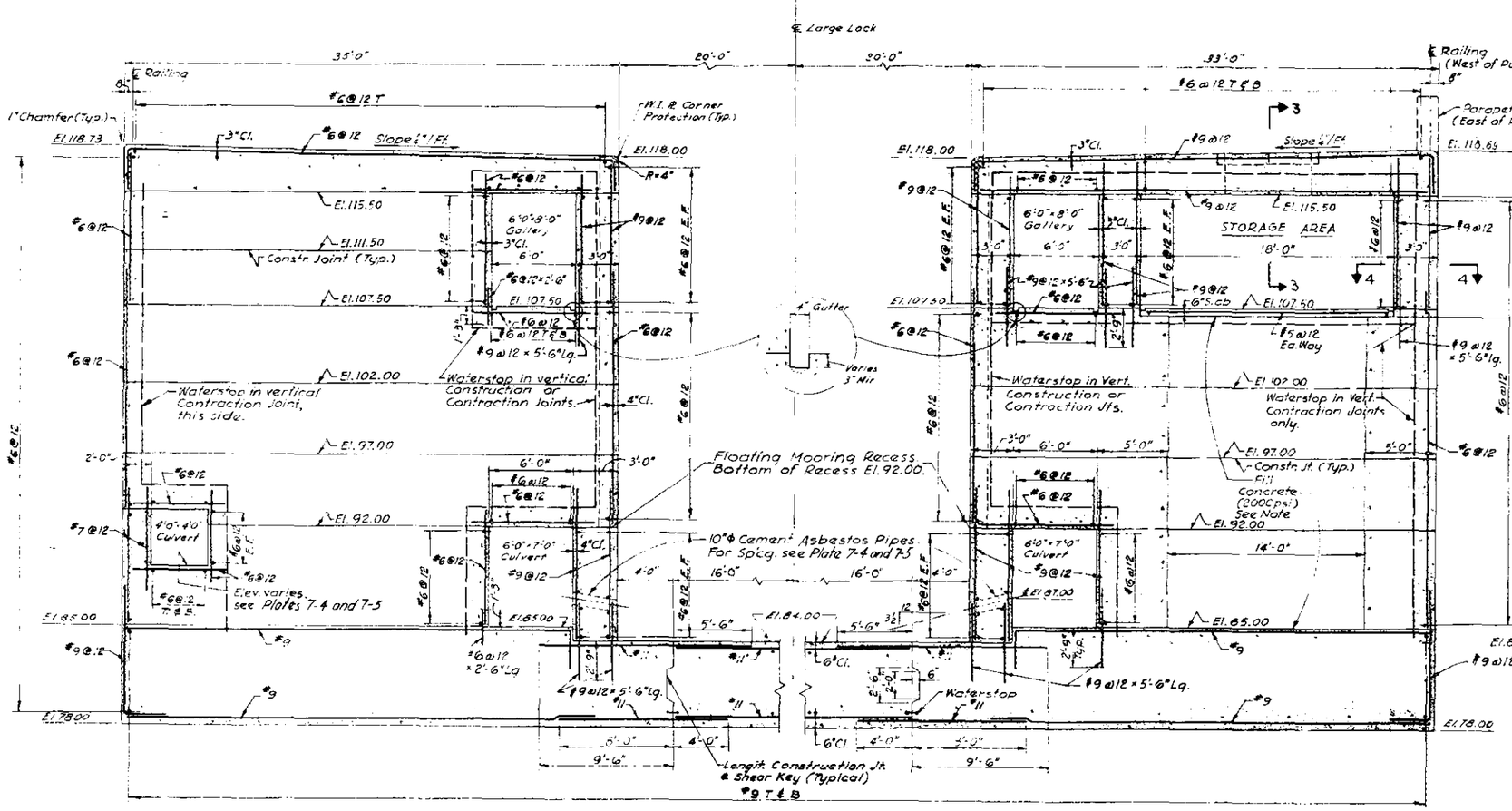
LOCK SECTIONS

SHEET 1

CHARLES RIVER BASIN — MASSACHUSETTS

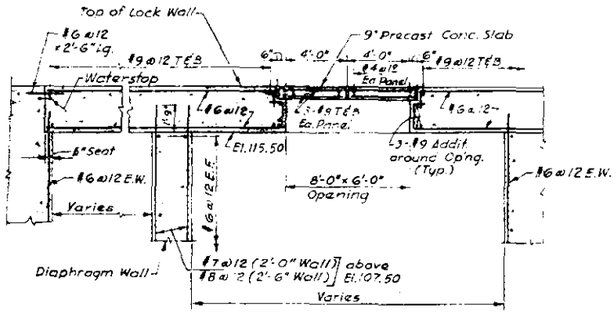
APPROVED:
CORPS ENGINEERS DIVISION

SCALE: 1/4" = 1'-0"
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CHA-2
SHEET

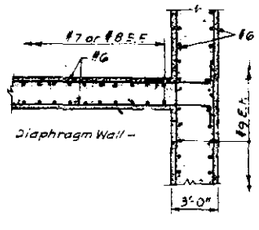


SECTION B-B

SECTION C-C



SECTION 3-3



SECTION 4-4

NOTES:

For location of Sections B-B & C-C see Plates 7-4, 7-5, 7-20, 7-23 & 7-24.

Fill Concrete to be placed monolithically with structural concrete.

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
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NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

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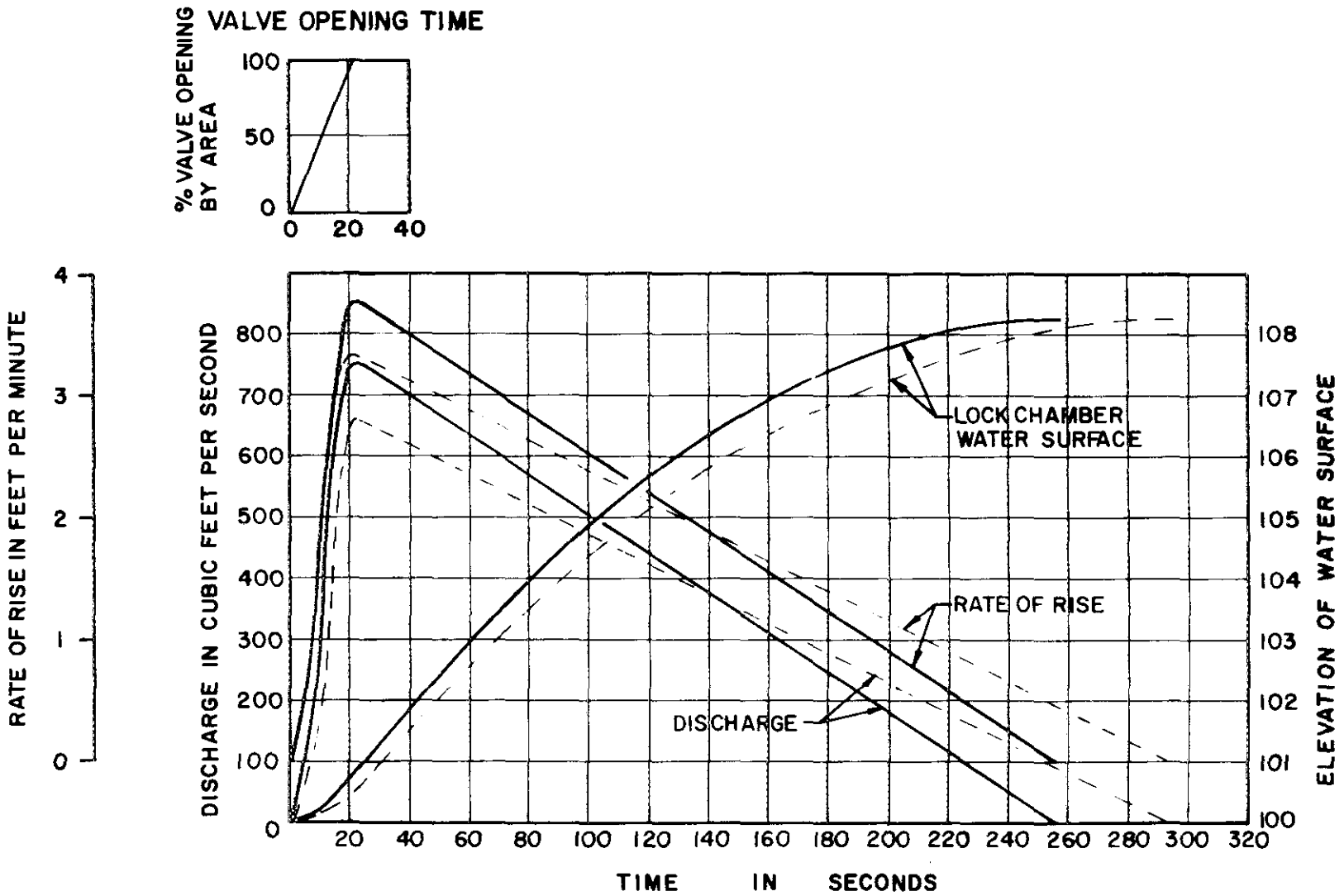
ARCHITECT-ENGINEER
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
LOCK SECTIONS
SHEET 2

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION
SCALE: 4"=1'-0"
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CNA-2
SHEET



LEGEND

7'X6' CULVERT ———

6'-6"X5' CULVERT - - - - -

PLATE 7-8

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

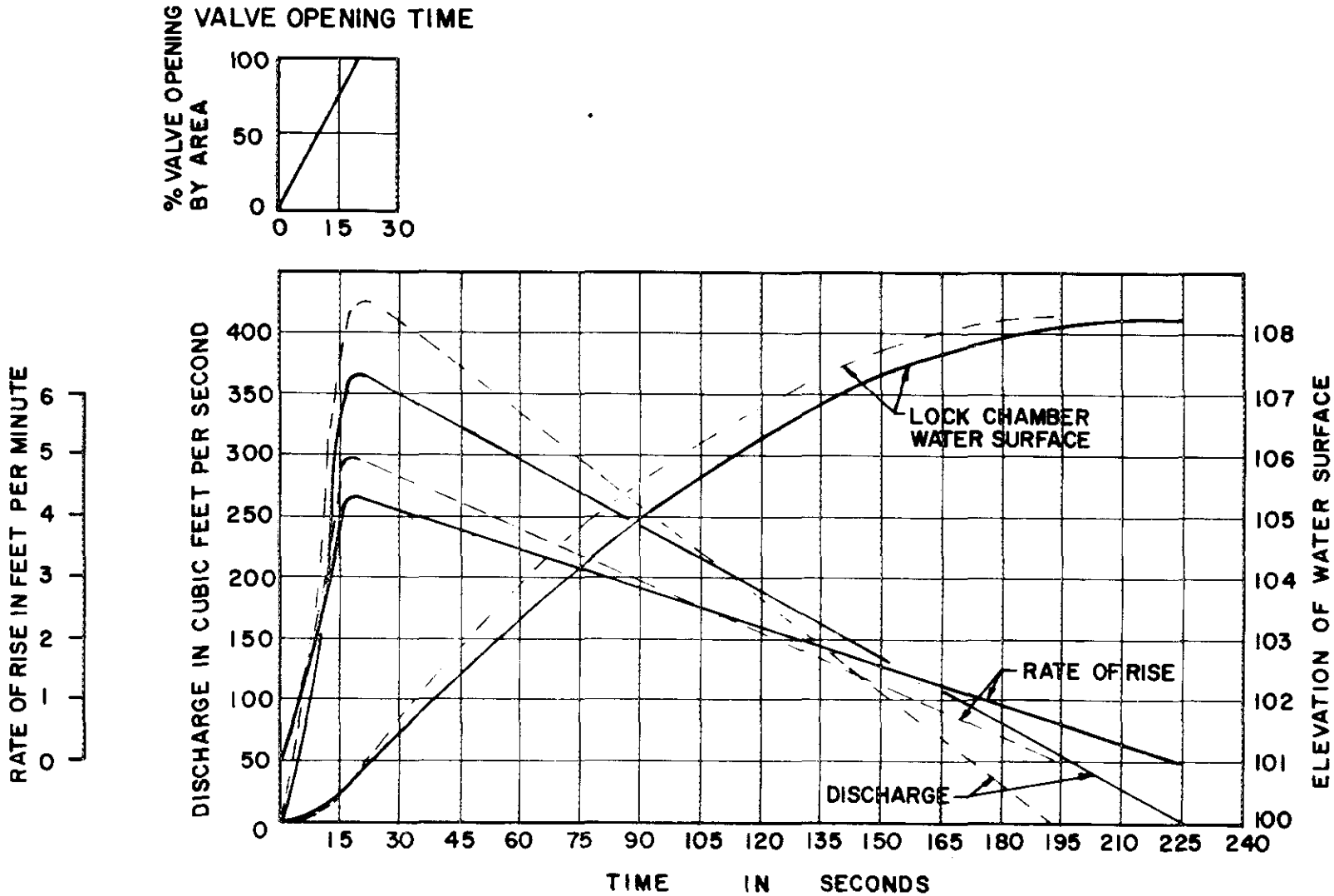
LARGE LOCK

FILLING CURVES

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION

CORPS OF ENGINEERS WALTHAM, MASS.



LEGEND

4'X4' CULVERT ———

4'-6"X4'-6" CULVERT - - - - -

PLATE 7-9

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

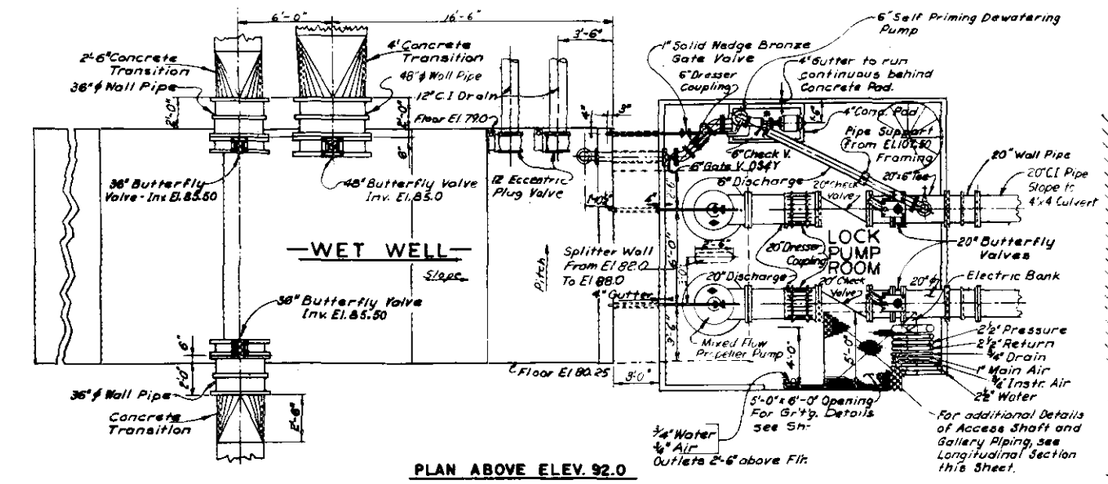
SMALL LOCK

FILLING CURVES

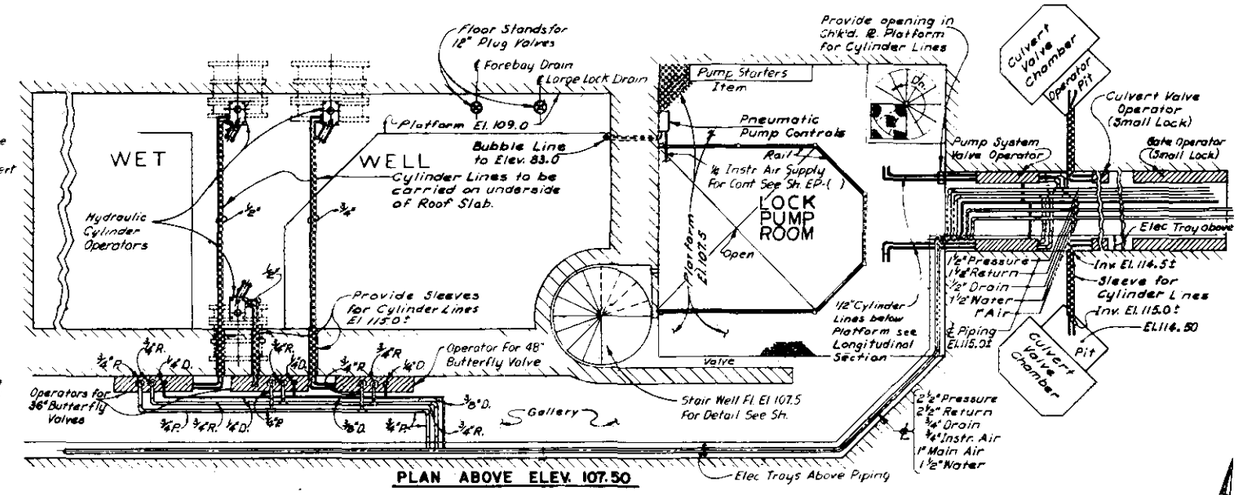
DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION

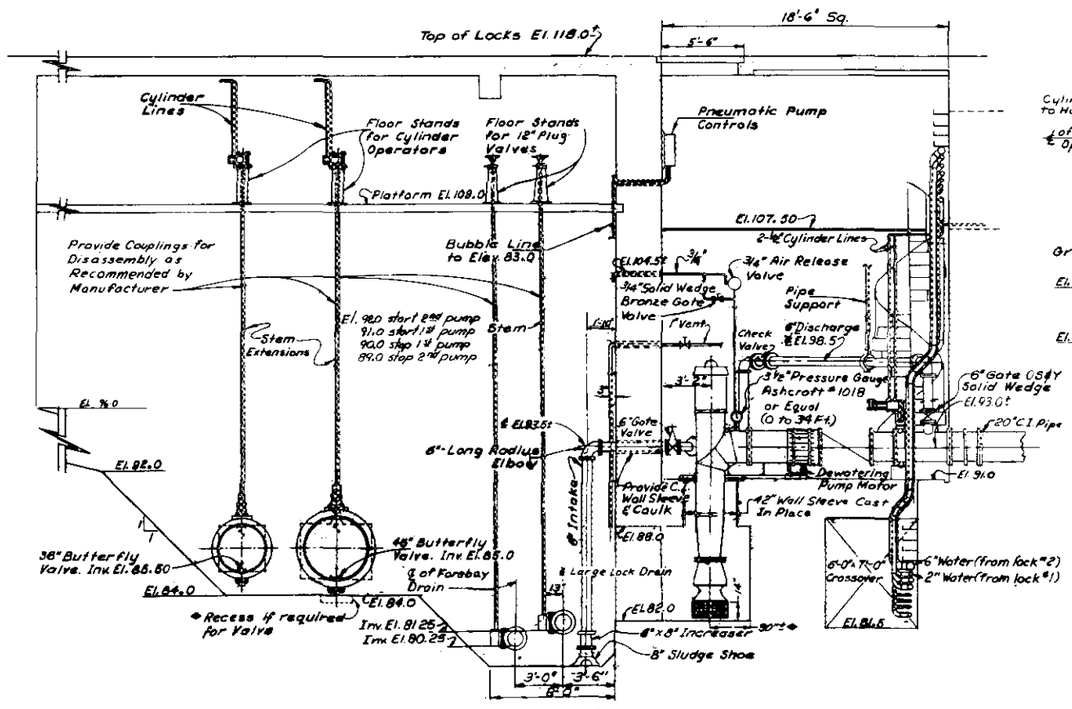
CORPS OF ENGINEERS WALTHAM, MASS.



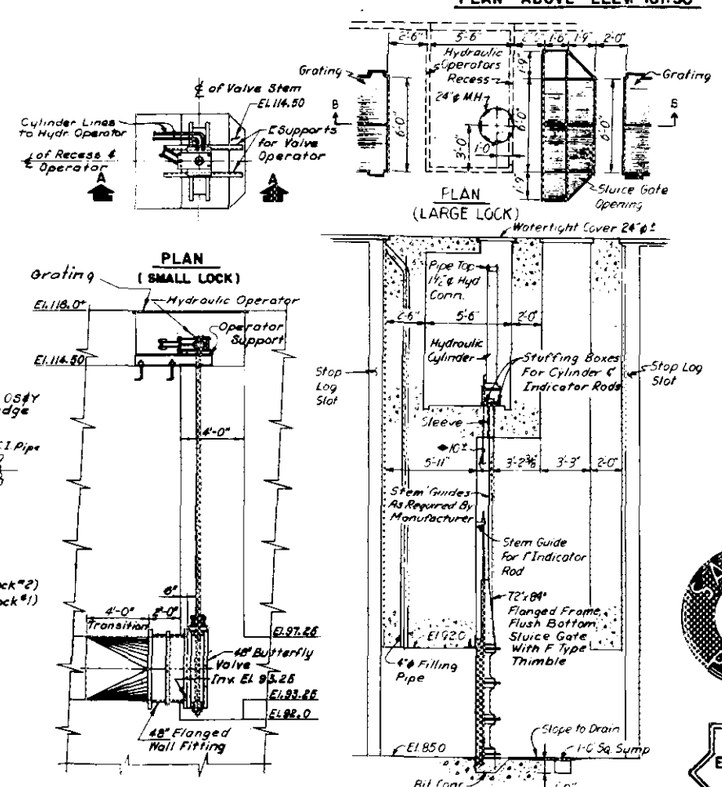
PLAN ABOVE ELEV. 92.0



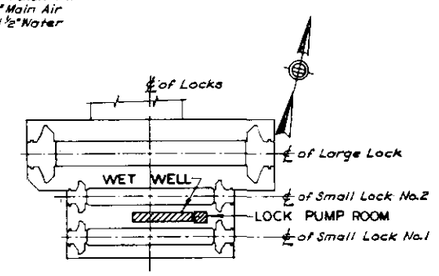
PLAN ABOVE ELEV. 107.50



LONGITUDINAL SECTION



CULVERT VALVES



KEY PLAN

SCALE: 1" = 100'-0"

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED

ARCHITECT-ENGINEER PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, TECH. ENG. BRANCH

APPROVAL RECOMMENDED

CHIEF, PROJECT BRANCH

CHIEF, ENGINEERING DIVISION

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

LOCK PUMP ROOM EQUIPMENT & CULVERT VALVE DETAILS

CHARLES RIVER BASIN — MASSACHUSETTS

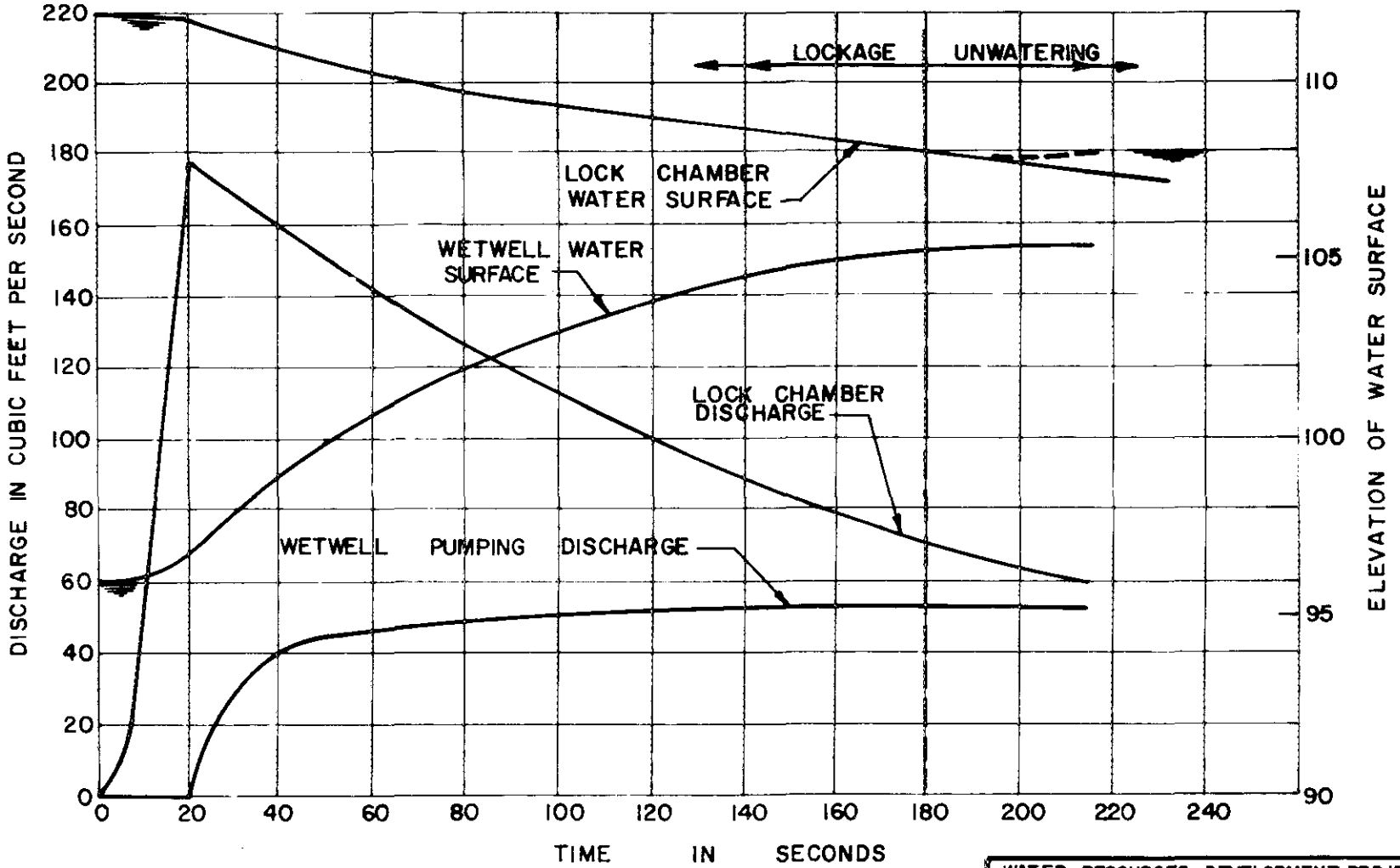
SCALE: 1/4" = 1'-0"

DATE:

SPEC. NO. DACW 33-73-B-

DWG. NO. CHA-2

SHEET 7



TIDE ELEVATION = 112.0 FT. (M.D.C. BASE)
FIXED POOL ELEVATION = 108.0 FT. (M.D.C. BASE)
VALVE OPENING TIME = 20 SEC.

PLATE 7-11

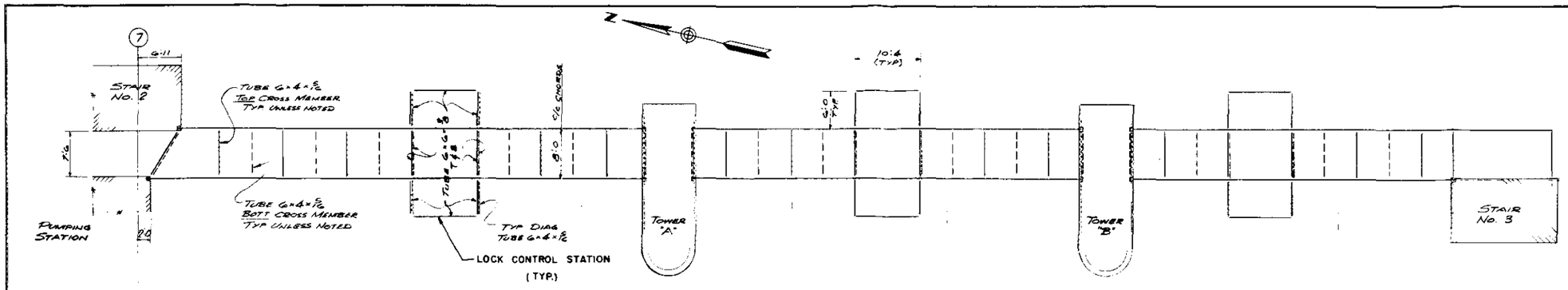
WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

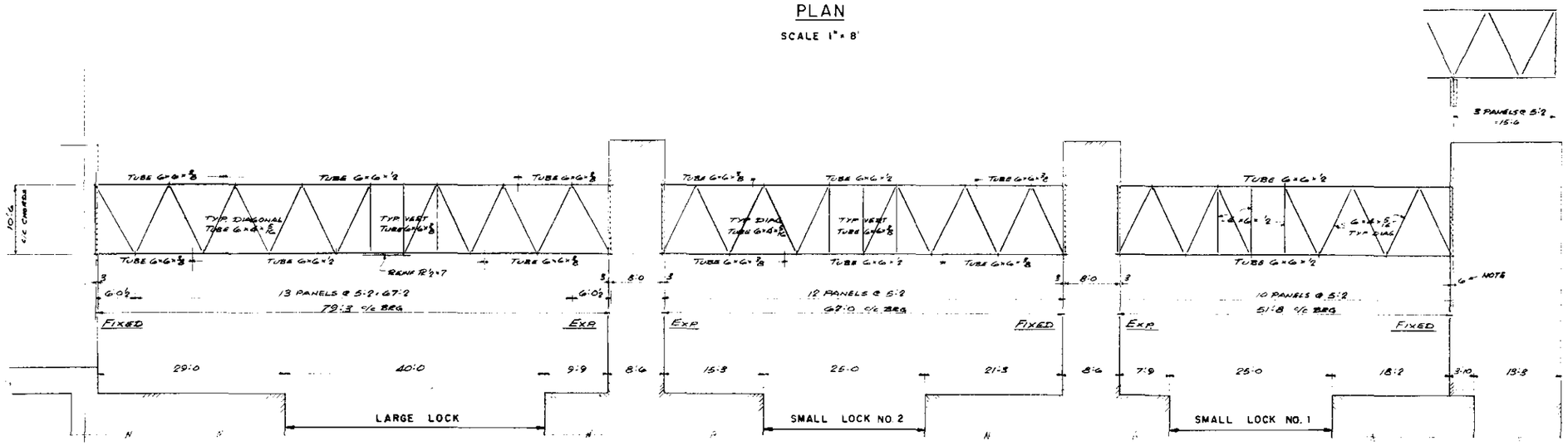
SMALL LOCK
PUMPING CURVES

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.



PLAN

SCALE 1" = 8'



ELEVATION

SCALE 1" = 8'

GRAPHIC SCALES

1" = 8' 8 0 8' 16'

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

WALKWAY

PLAN AND ELEVATION

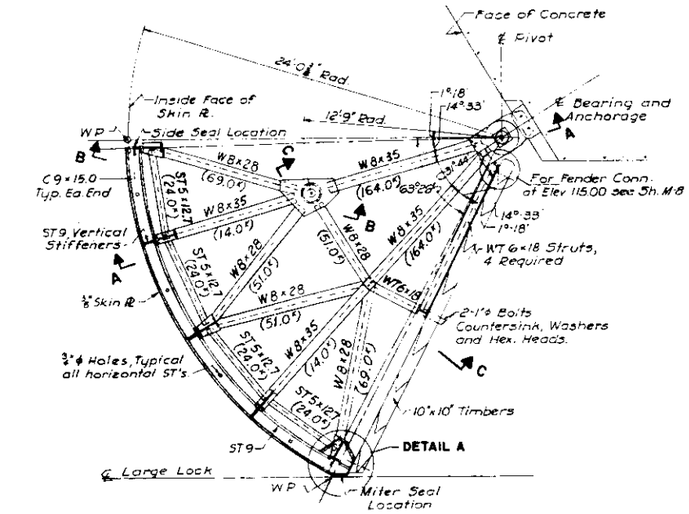
CHARLES RIVER BASIN MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

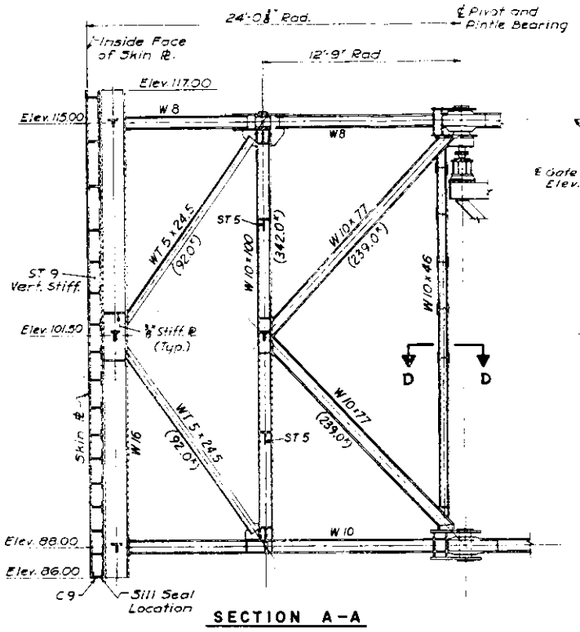
SCALE:
DATE:

SPEC. NO. DACW 33-
DWG. NO.
SHEET

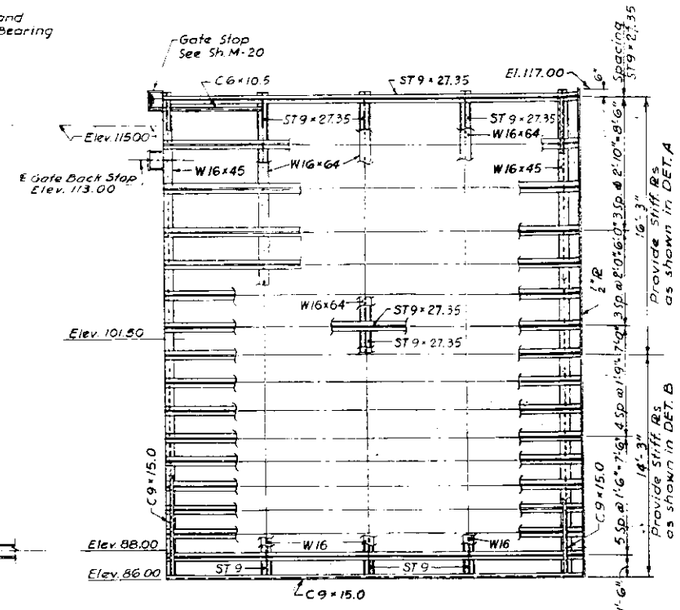
PLATE 7-12



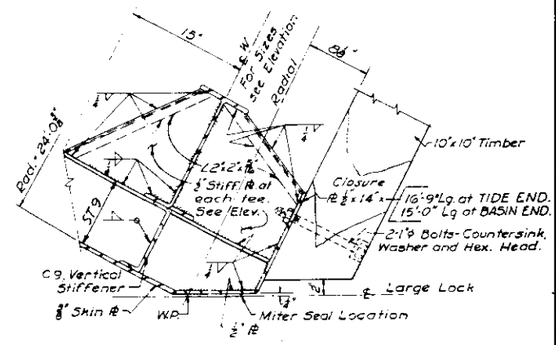
PLAN AT ELEV. 115.00



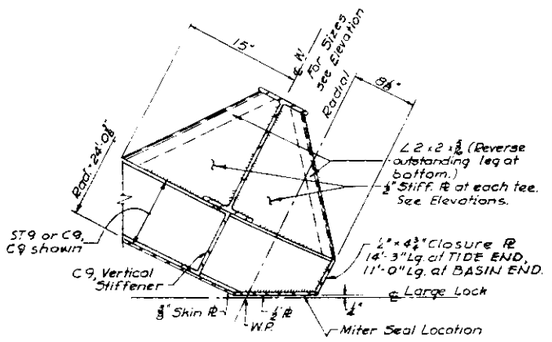
SECTION A-A



FRONT ELEVATION-DEVELOPED
(SKIN ℞ REMOVED)



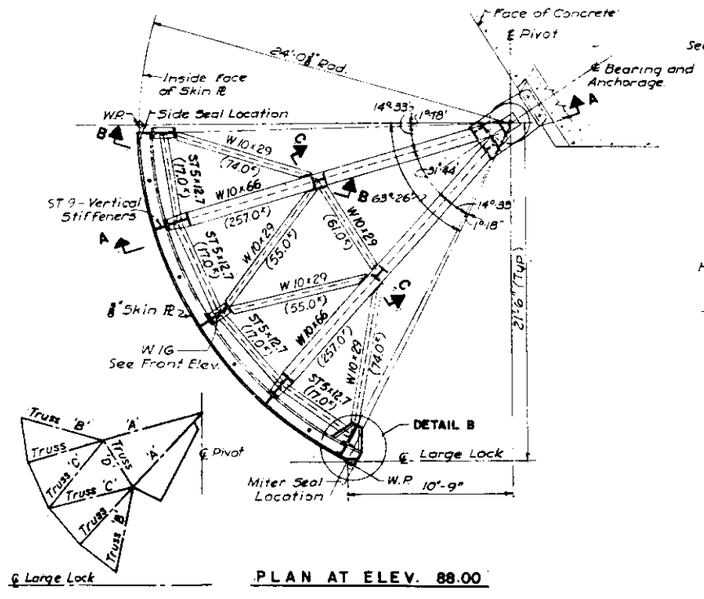
DETAIL A
SCALE: 1 1/2"=1'-0"



DETAIL B
SCALE: 1 1/2"=1'-0"

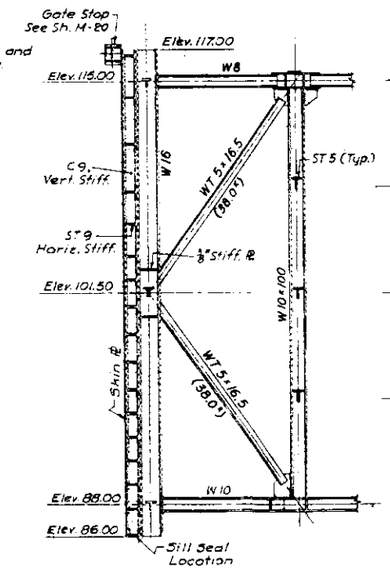
NOTE:
Details A & B at BASIN END similar except opp. hand.

NOTE:
SCALE IS 1/4"=1'-0" EXCEPT AS NOTED

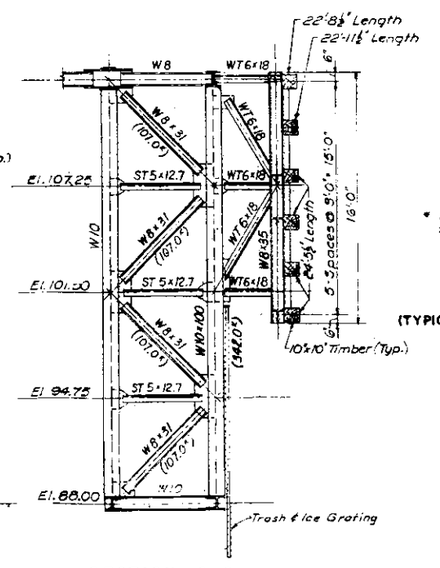


KEY PLAN
N.T.S.

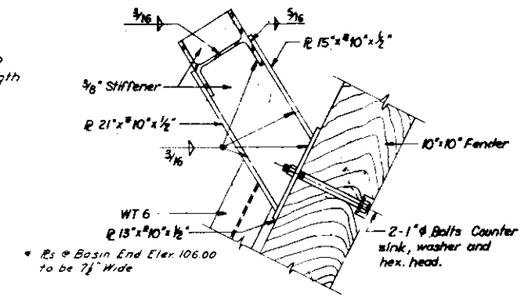
PLAN AT ELEV. 88.00



SECTION B-B



SECTION C-C



SECTION D-D
SCALE: 1 1/2"=1'-0"
(TYPICAL EXCEPT FOR FENDERS AT EL. 115.00)

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CH. BY
SUBMITTED
ARCHITECT-ENGINEER
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

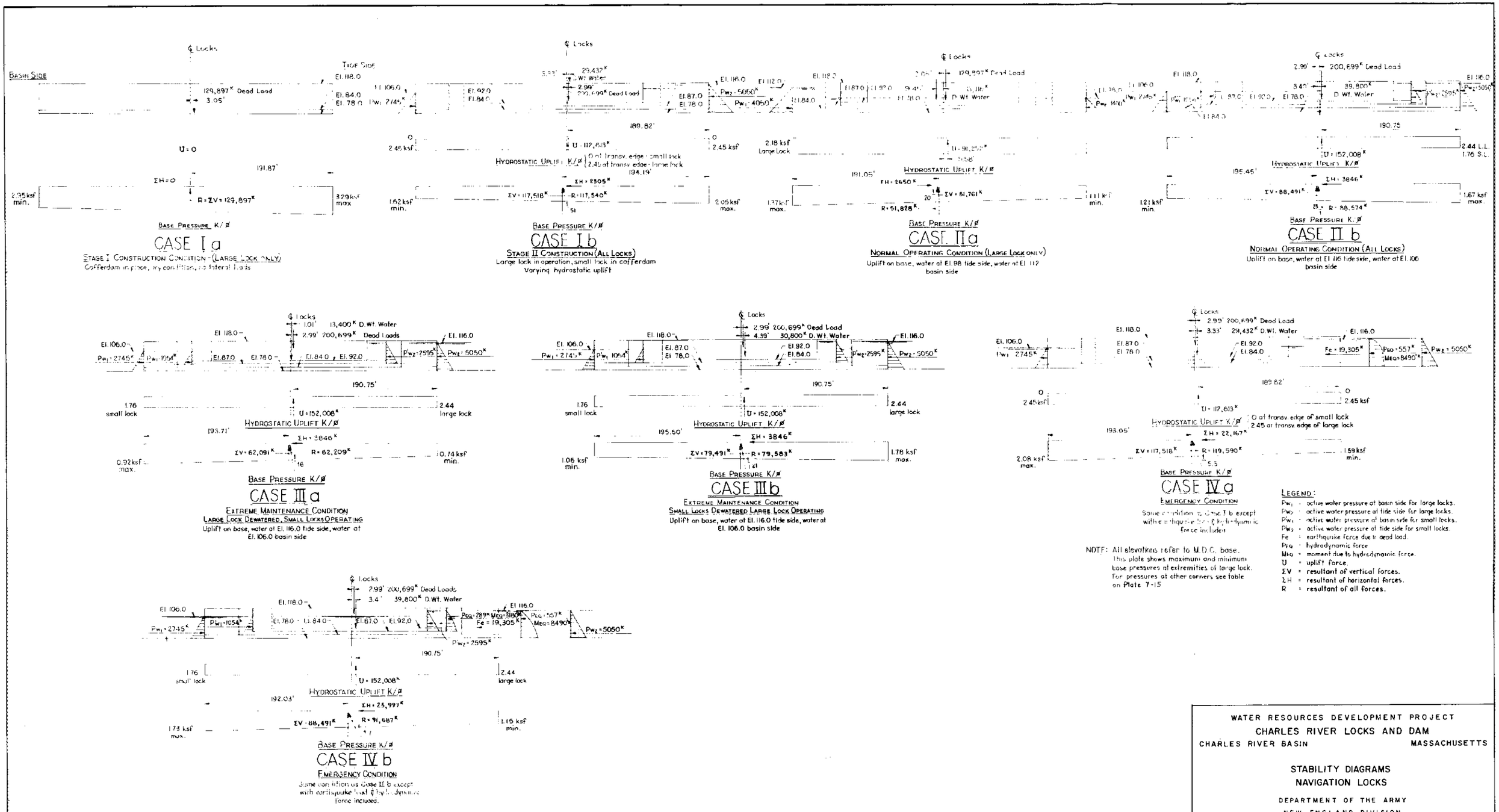
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
LARGE LOCK GATE FRAMING
TIDE END

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE: AS NOTED
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CHA-2
SHEET

PLATE 7-13



NOTE: All elevations refer to M.D.C. base.
This plate shows maximum and minimum base pressures at extremities of large lock. For pressures at other corners see table on Plate 7-15

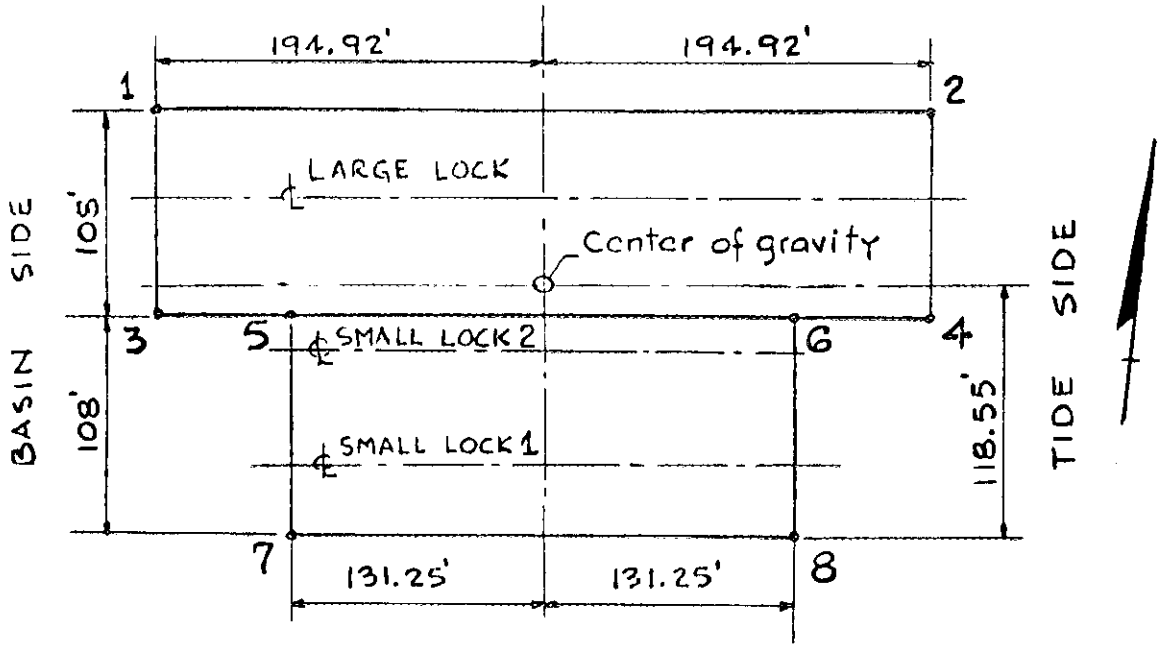
Legend:

- P_{w_1} = active water pressure at basin side for large locks.
- P_{w_2} = active water pressure at tide side for large locks.
- P'_{w_1} = active water pressure at basin side for small locks.
- P'_{w_2} = active water pressure at tide side for small locks.
- Fe = earthquake force due to dead load.
- P_{eq} = hydrodynamic force
- M_{eq} = moment due to hydrodynamic force.
- U = uplift force.
- ΣV = resultant of vertical forces.
- ΣH = resultant of horizontal forces.
- R = resultant of all forces.

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN — MASSACHUSETTS

STABILITY DIAGRAMS
NAVIGATION LOCKS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS — WALTHAM, MASS.



LOCK FOUNDATION PLAN

Scale: 1" = 100'

STABILITY SUMMARY TABLE

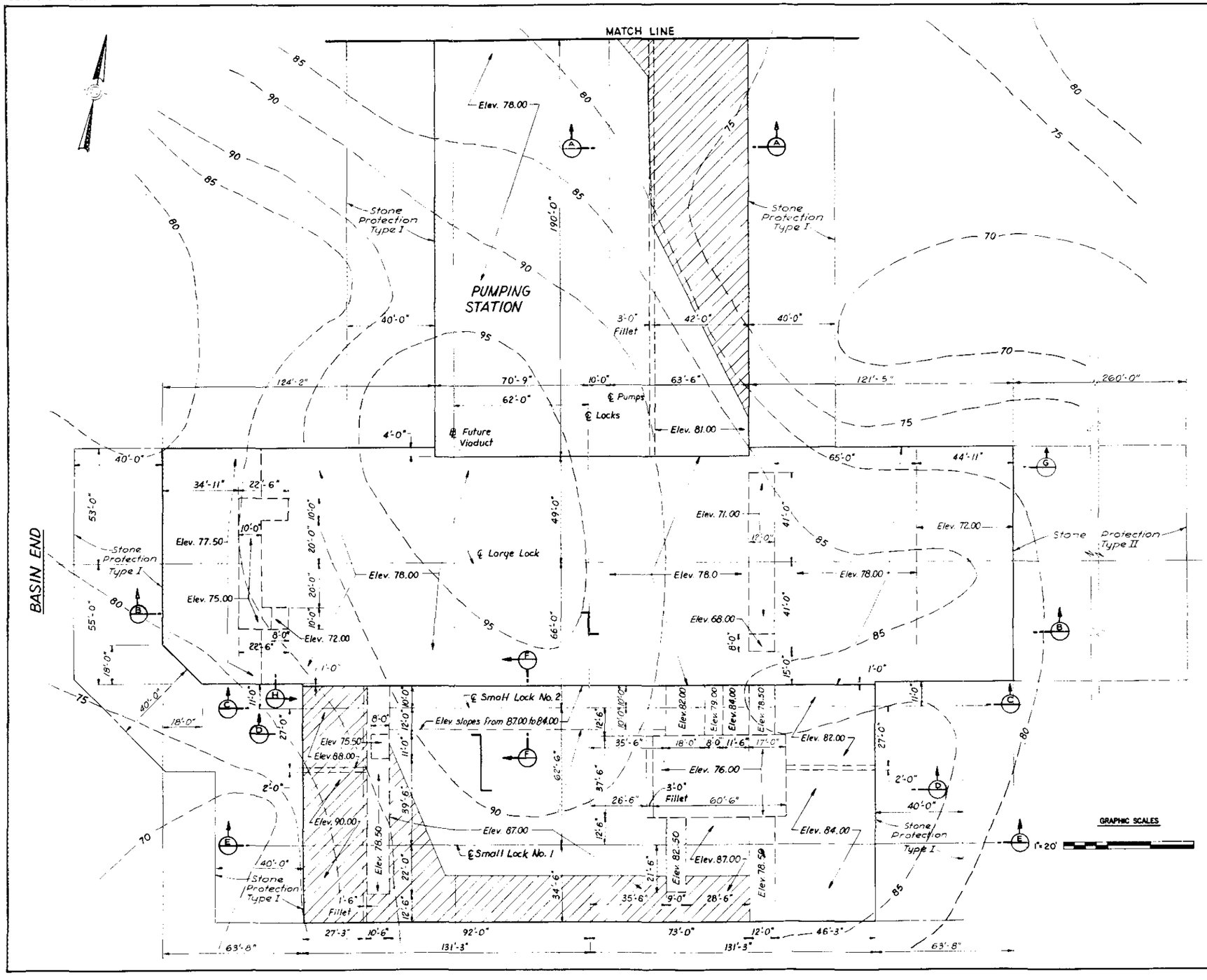
LOADING CASE	SOIL BEARING PRESSURES (ksf) AT CORNERS								SAFETY FACTORS	
	1	2	3	4	5	6	7	8	UPLIFT	SLIDING
I A	3.00	3.29	2.95	3.23	---	---	---	---	---	---
I B	2.00	2.05	1.62	1.67	1.63	1.66	1.25	1.29	2.05	6.0
II A	1.37	1.23	1.26	1.11	---	---	---	---	1.57	5.2
II B	1.65	1.67	1.21	1.24	1.22	1.23	0.78	0.80	1.58	11.5
III A	0.78	0.74	0.92	0.88	0.92	0.89	1.06	1.03	1.41	8.1
III B	1.76	1.78	1.06	1.08	1.06	1.08	0.36	0.38	1.52	10.3
IV A	2.08	1.96	1.71	1.59	1.69	1.61	1.31	1.23	2.05	2.7
IV B	1.73	1.59	1.30	1.15	1.27	1.18	0.84	0.74	1.58	1.8*

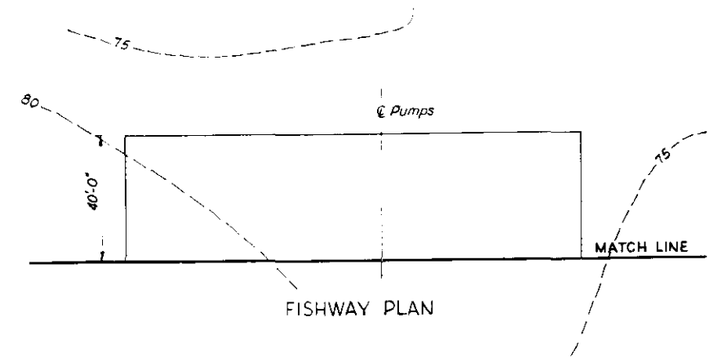
* Considered acceptable since the uplift and friction values are very conservative for this foundation.

Note
For loading conditions and stability diagrams refer to Plate 7-14

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS
STABILITY SUMMARY
NAVIGATION LOCKS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE 7-15





NOTES

1. Elevations shown indicate bottom of foundations.
2. For sections, see Plate 7-17.

LEGEND

Limits of lean concrete fill (interior limits are approximate)

Approx. surface of fill contours

GRAPHIC SCALES

1" = 20'

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
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ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED

ARCHITECT - ENGINEER

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, TECH. ENG. BRANCH

APPROVAL RECOMMENDED

CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

SUB-FOUNDATION PLAN

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:

CHIEF, ENGINEERING DIVISION

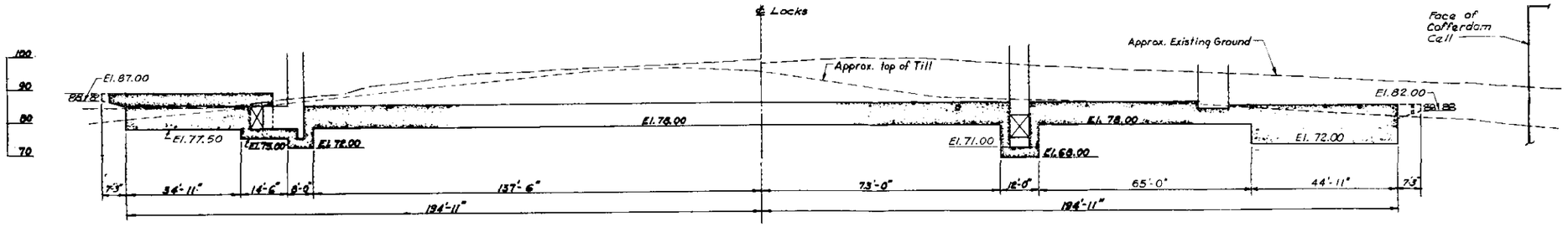
SCALE: 1" = 20'

DATE:

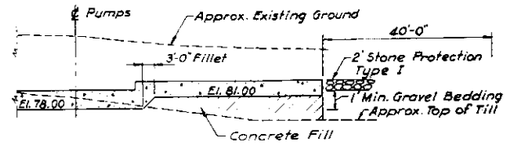
SPEC. NO. DACW 33-73-B-

DWG. NO. CHA-2

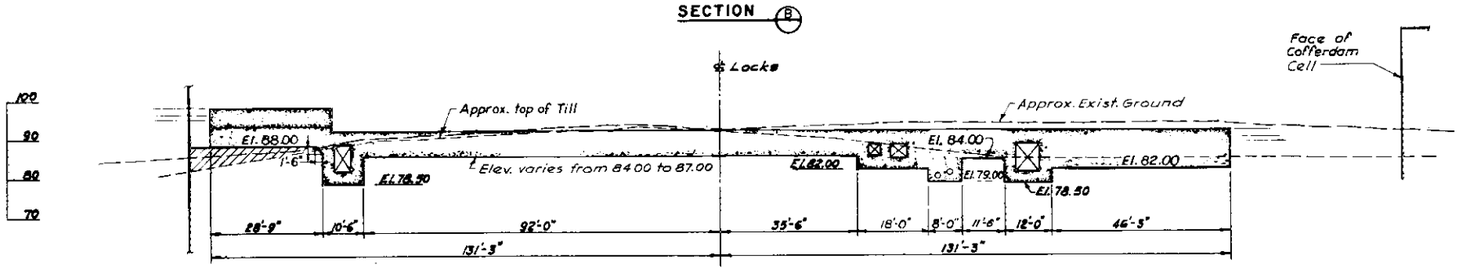
SHEET



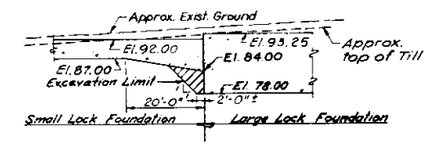
SECTION B



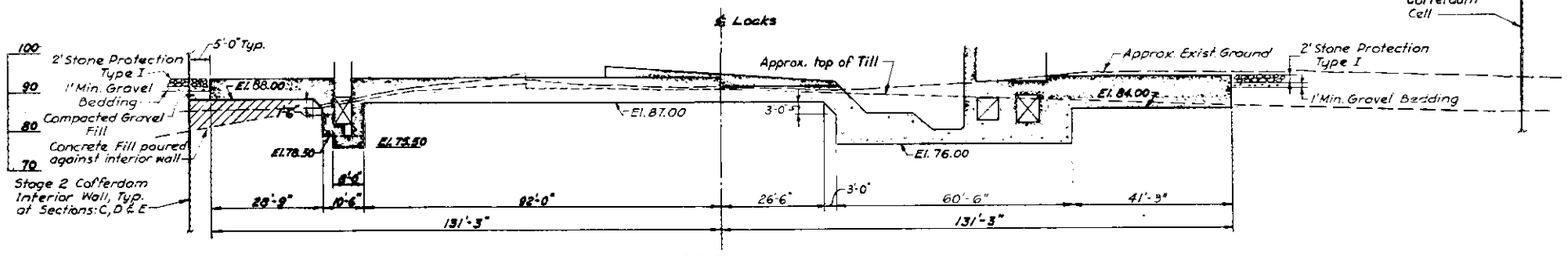
SECTION A



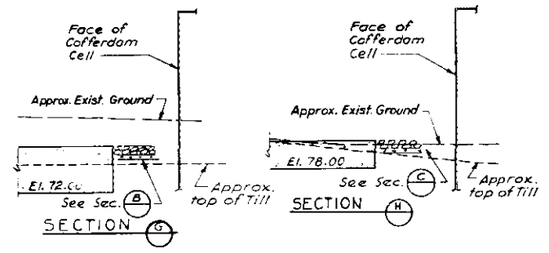
SECTION C



SECTION F

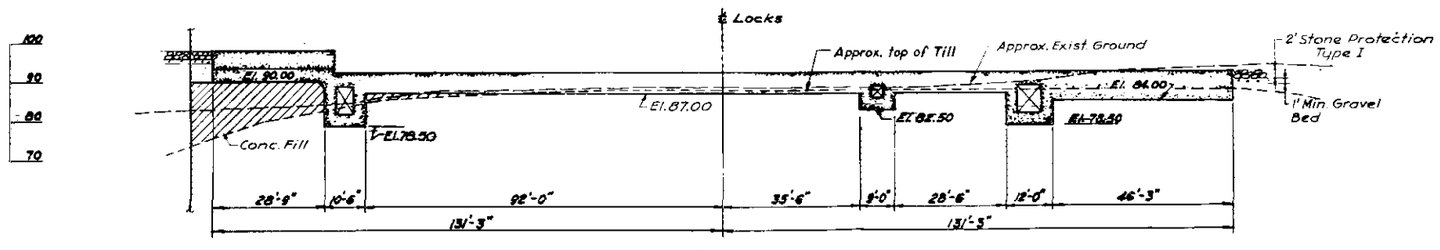


SECTION D



NOTES:

1. For location of Sections and legend see Plate 7-16.



SECTION E

1"=16' 0 16 32 48

SAVE $ PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
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ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

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ARCHITECT-ENGINEER
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

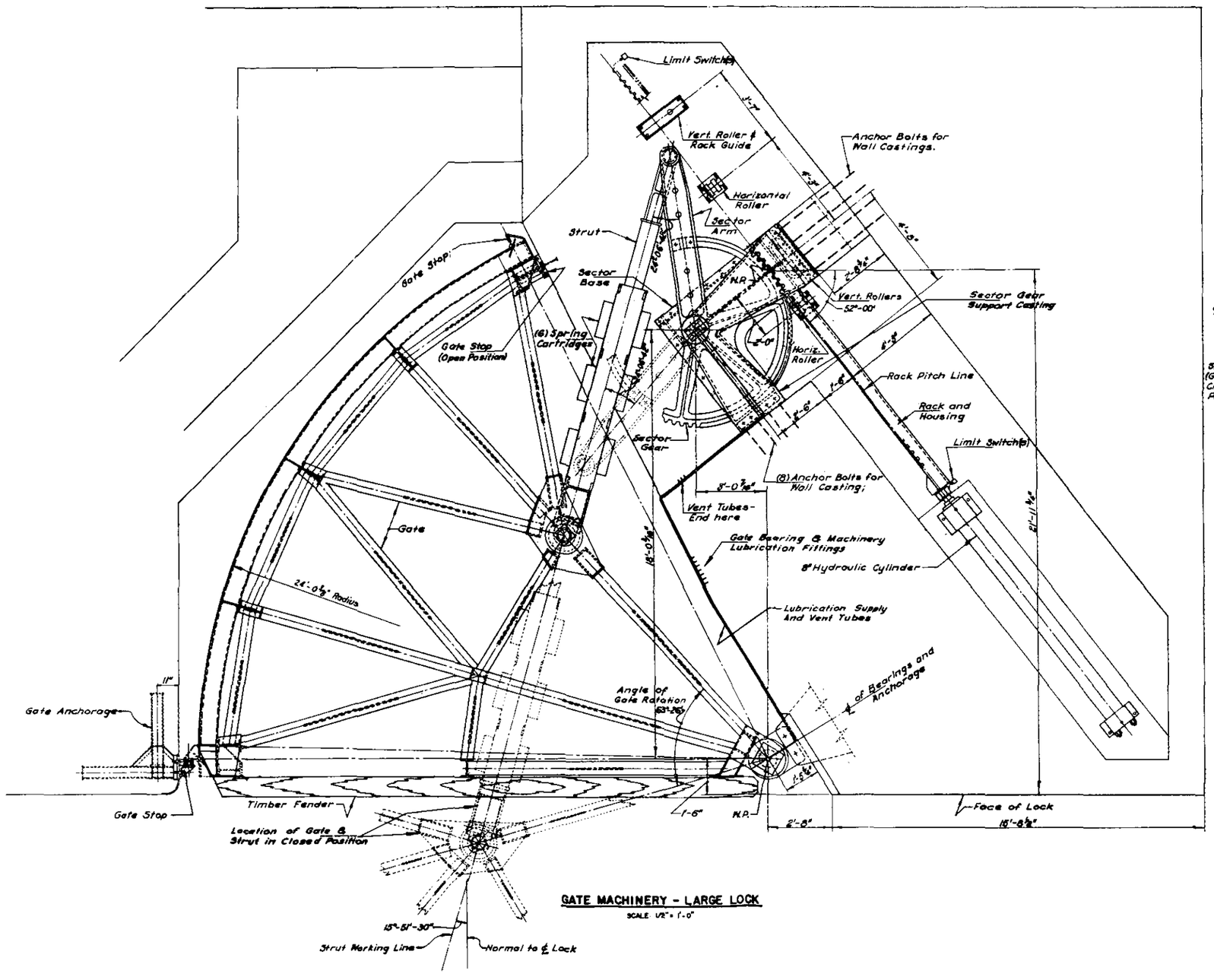
CHARLES RIVER DAM

SUB-FOUNDATION SECTIONS

CHARLES RIVER BASIN — MASSACHUSETTS

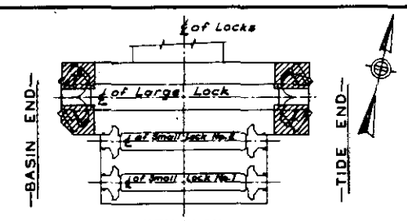
APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE:
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CHA-2
SHEET



GATE MACHINERY - LARGE LOCK

SCALE: 1/2" = 1'-0"



KEY PLAN

SCALE: 1" = 100'-0"

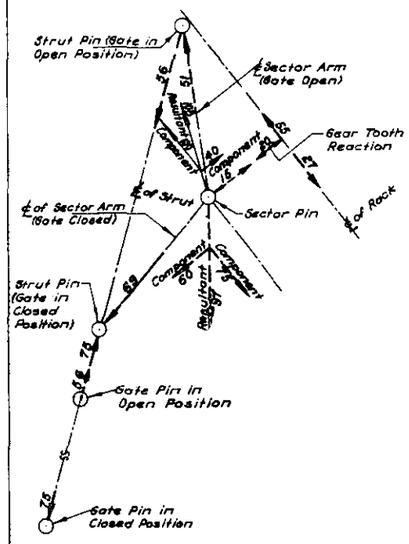


DIAGRAM OF FORCES

SCALE: 3/8" = 1'-0"

NOTES:

1. — — — → Represents max. forces in Kips resulting from jamming while opening.
2. ——→ Represents max. forces in Kips resulting from jamming while closing.
3. Operating force on the Strut for opening and closing is 28K. Other forces reduced by 28/75
4. Force required to hold Gate in closed position against Stop is 46K. Other forces reduced by 46/75
5. Forces shown apply to both Basin and Tide Gates.
6. Forces shown are based on 1100# oil pressure on Cylinder.

CHARLES A. MAGUIRE & ASSOCIATES, INC. WALTHAM, MASSACHUSETTS ARCHITECT-ENGINEER	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.
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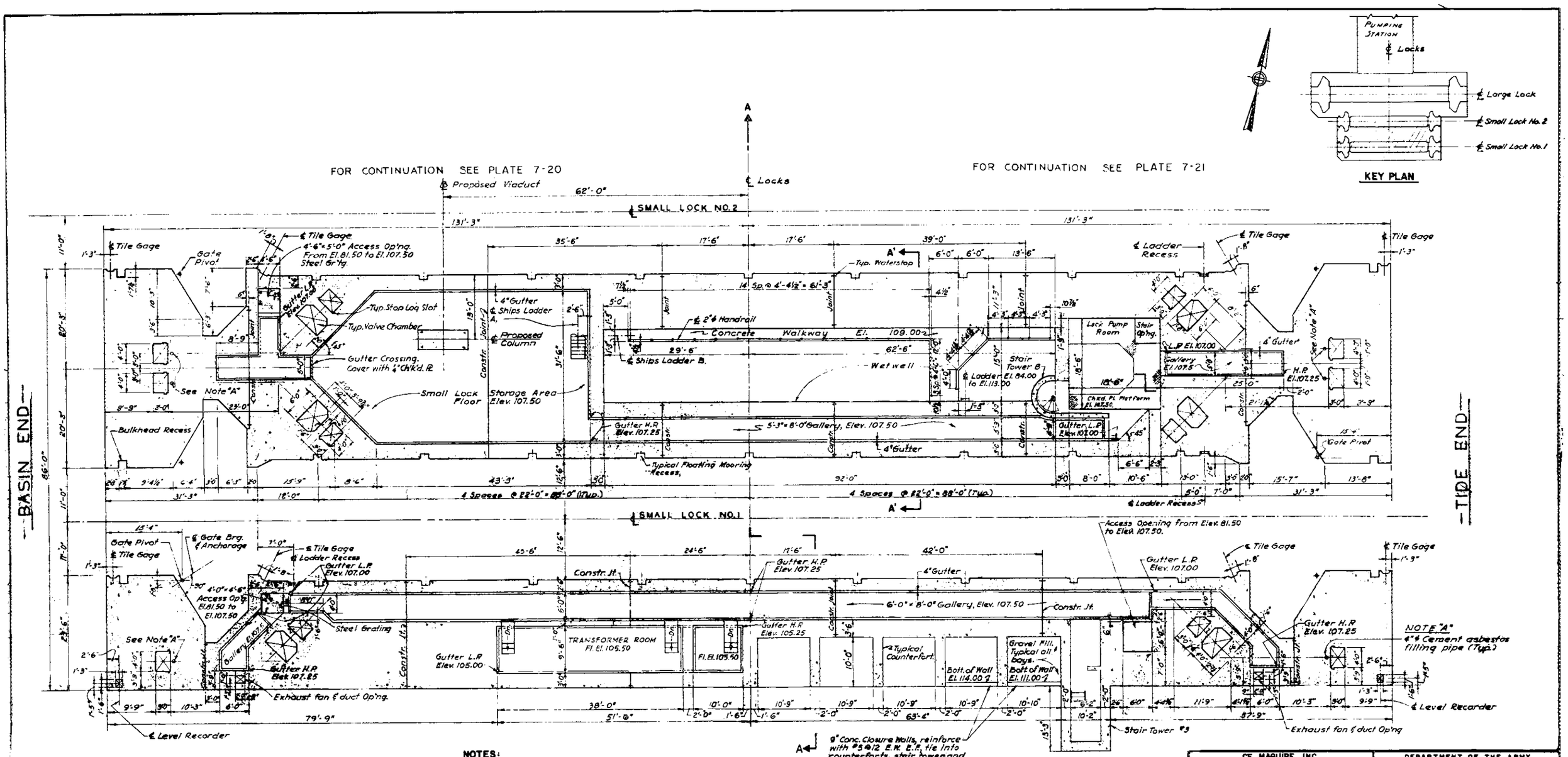
PLATE 7-18



NOTES:

For Sections A-A, and A'-A' see Plate 7-6.

CE MAGUIRE, INC.
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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT

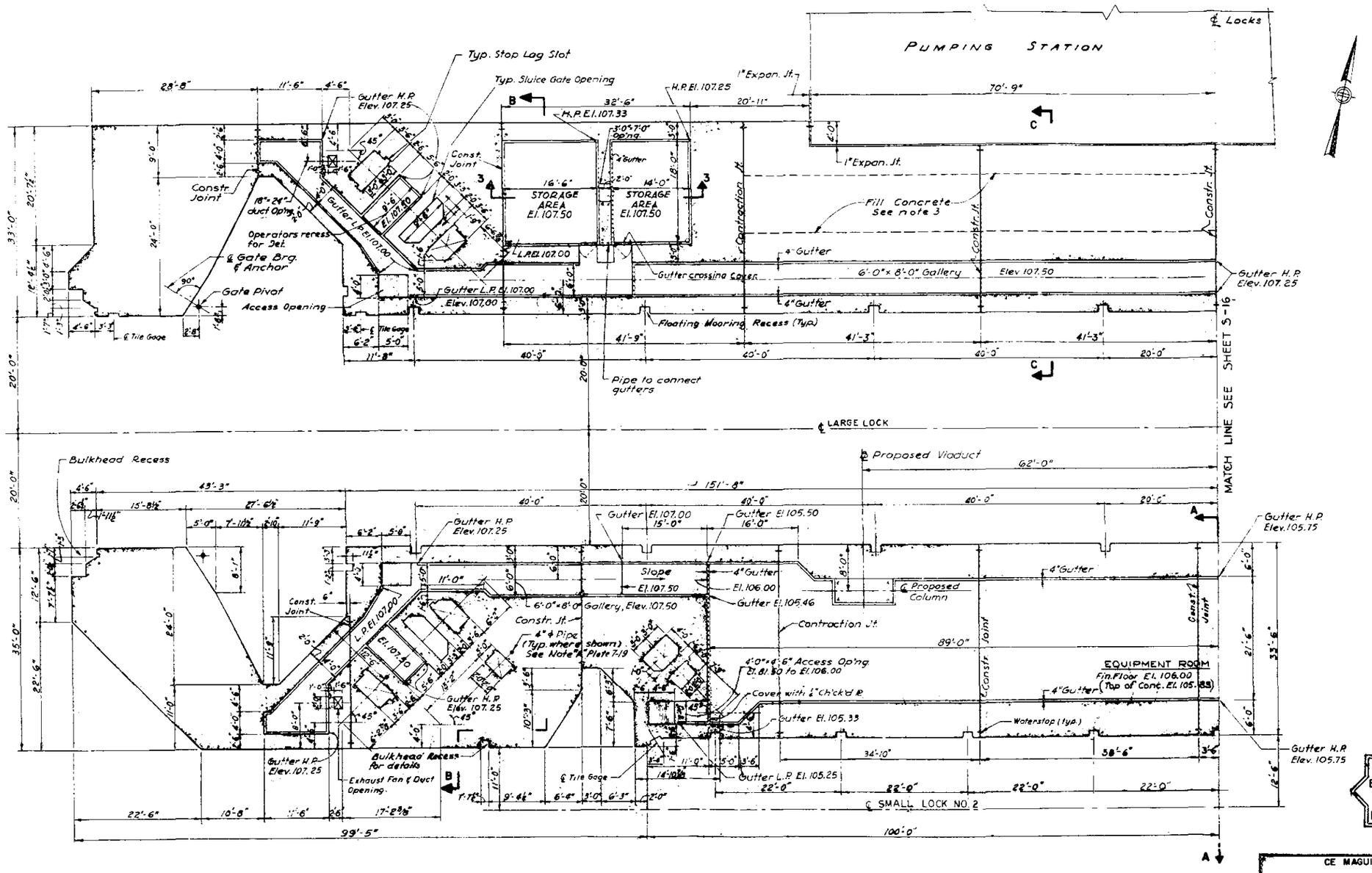
CHARLES RIVER DAM

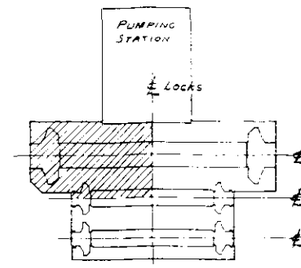
SMALL LOCKS GALLERY PLAN

CHARLES RIVER BASIN — MASSACHUSETTS

SCALE: 1/8" = 1'-0"
SPEC. NO. DACW 33-73-B-
DWG. NO. CRA-2
SHEET

VALUE ENGINEERING PAYS DIVIDENDS





KEY PLAN

NOTES:

1. For Section A-A see Plate 7-6
2. For Sections B-B C-C & 3-3 see Plate 7-7
3. Fill concrete to be placed monolithically with structural concrete.

VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

CE MAGUIRE, INC.
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CHIEF, PROJECT BRANCH

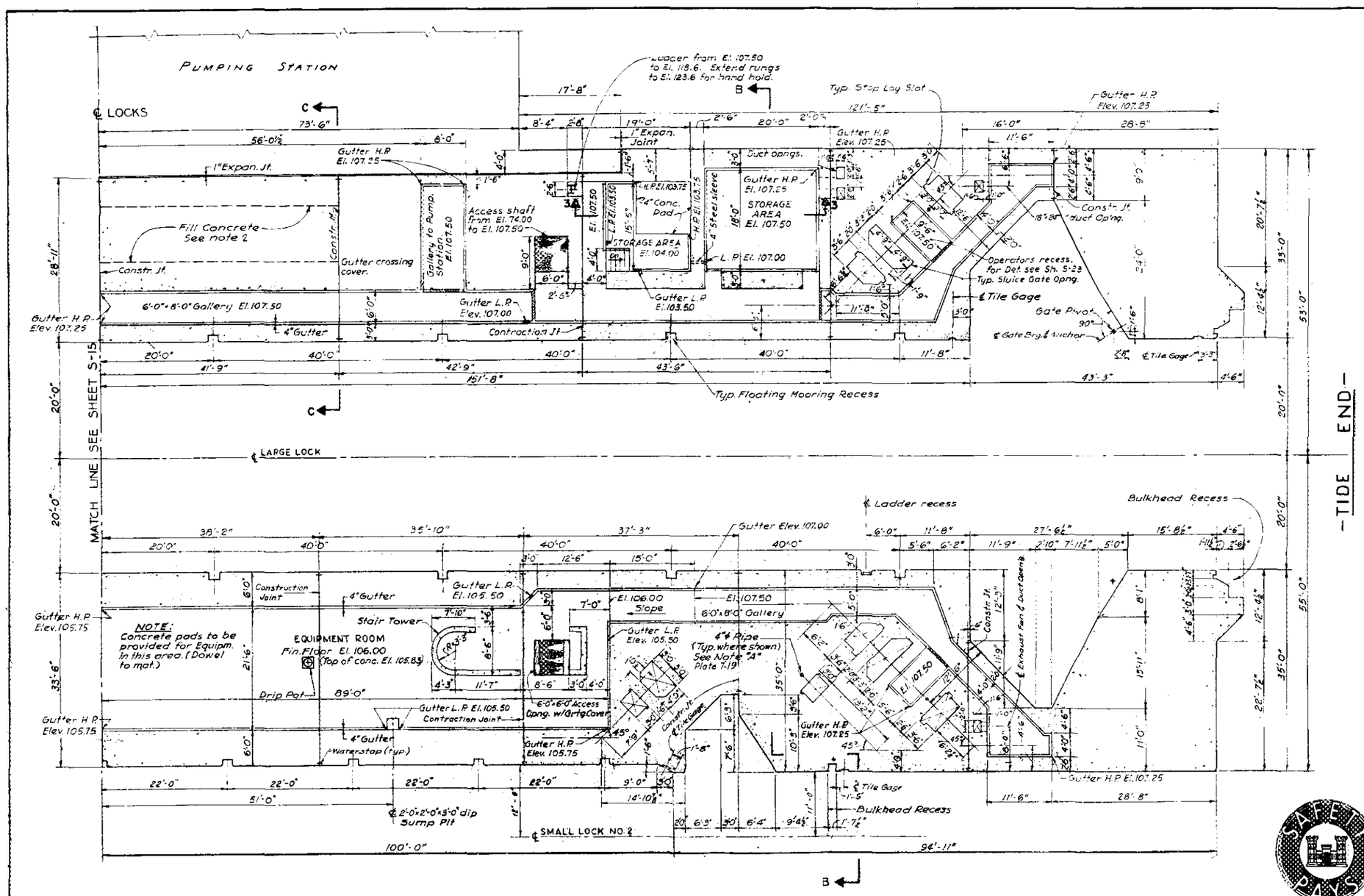
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
LARGE LOCK GALLERY PLAN
SHEET 1

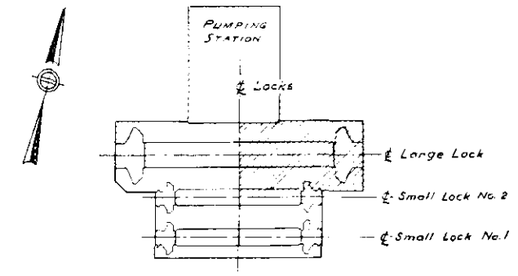
CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE: 1/8" = 1'-0"
DATE:
SPEC. NO. DACW 33-72-B-
DWG. NO. CMA-2
SHEET

REVISION	DATE	DESCRIPTION	BY





KEY PLAN

NOTES:

1. For Sections B-B, C-C and 3-3, See Plate 7-7
2. Fill concrete to be placed monolithically with structural concrete.

FOR CONTINUATION SEE PLATE 7-19

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

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WALTHAM, MASS.

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WATER RESOURCES DEVELOPMENT PROJECT

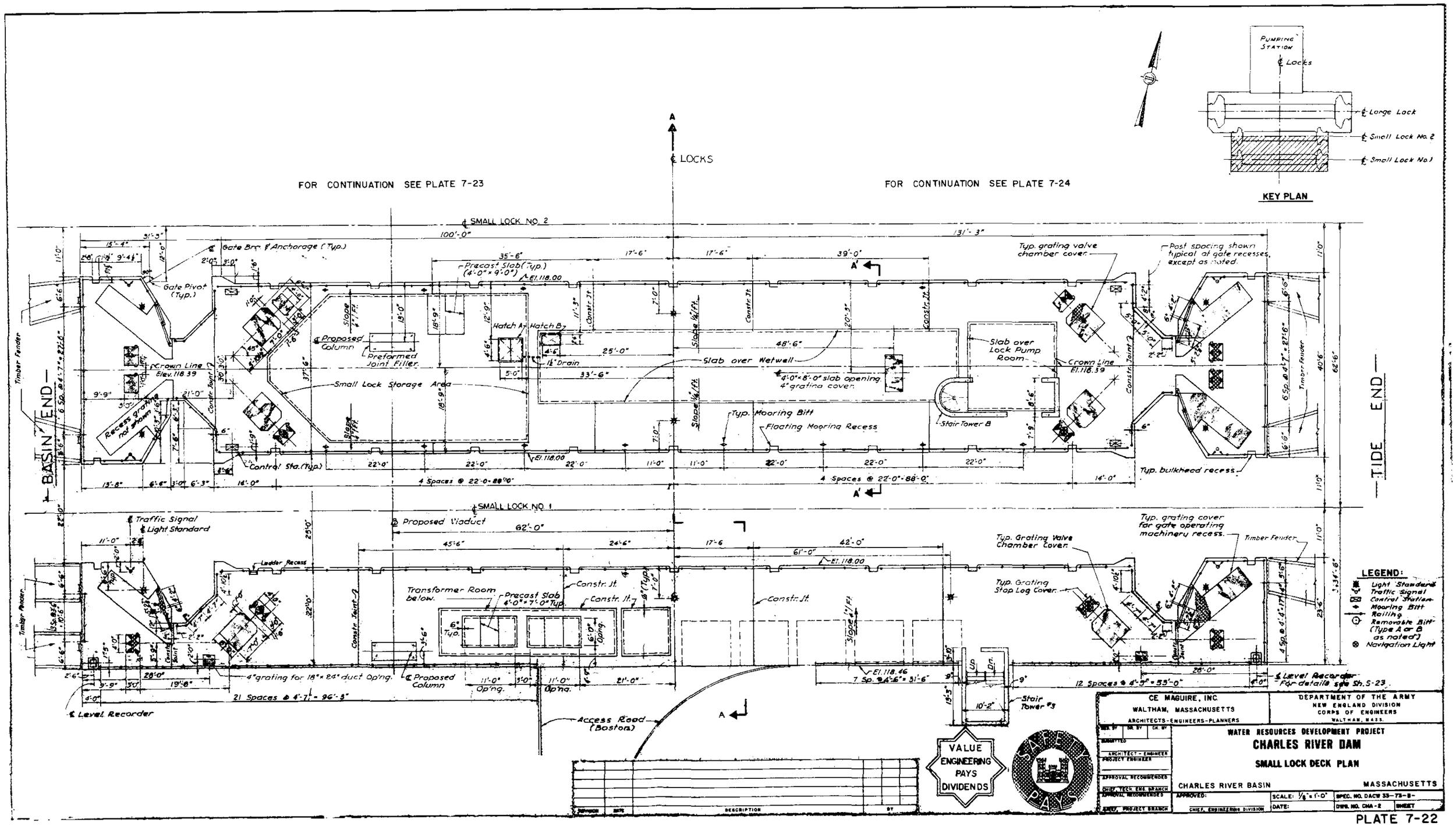
CHARLES RIVER DAM

LARGE LOCK GALLERY PLAN
SHEET 2

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE: 1/8" = 1'-0"
DATE:
SPEC. NO. DACW 33-73-B-
DWG. NO. CNA-2
SHEET



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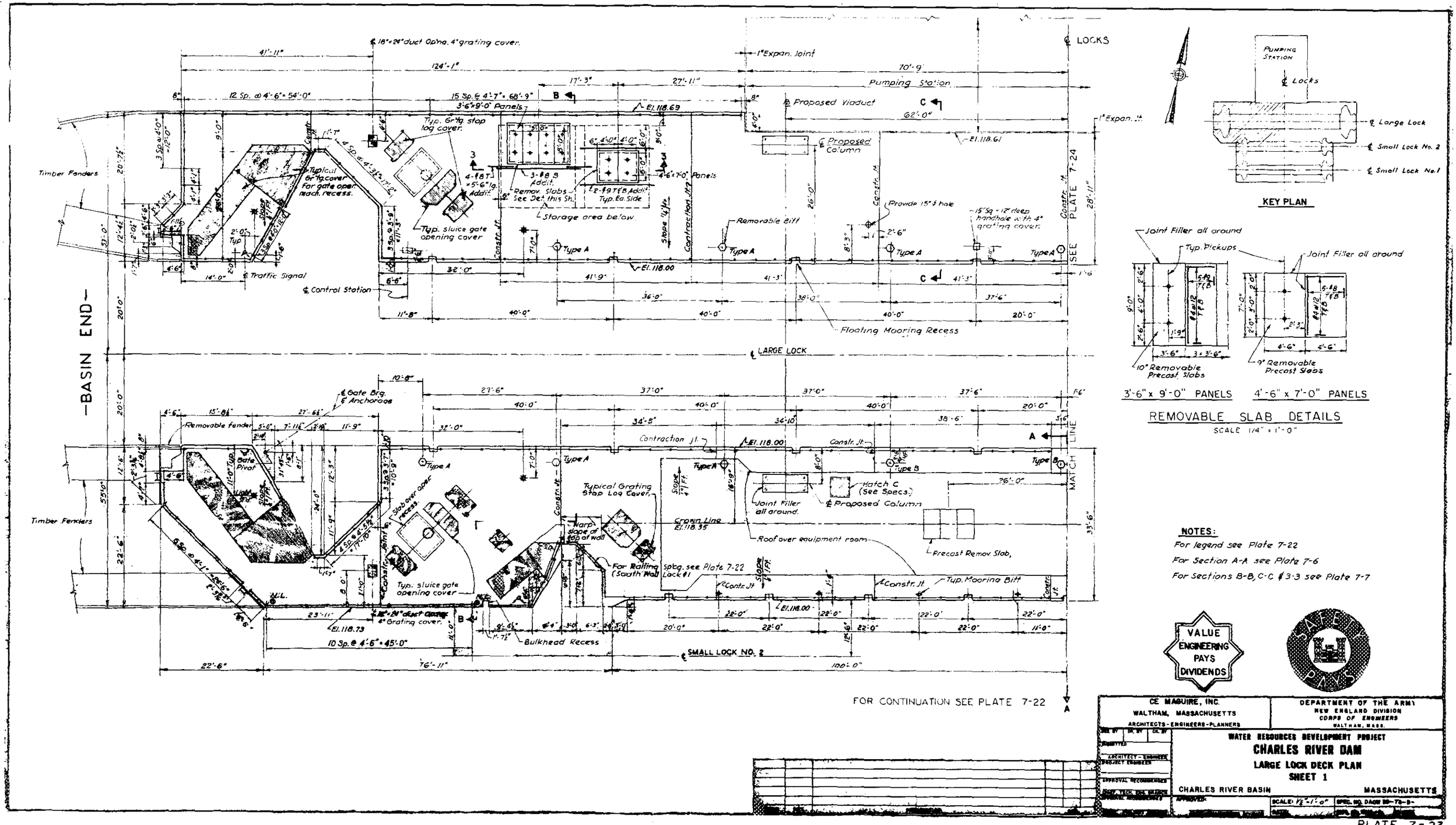
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
SMALL LOCK DECK PLAN

CHARLES RIVER BASIN — MASSACHUSETTS

SCALE: 1/8" = 1'-0" — SPEC. NO. DACW 33-73-B-
DATE: — DWG. NO. CHA-2 — SHEET

PLATE 7-22



NOTES:

For legend see Plate 7-22

For Section A-A see Plate 7-6

For Sections B-B, C-C & 3-3 see Plate 7-7

FOR CONTINUATION SEE PLATE 7-22

VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

CE MAGUIRE, INC.
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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT

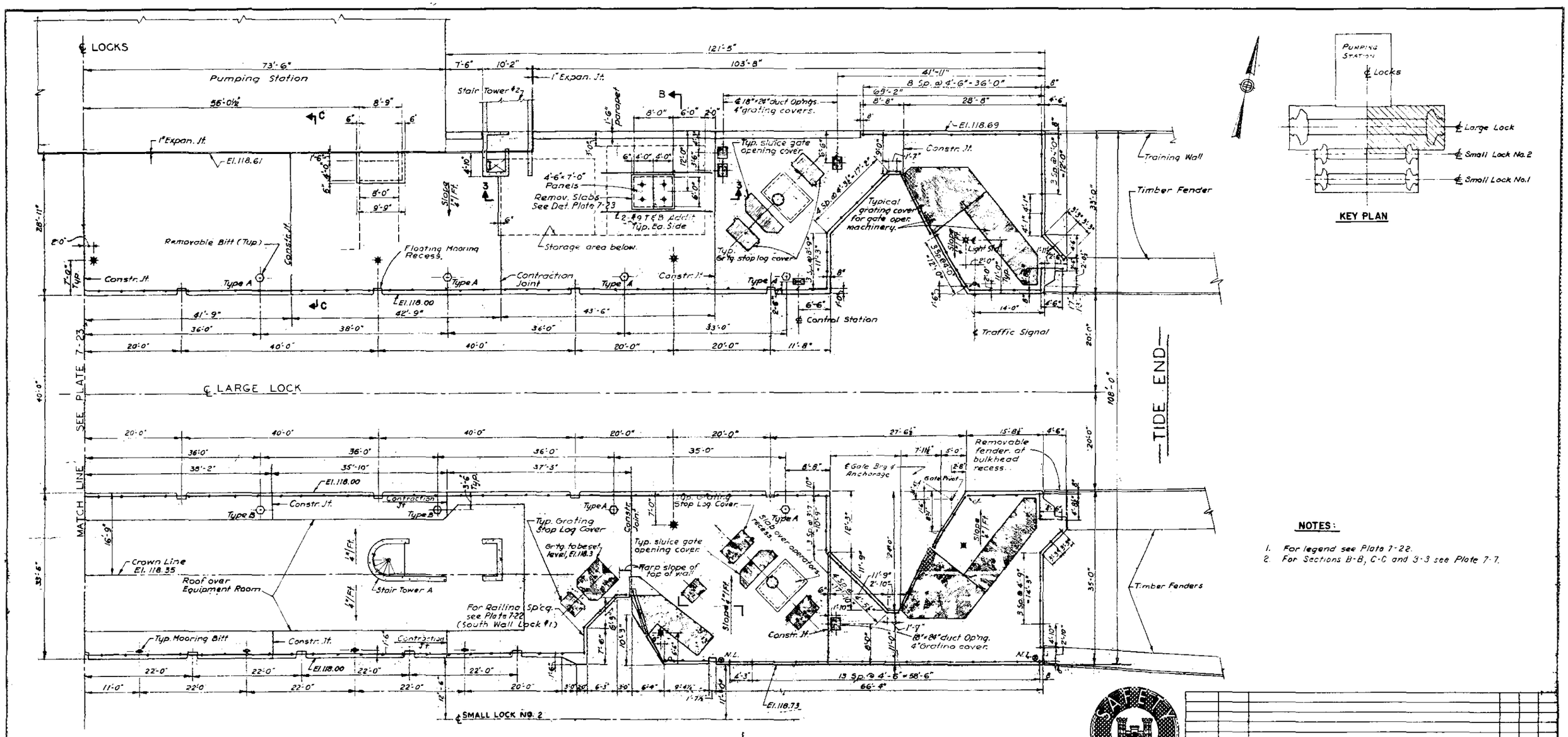
CHARLES RIVER DAM

LARGE LOCK DECK PLAN

SHEET 1

CHARLES RIVER BASIN MASSACHUSETTS

SCALE: 1/2"=1'-0"



NOTES:

1. For legend see Plate 7-22.
2. For Sections B-B, C-C and 3-3 see Plate 7-7.

FOR CONTINUATION SEE PLATE 7-22

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

CE MAGUIRE, INC.
WALTHAM, MASSACHUSETTS
ARCHITECTS-ENGINEERS-PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

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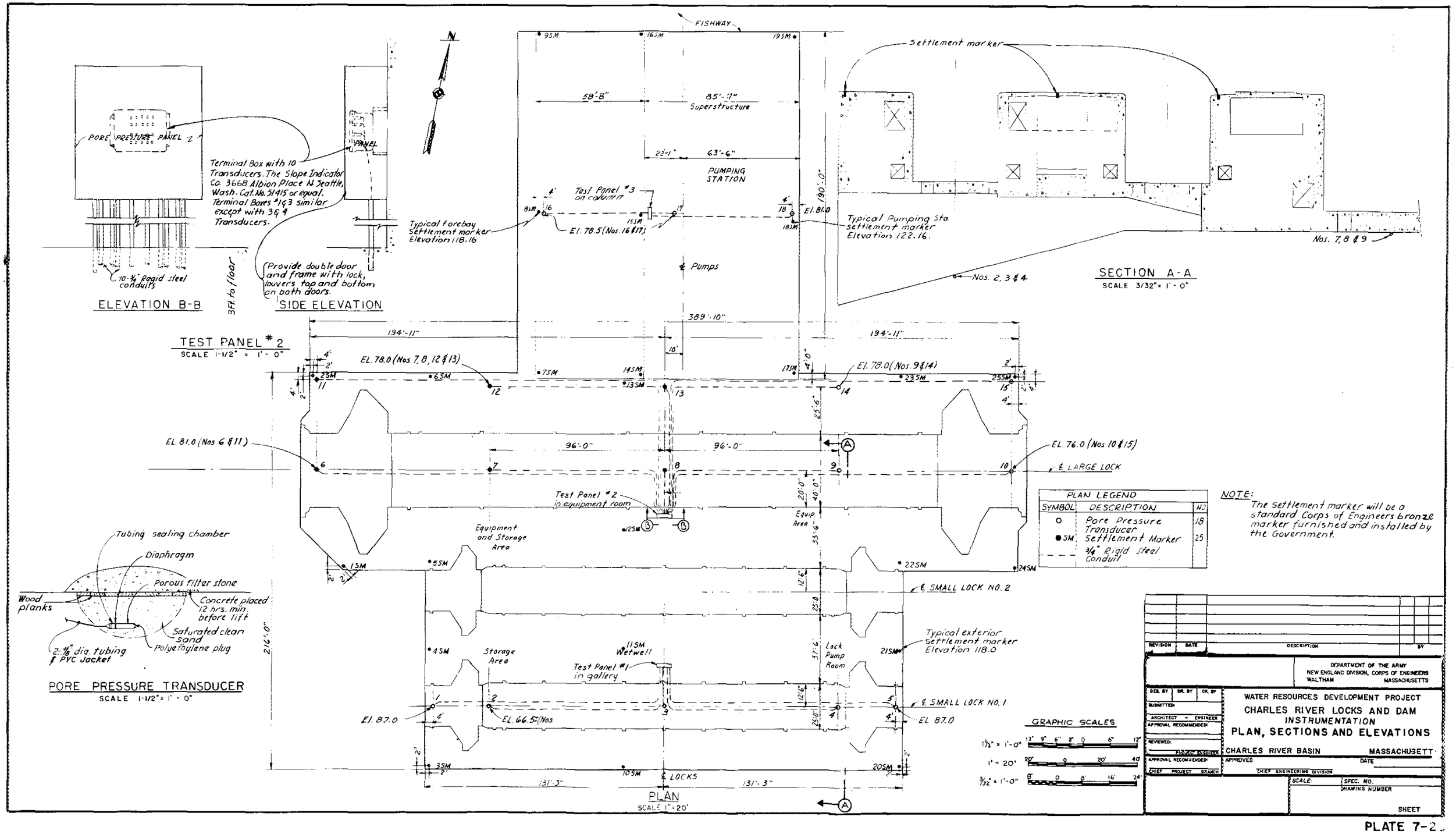
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
APPROVAL RECOMMENDED
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
LARGE LOCK DECK PLAN
SHEET 2

CHARLES RIVER BASIN — MASSACHUSETTS

APPROVED:
CHIEF, ENGINEERING DIVISION

SCALE: 1/8" = 1'-0" | DATE: | SPEC. NO. DACW 33-73-B- | DWG. NO. CHA-2 | SHEET



PLAN LEGEND		
SYMBOL	DESCRIPTION	NO.
○	Pore Pressure Transducer	18
● SM	Settlement Marker	25
- - -	3/4" Rigid Steel Conduit	

PLATE 7-2

APPENDIX A

STRUCTURAL DESIGN COMPUTATIONS

APPENDIX A

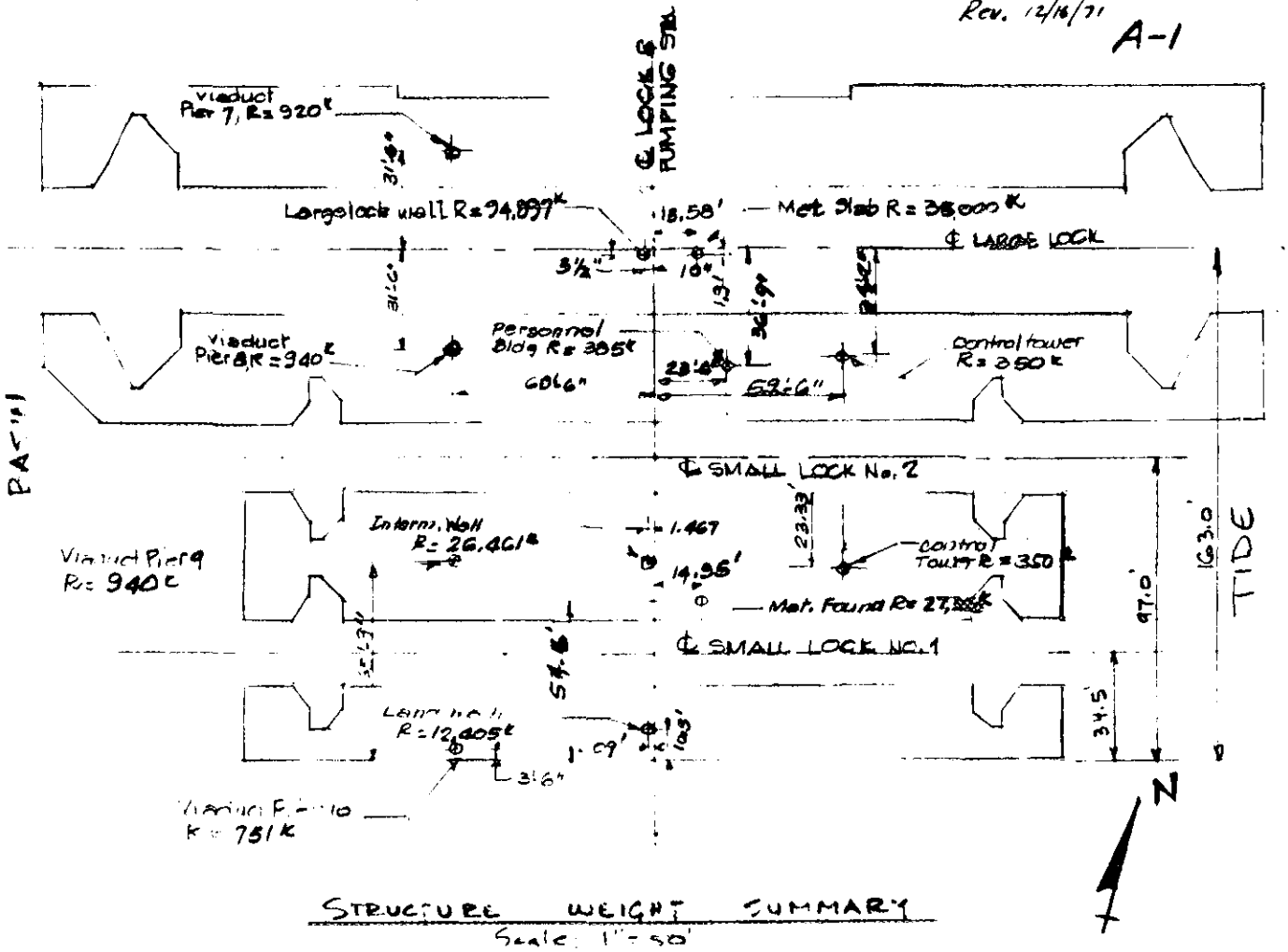
STRUCTURAL DESIGN COMPUTATIONS

Title	Page
Stability Analysis	A1-A21
Lock Design Criteria and Loadings	A22-A31
Structural Design of Lock Structure	A32-A43
Large Lock Gate Design	A44-A106A
Lock Design Computer Data	A107-A125
Structural Design - Walkway	A126-A167

PROJECT Charles River Dam & Lock
SUBJECT Navigation Lock & Facilities
Stability of Navigational Locks
COMP. RDR CHECK

ACC. NO.
SHEET NO. 1 OF
DATE ~~May 9~~ 19 71
CONT. NO. 1579.60
Rev. 12/16/71

A-1



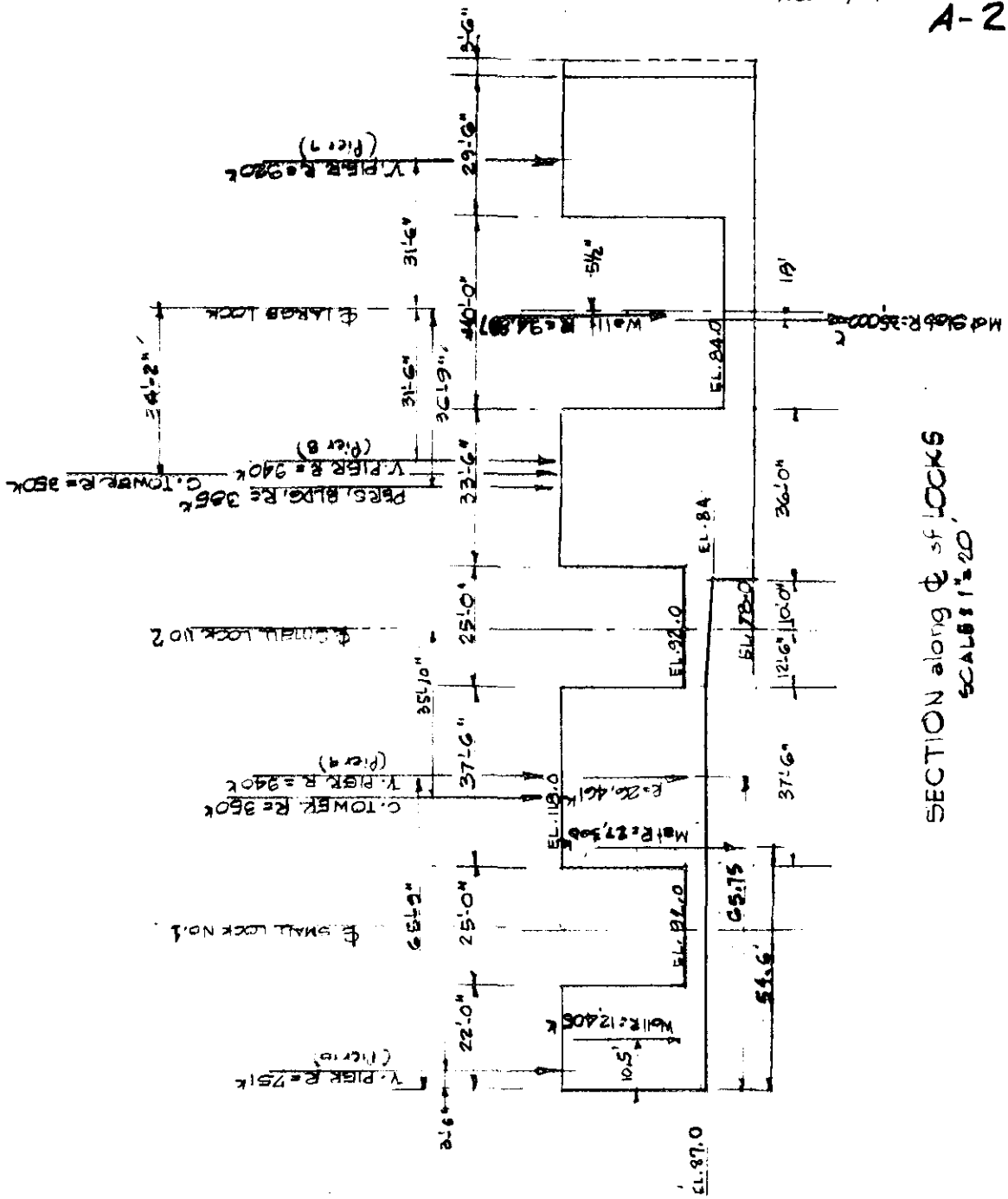
STRUCTURE WEIGHT SUMMARY

Scale: 1" = 50'

PROJECT Charles River Dam & Lock
SUBJECT Stability of Combined Locks
COMP. pop CHECK

ACC. NO.
SHEET NO. 2 OF
DATE May 4 1971
CONT. NO. 157260
Rev. 12/16/71

A-2



PROJECT C.R.D.&L. ACC. NO.
SUBJECT Stability of Combined Locks SHEET NO. 3 OF
Longitudinal Direction DATE May 1 1971
COMP. RDR CHECK CONT. NO. 1579.60

A-3

Computation of hydrostatic Uplift Max. high tide @ ocean El. 116.
Low tide @ River Basin El. 106.

AREA	Pressure	FORCE	Arm	M(-) Negative	Arm	M(+) positive
LARGE LOCK						
-162	-2.245	-364	-183.92			+ 67,000
4850	"	10,910	-167.46	- 1,820,000		
2026	2.44	4,950	-135.62	- 672,500		
5500	"	12,320	- 88.92	- 1,098,000		
15225	"	37,200	- 8.62	- 320,500		
7375	"	16,520			+97.38	+ 1,610,000
2026	"	4950			+136.34	+ 675,000
4850	2.567	12,450			+167.46	+ 2,085,000
-850	+0.394	+335	+56.76	- 52,500		
-984	+0.448	+441			+73.91	+ 32,600
41,690		99,712		- 3,973,500		+ 4,469,600
					+ 4.99	+ 496,100
SMALL LOCKS			Arm	M(-) Negative	Arm	M(+) Positive
3080	1.635	5,140	-116.8	- 600,000		
4950	1.86	9,210			+108.13	+ 996,000
18790	1.765	33,150	- 14.75	- 488,000		
1285	2.405	3,090			+79.0	+ 243,500
28105		50,580		-1,088,000		+1,239,500
					+2.99	+ 151,500
Neg. Areas						
-1162	+0.032	+ 37			+ 15.5	+ 573
-1125	+0.642	+ 722			+ 46.0	+ 33,200
- 355	+0.417	+ 148			+ 43.38	+ 6,425
- 113	+0.545	+ 62			+59.0	+ 3,660
- 306	+0.364	+ 111			+40.0	+ 4,440
- 992	+0.64	+ 636	- 97.25	- 61,900		
		+ 1,716		- 61,900		48,298
			- 7.93	- 13,602		
Small Locks along ℄		52,296			+2.66	+ 137,895
Total Combined Locks		152,008			+ 4.17	633,798

PROJECT CRL&D
SUBJECT Stability of Combined Locks
Longitudinal Direction
COMP. BAR CHECK
ACC. NO.
SHEET NO. 4 OF
DATE May 4 19 11
CONT. NO. 1579.1.1
A-4

Hydrostatic Uplift Varying Pressure Ocean High Tide @ EL 116.0 Edge of Large Lock
Zero Pressure @ Small Lock

Area	Pressure	Force	Arm	M(-) Negative	Arm	M(+) Positive
Large Lock						
-162	2.24	-362	-183.92			+66,600
4850	"	10,900	-167.46	-1,828,000		
2026	2.44	4,950	-135.62	-672,500		
5500	2.45	13,465	-88.92	-1,196,000		
15225	"	37,350	-8.62	-322,000		
7375	"	18080			+97.38	+1,760,000
2026	2.44	4,950			+136.34	+675,000
4850	2.565	12450			+167.46	+2,085,000
-850	0.385	+328	-156.76	-52,500		
-984	0.448	+442				
41,690		102,553		-4,071,000		+4,586,600
					5.0755	+515,600
Small Lock						
18790	0.278	5,220	-14.75	-77,000		
1285	0.60	772			+79.0	+61,000
4950	0.327	1,615			+108.13	174,500
3080	0.22	740	-116.8	-86,500		
28,106		8,347		-163,500		+235,500
					8.63	+72,000
Neg. Areas						
-1162						
-1125		Same as Preceeding Page				
-356						
-113						
-306						
-992						
		+1713		-61,900		+48,298
			-7.93	-13,602		
Small Lock Only		10,060			5.8	+58,398
Combined Locks		112,613			5.1	+573,998

PROJECT C.R.D & L — ACC. NO.
SUBJECT Stability of Combined Locks Longitudinal Direction — SHEET NO. 5 OF
DATE May 4 1971
COMP. RDL CHECK — CONT. NO. 1579.00

A-5

Computation of hydrostatic uplift — River Basin @ high tide El. 112.00; Ocean @ low tide El. 98.0

Area	Pressure	Force	Arm	M (-) Negative	Arm	M (+) Positive
Large Lock						
-162	1.989	-323#	-183.92			-59450
4850	"	9,660	-167.46	-1,620,000		
2026	2.180	4,420	-135.62	-600,000		
5600	"	12,000	-88.92	-1,068,000		
15225	"	33,200	-8.62	-286,000		
7375	"	16,100			+97.38	1,565,000
2026	"	4420			+136.34	603,000
4850	2.310	11,200			+167.46	1,875,000
-850	+0.394	335	-156.76	-52,500		
-984	+0.448	440			+73.91	+32,600
41690		91,252#		-3,626,500		+4,135,050
					+5.58	+508560
Small Locks						
3030	1.410	4,350#	-116.8	-508,000		
4950	1.602	7940			+108.13	+859,000
18790	1.505	28,220	-14.75	-417,000		
1285	2.14	2,750			+79.0	+217,000
28105		43,260#		-925,000		+1,076,000
						+151,000
Neg. Areas						
-1162	+0.232				+15.5	
-1125	+0.642				+46.0	
-355	+0.417	Same as preceding page			+43.38	
-113	+0.545				+59.0	
-306	+0.384				+40.0	
-992	+0.642		-97.25			
		+1716		-61,300		+48,298
				-13682		
For Small Lock (on 4)		44,976			3.05'	+137,318
Combined Locks		136,228				+645,868

PROJECT C.B. D&L
SUBJECT Stability of Combined Locks
Longt. Direction
COMP. PDK CHECK
ACC. NO.
SHEET NO. 6 OF
DATE May 4 1971
CONT. NO. 1528 in
A-6

Passive Water Pressure or dead weight of water in lock
High Ocean Tide El. 116.0 & Low River Basin Tide @ El. 106.0

	FORCE	ARM	MG-) Negative	ARM	MG+) Positive
Large Lock					
300 x 40 x 22 x .0642	26400#	—	—	—	—
2 x 429.2 x 33 x .0642	1820#			+161.85	+ 294,500
2 x 429.2 x 22 x .0642	1212	-161.85	- 196,200		
	29,432#			3.33	+ 98,200
Small Locks					
2 x 200 x 14 x .0642	9,000#	—	—	—	—
4 x 140 x 24 x .0642	864			+ 106.55	+ 90,600
4 x 140 x 14 x .0642	504	-106.55	- 53,200		
	10,368#			3.60'	+ 37,300
Combined Locks	39,800#			3.40'	+ 135,500

. . . High River Basin Tide El. 112.0 & Low Ocean Tide @ El. 98.0

Large Lock					
300 x 14 x .0642	10,800#	—	—	—	—
2 x 429.2 x 28 x .0642	1,544	-161.85	- 250,000		
2 x 429.2 x 14 x .0642	772			+161.85	+ 124,700
	13,116#	9.45'	- 125,300		
SMALL LOCKS					
2 x 25 x 200 x 6 x .0642	3852#	—	—	—	—
4 x 140 x 20 x .0642	720	-106.55	-76,800		
4 x 140 x 6 x .0642	216			+106.55	+23,050
	4,788#	11.23'	-53,750		
Combined Locks	17,904#	10.0'	-179,050		

PROJECT C.R.D.&L. ACC. NO.
SUBJECT Stability of Combined Locks SHEET NO. 7 OF
Longitudinal direction DATE May 4 1971
COMP. RCR CHECK T.S.K. CONT. NO. 1579.60

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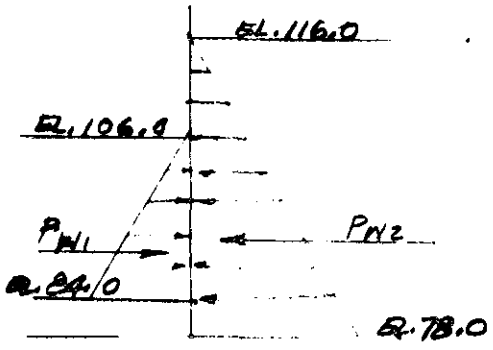
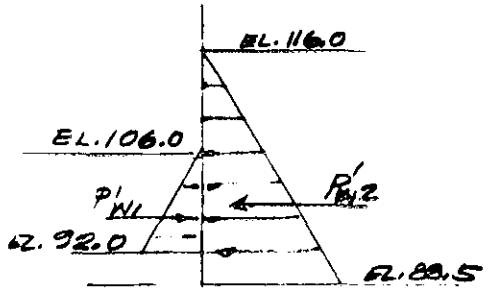
Active Water Pressures

Ocean high tide EL 116.0 & Low River Basin Tide EL 106.0

LARGE LOCK



SMALL LOCK



$P_{W1} = \frac{1}{2} \times 109 \times 38^2 \times .0642 = \underline{5050}^k$

$P_{W2} = \frac{1}{2} \times 109 \times 28^2 \times .0642 = \underline{2745}^k$

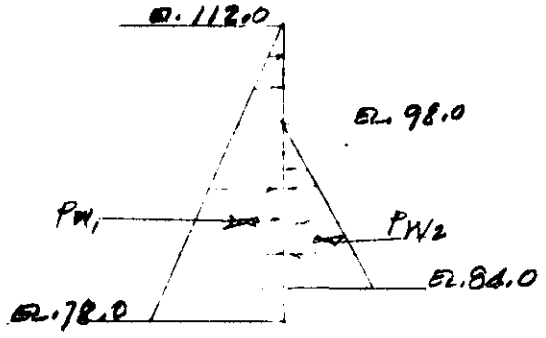
@ EL. 78.0, Moment $= 5050 \times 38/3 - 2745\left(\frac{28}{3}\right)$
$= \underline{38,400'k}$

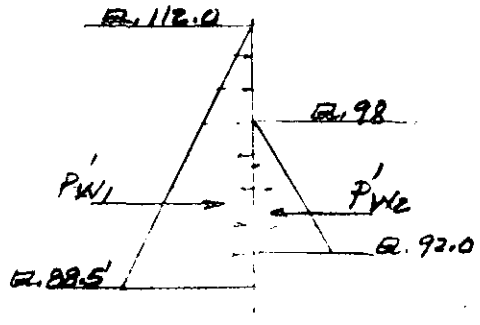
$P'_{W1} = \frac{1}{2} \times 107 \times \overline{27.5}^2 \times .0642 = \underline{2595}^k$

$P'_{W2} = \frac{1}{2} \times 107 \times 17.5^2 \times .0642 = \underline{1054}^k$

@ EL. 88.5, $M = 2595 \times \frac{27.5}{3} - 1054\left(\frac{17.5}{3}\right)$
$= \underline{16,650'k}$

River Basin high tide EL. 112.0 & Ocean Low Tide @ EL. 98.0





$P_{W1} = \frac{1}{2} \times 109 \times \overline{34}^2 \times .0642 = \underline{4050}^k$

$P_{W2} = \frac{1}{2} \times 109 \times \overline{20}^2 \times .0642 = \underline{1,400}^k$

@ EL. 78.0, $M = 4050\left(\frac{34}{3}\right) - 1400\left(\frac{20}{3}\right)$
$M = \underline{36,460'k}$

$P'_{W1} = \frac{1}{2} \times 107 \times \overline{23.5}^2 \times .0642 = \underline{1893}^k$

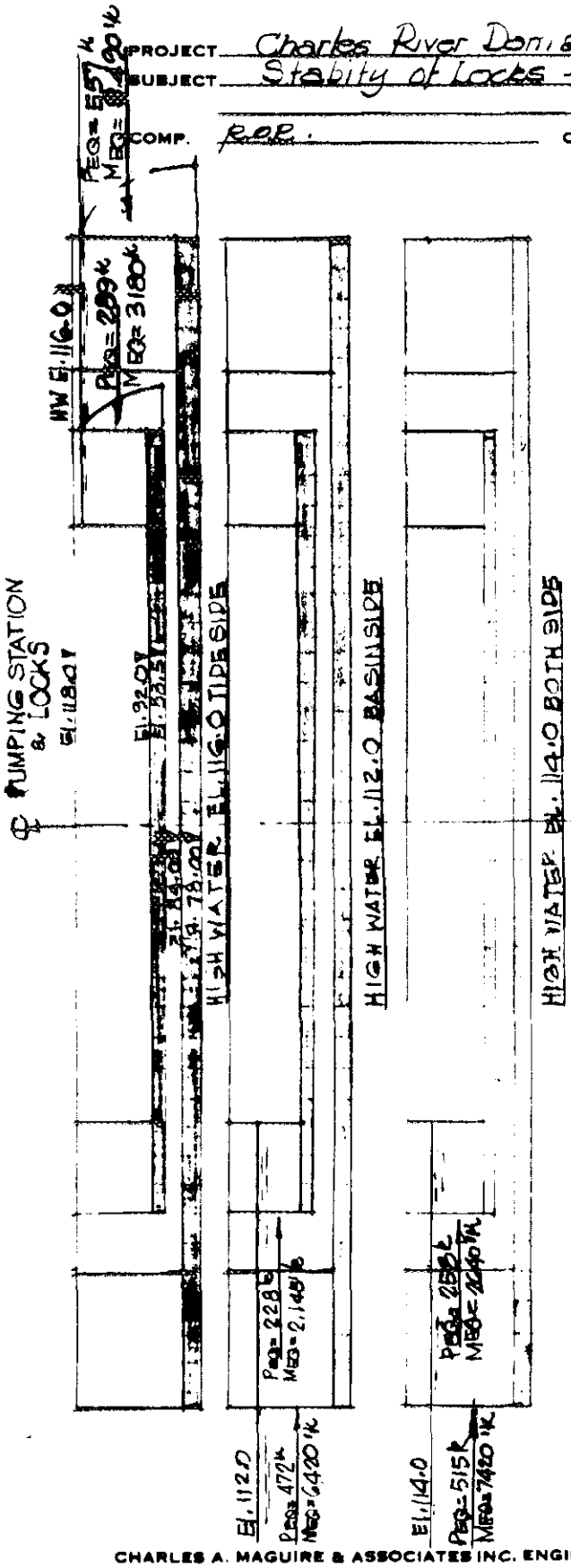
$P'_{W2} = \frac{1}{2} \times 107 \times 9.5^2 \times .0642 = \underline{310}^k$

@ EL. 88.5

$M = 1893\left(\frac{23.5}{3}\right) - 310\left(\frac{9.5}{3}\right)$
$= \underline{13,840'k}$

PROJECT Charles River Dam & Locks — ACC. NO.
SUBJECT Stability of Locks - Hydrodynamic force — SHEET NO. 8 OF
DATE May 4 1971
COMP. R.O.R. — CHECK [illegible] — CONT. NO. 1579-60

A-8



HYDRODYNAMIC·FORCE·DIAGRAM

Hydrodynamic force for different high water level:

$$C_e = \frac{51}{\sqrt{1-0.72\left[\frac{h}{1000 t_e}\right]}} = \frac{51}{\sqrt{1-0.72\left[\frac{40}{1000(1)}\right]}} = 51.72$$

$h = 118.0 - 78 = 40'$ for large lock

$h = 118.0' - 88.5' = 29.5'$

$$C_e = \frac{51}{\sqrt{1-0.72\left[\frac{29.5}{1000(1)}\right]}} = 51.62$$

For max. H.W. El. 116.0

$y = 116.0 - 78 = 38'$ for large lock

$P_e = \frac{2}{3} C_e \alpha y \sqrt{hy}$

$= \frac{2}{3} \times 51.72(0.1)(38)\sqrt{38 \times 40}$

$= 5120\ \#'/' \times 109' = 557^k$

$M_e = \frac{4}{15} C_e \alpha y^2 \sqrt{hy}$

$= \frac{4}{15} \times 51.72(0.1)(38)^2 \sqrt{38 \times 40}$

$= 77{,}900\ ft\#/' \times 109 = 8{,}490\ 'k$

$y = 116' - 88.5' = 27.5'$ for small locks

$P_e = \frac{2}{3} \times 51.62(0.1)(27.5)\sqrt{27.5 \times 29.5}$

$= 2{,}700\ \#'/' \times 107' = 289\ k$

$M_e = \frac{4}{15} \times 51.62(0.1)(27.5)^2 \sqrt{27.5 \times 29.5}$

$= 29{,}700\ ft\#/' \times 107' = 3{,}180\ 'k$

PROJECT Charles River Dam & Lock
SUBJECT Stability of Locks - Hydrodynamic Forces
COMP. RCK CHECK [illegible]

ACC. NO.
SHEET NO. 9 OF
DATE May 4 1971
CONT. NO. 1573.00

A-9

For max. H.W. @ El. 112.0

$y = 112 - 78 = 34'$ for large lock

$Pe = 2/3 \times 51.72 (0.1) 34 \sqrt{34 \times 40} = 4{,}330\#/' \times 109' = \underline{472\ k}$

$Me = \frac{4}{15} \times 51.72 (0.1)(34)^2 \sqrt{34 \times 40} = 59{,}000\ \#\#/' \times 109' = \underline{6{,}420\ 'k}$

$y = 112' - 88.5' = 23.5'$ for small locks

$Pe = 2/3 \times 51.62 (0.1)\ 23.5 \sqrt{23.5 \times 29.5} = 2{,}130\ \#/' \times 107' = \underline{228\ k}$

$Me = 4/15 \times 51.62 (0.1)(23.5)^2 \sqrt{23.5 \times 29.5} = 20{,}060\ \#\#/' \times 107' = \underline{2{,}145\ 'k}$

For max. H.W. @ El. 114.0

$y = 114.0 - 78 = 36'$ for Large Lock

$Pe = 2/3 \times 51.72 (0.1)\ 36 \sqrt{36 \times 40} = 4{,}725\ \#/' \times 109' = \underline{515\ k}$

$Me = 4/15 \times 51.72 (0.1)(36)^2 \sqrt{36 \times 40} = 68{,}100\ \#\#/' \times 109' = \underline{7{,}420\ 'k}$

$y = 114.0 - 88.5 = 25.5'$ for small locks

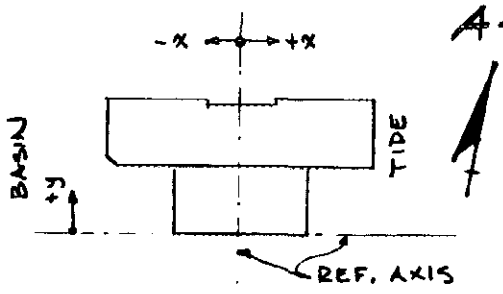
$Pe = 2/3 \times 51.62 \times (0.1)\ 25.5 \sqrt{25.5 \times 29.5} = 2{,}410\ \#/' \times 107' = \underline{258\ k}$

$Me = \frac{4}{15} \times 51.62 (0.1)(25.5)^2 \sqrt{25.5 \times 29.5} = 24{,}650\ \#\#/' \times 107' = \underline{2{,}640\ 'k}$

PROJECT CHARLES RIVER NAV. LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 10 OF
DATE Dec. 15 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

A-10

CENTER OF GRAVITY
OF DEAD LOAD
OF LOCK STRUCTURE



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ feet)	Moment $W\bar{x}$ (ft-kip)	Moment $W\bar{y}$ (ft-kip)
STAGE I					
Large lock walls	94,897	-0.83	162.54		
Large lock foundation mat	35,000	+13.58	161.1		
Σ D.L. STAGE I	129,897	3.05	162.15	+396,535	21,063,058
STAGE II					
Stage I (Large lock only)	129,897	3.05	162.15		
Viaduct Pier 7	920	-60.5	194.5		
Viaduct Pier 8	940	-60.5	131.5		
Control Tower on large lock	350	+59.5	128.83		
Personnel building	385	+23.5	123.5		
Small lock interior wall	26,461	-1.47	65.75		
Small lock land wall	12,405	-0.09	10.5		
Small lock foundation	27,300	+14.95	54.6		
Viaduct Pier 9	940	-60.5	65.75		
Viaduct Pier 10	751	-60.5	3.5		
Control tower on small lock	350	+59.5	61.17		
Σ D.L. FINAL CONDIT.	200,699	2.99	124.09	+600,169	24,904,473

PROJECT CHARLES RIVER NAVIGATION LOCK ACC. NO.
SUBJECT STABILITY - STAGE 2 SHEET NO. 11 OF
DATE DEC. 15 1971
COMP. L.E CHECK V.O CONT. NO. 1579.60

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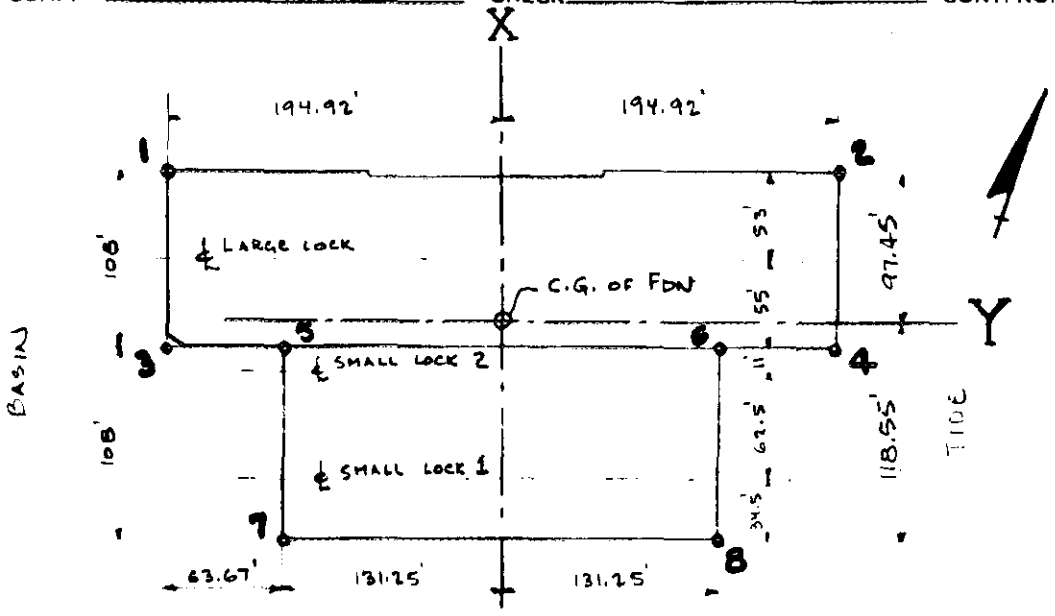

FOUNDATION PLAN
Scale 1" = 100'

FOUNDATION SECTION PROPERTIES:

AREA = 69,795 ft^2
I_x = 699,800,000 ft^4
I_y = 266,000,000 ft^4

SOIL BEARING PRESSURE (general formula)

$$S.B.P. = \frac{P}{A} \pm \frac{Pe_x x}{I_x} \pm \frac{Pe_y y}{I_y}$$

$$F.S. \text{ FOR UPLIFT} = \frac{\Sigma \text{ Wt. down}}{\Sigma \text{ Wt. up}}$$

$$F.S. \text{ FOR SLIDING} = \frac{0.5 \, \Sigma \text{ Wt.}}{\Sigma H}$$

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY - STAGE 1 SHEET NO. 12 OF
DATE Dec 20 1971
COMP. L.E. CHECK RD CONT. NO. 1579.60

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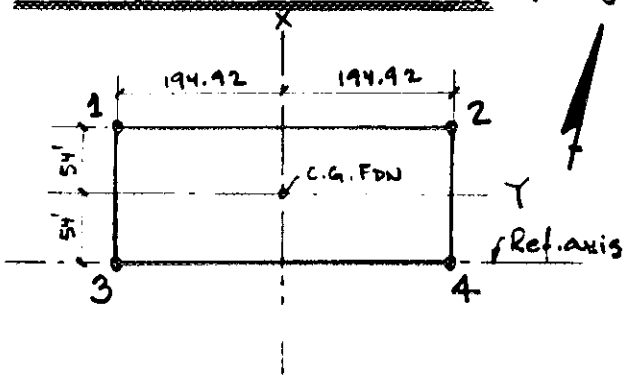
STAGE 1 STABILITY (Large Lock Alone)



Area = 41,690 ft^2
I_x = 533,200,000 ft^4
I_y = 40,900,000 ft^4

CASE I A (Dead Load of large lock only)

Weight = 129,897^k

$\bar{x}$ = 3.05' e_x = 3.05'

$\bar{y}$ = 162.15 - 108 = 54.15' e_y = 0.15'

SOIL PRESS.

```
        -194.92   S
            108   S
P1 =   2.996662  A0

         194.92   S
            108   S
P2 =   3.286312  A0

        -194.92   S
              0   S
P3 =   2.945254  A0

         194.92   S
              0   S
P4 =   3.234904  A0
```

F.S. sliding = ∞

F.S. uplift = ∞

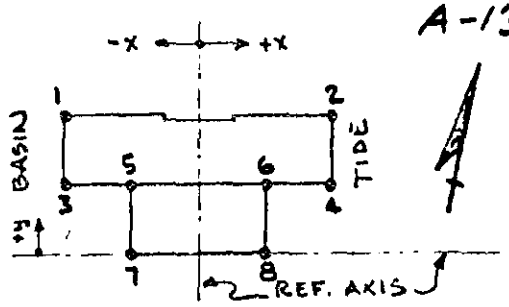
PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 13 OF
DATE 17 DEC 1971
COMP. L.E. CHECK KD CONT. NO. 1579.60

A-13

STABILITY

CASE IB

Stage II - Construct Condition
Large Lock in Operation,
Small locks in cofferdam



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Σ Dead Loads (all locks)	200,699	+2.99	+124.09	+600,169	+24,904,473
Water in Large Lock	29,432	+3.33	163.0		
Σ DOWN	230,131	3.03	129.07	698,098	29,702,154
Hydrostatic Uplift	-112,613	+5.1	131.0		
Longitudinal Moment	-	-	-	-38,400	-
Transverse Moment	-	-	-	-	-91,000
Σ TOTAL	117,518	0.73	126.44	85,373	14,858,852

SOIL BEARING PRESSURE

e_x = 0.726448 E0
e_y = 7.886792 E0

Pressures @ Corners (ksf)

1	1.999717 A0
2	2.046897 A0
3	1.623445 A0
4	1.670616 A0
5	1.631149 A0
6	1.662911 A0
7	1.254877 A0
8	1.286639 A0

F.S. UPLIFT = $\frac{230,131}{112,613}$ = 2.05

H_{E-W} = 2305^K

H_{N-S} = 9750^K

F.S. SLIDING $_{E-W}$ = $\frac{0.5 \times 117,518}{2305}$ = 25.6

F.S. SLIDING $_{N-S}$ = $\frac{0.5 \times 117,518}{9750}$ = 6.0

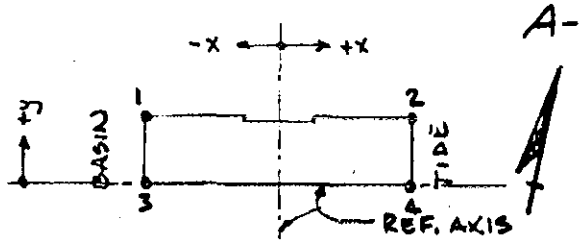
PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 14 OF
DATE Dec. 20 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

A-14

STABILITY

CASE II A

Normal operation of large lock while small locks are under construction.



COMPONENT	Weight (kips)	$\bar{X}$ (feet)	$\bar{Y}$ (feet)	Moment $W\bar{X}$ (ft-kips)	Moment $W\bar{Y}$ (ft-kips)
Dead Load of Large Lock	129,897	3.05	54.15		
Water in lock	13,116	-9.45	55.0		
Σ DOWN	143,013	1.90	54.23	272,239	7,755,303
Hydrostatic Uplift	-91,252	5.58	53.5		
Longitudinal moment	–	–	–	36,460	–
Transverse moment	–	–	–	–	-33,100
Σ TOTAL	51,761	-3.87	54.87	-200,487	2,840,220

SOIL PRESSURES

	-192·92	S
	108	S
P_1 =	1·373553	A0
	194·92	S
	108	S
P_2 =	1·227727	A0
	-194·92	S
	0	S
P_3 =	1·255505	A0
	194·92	S
	0	S
[illegible] =	1·108927	A0

$$\text{F.S. UPLIFT} = \frac{143013}{91252} = 1.57$$

$$H_{E\text{-}W} = 2650^k$$

$$H_{N\text{-}S} = 4960^k$$

$$\text{F.S. SLIDING}_{E\text{-}W} = \frac{0.5 \times 51761}{2650} = 9.8$$

$$\text{F.S. SLIDING}_{N\text{-}S} = \frac{0.5 \times 51761}{4960} = 5.2$$

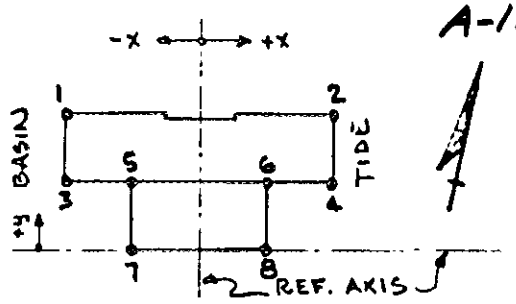
PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 15 OF
DATE 17 Dec 1971
COMP. L.E. CHECK TO CONT. NO. 1579.60

A-15

STABILITY

CASE IIB

Normal Operating Condition - all locks



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Σ Dead Loads (all locks)	200,699	+2.99	+124.09	+600,169	+24,904,473
Weight of water	39,800	3.40	136.5		
Σ DOWN	240,499	3.06	126.14	735,410	30,337,439
Hydrostatic Uplift	-152,008	4.17	124.0		
Longitudinal Moment	—	—	—	-55,050	—
Transverse Moment	—	—	—	—	+68,300
Σ TOTAL.	88,491	0.53	130.60	46,486	11,556,747

SOIL BEARING PRESSURE

e_x = 0.530000 E0
e_y = 12.050000 E0

Pressures @ Corners (ksf)

1	1.645389 A0
2	1.671507 A0
3	1.212523 A0
4	1.238644 A0
5	1.216791 A0
6	1.234377 A0
7	0.783927 A0
8	0.801513 A0

F.S. UPLIFT = $\frac{240,499}{152,008}$ = 1.58

H_{E-W} = 3846^K

H_{N-S} = 1630^K

F.S. SLIDING $_{E-W}$ = $\frac{0.5 \times 88491}{3846}$ = 11.5

F.S. SLIDING $_{N-S}$ = $\frac{0.5 \times 88491}{1630}$ = 27.0

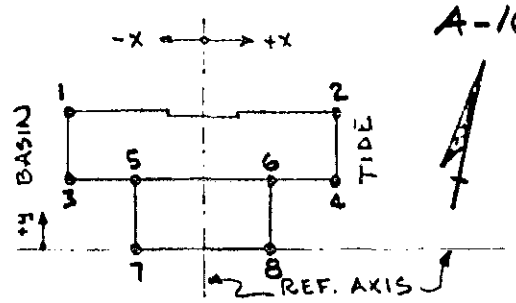
PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 16 OF
DATE DEC 20 1971
COMP. L.F. CHECK RO CONT. NO. 1579.60

A-16

STABILITY

CASE III A

Extreme Maint. Condition
(Large lock dewatered)



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Σ Dead Loads (all locks)	200,699	+2.99	+124.09	+600,169	+24,904,473
Weight of Water	13,400	1.01	65.75		
Σ DOWN	214,099	2.87	120.44	613,624	25,785,789
Hydrostatic Uplift	-152,008	4.17	124.0		
Longitudinal Moment	–	–	–	– 55,050	–
Transverse Moment	–	–	–	–	+68,300
Σ TOTAL	62,091	-1.21	112.82	-75,299	7,005,097

SOIL BEARING PRESSURE

e_x = +1.212686 E0
e_y = -5.733791 E0

Pressures @ Corners (ksf)

1	0.780116 A0
2	1.738402 A0
3	0.924619 A0
4	0.882906 A0
5	0.917806 A0
6	0.889713 A0
7	1.062310 A0
8	1.034222 A0

F.S. UPLIFT = $\frac{214099}{152008}$ = 1.41

H_{E-W} = 3846^k

H_{N-S} = 1630^k

F.S. SLIDING $_{E-W}$ = $\frac{0.5 \times 62091}{3846}$ = 8.1

F.S. SLIDING $_{N-S}$ = $\frac{0.5 \times 62091}{1630}$ = 19.0

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 17 OF
DATE DEC. 20, 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

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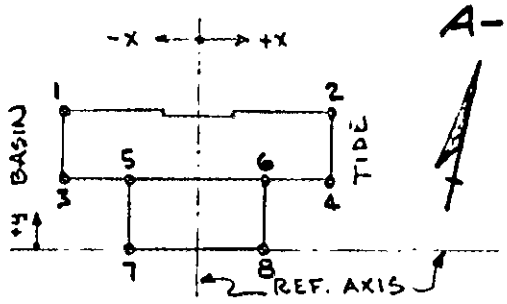
STABILITY

CASE III B

Extreme Maint. Condition
(Both Small locks dewatered)



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Σ Dead Loads (all locks)	200,699	+2.99	+124.09	+600,169	+24,904,473
Weight of water	30,800	4.39	163.0		
Σ DOWN	231,499	3.18	129.27	735,302	29,925,139
Hydrostatic Uplift	-152,008	4.17	124.0		
Longitudinal Moment	–	–	–	-58,050	–
Transverse Moment	–	–	–	–	+68,300
Σ TOTAL	79491	0.58	140.19	46,379	11,144,447

SOIL BEARING PRESSURE

e_x = 0.583430 E0
e_y = 21.044066 E0

Pressures @ Corners (KSF)

1	1.756390 A0
2	1.782113 A0
3	1.057846 A0
4	1.083575 A0
5	1.062048 A0
6	1.079372 A0
7	0.363504 A0
8	0.380828 A0

F.S. UPLIFT = $\frac{231499}{152008}$ = 1.52

H_{E-W} = 3846^k

H_{N-S} = 1630^k

F.S. SLIDING E-W = $\frac{0.5 \times 79491}{3846}$ = 10.3

F.S. SLIDING N-S = $\frac{0.5 \times 79491}{1630}$ = 24.4

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 18 OF
DATE Dec. 20 1971
COMP. L.E. CHECK RQ CONT. NO. 1579.60

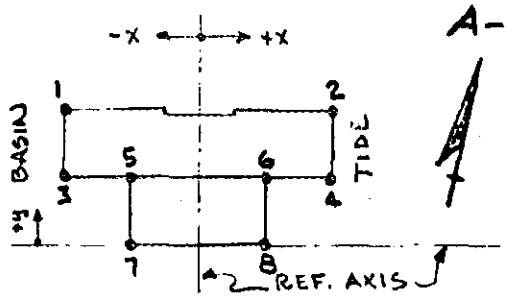
A-18

STABILITY

CASE IV A

Emergency Condition

(Same as IB with Earthquake)



Component	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Case IB	117,518	0.73	126.44	85,373	14,858,852
EQ & Hydrodynamic	–	–	–	-303,000	–
Σ TOTAL	117,518	-1.85	126.44	-217,627	14,858,852

Soil Bearing Pressure

e_x = -1.848312 EQ
e_y = 7.888324 EQ

Pressures @ Corners (ksf)

1	2.083811 AQ
2	1.962959 AQ
3	1.707431 AQ
4	1.586580 AQ
5	1.687693 AQ
6	1.606317 AQ
7	1.311313 AQ
8	1.229937 AQ

F.S. UPLIFT = $\frac{230131}{112613}$ = 2.05

H_{E-W} = 22,167^K

H_{N-S} = 9750^K

F.S. SLIDING $_{E-W}$ = $\frac{0.5 \times 117518}{22167}$ = 2.7

F.S. SLIDING $_{N-S}$ = $\frac{0.5 \times 117518}{9750}$ = 6.0

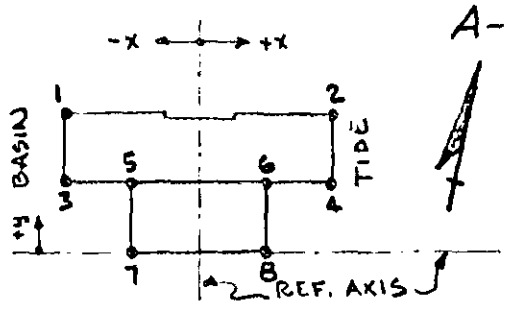
PROJECT CHARLES RIVER NAVIGATION LOCK ACC. NO.
SUBJECT STABILITY SHEET NO. 19 OF
DATE Dec. 20 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

A-19

STABILITY

CASE IV B

Emergency Condition
(Same as II B with Earthquake)



COMPONENT	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Case II B	88,491	0.53	130.60	46,486	11,556,747
EQ & Hydrodynamic	–	–	–	-303,000	–
Σ TOTAL	88,491	-2.89	130.60	-256,514	11,556,747

SOIL BEARING PRESSURE

e_x = -2.894044 FT
e_y = 12.048524 FT

Pressures @ Corners (KSF)

1	1.729608 KSF
2	1.087316 KSF
3	1.296744 KSF
4	1.154403 KSF
5	1.273305 KSF
6	1.177691 KSF
7	0.840641 KSF
8	0.744827 KSF

F.S. UPLIFT = $\frac{240499}{152008}$ = 1.58

H_{E-W} = 23,997^K

H_{N-S} = 1630^K

F.S. SLIDING E-W = $\frac{0.5 \times 88491}{23997}$ = 1.8

F.S. SLIDING N-S = $\frac{0.5 \times 88491}{1630}$ = 27.0

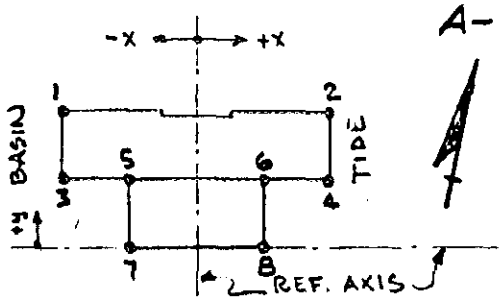
PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STABILITY SHEET NO. 20 OF
DATE Dec. 20 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

A-20

STABILITY

CASE IV C

Emergency Condition
(Same as III A with Earthquake)



Component	Weight (kips)	$\bar{x}$ (feet)	$\bar{y}$ (feet)	Moment $W\bar{x}$ (ft-kips)	Moment $W\bar{y}$ (ft-kips)
Case III A	62091	-1.21	112.82	-75,299	7,005,097
Earthquake & Hydrodyn	—	—	—	-303,000	—
Σ Total	62,091	-6.09	112.82	-378,299	7,005,097

Soil Bearing Pressure

e_x = -6.093836 E0
e_y = -5.731817 E0

Pressures @ Corners (ksf)

1	0.864599 A0
2	0.654085 A0
3	1.008994 A0
4	0.798481 A0
5	0.974615 A0
6	0.832863 A0
7	1.119009 A0
8	0.977259 A0

F.S. UPLIFT = $\frac{214099}{152008}$ = 1.41

H_{E-W} = 23,997^K

H_{N-S} = 1630^K

F.S. SLIDING $_{E-W}$ = $\frac{0.5 \times 62091}{23997}$ = 1.3

F.S. SLIDING $_{N-S}$ = $\frac{0.5 \times 62091}{1630}$ = 19.0

PROJECT CHARLES RIVER NAVIGATION LOCKS
SUBJECT STABILITY ANALYSIS SUMMARY
COMP. L.E. CHECK RO
ACC. NO.
SHEET NO. 21 OF
DATE DEC. 20 1971
CONT. NO. 1379.60

STABILITY ANALYSIS SUMMARY

LOADING CONDIT.	SOIL BEARING PRESSURES (KSF) AT CORNERS								SAFETY FACTORS	
	1	2	3	4	5	6	7	8	UPLIFT	SLIDING
I A	3.00	3.29	2.95	3.23	–	–	–	–	–	–
I B	2.00	2.05	1.62	1.67	1.63	1.66	1.25	1.29	2.05	6.0
II A	1.37	1.23	1.26	1.11	–	–	–	–	1.57	5.2
II B	1.65	1.67	1.21	1.24	1.22	1.23	0.78	0.80	1.58	11.5
III A	0.78	0.74	0.92	0.88	0.92	0.89	1.06	1.03	1.41	8.1
III B	1.76	1.78	1.06	1.08	1.06	1.08	0.36	0.38	1.52	10.3
IV A	2.08	1.96	1.71	1.59	1.69	1.61	1.31	1.23	2.05	2.7
IV B	1.73	1.59	1.30	1.15	1.27	1.18	0.84	0.74	1.58	1.8
IV C	0.86	0.65	1.01	0.80	0.97	0.83	1.12	0.98	1.41	1.3

A-21

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT LOCK DESIGN PROCEDURE SHEET NO. 1 OF
DATE Dec. 9 19 71
COMP. L.E. CHECK RD CONT. NO. 1579.60

A-22

Structural Analysis is carried out by the finite element method applied to the problem of a beam on elastic foundation. This is accomplished by a computer program.

The printed output includes displacements, rotations, soil reactions, shears and moments at preselected points.

Utilizing computer output, the required base slab thickness is selected and reinforcement designed considering shear, moment, axial thrust and uplift forces.

Lean concrete fill is required underneath the small locks to replace soft and organic silts. In order to properly utilize the concrete fill in the design, two design approaches have been considered:

a) Neglect the effect of lean concrete

b) Consider an average thickness of 10 feet of lean concrete fill under the base slab of the small locks. The lean concrete has been considered as part of the structure for stiffness only.

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT DESIGN CRITERIA SHEET NO. 2 OF
DATE OCT. 19 71
COMP. L.E. CHECK RO CONT. NO. 1579.60

A-23

DESIGN CRITERIA (per C.O.E. Engineering Manuals & Directives)

CONCRETE

$f'_c = 3000$ psi
$f_c = 0.35 f'_c = 1050$ psi
$v_c = 1.1\sqrt{f'_c} = 60$ psi
$E_c = 3.5 \times 10^6$ psi $= 504{,}000$ ksf

Minimum Cover: Bottom of base mat 6"
Other surfaces 4"

REINFORCEMENT $f_s = 20{,}000$ psi

EARTHQUAKE Apply 0.1g at center of gravity
Working stresses to be increased by 33⅓%

DESIGN WATER ELEVATIONS

	Basin Side	Tide Side
High water	El. 112	El. 116
Low water	El. 106	El. 98

For dewatered maintenance condition, use max. El. 114

HYDROSTATIC UPLIFT

Uplift will be assumed to act upon 100% of the area of the plane upon which it impinges.

DESIGN DEAD LOADS

Concrete	150	p.c.f.
Water	64	p.c.f.
Earth	125	p.c.f. (dry)
	140	pcf (sat.)

SUBGRADE MODULUS 100 lb/cu.in = 172.8 kips/cu.ft

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT LOADING CONDITIONS SHEET NO. 3 OF
DATE DEC. 15 1971
COMP. L.E. CHECK R.O CONT. NO. 1579.60

A-24

LOADING CONDITIONS FOR STRUCT. DESIGN

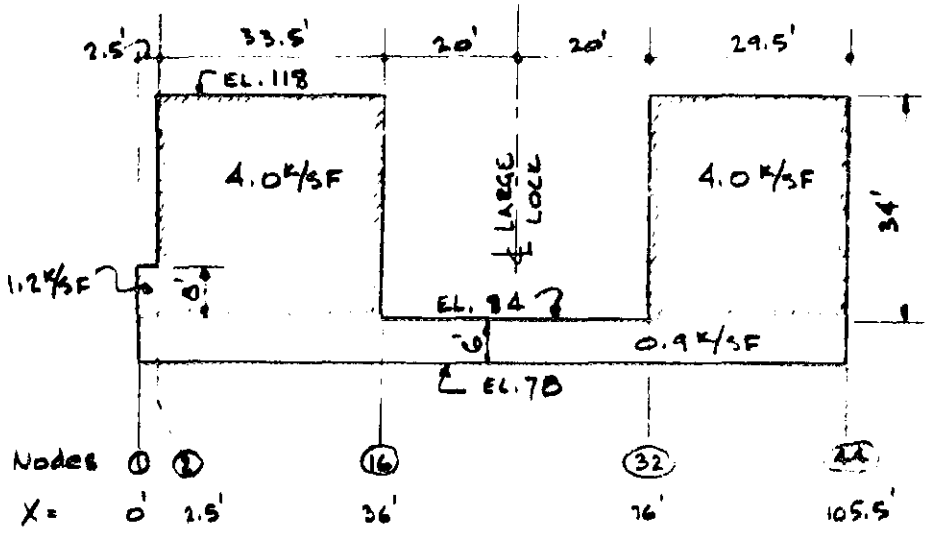
	Corresponding Stability Cases	
	No Earthq.	With Earthq.
STAGE I (Large Lock Only)		
1. Dead load of large lock only - no water	Ia	—
2. Water at El. 98 in large lock with Uplift	IIa	—
STAGE II (All locks together)		
1. Dead load of Structure, Uplift at 116, All locks dry	—	—
2. Water at 116 in all locks	IIb	IVb
3. Large lock at 114, others dry	IIIb	—
4. Small locks at 114, large lock dry	IIIa	IVc
5. Small lock #2 dry, others at 114	—	—
6. Dead load of Structure, Uplift at 98, All locks dry	—	—
7. Water at 98 inside and outside large lock (sm. locks dry)	—	—
8. Water at 114 inside and outside large lock (sm. locks dry)	Ib	IVa

Each of the above loading conditions have been analyzed twice - without earthquake and with earthquake.

For earthquake conditions, the allowable stresses may be increased by 33⅓ %.

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT MODEL FOR STRUCTURAL ANALYSIS SHEET NO. 4 OF
(STAGE 1) DATE Dec. 9 1971
COMP. L.E. CHECK RO CONT. NO. 1979-60

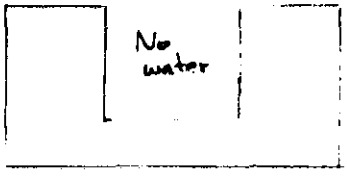
A-25



TYP. SECT. THRU LARGE LOCK (STAGE 1)

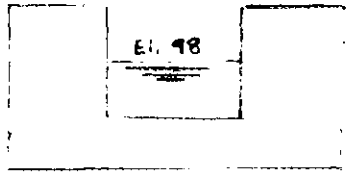
Scale 1" = 25'

STAGE 1 LOADING CONDITIONS



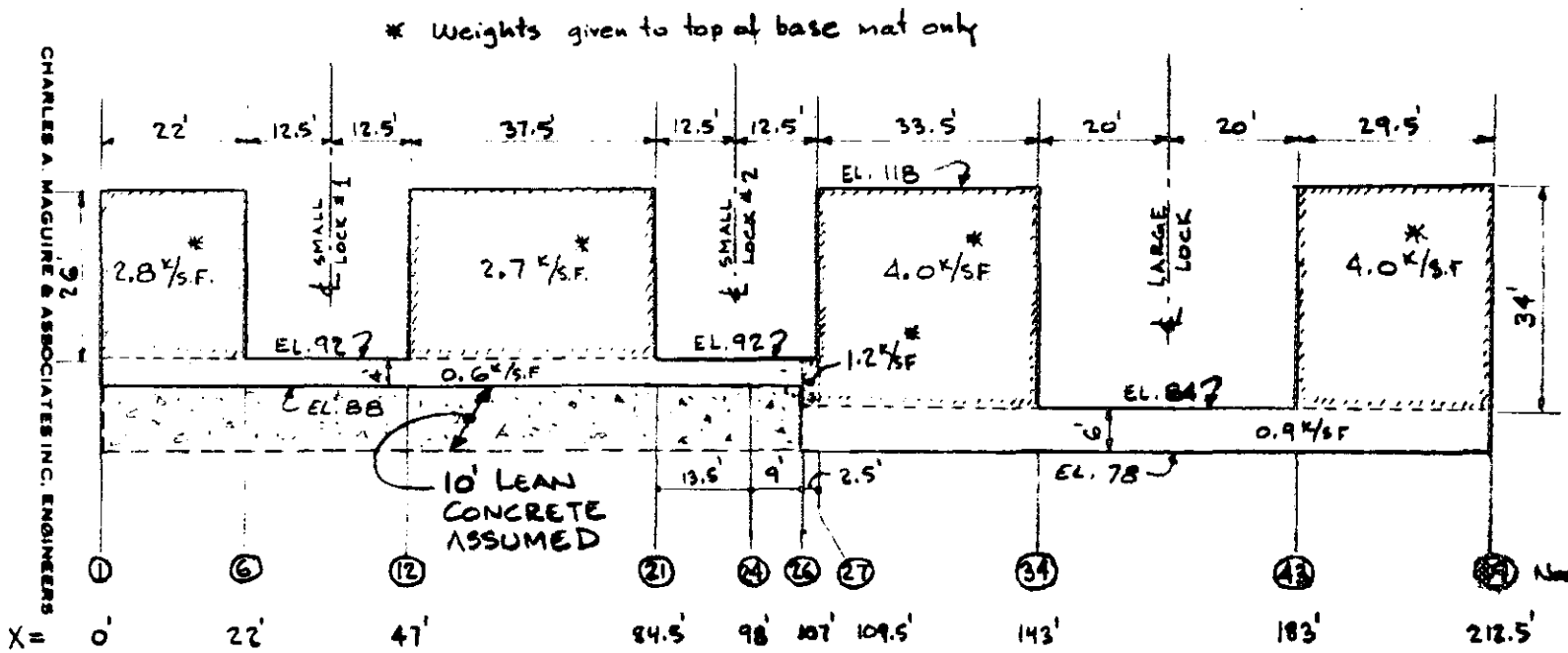
No uplift

LOAD COND # 1



Uplift @ 98

LOAD COND # 2



TYPICAL SECTION THRU LOCKS (STAGE 2)

(Used in computer analysis)

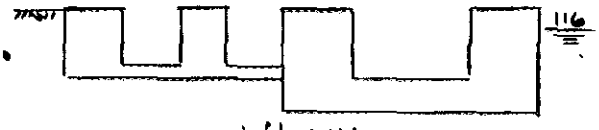
Scale: 1" = 25'

CHARLES A. MAGUIRE & ASSOCIATES INC. ENGINEERS

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT LOADING CONDITIONS - STAGE 2 SHEET NO. 6 OF
DATE Nov. 23 1971
COMP. L.E. CHECK RO CONT. NO. 1579.60

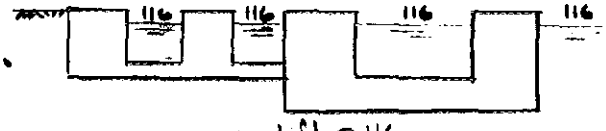
A-27

1.



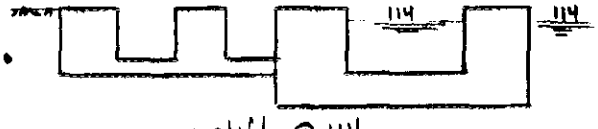
uplift @ 116

2.



uplift @ 116

3.

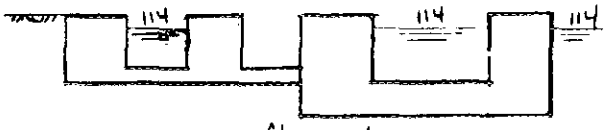


uplift @ 114

4.

uplift @ 114

5.



uplift @ 114

6.

uplift @ 98

7.

no uplift (in cofferdam) uplift @ 98

8.

no uplift (in cofferdam) uplift @ 114

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT LOAD DETERMINATION FOR COMPUTER INPUT SHEET NO. 7 OF
DATE Nov. 1 1971
COMP. G.E. CHECK RO CONT. NO. 1579.60

A-28

TRY 4' Base for small locks #1 & 2 based on preliminary computer runs of 10/14/71 and 10/20/71

Uplift (water @ El. 116)

Small locks : $28 \times .064 = 1.79$ ksf

Large locks : $38 \times .064 = 2.43$ ksf

Water @ 116 (Max. operating cond.)

Small locks : $W = 24 \times .064 = 1.54$ ksf

$H = \frac{1}{2} \times .064 \times 24^2 = 18.4^k$

$M = 18.4\left(\frac{24}{3} + 2\right) = 184'^k$

Large locks : $W = 32 \times .064 = 2.05$ ksf

$H = \frac{1}{2} \times .064 \times 32^2 = 32.8^k$

$M = 32.8\left(\frac{32}{3} + 3\right) = 450'^k$

Water @ 114 (Mainten. Cond.)

Small locks : $W = 22 \times .064 = 1.41$ ksf

$H = \frac{1}{2} \times .064 \times 22^2 = 15.5^k$

$M = 15.5\left(\frac{22}{3} + 2\right) = 145'^k$

Large locks : $W = 30 \times .064 = 1.92$ ksf

$H = \frac{1}{2} \times .064 \times 30^2 = 28.8^k$

$M = 28.8\left(\frac{30}{3} + 3\right) = 373'^k$

PROJECT Charles River Locks ACC. NO.
SUBJECT Load Determination for Computer Input (Based on 4' slab in small locks) SHEET NO. B OF
DATE Nov. 4 1971
COMP. L.E. CHECK RD CONT. NO. 1579.60

A-29

Uplift with water @ El. 98

Large lock 20 x .064 = 1.28 ksf

Small locks 10 x .064 = 0.64 ksf

Uplift with water @ El. 114

Large lock 36 x .064 = 2.30 ksf
Small locks 26 x .064 = 1.67 ksf

Water @ El. 98 inside large lock

$W = 14 \times .064 = 0.90$ ksf

$H = \frac{1}{2} \times .064 \times 14^2 = 6.25^k$

$M = 6.25 \left(\frac{14}{3} + 3\right) = 48'^k$

Earthquake Force (10% g)

Node 1 & 6 $\frac{1}{2} \times 6.1 \times 15 = 46^k$

12 & 21 $\frac{1}{2} \times 10.1 \times 15 = 76^k$

27 & 34 $\frac{1}{2} \times 13.3 \times 20 = 133^k$

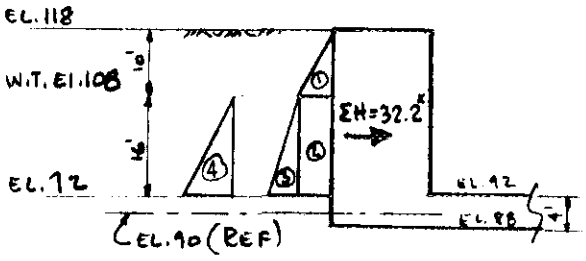
43 & 49 $\frac{1}{2} \times 11.9 \times 20 = 119^k$

PROJECT Charles River Nav. Locks ACC. NO.
SUBJECT Lateral Pressures SHEET NO. 9 OF
DATE Nov. 8 1971
COMP. L.E CHECK RO CONT. NO. 1579.60

A-30

LATERAL EXTERNAL PRESSURES

a) Small Lock Side (Earth & Water)



$\gamma_{dry} = 125\ \#/cf$

$\gamma_{sat} = 140\ \#/cf$

$\gamma_{subm} = 76\ \#/cf$

$\gamma_{wat.} = 64\ \#/cf$

use at rest press. i.e. $K = 0.5$

$p_1 = 0.5(.125)10 = 0.625$ $\quad M_1 = .625 \times \frac{10}{2}\left(\frac{10}{3} + 18\right) = 67\ ^{1k}/_1$

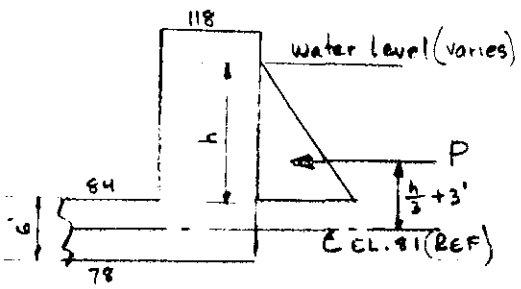
$p_2 = 0.5(.125)16 = 1.000$ $\quad M_2 = 1.00 \times 16\left(\frac{16}{2} + 2\right) = 160$

$p_3 = 0.5(.076)16 = 0.608$ $\quad M_3 = .608 \times \frac{16}{2}\left(\frac{16}{3} + 2\right) = 36$

$p_4 = .064 \times 16 = 1.025$ $\quad M_4 = 1.025 \times \frac{16}{2}\left(\frac{16}{3} + 2\right) = 60$

$\Sigma M_{El.90} = 323\ ^{1k}/_1$

b) Large Lock Side (Water only)



$M_{@EL.81} = \frac{1}{2} \times .064\, h^2\left(\frac{h}{3} + 3'\right)$

W.L.	h	P $.064\frac{h^2}{2}$	(arm) $\frac{h}{3} + 3'$	Mom, @El. 81
98	14	6.26^k	7.67'	$48\ ^{1k}/_1$
114	30	28.8^k	13'	$373\ ^{1k}/_1$
116	32	32.8^k	13.67'	$450\ ^{1k}/_1$

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT INDEX OF COMPUTER RUNS SHEET NO. 10 OF
DATE DEC. 9 1971
COMP. W.E. CHECK RO CONT. NO. 1579.60

A-31

SUMMARY OF ENCLOSED COMPUTER ANALYSES

1) Stage 1 - no earthquake
2) Stage 1 - with earthquake
3) Stage 2 - fill concrete neglected - no earthquake
4) Stage 2 - fill concrete neglected - with earthquake
5) Stage 2 - fill concrete included - no earthquake
6) Stage 2 - fill concrete included - with earthquake

FOR COMPUTER OUTPUT SHEETS SEE END OF APPENDIX "A"

Note: All units are in KIPS and FEET

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STRUCT. DESIGN - LARGE LOCK SHEET NO. 1 OF
DATE Dec. 9 1971
COMP. L.E. CHECK RD CONT. NO. 1579.60

A-32

LARGE LOCK BASE SLAB DESIGN

Summary of Max Design Values

Computer Analysis Case	Axial* Load (kips)	Shear (KIPS)	Bending Moment (FT-KIP) Tens. on bott south	Tens. on top middle	Tens on bott North
Stage 1	6.3	26	166	195	118
Stage 1 with earthquake	19.6	20	66	161	4
Stage 2, no fill conc.	32.8	34	203	264	136
Stage 2, no fill conc. + EQ	46.1	30	132	240	181
Stage 2, fill conc.	32.8	39	287	275	138
Stage 2, fill conc. + EQ	46.1	35	229	229	178

* Max. axial load is not necessarily concurrent with max. moment & shear

Try 6' thick base slab $d_{avail.} = 72" - 6" cov. - 1" = 65"$

Resist. Mom $= \frac{Kbd^2}{12000} = \frac{152 \times 12 \times 65^2}{12000} = 643^{1k} > 287$ OK

Shear stress $v = \frac{V}{bd} = \frac{39000}{12 \times 65} = 50 psi < 1.1\sqrt{f'c} = 60 psi$ OK

∴ 6' base slab satisfactory

Uplift condition

The computer output does not analyze uplift condition - must do manually.

For uplift @ El. 116 with lock empty

$w_u = 2.42 ksf - 0.90 = 1.53 ksf$ net

For simply supp. ends & mom $= \frac{1}{8} wl^2$
For fixed end & mom $= 1/24 wl^2$
} we have a condition somewhere between these

Uplift Condition – cont.

By mom. distr. – Relative stiffnesses

$I_{slab} = \frac{6^3}{40} = 5.4 \rightarrow 1$

$I_{wall} = \frac{29.5^3}{34} = 754 \rightarrow 138$

The wall is very stiff and slab moment would be insignificant if moment distribution done

ACI 318-63 recommends a factor of $\frac{1}{14} wl^2$ @ ℄

Conservatively assume $M_{℄} = \frac{1}{12} wl^2 = \frac{1}{12} \times 1.53 \times 40^2 = 204^{'k} < 275^{'k}$

∴ Uplift condition does not govern slab design

Reinf. Design

$M_{max.\ top} = 275^{'k}$ $M_{max.\ bott} = 287^{'k}$ $P_{ax.} = 32.8^k$ (tens.)

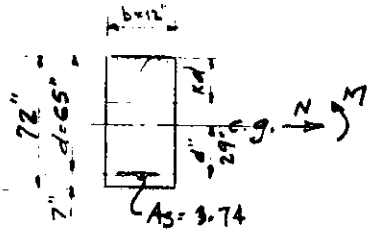
Design bott. reinf. and use same on top, since moments almost same

As req'd (bending only) $= \frac{287}{1.44 \times 65} = 3.06$ in²/ft

Design reinf. for bending and axial tension

Procedure: ACI R/C Design Handbook (SP-3), Example 19

To account for tension, try #11 @ 5" ($A_s = 3.74$, $\Sigma_o = 10.6$)



$f'_c = 3000$ $f_c = 1050$ $n = 9.2$

$f_s = 20{,}000$ $M = 287^{'k}$ $N = -32.8^k$

$$e = \frac{12M}{N} + d'' = \frac{12 \times 287}{-32.8} + 29'' = -76$$

$$\frac{e}{d} = \frac{-76}{65} = -1.17$$

Try $j = 0.90$ $i = \frac{1}{1 - \frac{jd}{e}} = \frac{1}{1 - \frac{0.90}{(-1.17)}} = 0.565$

$$m = q = \frac{n A_s i}{bd} = \frac{9.2 \times 3.74 \times 0.565}{12 \times 65} = .025$$

$$k = \sqrt{m^2 + 2q} - m = \sqrt{.025^2 + 2(.025)} - .025 = .20$$

PROJECT CHARLES RIVER NAV LOCKS ACC. NO.
SUBJECT STRUCT. DES. – LARGE LOCK SHEET NO. 3 OF
DATE Dec. 10 1971
COMP. LET CHECK RO CONT. NO. 1579.60
Rev. 12/15/71

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Reinf Design – Cont

From Table 13 for $k = .20$ and $z = 0.33$ $j = 0.93$

for $j = 0.93$ $i = \dfrac{1}{1 - \dfrac{0.93}{(-1.17)}} = 0.56$

check stresses:

$$f_s = \frac{1000N}{j A_s i} \times \frac{e}{d} = \frac{(-32800)(-1.17)}{0.93 \times 3.74 \times 0.56} = 19{,}700 \text{ psi} < 20{,}000 \quad \underline{\underline{OK}}$$

$$f_c = \frac{f_s}{n} \times \frac{k}{1-k} = \frac{19{,}700}{9.2} \times \frac{.20}{.80} = 545 \text{ psi} < 1050 \quad \underline{\underline{OK}}$$

Check bond & embedment

Allow. bond (top) for # 11 bar $= \dfrac{3.4\sqrt{f'_c}}{D} = 132$ psi

$u_{req'd} = \dfrac{V}{jd\Sigma_o} = \dfrac{32800}{0.93 \times 65 \times 10.6} = 51$ psi < 132 psi $\underline{\underline{OK}}$

to develop bar capacity

Req'd embedm. (top) $= \dfrac{f_s A}{u \Sigma_o} = \dfrac{20{,}000 \times 3.74}{132 \times 10.6} = 53$ inches (say 4'-6")

Allow bond for bottom #11 bars $= \dfrac{4.8\sqrt{f'_c}}{D} = 187$ psi

Req'd embedm. (bott.) $= \dfrac{20{,}000 \times 3.74}{187 \times 10.6} = 38''$ say 3'-6" (30 dia.)

Summary of Large Lock Slab Design

Use 6' thick floor slab

Reinf. # 11 @ 5" Top & Bottom

Embedment in walls: Top 4'-6"

Bott 3'-6"

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STRUCT. DESIGN - SMALL LOCKS SHEET NO. 4 OF
DATE Dec. 10 19 71
COMP. LE. CHECK RO CONT. NO. 1579

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SMALL LOCK BASE SLAB DESIGN

Summary of Design Values

CASE	SMALL LOCK #1				SMALL LOCK #2			
	Shear (kips)	Tension on bott. South	Tension on top Middle	Tension on bott. North	Shear (kips)	Tension on bott. South	Tension on top Middle	Tension on bott North
No fill conc.	20	91	95	99	25	103	57	168
No fill conc. + EQ	23	97	117	123	28	75	62	203
Fill Concrete	23	* 80	281	* 65	28	255	153⊕	445
Fill Conc. + EQ	26	* 10	331	* 56	32	223	163⊕	503

Notes: * Max. design moment at these points causes tension on top, however moment value is less than at middle of slab.

⊕ Max. design moment at these points causes tension on bottom, however moment value is intermediate between South and North edges.

Axial loads in slab

a) Water @ 116 inside 18.4^k tension
b) Water @ 114 inside 15.5^k tension
c) Earth & water outside 32.2^k compression } Lock 1 only
d) Combination of a & c 13.8^k compression } Lock 1 only
e) Combination of b & c [illegible] compression } Lock 1 only

Refer to loading diagrams for applicable axial load conditions.

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
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REQ'D BASE SLAB THICKNESS

Small lock #1

No earthquake $d_{req'd} = \sqrt{\frac{281}{.152}} = 43''$

With earthquake $d_{req'd} = \sqrt{\frac{331}{.152 \times 1.33}} = 40.5''$

Min. thickness = 43" + 6" cover + 1 = 50" try 5'-0" (To limit reinf. to #11)

Small lock #2 @ junction with large lock

No earthquake $d_{req'd} = \sqrt{\frac{445}{.152}} = 54''$

With earthquake $d_{req'd} = \sqrt{\frac{303}{.152 \times 1.33}} = 50''$

Req'd thickness at junction = 54" + 6" cover + 1 = 61" try 8'-0" (To limit reinf. to #11)

Taper small lock slab from 8'-0" at junction with large lock to 5'-0" at node point 21

Shear Stress in slab

For 5'-0" min. slab $d = 53''$

(no earthq.) $v = \frac{V}{bd} = \frac{28000}{12 \times 53} = 44$ psi $< 1.1\sqrt{f'_c} = 60$ psi OK

(with earthq.) $v = \frac{32000}{12 \times 53} = 50$ psi $< 1.1\sqrt{f'_c} \times 1.33 = 80$ psi OK

Check Uplift

Max. uplift with water @ 116 and lock empty

$w_{net} = 1.79$ ksf $- 0.75 = 1.04$ ksf

$M_{\mathbb{L}} \sim \frac{1}{12} \times 1.04 \times 25^2 = 54^{1k}$ < design values due to other loading conditions ∴ uplift does not govern design of slab

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
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Reinf. Design Small Lock # 1 (5'-0" slab, d = 53") A-37

Top Bars (Loading cond. to investigate - no earthquake governs)

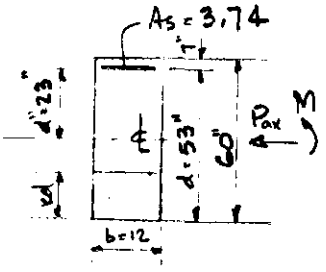
Load. Cond. # 7 M = 281'^k Pax = 0
Load Cond. # 3 M = 146'^k Pax = 32.2^k compr.

L.C. # 7 As req'd = $\frac{281}{1.44 \times 53}$ = 3.70 in²/ft

Try #11 @ 5" (As = 3.74, Σ_o = 10.6)

Check Load. Cond. # 3 for combined bending & axial load

Procedure: Example 14, ACI R/c Des. Handbook



$e = \frac{12M}{N} + d'' = \frac{12 \times 146}{32.2} + 23 = 77.5''$

$\frac{e}{d} = \frac{77.5}{53} = 1.45$

From Table 10a i = 2.40

$m = q = \frac{nA_s i}{bd} = \frac{9.2 \times 3.74 \times 2.40}{12 \times 53} = .13$

From table 11 k = .396 From table 13 j = 0.87

From table 10a $i_{act.}$ = 2.50

Check Stresses:

$f_s = \frac{1000N}{jA_s d} \times \frac{e}{d} = \frac{32200 \times 1.45}{0.87 \times 3.74 \times 2.50} = 5750$ psi low

$f_c = \frac{f_s}{n} \times \frac{k}{1-k} = \frac{5750}{9.2} \times \frac{0.396}{0.604} = 410$ psi low

Loading condition # 3 does not govern

Use #11 @ 5" Top as req'd by load cond. # 7

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STRUCT. DESIGN - SMALL LOCKS SHEET NO. 7 OF
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Check Bond & Embedment

Allow. bond stress for top # 11 bar $= \frac{3.4\sqrt{f'c}}{D} = 132$ psi

$u_{req'd} = \frac{V}{jd\Sigma_o} = \frac{23000}{0.87 \times 53 \times 10.6} = 47$ psi < 132 ok

Req'd. Embedment (to develop bar) $= \frac{f_s A}{u \Sigma_o} = \frac{29000 \times 3.74}{132 \times 10.6} = 53''$ use 4'-6"

Bottom Bars

Load Cond. #8 $M = 99^{1k}$ $P_{ax} = 0$

Load Cond. #6 $M = 91^{1k}$ $P_{ax} = 32.2^k$ compr.

Load Cond #2 $M = 49^{1k}$ $P_{ax} = 18.4^k$ tension

A_s req'd $= \frac{99}{1.44 \times 53} = 1.30$ in²/ft

Try #11 @ 12" ($A_s = 1.56$, $\Sigma_o = 4.43$)

Check Load. Cond. #6 for Combined Bending & Axial Compression

$e = \frac{12 \times 91}{32.2} + 23 = 56.9''$ $\frac{e}{d} = \frac{56.9}{53} = 1.08$

$i = \frac{1}{1 - \frac{0.87}{1.08}} = 5.25$

$m = q = \frac{9.2 \times 1.56 \times 5.25}{12 \times 53} = .118$

from Table 11 $k = .384$ Table 13 $j = 0.87$
$\therefore i_{act.} = 5.25$

Check stresses:

$f_s = \frac{32200 \times 1.08}{0.87 \times 1.56 \times 5.25} = 4880$ psi low

$f_c = \frac{4880}{9.2} \times \frac{0.384}{0.616} = 332$ psi ok

Loading #6 with axial compr. does not govern

Bottom Bars - con't

Check load Cond. # 2 for combined bending & axial tension

$$e = \frac{12 \times 49}{-18.4} + 23 = -9 \qquad \frac{e}{d} = \frac{-9}{53} = -0.17$$

try $j = 0.87$ $\quad i = \dfrac{1}{1 - \dfrac{0.87}{(-0.17)}} = .164$

$$m = q = \frac{9.2 \times 1.56 \times 0.164}{12 \times 53} = .0037$$

$$k = \sqrt{.0037^2 + 2(.0037)} - .0037 = .082$$

$$j = 1 - 2k = 1 - (0.33 \times .082) = .97$$

$$i_{rev.} = \frac{1}{1 - \dfrac{0.97}{(-0.17)}} = .149$$

check stresses.

$$f_s = \frac{(-18400)(-0.17)}{0.97 \times 1.56 \times 0.149} = 13{,}800 \text{ psi} < 20{,}000 \text{ ok}$$

$$f_c = \frac{13800}{9.2} \times \frac{.082}{.918} = 134 \text{ psi} < 1050 \text{ ok}$$

Loading Cond # 2 with axial tension does not govern

$\therefore$ use # 11 @ 12" Bott. as reqd by load cond # 8

Check Bond & Embedment

Allow Bond (bott.)(#11 bar) $= \dfrac{4.8\sqrt{f'c}}{D} = 187$ psi

$$u \text{ reqd} = \frac{V}{jd\Sigma_o} = \frac{23000}{0.97 \times 53 \times 4.43} = 101 \text{ psi} < 187 \text{ ok}$$

Reqd. embedment (to develop #11 bar) $= \dfrac{f_s A}{u \Sigma_o} = \dfrac{20{,}000 \times 1.56}{187 \times 4.43} = 38''$

use 3'-6" min. (30 dia)

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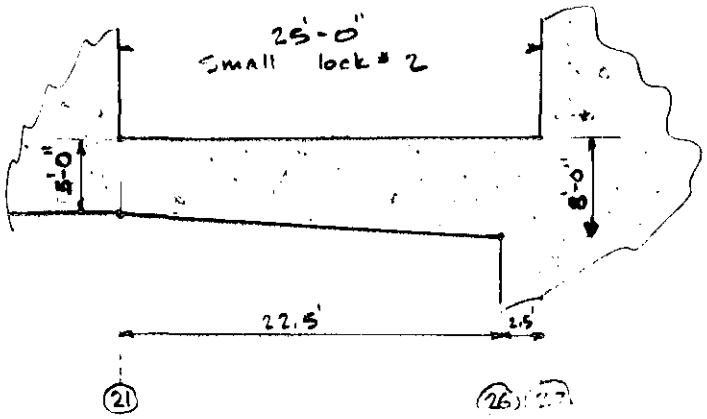
SMALL LOCK # 1 DESIGN SUMMARY

Use 5'-0" thick floor slab

Top reinf # 11 @ 5" Embedment 4'-6"

Bott reinf. # 11 @ 12" Embedment 3'-6"

REINF DESIGN SMALL LOCK # 2 (variable thickness slab)



Top Bars (conservatively use min $d = 60" - 7" = 53"$)

Loading # 5 $M = 153^k$ $P_{ax} = 28.8^k$ compr.

Design reinf for moment only, conservatively neglecting axial compression which would reduce reinf requirement

$$A_s \text{ reqd} = \frac{153}{1.44 \times 53} = 2.0 \text{ in}^2$$

Use # 11 @ 9" ($A_s = 2.08$, $\Sigma_o = 5.9$)

$$u_{reqd} = \frac{28000}{0.87 \times 53 \times 5.9} = 103 \text{ psi} < \frac{3.4\sqrt{f'_c}}{D} = 132 \text{ psi} \quad \text{OK}$$

$$\text{Reqd. embedm.} = \frac{28000 \times 2.08}{132 \times 5.9} = 53" \quad \text{use } 4'\text{-}6" \text{ min}$$

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STRUCT. DESIGN - SMALL LOCKS SHEET NO. 10 OF
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BOTTOM BARS

A-4/1

Max. Mom. occurs @ junction with large lock.
Assume 8'-0" conc. thickness there and taper to 5'-0"

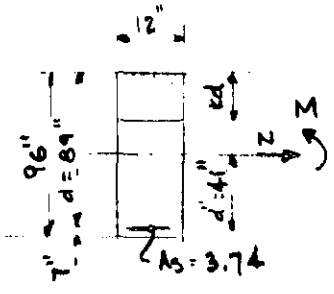
Load Cond. # 4 $M_{max.} = 445^{'k}$ $P_{ax} = 15.5^k$ (tension) (no EQ)

with EQ $M = \frac{503}{1.33} = 380^{'k} < 445^{'k}$ ∴ EQ does not govern

For 8'-0" slab $d = 96" - 6"$ cov. $- 1" = 89"$

A_s req'd. (bending only) $= \frac{445}{1.44 \times 89} = 3.5 \text{ in}^2/'$

Try #11 @ 5" ($A_s = 3.74$, $\Sigma_o = 10.6$) to account for tension



$$e = \frac{12 \times 445}{-15.5} + 4 = -303$$

$$\frac{e}{d} = \frac{-303}{89} = -3.4$$

$$i = \frac{1}{1 - \frac{0.90}{(-3.4)}} = .790$$

$$m = q = \frac{9.2 \times 3.74 \times 0.790}{12 \times 89} = .026$$

$$k = \sqrt{.026^2 + 2(.026)} - .026 = .204$$

from table 13 $j_{act} = 0.93$

$$\therefore i_{act} = \frac{1}{1 - \frac{0.93}{(-3.4)}} = 0.78$$

Stresses:

$$f_s = \frac{(-15500)(-3.4)}{0.93 \times 3.74 \times 0.78} = 19400 \text{ psi} < 20{,}000 \text{ ok}$$

$$f_c = \frac{19400}{9.2} \times \frac{.204}{.796} = 538 \text{ psi} < 1050 \text{ ok}$$

∴ # 11 @ 5" satisfactory

PROJECT CHARLES RIVER NAVIGATION LOCKS ACC. NO.
SUBJECT STRUCT DESIGN - SMALL LOCKS SHEET NO. 11 OF
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Check Bond & Embedment (@ thinnest section)

$$u_{reqd} = \frac{18000}{0.90 \times 53 \times 10.6} = 55 \text{ psi} < \frac{4.8\sqrt{f'_c}}{D} = 187 \quad \text{OK}$$

Reqd Embedment (to develop #11 bar)

$$L = \frac{20000 \times 3.74}{187 \times 10.6} = 38'' \qquad \text{use } 3'\text{-}6'' \ (30 \text{ dia.})$$

SMALL LOCK #2 DESIGN SUMMARY

Use sloping slab, varying in thickness from 5'-0" to 8'-0"

Top Reinf.	#11 @ 9"	Embedment 4'-6"
Bott. Reinf	#11 @ 5"	Embedment 3'-6"

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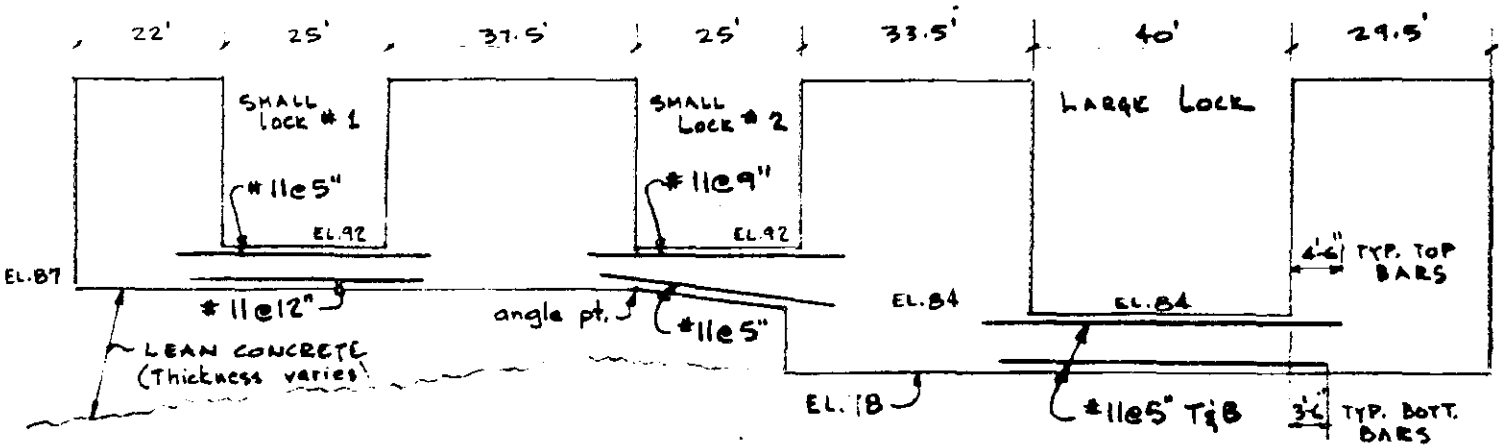

NAVIGATION LOCK BASE SLAB DESIGN SUMMARY

Scale: 1" = 25' ±

PROJECT Charles River Dam
SUBJECT Large Lock Gate - Tide End
Framing Plan
COMP. AD CHECK BS/RE

ACC. NO. 1956 31
SHEET NO. 1 OF
DATE July 31 1972
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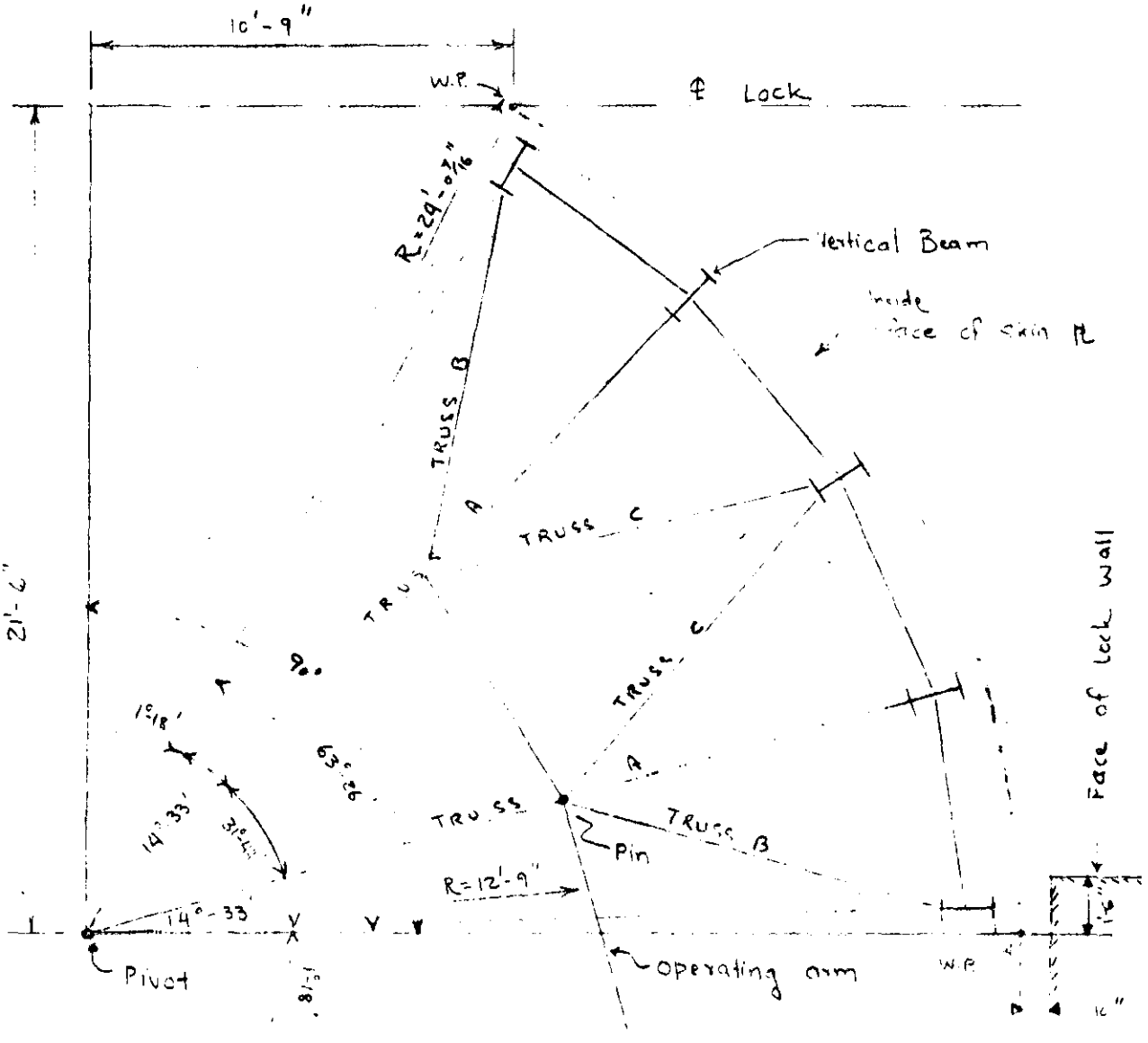

Framing Plan

Scale 1/4" = 1'

Large Lock Gate - closed position -

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PROJECT Charles River Dam ACC. NO. 1856-31
SUBJECT Large Lock gate - Tide End SHEET NO. 2 OF
DATE July 31 1972
COMP. AD CHECK RB/RE CONT. NO.

A-45

Basic Dimension : Development of dimension :

Lock is 40' wide

Locate pivot 1'-6" behind face of lock wall

When the gates are closed: W.P. on front edge is located @ 10'-9" along the ℄ of the lock from the intersection of a perpendicular with the ℄ of the lock. The rear edge of each gate is parallel to the face of wall of lock.

from Rt. angle Δ distance of W.P. on front edge from the pivot

$\sqrt{(21.5)^2+(10.75)^2} = 24.038 = 24'-\frac{7}{16}''$

$\measuredangle A = \tan^{-1} .5 = 26°-34'$

included ∠ in Sector $= 90-(26°.34') = 63°-26' = \frac{63.43}{57.296} = 1.1071$

arc length (WP to WP) $= 24.038 \times 1.1071 = 26.612'$

∠ between W.P and end vert. beam $= 1°-18' = .0227$

arc length (WP and end vert. beam) $= 24.038 \times .0227 = .545$

arc length (c to c end vert. beams) $= 26.612' - (2 \times .545 = 1.09) =$

radius to intersection of trusses A and B $= 12'-9''$

∠ between trusses A and B $= 31°-44'$ (locating quarter pts. on arc)

Projected length (c to c vert. beams) $= 24.038 \times \sin\left(\frac{31°-44'}{2}\right) = 6.563'$

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 3 OF
Design Data DATE Aug. 1 1972
COMP. AD CHECK RE CONT. NO.

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Water Levels - Tidal

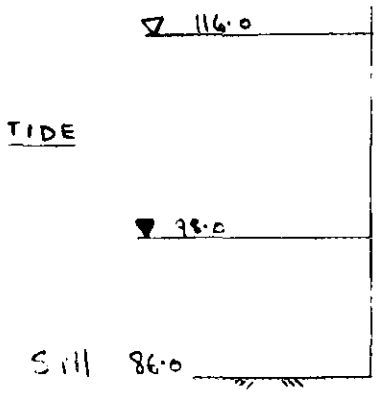
High Water El. 116.0 ✓

Low Water El. 98.0 ✓

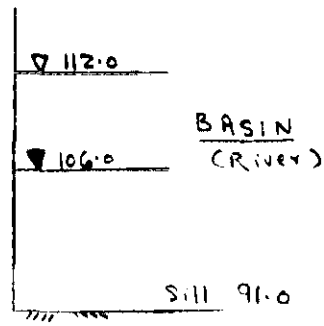
Water levels - Basin

High Water El. 112.0 ✓

Low Water El. 106.0 ✓



LOCK



Top of Sills

Basin End 91.0 ✓
Tide End 86.0 ✓

Design Conditions :

NOTE : SEE SHEETS #45 THRU 48 AND #50 THRU 55 FOR THE POSSIBLE COMBINATION OF EACH CASE WITH THE FOLLOWING LOAD CONDITIONS.

1. HYDROSTATIC LOAD
2. OPERATING LOAD
3. STOP LOAD
4. JAMMING LOAD

Case I Non operating

High Tide 116.0 and Lock empty

Case II Max operating head

High Tide 116.0 and Low Basin 106.0

Case III Max. operating head

High Basin 112.0 and Low Tide 98.0 ✓

Case IV Non operating

~~Tidal Gates Lock @ 116.0 High Tide~~
~~Basin " " @ 112.0 High Basin~~

Lock ~~[illegible]~~ @ El. 110 (M.H.T.) Gate chambers empty (Maintenance of gates), sh 63

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PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large lock gates - Tide end SHEET NO. 4 OF
Front Vertical Beams DATE Aug. 1972
COMP. AD CHECK RE CONT. NO.

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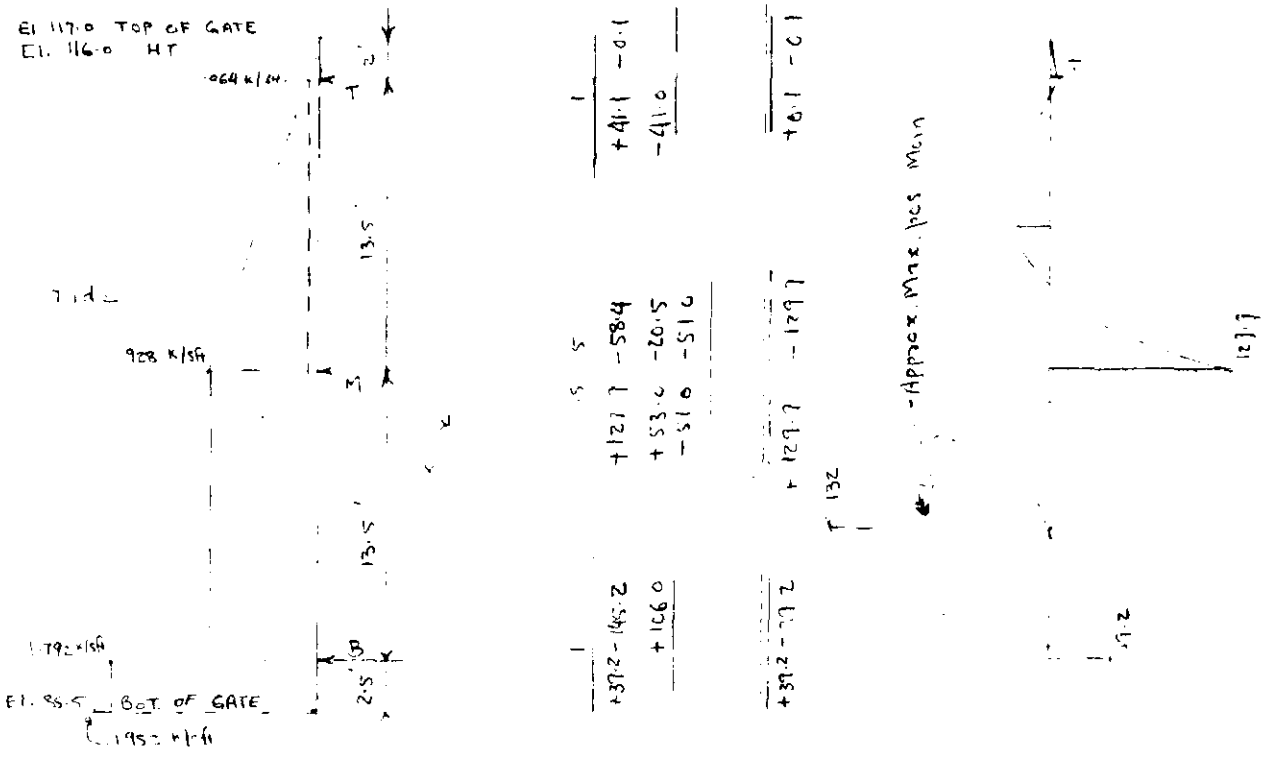
Vertical Beam Design

Hydrostatic Pressure - Lock empty high Tide case I

Proj length of face = 6.563' say 6.6'
W = 64 #/CF = 64 × 6.6 × d #/Ft



Cantilever Moments Top = $\frac{.064 \times 1}{2} \times 6.6 \times 33$ = .071 ft-k

Bottom: $\begin{cases} .064 \times 6.6 \times 28 \times \frac{2.5^2}{2} = 37.0 \\ .064 \times 6.6 \times \frac{2.5^2}{3} \times \frac{2}{3} \times 2.5 = 2.2 \end{cases}$ = 39.2 ft-k

Fix End Moments

FE $M_{(JM)}$ $\begin{cases} .064 \times 6.6 \times 1 \times \frac{13.5^2}{12} = 6.41 \\ .064 \times 6.6 \times 13.5 \times \frac{13.5^2}{30} = 34.67 \end{cases}$ = 41.08 ft-k

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 5 OF
Front Vertical Beams DATE Aug. 1972
COMP. AD CHECK [illegible] CONT. NO.

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$FEM_{(MT)}$ $\left\{ \begin{array}{l} .064 \times 6.6 \times 13.5 \times \frac{13.5^2}{20} = 52.0 \\ \qquad\qquad\qquad\qquad\qquad\quad 6.41 \end{array} \right.$ $= 58.41$ 1-k

$FEM_{(MB)}$ $\left\{ \begin{array}{l} .064 \times 6.6 \times 14.5 \times \frac{13.5^2}{12} = 93.2 \\ .064 \times 6.6 \times 13.5 \times \frac{13.5^2}{30} = 34.67 \end{array} \right.$ $= 127.87$ 1-k

FEM_{BM} $\left\{ \begin{array}{l} 93.2 \\ .064 \times 6.6 \times 13.5 \times \frac{13.5^2}{20} = 52.0 \end{array} \right.$ $= 145.2$ 1-k

Reactions

$(.064 \times 6.6 \times 1)(13.5/2) = 2.85$
$(1/3)(.064 \times 6.6 \times 13.5)(13.5/2) = 12.82$
$(.064 \times 6.6 \times 1)(1/2) = .211$
$-(129.9 - 0.1)(1/13.5) = -9.6$

$T = 6.281$ k

$2 \times 12.82 = \left.\begin{array}{r} 2.85 \\ 25.64 \\ 9.6 \end{array}\right\} 38.09$

$(.064 \times 6.6 \times 14.5)(13.5/2) = 41.34$
$= 12.82$ $\quad$ (= .87
$(129.9 - 39.2)(1/13.5) = 6.73$

$M = 98.98$ k

41.34
25.64
Cantil part $\left\{ \begin{array}{l} (.064 \times 6.6 \times 2.5 \times 2.5) = 29.6 \\ (.064 \times 6.6 \times 2.5)(2.5/2) = 1.32 \end{array} \right.$
-6.73

$B = 91.70$ k

Check total load $= \frac{1}{2} \times .064 \times 6.6 \times (30.5)^2 = 196.28$ k

$T + M + B = 6.28 + 98.98 + 91.7 = 196.96$ k ok

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PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates. Tide End — SHEET NO. 6 of
Frame Vertical Beams — DATE Aug. 1977
COMP. AD — CHECK JD/RB — CONT. NO.

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Midspan Moment

$$M_x = (91.7-30.92)(13.5-x) - (.064\times 6.6)(14+x)\frac{(13.5-x)^2}{2} - \left(\tfrac{1}{2}\right)(.064\times 6.6)(13.5-x)(13.5-x)^2\left(\tfrac{2}{3}\right) - 39.2$$

$$= (60.78)(13.5-x) - (.211)(14+x)(13.5-x)^2 - (.141)(13.5-x)^3 - 39.2$$

x is measured downward from M

$$M_7 = 60.78\times 6.5 - .211\times 21\times 6.5^2 - .141\times 6.5^3 - 39.2 = 129.2 \text{ 'k}$$

$$M_{7.5} = 60.78\times 6 - .211\times 21.5\times 6^2 - .141\times 6^3 - 39.2 = 131 \text{ 'k}$$

$$M_{7.25} = 60.78\times 6.25 - .211\times 21.25\times 6.25^2 - .141\times 6.25^3 - 39.2 = 131.6 \quad \text{say } 132 \text{ 'k}$$

max. positive midspan moment approx. 132 'k @ 7.25' from M down

Allowable bending stress = 16.2 KSI per C.O.E.

Interior beam $= \frac{132\times 12}{16.2} = 97.8 \text{ in}^3$ — 16 WF64 — $S = 104 \text{ in}^3$

end beam $= \frac{(1/2)(132)(12)}{16.2} = 49 \text{ in}^3$ — 16 WF 36 — $S = 56.5 \text{ in}^3$

Check for Lateral support of Compression flange

unbraced length $= 13.5\times 12 = 162$ in

r_T = 2.28 in. — 16 WF64 — $r_y = 1.91$
1.81 in — 16 WF 36 — $r_y = 1.45$

l/r_y = 85 — 16 WF64
112 — 16 WF 36

allowable Comp. $F_b = .45\, k_2 F_y = k_2(16.2)$

$$k_2 = 1 - \frac{(l/r)^2}{2C_c^2 C_b}$$

$C_b = 1.0$ $\quad C_c^2 = \frac{2\pi^2 E}{F_y} = \frac{2\times 9.88\times 29{,}000}{36} = 15{,}930$ $\quad C_c = 126$ for A-36

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 7 OF
Front Vertical Beams DATE Aug. 1972
COMP. AD CHECK [illegible] CONT. NO.

A-50

$k_2 = 1 - \frac{\cancel{(77)}^{85}{}^2}{2 \times 15{,}930} = \cancel{.842}\ .772$ for 16WF64 and $\cancel{.75}\ .61$ for 16WF36

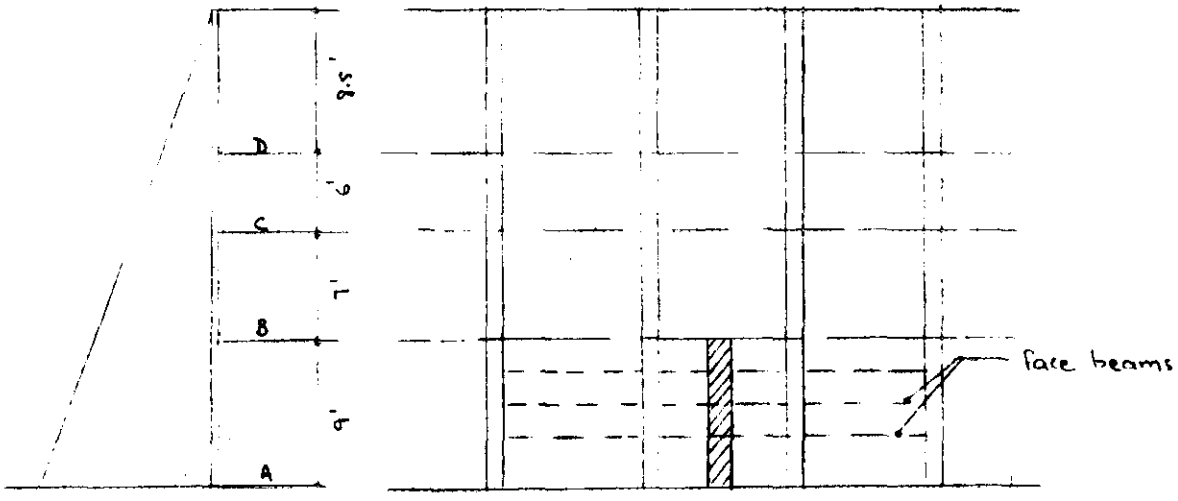
$F_b = .842 \times 16.2 = \cancel{13.6}\ 12.5$ ksi " $.75 \times 16.2 = \cancel{12.1}\ 9.9$ ksi " (Can be obtained from Appendix also)

or $F_b = \frac{9{,}000{,}000}{l\ d/A_f}$ $\frac{9{,}000{,}000}{13.5 \times 12 \times 2.6} = 21{,}400$ psi Use 16.2 ksi

$\frac{9{,}000{,}000}{13.5 \times 12 \times 5.3} = 10{,}500$ psi Use 12.1 ksi

for end beam $S_x = \frac{(\frac{1}{2})(132)(12)}{12.1} = 65.5\ in^3$ 16WF45 $S_x = 72.5\ in^3$

Spacing of Face Beams



Continuous 1' wide Strip (3/8 thick Skin PL)

(a) Waterpressure @ A $w = .064 \times 30.5 = 1.95$ k/ft/ft

+ M inbetween Tees $= \frac{ws^2}{12}$ S = Spacing of Tees

− M Over Tees $= \frac{ws^2}{10}$

assuming one directional bending* and neglecting curvature of PL

Try spacing of 1'-6" span $= 1.5 + \cancel{.25}$ = ~~1.25~~ 1.5 (knife edge, see sh. 9)

$S_{PL} = \frac{12 \times (.375)^2}{6} = .282\ in^3$

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* in reality PL bends in two directions.

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide end Front Vertical Beams — SHEET NO. 8 OF ___

DATE Aug. 1972

COMP. AD — CHECK JJS/RB — CONT. NO. A-51

ALLOWABLE EM-2101 MANUAL 18 ksi (compact)
HOWEVER ONLY 4½% OVER

$M = \frac{1.95 \times 1.52^2}{10} = .44$ $\quad f = \frac{.44 \times 12}{.281} = 18.9$ ksi ok

6 sp @ 1'-6" = 9'

(b) Waterpressure @ B $\quad w = .064 \times 21.5 = 1.38$ k/'

Try Spacing 1'-9" span = 1'-6"

$M = \frac{1.38 \times 1.75^2}{12} = .31$ 'k $\quad f = \frac{.31 \times 12}{.281} = 15$ ksi ok

4 sp. @ 1'-9" = 7'

(c) Waterpressure @ C $\quad w = .064 \times 14.5 = .93$ k/'

try spacing 2'-0" Span 1'-9"

$M = \frac{.93 \times 2.0^2}{12} = .31$ 'k $\quad f = \frac{.31 \times 12}{.281} = 13.4$ ksi ok

3 @ 2'-0" = 6'

(d) Water pressure @ D $\quad w = .064 \times 8.5 = .55$ k/'

try spacing 3'-0" → Span = 2.75

$M = \frac{.55 \times 3.0 \times 2.75^2}{12} = .412$ $\quad f = \frac{.412 \times 12}{.281} = 17.5$ ok

try spacing 2'-9" → Span = 2.5

$M = \frac{.55 \times 2.75 \times 2.5^2}{12} = .415$ $\quad f = \frac{.415 \times 12}{.281} = 17.0$ ksi ok

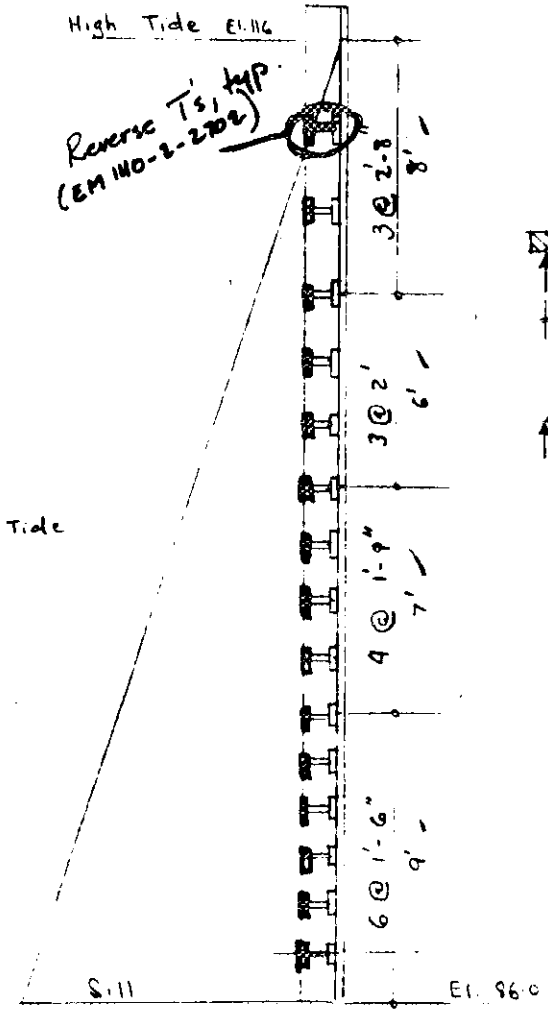
3 sp @ 2'-9" = 8'-3"

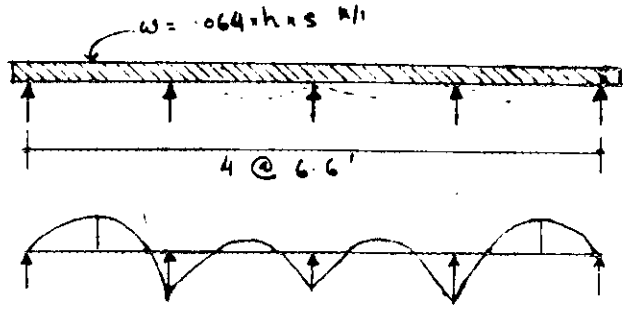
NOTE THE ALLOWABLE STRESS USED WAS ONLY 0.45 F_y WHEN ACTUALLY 0.50 F_y IS ALLOWED PER EM-2101 MANUAL C.O.E. (for compact sections, p. 8 [illegible])

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 9 OF
Face Beams DATE Aug. 1972
COMP. AD CHECK [illegible] CONT. NO.

A-52

Face Beam Design (Lock empty)





+ M outer spans = $.0772\, wl^2$

− M first int. supp = $.1071\, wl^2$ } AISC

$\Delta_{max} = .0065 \dfrac{wl^4}{EI}$ outer spans

h = Water head
s = spacing of face beam

The face beam next to bottom one is critical

$w = .064 \times 28.5 \times 1.5 = 2.74$ k/'

$M = .1071 \times 2.74 \times 6.6^2 = 12.8$ 'k

$S_{req} = \dfrac{12.8 \times 12}{16.2} = 9.5$ in³ ST 9 × 27.35 $S = 9.61$ in³

Check when spacing changes: $w = .064 \times 21 \times 1.75 = 2.35 < 2.74$

$.064 \times 14 \times 2 = 1.77$

$.064 \times 8 \times 2.67 = 1.37$

$\Delta = .0065(2.74)(6.6)^4(12)^3 \div (29{,}000 \times 62.4) = .032$ "

PROJECT Charles Rivers Dam — ACC. NO. 1856.31

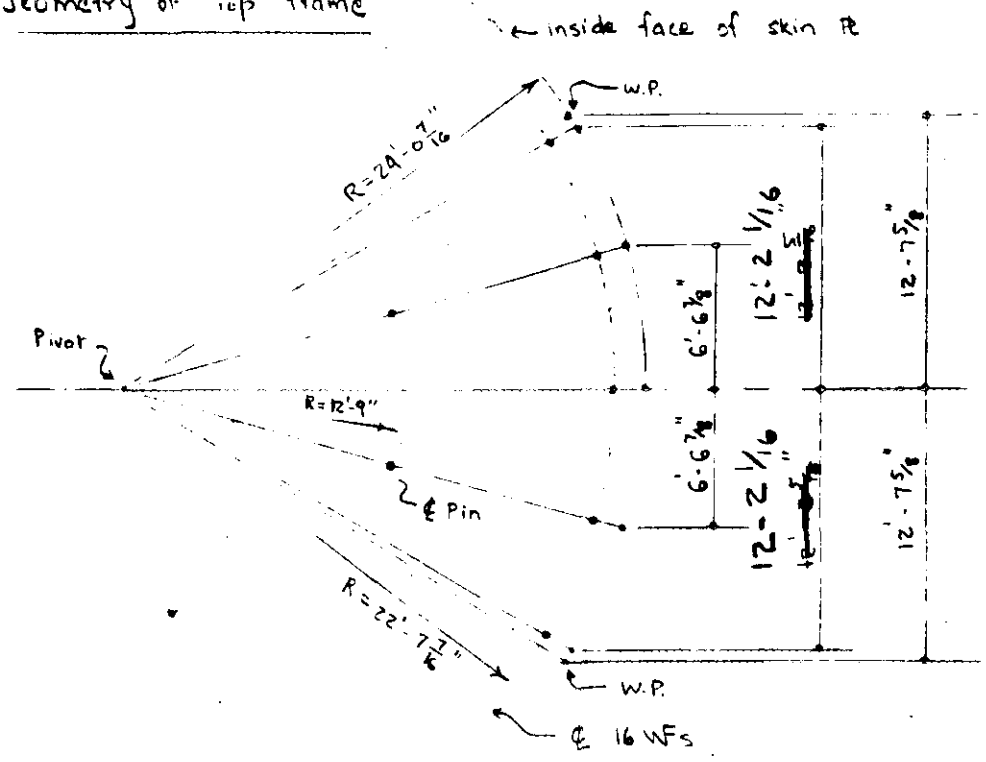
SUBJECT Large Lock Gates · Tide End Design Dimensions — SHEET NO. 10 OF ___

DATE Aug. 1972

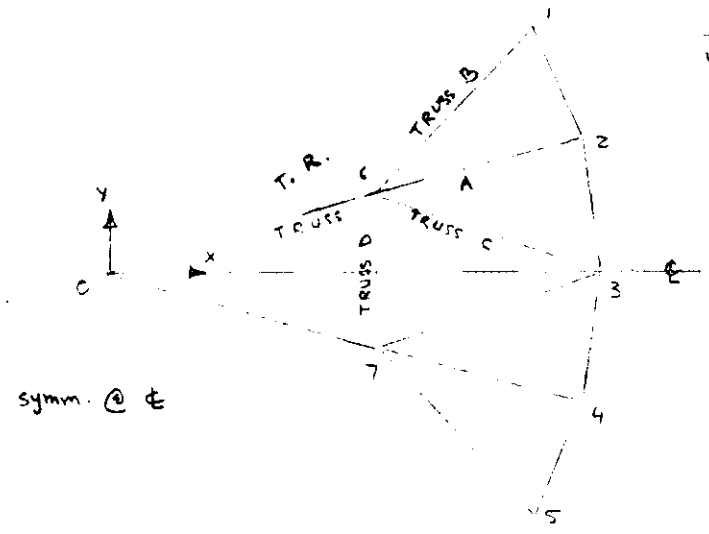
COMP. AD — CHECK [illegible] — CONT. NO. ___

A 53

Geometry of Top frame



Gate · half closed position



symm. @ ℄

∠		Sine	Co sine
W.P. makes with ox	31°-43'	·5275	·851
∠ 1-ox	30°-26'	·5065	·8622
∠ 2-ox	15°-52'	·2734	·9619

Ref axes ox & oy

	Joint	1 & 5	2 & 4	3	6 & 7
coordinate	X	19.503	21.758	22.62	12.264
"	Y	11.457	6.155	0	3.486

PROJECT Charles River Dam — ACC. NO. 1856.31

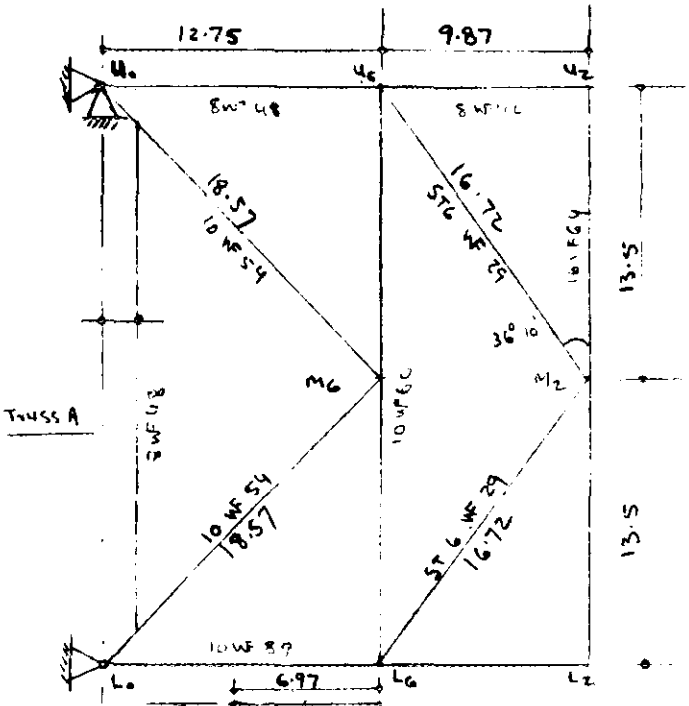
SUBJECT Large lock gates - Tide End — SHEET NO. 11 OF

Design Dimensions — DATE Aug. 1972

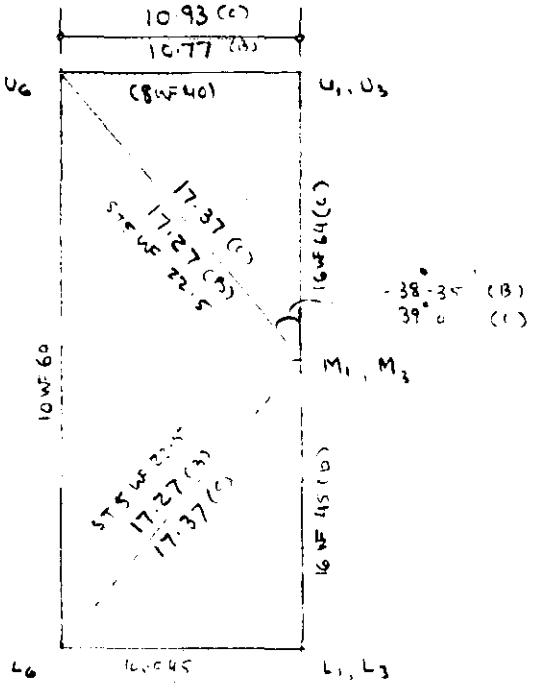
COMP. AD — CHECK [illegible] — CONT. NO.

A-54

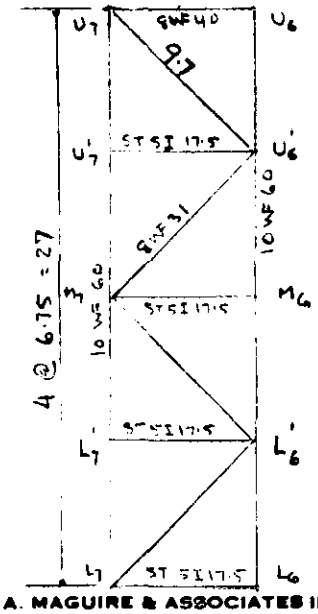
Member	1-2 & 4-5	2-3 & 3-4	1-6 & 5-7	2-6 & 4-7	3-6 & 3-7	6-0 & 7-0	6-7
X_0	2.255	.862	7.239	9.494	10.356	12.264	0
Y_0	5.272	6.195	7.971	2.699	3.486	3.486	2(3.486)
$L=\sqrt{x_0^2+y_0^2}$	5.734	6.242	10.767	9.871	10.926	12.752	6.972



Truss A



Truss B & C



Truss D

PROJECT Charles River Dam
SUBJECT Large Lock gates - Tide End
Dead Load
COMP. AD CHECK
ACC. NO. 1856.31
SHEET NO. 12 OF
DATE Aug. 1978
CONT. NO.

A-55

Dead Load Estimation

Wgt. of Sill Seal

neoprene rubber	$(2\times3\times\frac{3}{4}+2\pi\times1^2)(\frac{94}{144})$	=	7.1
front face PL	$5\frac{3}{4}\times\frac{3}{4}$	=	14.7
"	$3\times\frac{5}{16}$	=	3.2
"	$10\frac{1}{4}\times\frac{3}{8}$	=	13.1
Top PL	$10\times\frac{3}{8}$	=	12.8
Bottom PL	$6\times\frac{3}{8}$	=	7.7
Back PL	$3\frac{1}{2}\times\frac{3}{8}$	=	4.5
Packing PL	$6\times\frac{3}{8}$	=	7.7
$\frac{7}{8}$" - 5 bolts	@ .6 lb	=	3.0
Stiff. PL	$8\frac{3}{8}\times10\frac{1}{4}\times\frac{3}{8}$ $(13.1)(\frac{8.38}{12})(\frac{10}{26.61})$	=	3.5
			77.3 lb.

Say 80 lb / lin. ft. of arc

length of arc (sh. 2) = 26.612'

Wgt. of Side Seal

Same details taken as Sill Seal viz. 80 lb. / lin. ft. of gate ht.

ht. of the gate = 31'

Wgt. of miter Seal

rubber		3.5
PL	$3\frac{1}{8}\times\frac{3}{4}$	8.3
L	$3\times2\times\frac{3}{8}$	5.9
Bar	$1\frac{5}{8}\times\frac{5}{8}$	3.7
Bolts	2 @ .6	1.2
		22.6 lb

say 25 lb. / lin ft. of gate ht.

(Mystic River Gates - design comps. and shop drawings used to deduce some of the wgts.)

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock gates - Tide End — SHEET NO. 13 OF
Dead Load — DATE Aug. 1973
COMP. AD — CHECK — CONT. NO.

A-56

Wgt of Trash Rack and ice grating

Upper grating — Radius 24.038

10x10 timber	$6 \times \frac{100}{144} \times 50$	=	209
7x 1/4 PL	10 x 17.9	=	179
4x 1/2 bars	2x5x2.17 x 6.8	=	147.4
1"φ bolts 14" long	$6 \times \frac{12}{18} \times 3.6$	=	14.4
			549.8 lb/ft

Lower Grating — length 12.75 + 10.77 = 23.52

4 x 1/2 bars	17 x 2 x 6.8	=	231
L 7x4x1/2	$\frac{8 \times 5.5 \times 17.9}{23.52}$	=	33.6
18x1/2 bent PL	$\frac{12 \times 5.5 \times 30.6}{23.52}$	=	86
5x 1/2 PL	6 x 8.5	=	51
4x1/2 strap	4 x 6.8	=	27.2
L 7x4x1/2	2x 17.9	=	35.8
L 6x4x1/2	$\frac{2 \times 5.5 \times 16.2}{23.52}$	=	7.6
			472.2 lb/ft

Total wgt. of upper & lower T.R. 549.8 x 24.038 + 472.2 x 23.52 = 24,300
add 5% for misc. conn PL, etc. = 1200
25,500 #

Wgt of walkway

Arc length along inside face of skin PL = 26.612'
Arc length along ℄ of rail = 24.5 + (7.3+5)(1/2) = 25.53'

1 1/2" φ std. rail	Alr	2 x 2 x 25.53 x .94	=	95.8
1 1/2" φ std. post	"	14 x 3.5 x .94	=	46.1
L 8x6 x 5/8	"	25.53 x 9.84	=	251.0
L 6x6 x 3/8	"	25.53 x 5.12	=	130.6
6 [2.83	"	(2x25.53 + 7)(2.83)	=	164.2
8 WF 5.9	"	5 x 3.5 x 5.9	=	103.1
L 2 1/2 x 2 1/2 x 1/4	"	4 x 6 x 1.4	=	33.6
1 x 3/16 grating	"	12 x 3 x .22 x 26.61	=	216.5
				1034.9
5% conn PL bolts				50.0
				1084.9 ≈ 40.77 lb./ft.

CHARLES A. MAGUIRE & ASSOCIATES INC. ENGINEERS

PROJECT Charles River Dam — ACC. NO. 1956.31
SUBJECT Large Lock Gate Tide End Dead Load — SHEET NO. 14 OF ___
DATE Aug. 1972
COMP. AD — CHECK [illegible] — CONT. NO. ___

A-57

Arc length = $\frac{26.612}{4}$ = 6.653' gate ht = (117.0 − 86.0) = 31'

Skin Pl 3/8"	6.653×31×15.3	=	3,160
Vertical beam	31×64	=	1,985
face beams	17×6.653×27.35	=	3096
Bottom Seal	6.653×80	=	533
Vert. Stiffner	31×27.35	=	847
Walkway	6.653×40.77	=	272
			9,893 # @ each int. vert. beam

Skin Pl 3/8"	3.33×31×15.3	=	1,580
vert. beam	31×45	=	1,395
face beams	17×3.33×27.53	=	1,548
Vert Stiff.	31×27.35	=	847
Bottom Seal	3.33×80	=	267
walkway	3.33×40.77	=	136
			5,773 #

Side Seal 80×31 = 2480 #

miter Seal 25×31 = 775 #

Load @ end vert. beam @ Side Seal location = 5773 + 2480 = 8253 #

@ miter Seal location = 5773 + 775 = 6548 #

DL of frame members (assumed)

Truss A

U_0U_6	(12.75)(48)	=	612 #
U_0M_6	(18.57)(54)	=	1000
U_0L_0	(23.82)(48)	=	1143
U_6U_2	(9.87)(40)	=	395
U_6M_2	(16.72)(29)	=	485
U_6M_6	(13.5)(60)	=	810
L_0L_6	(12.75)(89)	=	1136
L_6L_2	(9.87)(89)	=	878
U_2M_2	(13.5)(64)	=	864

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 15 OF
Dead Load — DATE Aug. 1972
COMP. AD — CHECK — CONT. NO.

A 58

Truss B

U_6U_1	(10.77)(40)	=	430 #
U_6L_6	- accounted for in truss A		
U_6M_1	(17.27)(22.5)	=	388
L_6L_1	(10.77)(45)	=	484

Truss C

U_6U_3	(10.93)(40)	=	437
U_6M_3	(17.37)(22.5)	=	390
L_6L_3	(10.93)(45)	=	492

Truss D

U_6U_7	(6.17)(40)	=	278
U_6U_6'	(6.75)(60)	=	405
$U_6'U_7$	(9.7)(31)	=	300
$U_6'U_7'$	(6.97)(17.5)	=	122

face Truss

U.M.L	1-2, 4-5	(5.73)(17.5)	=	100
"	2-3, 3-4	(6.24)(17.5)	=	109

Trash Rack supporting assembly

$(12.75)(\sin 14°-33') = 3.2'$

$\sqrt{(6.75)^2+(3.2)^2} = 7.45'$

ST 2 WF 18	3×3.2×18	=	173	@ $U_6-M_6-L_6$
"	2×7.45×18	=	268	
8 WF 35	1×16×35	=	560	
ST 6 WF 18	4×12.75×18	=	918	equally between $U_6M_6L_6$ and U_2L_6

Point Load (self wgt. of members only)

Joint takes half wgt. of each member

Truss A

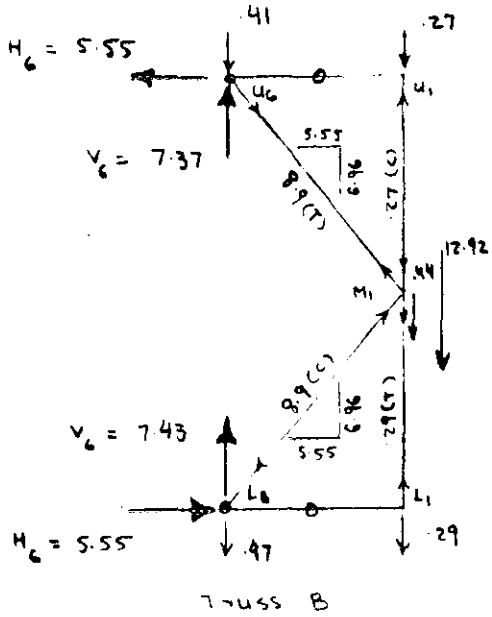
@ U_0	306+500+572	=	1378 #	from single truss A
L_0	500+572+568	=	1640	"
U_6	306+198+405+243	=	1152	
M_6	1000+810	=	1810	
L_6	405+568+243+439	=	1655	
U_2	198+105	=	303	
M_2	485+105	=	590	

PROJECT Charles River Dam ACC. NO. 1856.21
SUBJECT Large Lock Gates - Tide End SHEET NO. 16 OF
Dead Load DATE Aug. 1972
COMP. AD CHECK AB CONT. NO.

A 59

L_2	439 + 109	= 548 #	
Truss B			
U_6	215 + 194	= 409	
L_6	242 + 194	= 436	
U_1	215 + 50	= 265	
M_1	388 + 50	= 438	
L_1	242 + 50	= 292	
Truss C			
U_6	218 + 195	= 413	
L_6	246 + 195	= 441	
U_3	218 + 55	= 273	
M_3	390 + 55	= 445	
L_3	246 + 55	= 301	
Truss D			
U_6	139	= 139	
U_7	139 + 150	= 289	
U'_6	61 + 300	= 361	also M_7 and L'_6
U'_7	61	= 61	" M_6, L'_7 and L_6
L_7	61 + 150	= 211	

DL analysis Ref. See Sh. 12 Thru. 16 for load determ.



Truss B

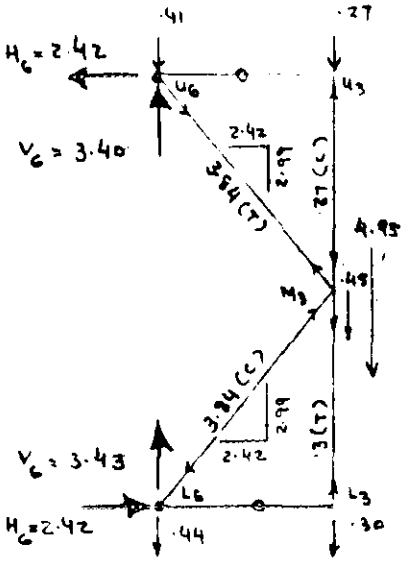
Assuming 25% each @ U_6-L_6 and U_1-M_1-L_1
balance 50% @ U_6-M_6-L_6
Wgt of trash rack @ U_1-M_1-L_1 = .25 x 25.5 = 6.37 #
Load @ end vert. beam " (sh 14) = 6.55
12.92

[All the forces are in kips unless shown otherwise.]

CHARLES A. MAGUIRE & ASSOCIATES INC. ENGINEERS

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock gates - Tide End SHEET NO. 17 OF
Dead Load DATE Aug. 1972
COMP. AD CHECK [illegible] CONT. NO.

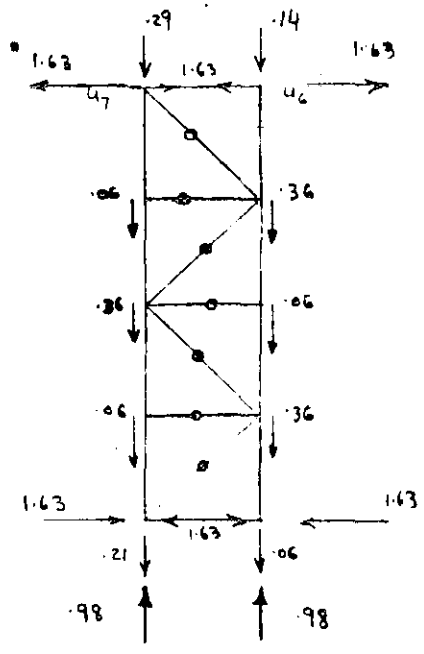
A-60



Truss C

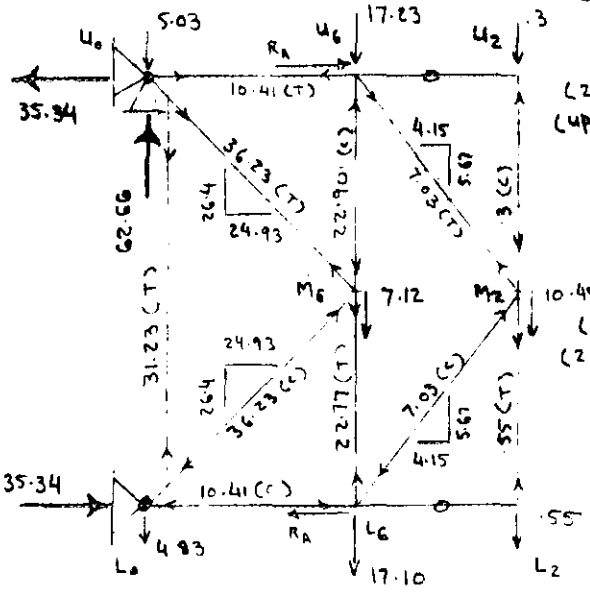
Loads

DL (assumed) of members gate, trash rack, walkway At Jt. 3 since two 'c' trusses ~~meet this vert. load is divided~~ equally.



Truss D

(* from analysis of jt. 6 sh 15)



Truss A

Loads on truss "A"

U_0

	members DL (Sh. 15)		1.38
(2 chords) →	trash rack (Sh. 16)	$(6.37)\frac{1}{2}$	= 3.19
(upper ch.)	t.r. supp. assembly (Sh. 15)	$(.92)\frac{1}{2}$	= .46
			5.03

Similarly $L_0 = 1.64 + 3.19 = 4.83$

U_6

	members DL (Sh. 15)		1.15
(3 chords) →	trash rack	$(2 \times 6.37)(\frac{1}{3})$	4.25
(2 chords) →	t.r. supp. ass. (Sh. 15)	$\frac{1}{2} \times 1.46$	.73
	Vert. reactions truss B, C & D (Sh.		11.10
			17.23

$M_6 = 1.81 + 4.25 + .73 + .33 = 7.12$

$L_6 = 1.66 + 4.25 + 11.19 = 17.10$

$U_2 =$ (Sh 15) $= .30$

M_2 $.59 + 9.89$ (Sh. 14) $= 10.48$

$L_2 = .55$

R_A = total of components of all the horiz. reactions of trusses B, C and D in the plane A

Check M @ L_0 $(35.34)(27) = (41.45)(12.75) + (11.33)(22.62) + R_A(27)$

$R_A = 6.27 \simeq 6.26$ See next sh

Assumption: Ext. DL of trash rack, gate etc. applied equally @ 3 levels U, M, & L

PROJECT Charles River Dam — ACC. NO. 1856 31

SUBJECT Large Lock gates · Tide End — SHEET NO. 18 OF

Dead Load — DATE Aug. 1972

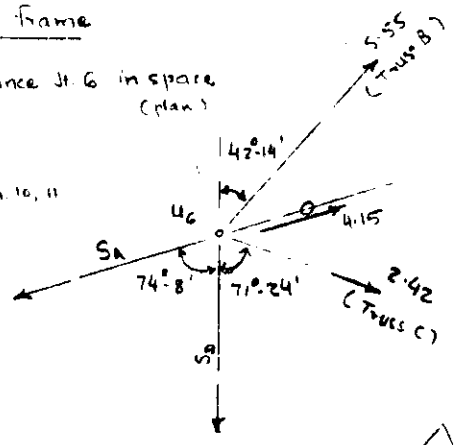
COMP. AD — CHECK — CONT. NO.

A-61

Top frame

Balance Jt. 6 in space (plan)

ref. sh. 10, 11



L	Sine	Cosine
42°-14'	.67214	.74040
71°-24'	.94776	.31896
74°-8'	.96190	.27340

$(S_A)(.9619) = (5.55)(.67214) + (2.42)(.94776) + (4.15)(.9619)$

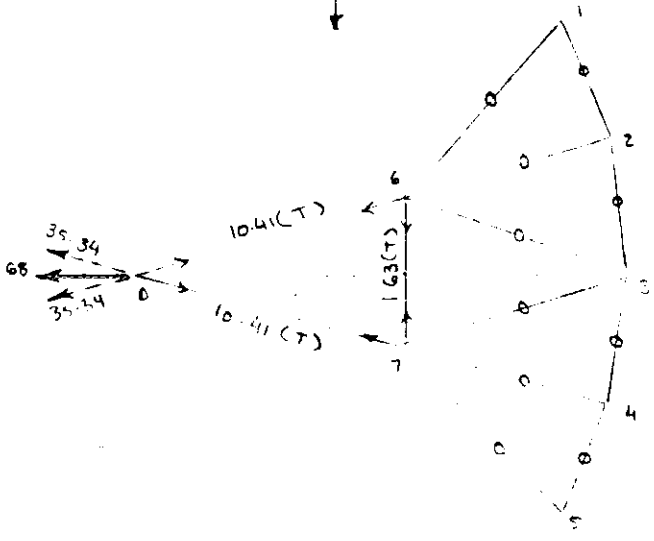
$S_A = 10.41$

$S_D = (5.55)(.74040) - (10.41-4.15)(.2734) - (2.42)(.31896)$

$= 1.63$

$R_A = S_A - 4.15 = 10.41 - 4.15 = 6.26$

(reaction comp. of trusses B, C and D in the plane of A)



Lower Frame

Similar forces of equal magnitude but in opp. dir.

Assumption : Trash Rack is on face 0-6-1 hence this face is heavier than the other face 0-7-5 however for simplicity of design symmetrical condition of loading is assumed i.e as if the other face also has to support trash rack etc.

PROJECT Charles River Dam — ACC. NO. 1856.31

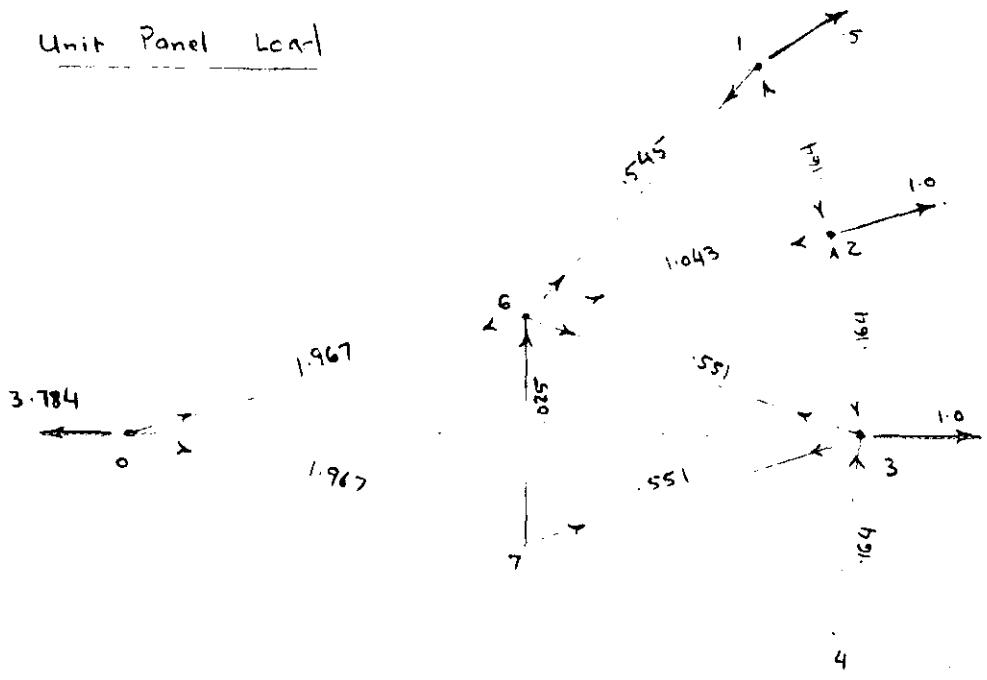
SUBJECT Large lock gates - Tide End — SHEET NO. 19 OF

Unit Panel Load — DATE Aug. 1972

COMP. AD — CHECK — CONT. NO.

A 62

Unit Panel Load



Pt. Loads due to hydrostatic forces

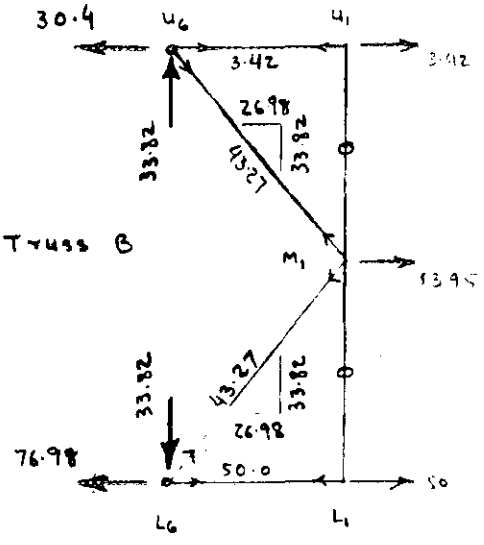
Plane of Truss B	@	U_1	(6.28)(.545)	=	3.42
		M_1	(98.98)(.545)	=	53.95
		L_1	(91.70)(.545)	=	50.00
Truss C		L_3	(6.28)(.551)	=	3.46
		M_3	(98.98)(.551)	=	54.49
		L_3	(91.70)(.545)	=	50.50
Truss A		U_2	(6.28)(1.043)	=	6.55
		M_2	(98.98)(1.043)	=	103.11
		L_2	(91.70)(1.043)	=	95.67
Struts 1-2, 2-3, 3-4, 4-5		U frame	(6.28)(.164)	=	1.03
		M plane	(98.98)(.164)	=	16.23
		L frame	(91.7)(.164)	=	15.0

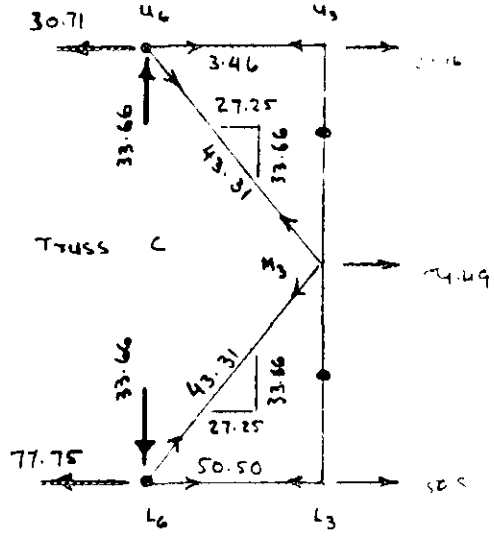
PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock gates . Tide End SHEET NO. 20 OF
Hydrostatic Loads DATE Aug. 1972
COMP. AR CHECK CONT. NO.

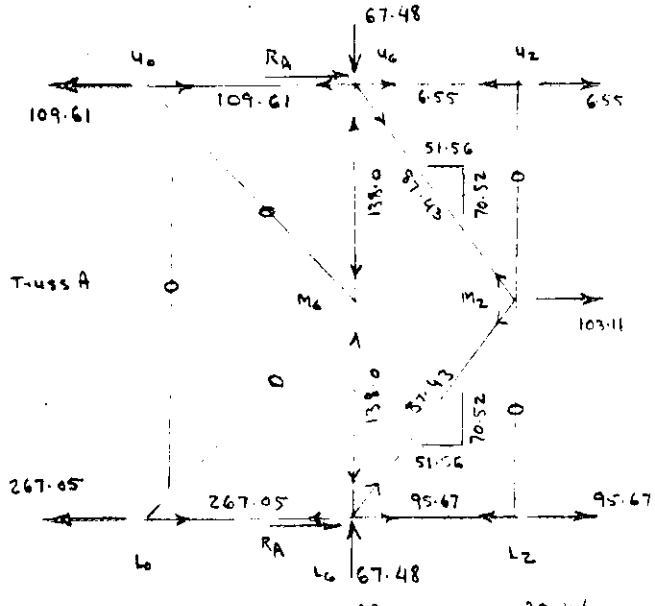
A 63

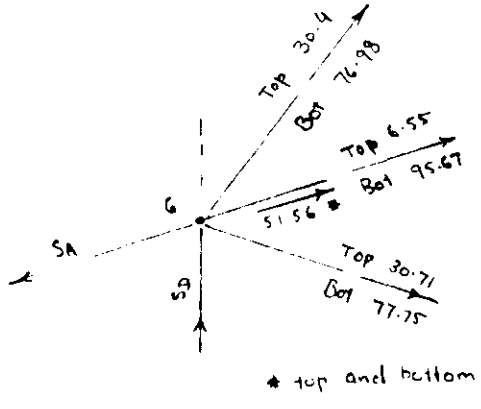
Hydrostatic Analysis

Case I high tide, lock empty Non operating head









Jt. 6 in plan

u_6

$\leftarrow$ $(S_A)(.9619) = (30.4)(.67214) + (30.71)(.94776) + (51.56 + 6.55)(.9619)$

$S_A = 109.61$

$\downarrow$ $S_D = (30.4)(.7404) - (109.61 - 58.11)(.2734) - (30.71)(.31576)$

$= -1.37$

$R_A = 109.61 - 58.11 = 51.50$

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 26 OF

Hydrostatic Loads — DATE Aug. 1972

COMP. AD — CHECK — CONT. NO.

A64

L_6

$$(S_A)(.9619) = (76.98)(.67214) + (77.75)(.94776) + (51.56 + 95.67)(.9619)$$

147.23

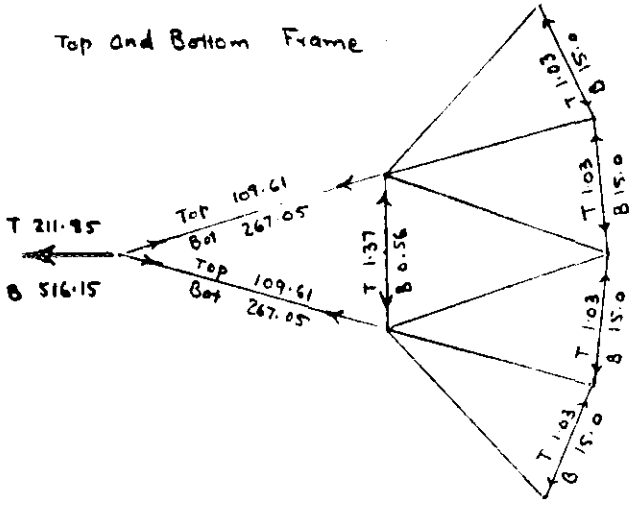
$$S_A = 267.05$$

$$S_D = (267.05 - 147.23)(.2734) + (77.75)(.31896) - (76.98)(.7404)$$

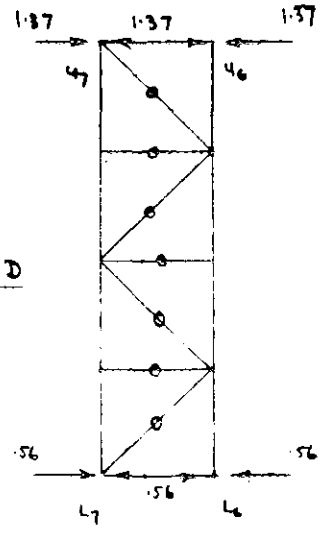
$$= .56$$

$$R_A = 267.05 - 147.23 = 119.82$$

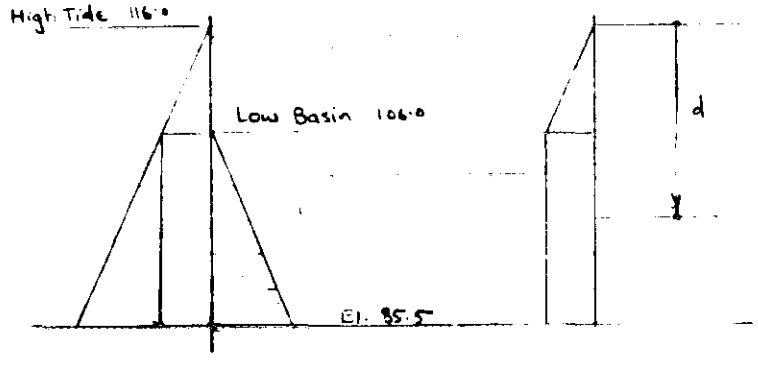
Top and Bottom Frame



Truss D



Case II



$$w = (64\ \#/cft)(6.6')(d) = 422.4\,d\ \#/ft \quad \text{say } .423\,d\ k/l \qquad 0 < d < 10$$

$$.423 \times 10 = 4.23\ k/l \qquad 10 < d < 30.5$$

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates Tide End — SHEET NO. 22 OF

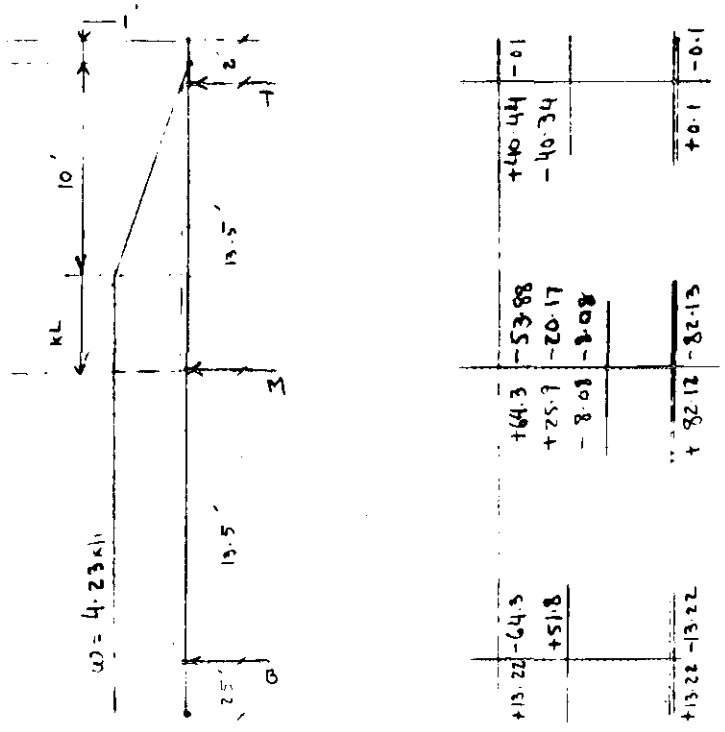
Hydrostatic Loads — DATE Aug. 1972

COMP. AD — CHECK [illegible] — CONT. NO.

A 65

Hydrostatic Loads

Case II Operating head: high Tide 116.0 Low Basin 106.0



$K = \frac{4.5}{13.5} = .333$

$K_1 = \frac{9}{13.5} = .667$

Cantilever Moments Top $(.423)(1)(\frac{1}{2})(.33) = .07$ Say .1 ik

Bot $(4.23)(2.5)(2.5)(\frac{1}{2}) = 13.22$ ik

Fix End Moments

4.23
.423
3.807

F.E. M_{TM}

uniform discont.	$\frac{w\ell^2}{12} k^3(4-3K) = \frac{(3.807)(13.5)^2}{12}(.33)^3(4-1)$	= 6.43
" cont.	$w\ell^2/12 = (.423)(13.5)^2(\frac{1}{12})$	= 6.43
triangular discont	$\frac{w\ell^2}{30} K_1^2(10-15K_1+6K_1^2) = \frac{(3.807)(13.5)^2}{30}(.67)^2(2.67)$	= 27.58
		40.44

F.E. M_{MT}

Uniform Cont	$w\ell^2/12$	= 6.43
" discont	$\frac{w\ell^2}{12} k^2(6-8k+3k^2) = \frac{(3.807)(13.5)^2}{12}(.33)^2(3.66)$	= 23.55
triangular discont	$\frac{w\ell^2}{20} K_1^3(5-4K_1) = \frac{(3.807)(13.5)^2}{20}(.67)^3(5-2.67)$	= 23.90
		53.88

Fix beam formulas Ref. State of Calif. Bridge design Manual

$$FE\ M_{MB} = wl^2/12 = \frac{(4.23)(13.5)^2}{12} = 64.3 = -FE\ M_{BM}$$

Reactions

$(.423)(13.5)(\frac{1}{2})$		$= 2.85$
$w(kL)^2(\frac{1}{2})(\frac{1}{L}) = (3.807)(4.5)^2(\frac{1}{2})(\frac{1}{13.5})$		$= 2.87$
$w(k_1L)(\frac{1}{2})(kL+\frac{1}{3}k_1L)(\frac{1}{L}) = (3.807)(9)(7.5)(\frac{1}{13.5})(\frac{1}{2})$		$= 9.52$
$(\frac{1}{2})(.423)(1)$		$= .21$
$-(82.13-0.1)(\frac{1}{13.5})$		$= -6.08$
	R_T	$= 9.37$
$(3.807)(4.5) - 2.87$		2.85
$(3.807)(9)(\frac{1}{2}) - 9.52$		14.26
		7.61
		6.08
$(4.23)(13.5)(\frac{1}{2})$		28.50
$(86.13-13.22)(\frac{1}{13.5})$		5.40
	R_M	$= 64.70$
$(4.23)(2.5)$		28.50
		10.58
		-5.40
	R_B	$= 33.68$

Check Loads $(\frac{1}{2})(4.23)(10) + (4.23)(20.5) = 107.78$
$R_T + R_M + R_B = 107.75$

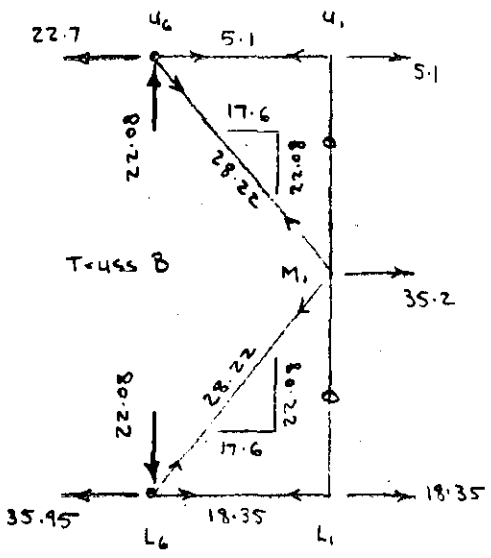
unit panel loads multiplied with these reactions will give pt. loads for the case II Proceed then just as in case I for the Analysis (Refer Sh. 19, 20, 21)

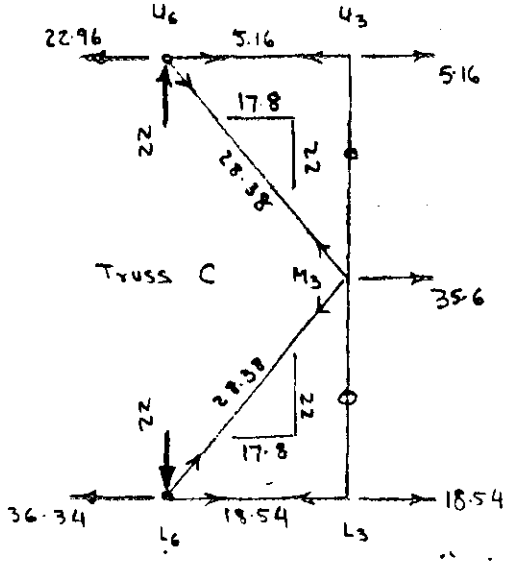
$9.37 \times .545 = 5.1$
$64.7 \times .545 = 35.2$
$33.68 \times .545 = 18.35$
Truss B

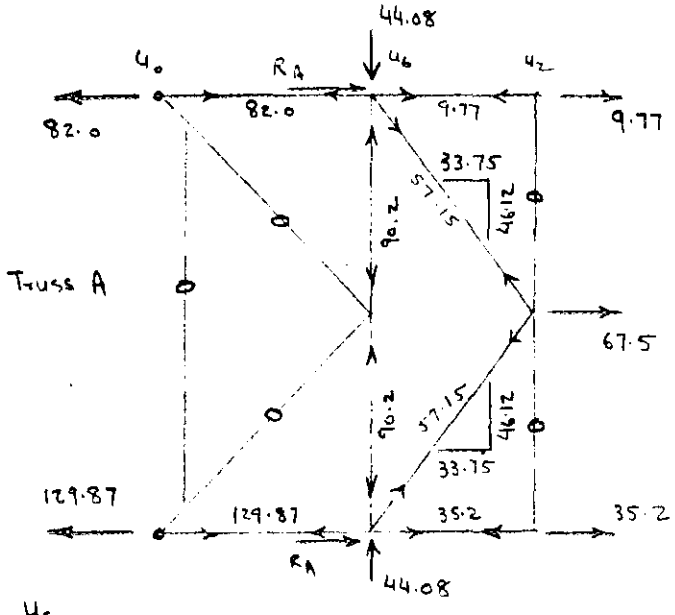
Similarly pt. loads are obtained for Trusses C and A

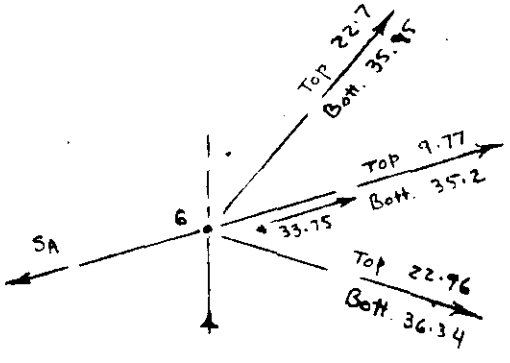
Case II (contd.)

Operating head: high Tide 116.0 Low Basin 106.0









* top and bottom

U_6

$$(S_A)(.9619) = (22.7)(.67214) + (22.96)(.94776) + (43.52)(.9619)$$

$$S_A = 82.0$$

$$S_D = (22.96)(.31896) + (82.0 - 43.52)(.2734) - (22.7)(.7404)$$

$$= 1.036$$

$$R_A = 82.0 - 43.52 = 38.48$$

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 25 OF
Hydrostatic Loads — DATE Aug. 1972
COMP. AD — CHECK — CONT. NO.

A 68

L_6

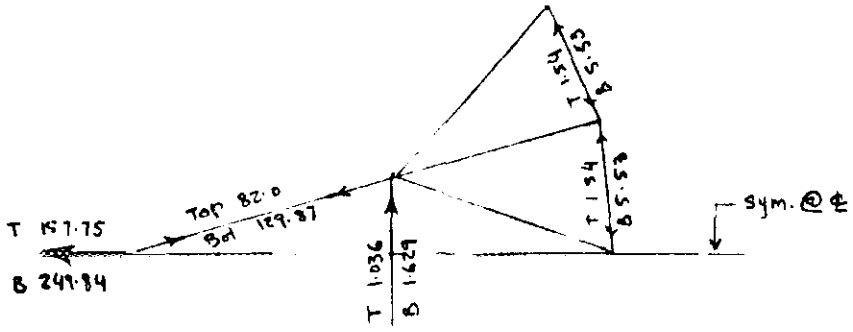
$(SA)(.9619) = (35.95)(.67214) + (36.34)(.94776) + (68.95)(.9619)$

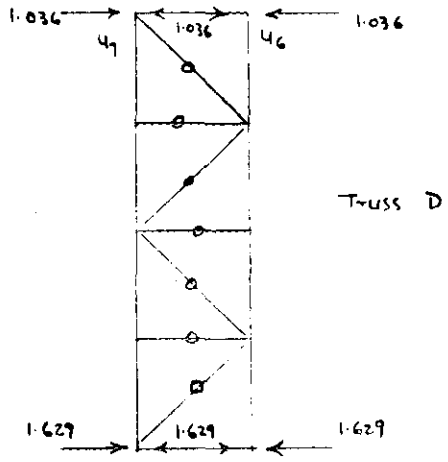
$S_A = 129.87$

$S_B = (36.34)(.31896) + (129.87 - 68.95)(.2734) - (35.95)(.7404)$

$= 1.629$

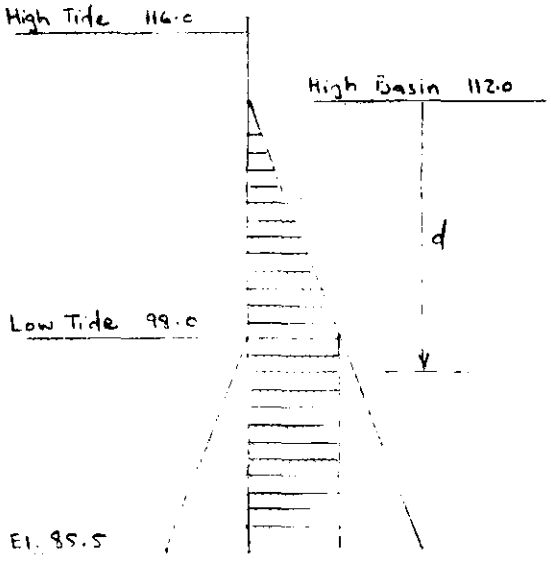
$R_A = 60.92$





Case III

Operating head : Low Tide 98.0 High Basin 112.0



$w = .423\ d$ k/l $\quad 0 < d < 14$

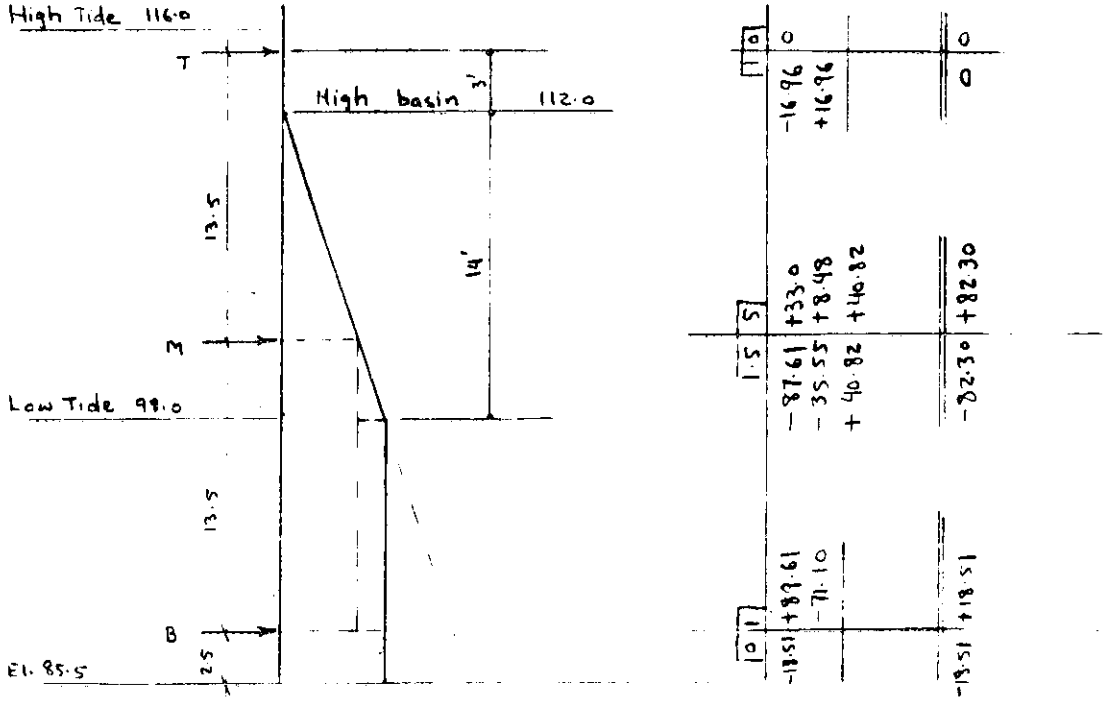
$w = .423 \times 14 = 5.922$ k/l $\quad 14 < d < 26.5$

PROJECT Charles River Dam — ACC. NO. 1556.31
SUBJECT Large Lock Gates · Tide End — SHEET NO. 26 OF
Hydrostatic Loads — DATE Aug. 1973
COMP. AD — CHECK — CONT. NO.

A69

Hydrostatic Loads

Case III — Operating head : Low Tide 98.0 high Basin 112.0



$M_{cant.}$ @ B = 5.922 × 2.5 × 1.25 = 18.51

Fix End Moments

(Ref. Bridge Design Manual State of Calif.)

Upper Span — $K = \frac{10.5}{13.5} = .778$ $\quad w = .423 \times 10.5 = 4.44$ k/l

FE $M_{TM} = \frac{wl^2}{60} k^3(5-3K) = \frac{(4.44)(13.5)^2}{60}(.778)^3(2.67) = 16.96$

FE $M_{MT} = \frac{wl^2}{60} k^2(10-10K+3K^2) = \frac{(4.44)(13.5)^2}{60}(.778)^2(4.031) = 33.0$

Lower Span — Subtract triangular portion, $k = \frac{3.5}{13.5} = .26$

$w = .423 \times 3.5 = 1.48$

@ support M, subtracting mom $= \frac{(1.48)(13.5)^2}{60}(.26)^2(7.603) = 2.33$

@ support B " $= \frac{(1.48)(13.5)^2}{60}(.26)^3(4.22) = .33$

FE $M_{MB} = \frac{(5.922)(13.5)^2}{12} - 2.33 = 87.61$

FE $M_{BM} = (5.922)(13.5)^2/12 - .33 = 89.61$

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End Hydrostatic Loads — SHEET NO. 27 OF ____

DATE Sept 5 1972

COMP. AD — CHECK DS — CONT. NO. ____

A 70

Reactions

$(\frac{1}{2})(4.44)(10.5)(3.5)(\frac{1}{13.5})$	= 6.05
$-(82.3)(\frac{1}{13.5})$	= -6.10
$R_T =$	-0.05

$(\frac{1}{2})(4.44)(10.5) - 6.05$	17.26
$(82.3)(\frac{1}{13.5})$	6.10
$(\frac{1}{2})(4.44)(13.5)$	30.00
$(3.5)(.423)(10)(5)(\frac{1}{13.5})$	5.50
$(\frac{1}{2})(3.5)(.423)(3.5)(10 + 1.17)(\frac{1}{13.5})$	2.14
$(82.3 - 18.51)(\frac{1}{13.5})$	4.73
$R_M =$	65.73

$(3.5)(.423)(10) - 5.5$	30.00
$(\frac{1}{2})(3.5)(.423)(3.5) - 2.14$	9.30
5.922×2.5	45
	14.80
	- 4.73
$R_B =$	49.82

Loads $= (\frac{1}{2})(5.922)(14) + (5.922)(12.5) = 115.5$

$R_T + R_M + R_B = (65.73 + 49.82 - .05) = 115.5$

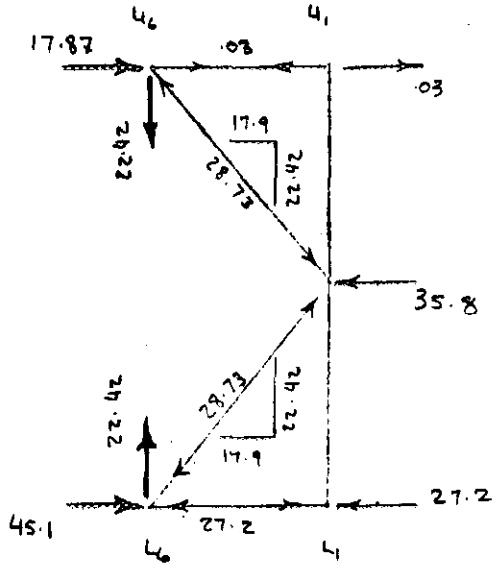
PROJECT Charles River Dam — ACC. NO. 956.31

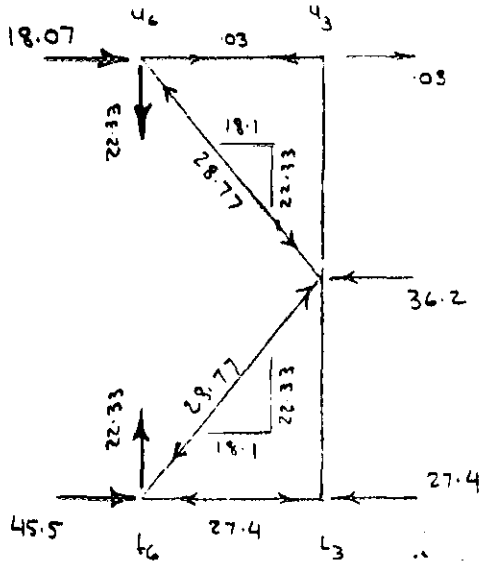
SUBJECT Large Lock Gates. Tide End Hydrostatic Loads — SHEET NO. 28 OF ____

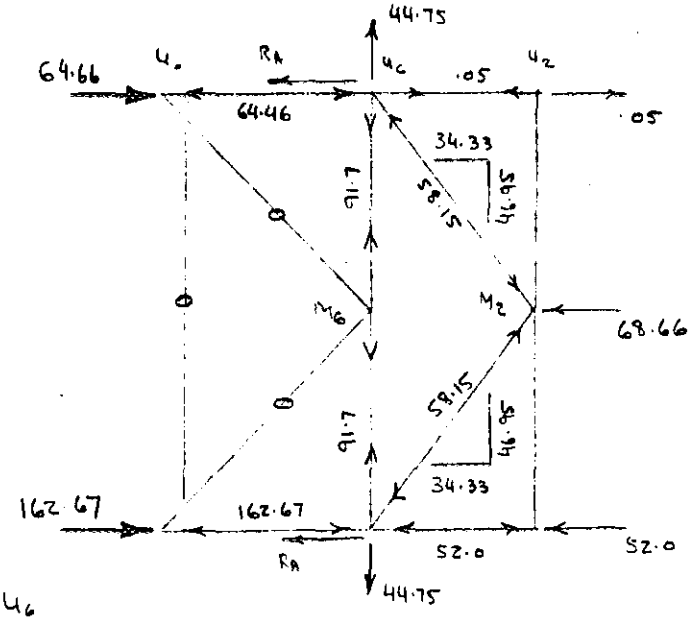
DATE Sept. 1972

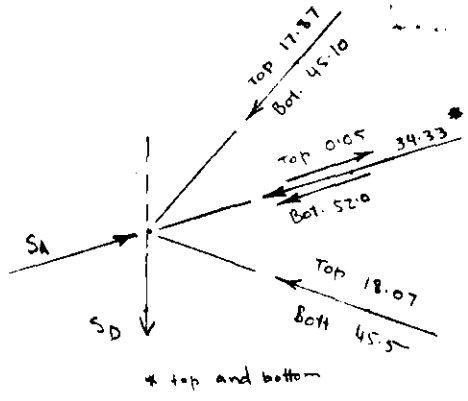
COMP. AD — CHECK AB — CONT. NO. ____

A 71









u_6

$\rightarrow$ $(S_A)(.9619) = (17.87)(.67214) + (18.07)(.94776) + (34.28)(.9619)$

$S_A = 64.46$

$\downarrow$ $S_D = (64.46 - 34.28)(.2734) + (18.07)(.31996) - (17.87)(.7404)$

$= 0.78$

$R_A = 64.46 - 34.28 = 30.18$

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates Tide End — SHEET NO. 27 OF
Operating Loads — DATE Sept. 1972
COMP. AD — CHECK — CONT. NO.

A72

L_6

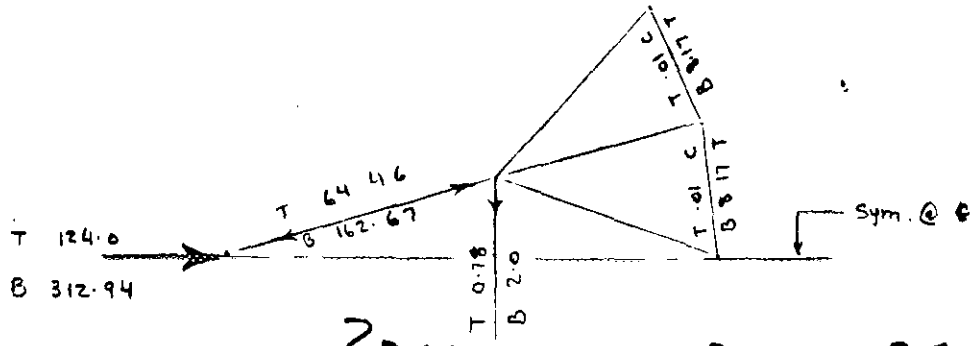
$\rightarrow (S_A)(.9619) = (45.10)(.67214) + (45.5)(.94776) + (86.33)(.9619)$

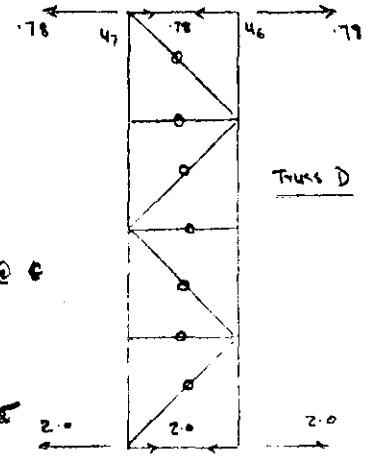
$S_A = 162.67$

$\downarrow S_D = (162.67 - 86.33)(.2734) + (45.5)(.31896) - (45.10)(.7404)$

$= 2.0$

$R_A = 76.34$





DESIGN ASSUMTIONS BASED ON THE MYSTIC RIVER GATE DESIGN
1. 12.0' Max. Head Diff.
2. FRICTION COEFFICIENT = 1.10
3. WATER = 64#/ft
4. ADD 25% FOR INACTIVE SEAL

AREA OF SEAL ACTIVE UNDER PRESSURE $= 1.0 \times 3 \times \frac{1}{12} = 0.25$ ft
PRESSURE ON SEAL $= 64 \times 12 = 768$ #/ft
PRESSURE × AREA $768 \times 0.25 = 192$ #/1 ON SEAL

Operating Loads

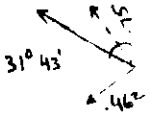
Friction :

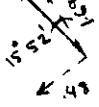
(1) Frictional force = 192 #/ft. on bottom seal
(2) Co-efficient of friction = 1.1
(3) Add 25% for inactive seal and misc.

Friction force $= 1.1 \times 1.25 \times 192 = 264$ #/ft.

panel loads $P = 6.653 \times .264 = 1.76$ k ; Sh. 19.1

Exterior panel loads $= P/2 = .88$ k





$(1.76)(\cos 15°52') = 1.76 \times .9619 = 1.69$
$(1.76)(\sin 15°52') = 1.76 \times .2734 = .48$

$(.88)(\cos 31°43') = .88 \times .85066 = .75$
$(.88)(\sin 31°43') = .88 \times .52572 = .462$

Resultant friction $F = 1.76 + 2(1.69 + .75) = 6.64$ k

Operating load $F_c(12.75 \cos 31°43') = 1.76 \times 4 \times 24.04$ taking mom. @ c

$F_o = 15.6$

$F_{ox} = (15.6)(\sin 47°35') = 11.51$ $F_{oy} = (15.6)(\cos 47°35') = 10.5$

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 30 OF

Operating Loads — DATE Sept. 1972

COMP. AD — CHECK — CONT. NO.

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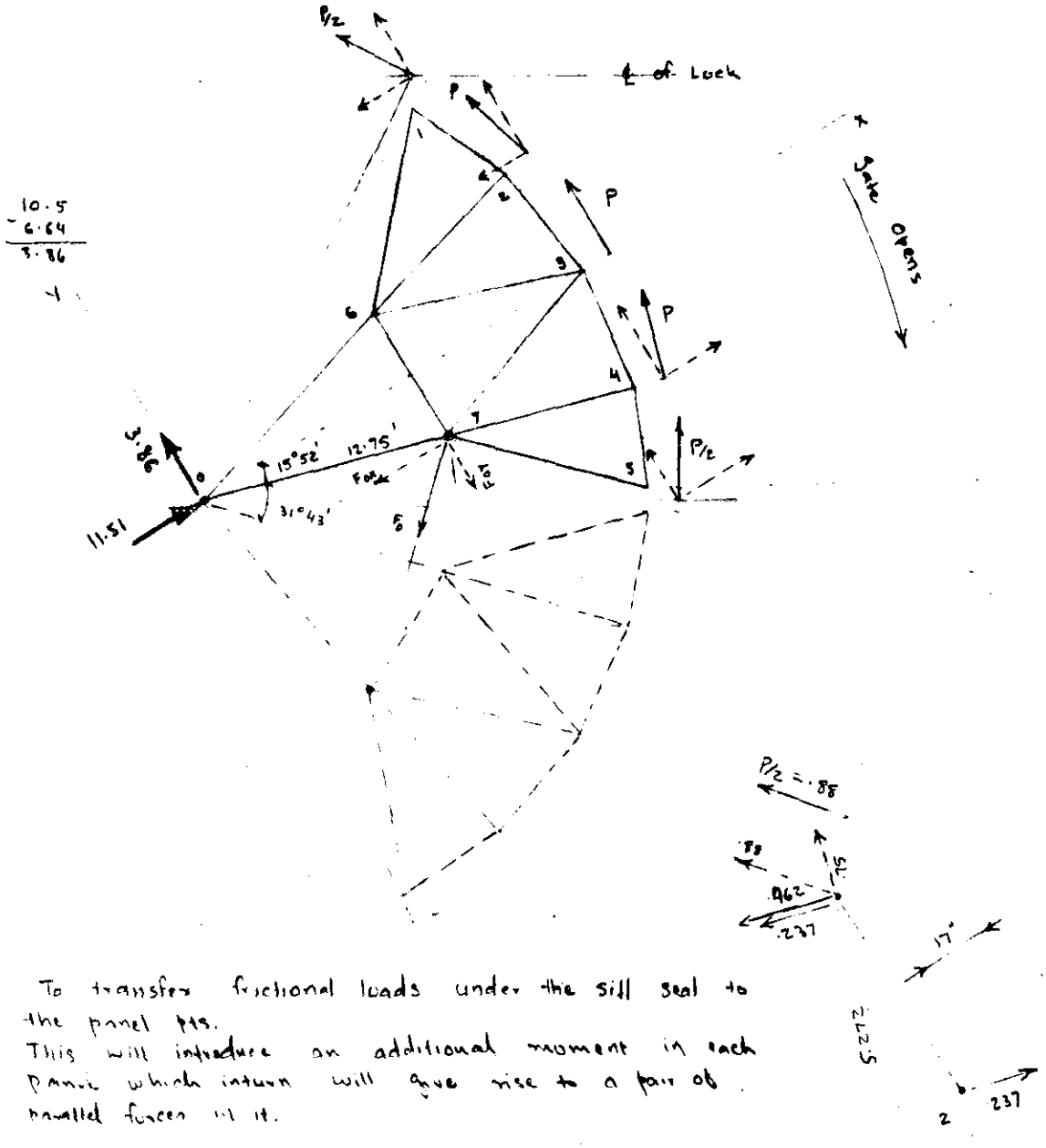


To transfer frictional loads under the sill seal to the panel pts.
This will introduce an additional moment in each panel which inturn will give rise to a pair of parallel forces in it.

Exterior panel :

$(.88 \times 1.42) \div (5.272) = .237$

Interior Panel

$(1.76 \times 1.42) \div (6.185) = .404$

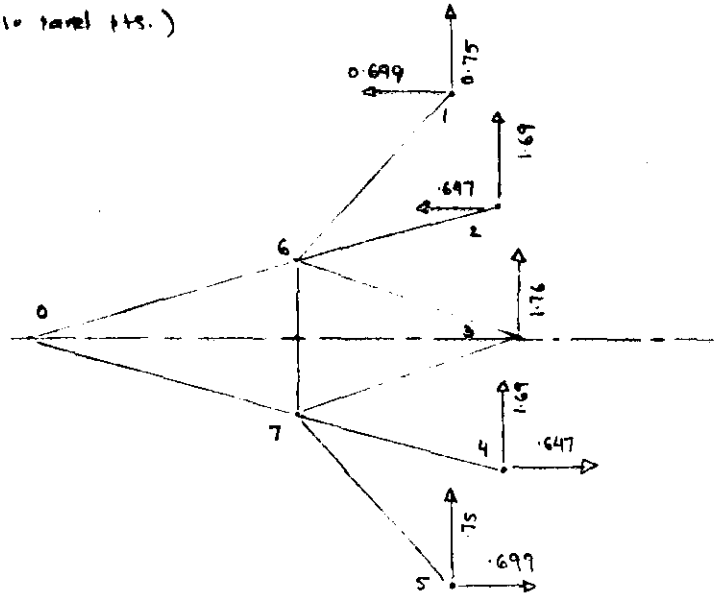
PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock gates - Tide End operating Loads — SHEET NO. 31 OF ___
DATE Sept. 1973
COMP. AD — CHECK ___ — CONT. NO. ___

A 74

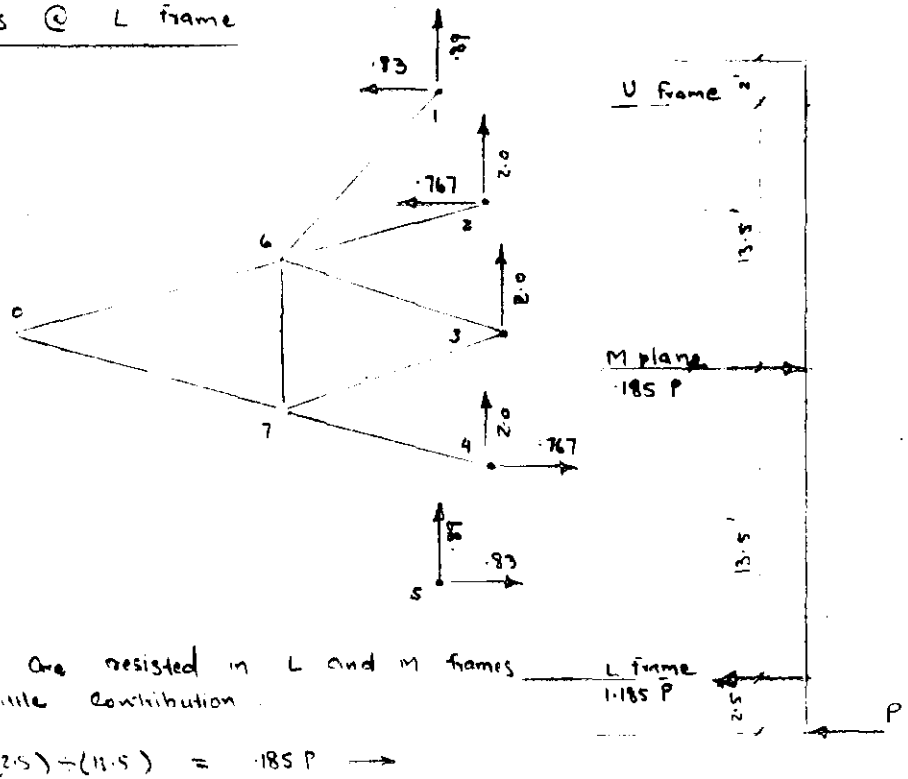
Case I

Frictional Loads @ Sill Seal

(transferred to tank pts.)



Frictional loads @ L frame



Frictional loads are resisted in L and M frames
U frame has little contribution

@ M frame $P(2.5) \div (13.5) = .185\,P \rightarrow$
L plane $= 1.185\,P \leftarrow$

PROJECT Charles River Dam — ACC. NO. 1856.31

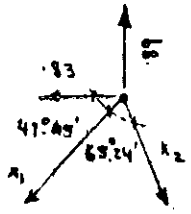
SUBJECT Large Lock Gates - Tide End — SHEET NO. 32 OF

Operating Loads — DATE Sept. 1972

COMP. AD — CHECK AB — CONT. NO.

A 75

L_1



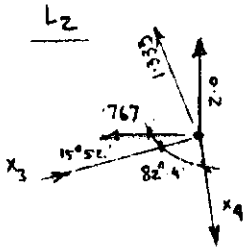
$\downarrow \quad x_1(.7402) + x_2(.9195) = .89$

$\rightarrow \quad x_2(.3931) - x_1(.6724) = .83$

$x_1 = -.455$

$x_2 = 1.333$

L_2



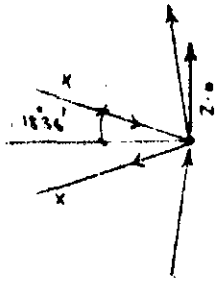
$\downarrow \quad -x_3(.2734) + x_4(.9904) = 2.0 + (1.333)(.9195)$

$\rightarrow \quad x_3(.9619) + x_4(.138) = .767 + (1.333)(.3931)$

$x_3 = .841$

$x_4 = 3.492$

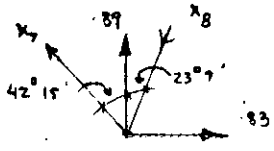
L_8



$2(x)(.319) = 2 + 2(3.492)(.9904)$

$x = 14.0$

L_5



$(x_8)(.9195) - (x_7)(.7402) = .89$

$(x_7)(.6724) + (x_8)(.3931) = .83$

$x_7 = .455$

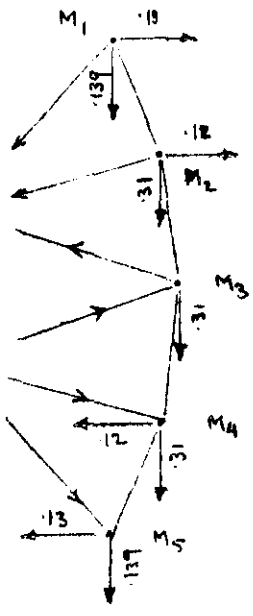
$x_8 = 1.333$

ϕ	Sine	Cos
47° 45'	.7402	.6724
31° 43'	.5257	.8507
23° 10'	.3934	.9194
18° 36'	.319	.9478
15° 52'	.2734	.9619
7° 56'	.138	.9904

PROJECT Charles River Dam — ACC. NO. 1856·31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 33 OF
Operating Loads — DATE Sept. 1972
COMP. AD — CHECK — CONT. NO.

A 76

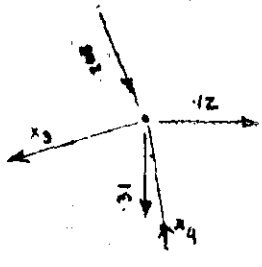
Frictional loads @ M plane



M_1

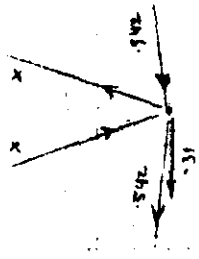
$x_2(\cdot 9195) - x_1(\cdot 7402) = \cdot 139$
$x_2(\cdot 3931) + x_1(\cdot 6724) = \cdot 13$
$x_1 = \cdot 071$
$x_2 = \cdot 208$

M_2



$x_4(\cdot 9904) - x_3(\cdot 2734) = \cdot 31 + (\cdot 208)(\cdot 9195)$
$x_4(\cdot 138) + x_3(\cdot 9619) = \cdot 12 + (\cdot 208)(\cdot 3931)$
$x_3 = \cdot 131$
$x_4 = \cdot 542$

M_3

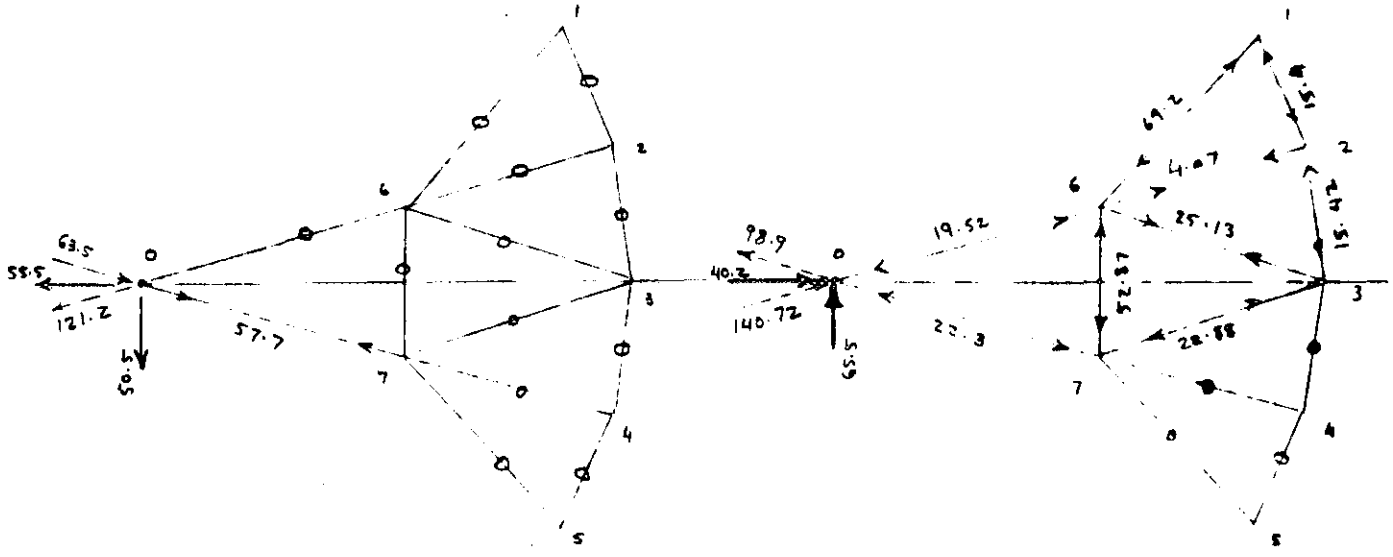


$2(x)(\cdot 319) = \cdot 31 + 2(\cdot 542)(\cdot 9904)$
$x = 2\cdot 17$

due to symmetry of geometry and loading @ M_3 and M_4 similar forces of opposite direction act on @ M_1 and M_2

PROJECT Charles River Dam. ACC. NO. 1956.31
SUBJECT Large Lock gates - Tide End SHEET NO. 48 OF
Jamming force DATE Sept. 1973
COMP. AD CHECK RR CONT. NO.

A 85



Jamming Force Case III

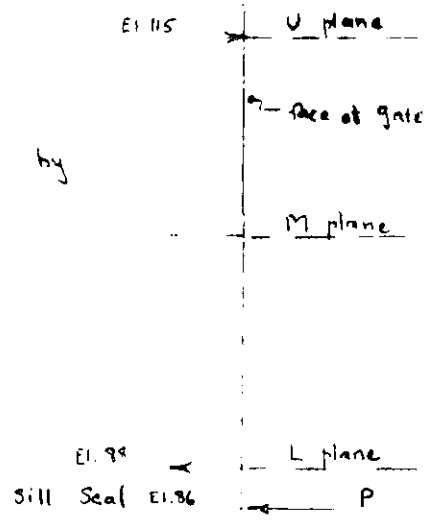
Check Jamming @ Sill Seal El 86.0

Jamming force @ $L_1 = P\left(\frac{29}{27}\right) = 1.074\ P$
$U_1 = P\left(\frac{2}{27}\right) = .074\ P$

Shear @ Jt. 2 $(75)(10.84) \div 22.62 = 36$ k
Torsion between upper and lower frames is resisted by the shear keys @ Jt. 2

Shear @ $L_2 = .074 \times 36 = 2.66$
$U_2 = 1.074 \times 36 = 38.63$

P = 77 k (Sh. 40)
Jamming force @ $L_1 = 77 \times 1.074 = 82.7$
$U_1 = 77 \times .074 = 5.7$



Torsion between the upper and lower frames

$(5.7)(10.8) + (38.63)(22.62) = 934.3$
$(82.7)(10.58) + (2.66)(22.62) = 934.2$ } balanced

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates . Tide End — SHEET NO. 35 OF ___
Operating Loads — DATE Sept. 1972
COMP. AD — CHECK ___ — CONT. NO. ___

A 78

FRICTION LOAD ON TRUSS D

L_6

$\rightarrow \quad (S_A)(.9619) = (.419)(.67214) + (12.91)(.94776) + (.775)(.9619)$

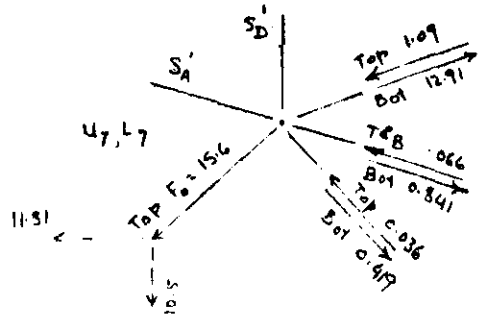
$S_A = 13.78$

$R_A = 13.78 - .775 = 13.01$

$\downarrow \quad S_D = (13.01)(.2734) + (12.91)(.31896) - (.419)(.7404)$

$= 7.37$

@ U_7



$\rightarrow \quad (S_A')(.9619) = (.036)(.67214) + (1.09)(.94776) + (.066)(.9619) + 11.51$

$S_A' = 13.13$

$\uparrow \quad S_D' = (13.13)(.2734) + (1.09)(.31896) + 10.5 - (.036)(.7404)$

$= 14.401$

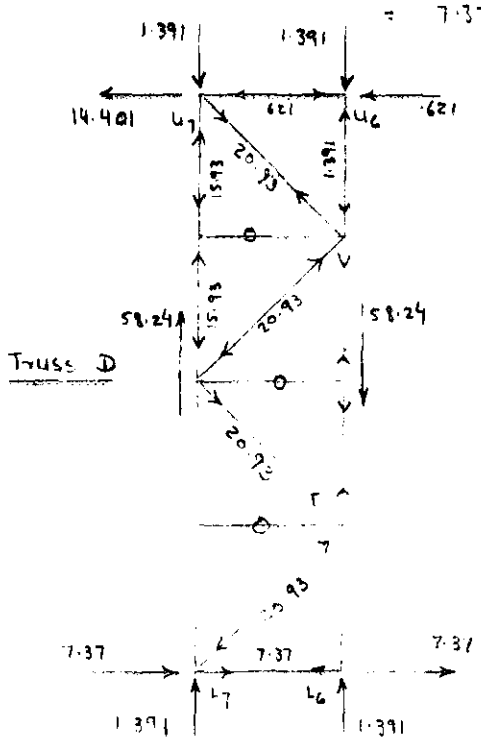
@ L_7

$\leftarrow \quad (S_A')(.9619) = (.419)(.67214) + (12.91)(.94776) + (.775)(.9619)$

$S_A' = 13.78$

$\downarrow \quad S_D' = (13.005)(.2734) + (12.91)(.31896) - (.419)(.7404)$

$= 7.37$



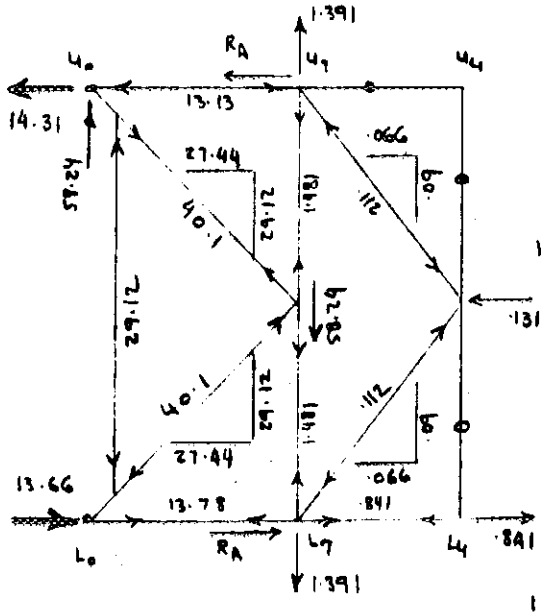
Balancing Shear $= \dfrac{(15.022)(27)}{6.97} = 58.24$

Apply to trusses at 0-6-2 and 0-7-4

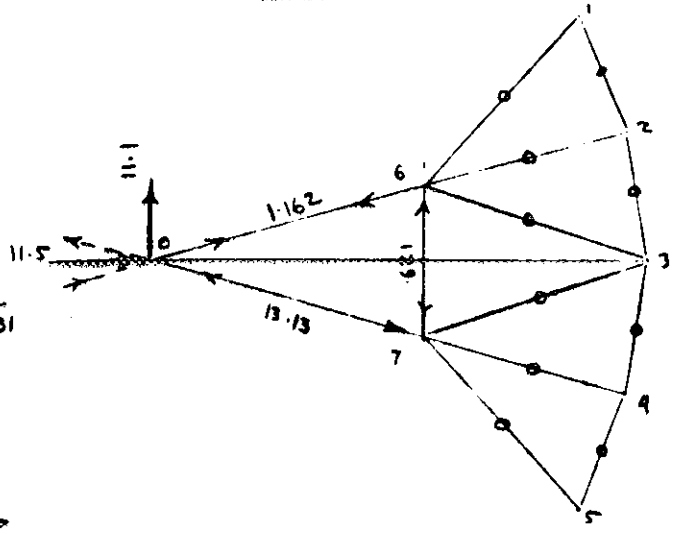
PROJECT Charles River Dam. ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End Operating Loads SHEET NO. 36 OF
DATE Sept. 1972
COMP. AD CHECK CONT. NO.

A 79

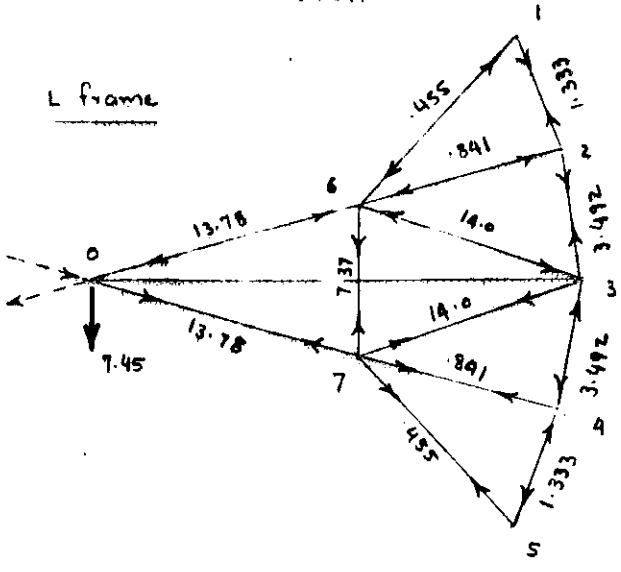
Truss A 0-7-4

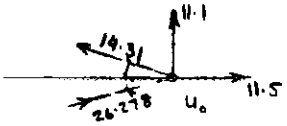


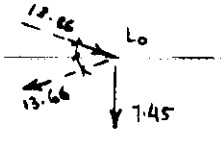
U-frame



L frame







Notes: (1) All the stresses are reversible when the gate closes.

(2) Since seal friction force is small and there is a possibility of some dirt getting wedged in the bottom seal and for the reason of complicated design mechanism double all the stresses in this case while designing members. (per original design comps.)

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 32 OF
Operating Loads — DATE Sept. 1972
COMP. AD — CHECK — CONT. NO.

A 80

Case II
Frictional Loads @ miter Seal

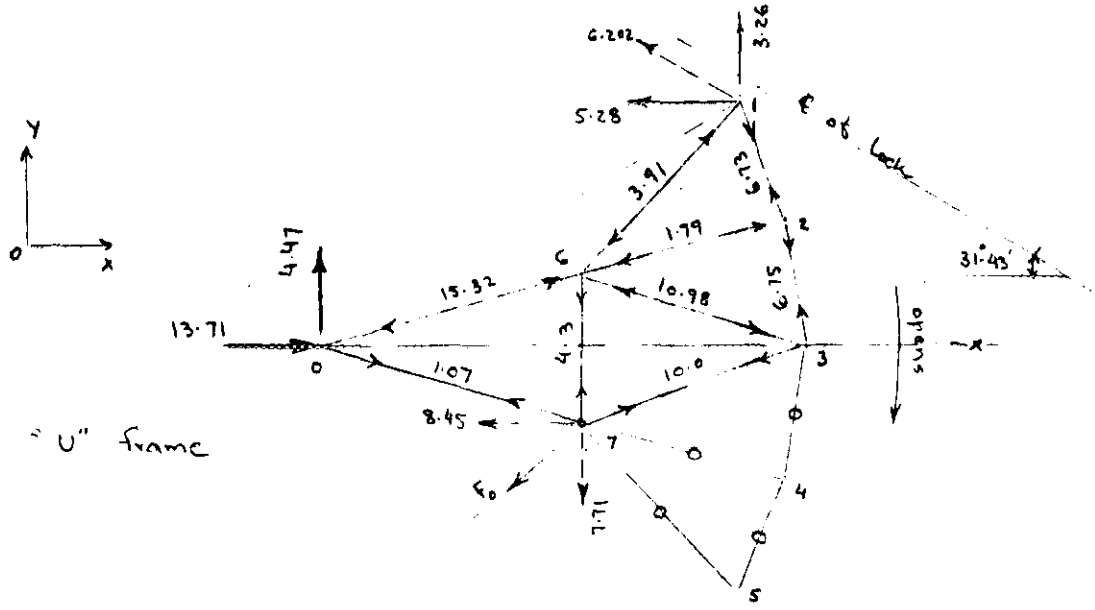
(1) Friction @ miter Seal comes into play only when gates open
(2) Friction force = 264 #/ft. (sh. ~~30~~ 29)
Only half the value is effective for the seal below middle frame.
Ref: Mystic River - Small Lock Design -

Int. load $P = (\frac{1}{2})(16)(.264) + (15.5)(.264) = 6.202$ k

(3) Assume this force to act @ ft. 1 parallel to ℄ of lock and resisted by top frame only.
Neglect small eccentricity.

(Sh. 10,31) $\angle 1\text{-}0x = 30°\text{-}26'$

$P_y = (6.202)(.8622) = 5.35$
$P_x = (6.202)(.5065) = 3.14$
$P_M = (6.202)(1.42) \div (5.272) = 1.67$



Operating load $F_0(12.75 \cos 31°43') = P \times 22 \cos 27°51'$ $\Sigma M_0 = 0$
$F_0 \times 12.75 \times .8507 = 6.202 \times 22 \times .8842$
$F_0 = 11.45$

$F_{0x} = (11.45)(\sin 47°35') = (11.45)(.7383) = 8.45$
$F_{0y} = (11.45)(\cos 47°35') = (11.45)(.6745) = 7.71$

$\Sigma x = 0$, $\Sigma y = 0$

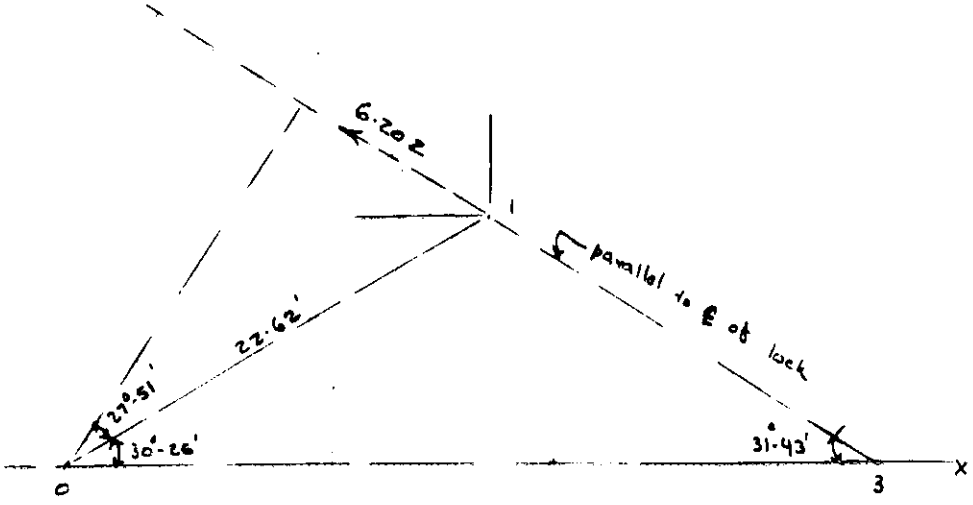
PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 38 OF ___

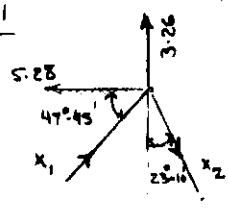
operating Loads — DATE Sept. 1972

COMP. AD — CHECK RE — CONT. NO. ___

A 81



J1.1

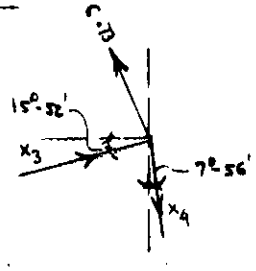


→ $(x_1)(.6742) + (x_2)(.3934) = 5.28$

↓ $-(x_1)(.7402) + (x_2)(.9194) = 3.26$

Solving.. $x_1 = 3.91$ $x_2 = 6.73$

J1.2

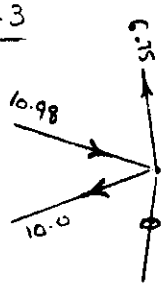


→ $(x_3)(.9619) + (x_4)(.138) = (6.73)(.3934)$

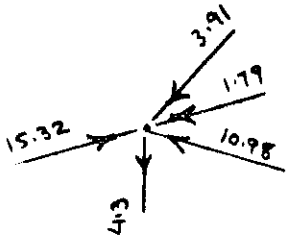
↓ $-(x_3)(.2734) + (x_4)(.9904) = (6.73)(.9194)$

Solving... $x_3 = 1.79$ $x_4 = 6.75$

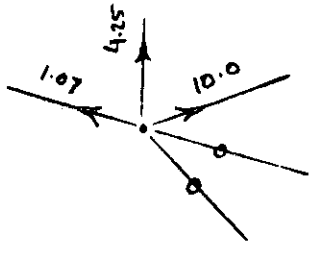
J1.3



J1.6



J1.7



$\Sigma x = 0$ $\Sigma y = 0$

$8.45 + 5.28 = 13.73$ vs. 13.71

$7.71 - 3.26 = 4.45$ vs. 4.47

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 39 OF
Stop Load — DATE Sept. 1972
COMP. AD — CHECK AB — CONT. NO.

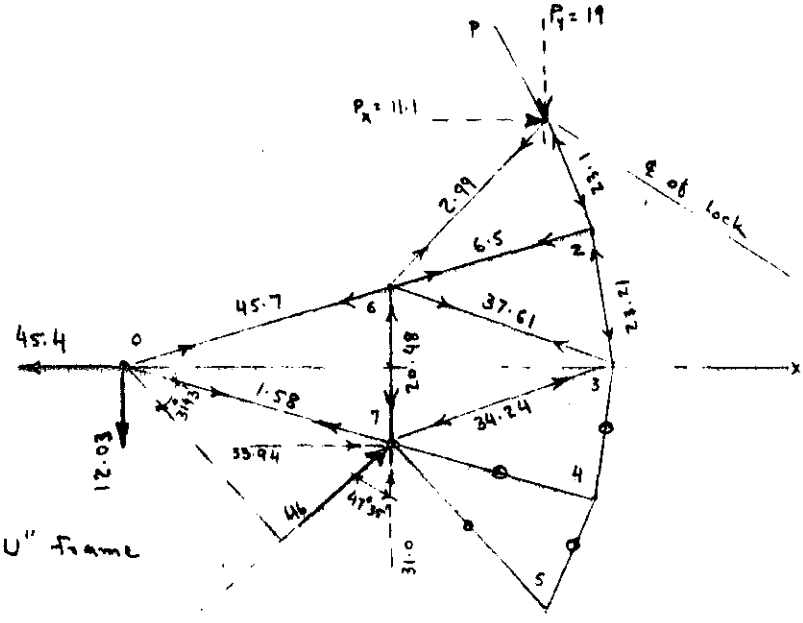
AB2

Stop Load (LOAD REQ'D TO HOLD GATE IN CLOSED POSITION "ONLY FORCE")
(Non Operating Case)

MECHANICAL DEPT.

(1) The load on the piston required to hold the gates in closed position (= Stop load) is to be 46 K per Sh. M-16 of M-20
(2) The load is applied @ El. 116.0 and acts tangentially
(3) U-frame takes full load

> per Design Example



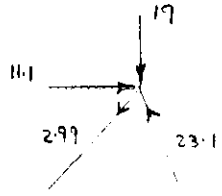
$\Sigma M_0 = 0$

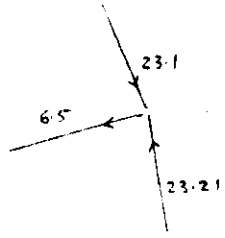
$(46)(12.75 \cos 31°43') = (P)(22.62)$

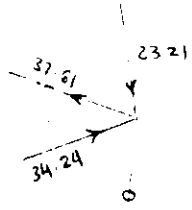
$P = 22$

$P_y = (22)(\cos 30°26') = 19$

$P_x = (22)(\sin 30°26') = 11.1$







Check $\Sigma X = 33.94 + 11.1 = 45.04$

$\Sigma Y = 31.0 - 19 = 12.0$

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock gates - Tide End SHEET NO. 40 OF
Jamming Force DATE Sept. 1972
COMP. AD CHECK [illegible] CONT. NO.

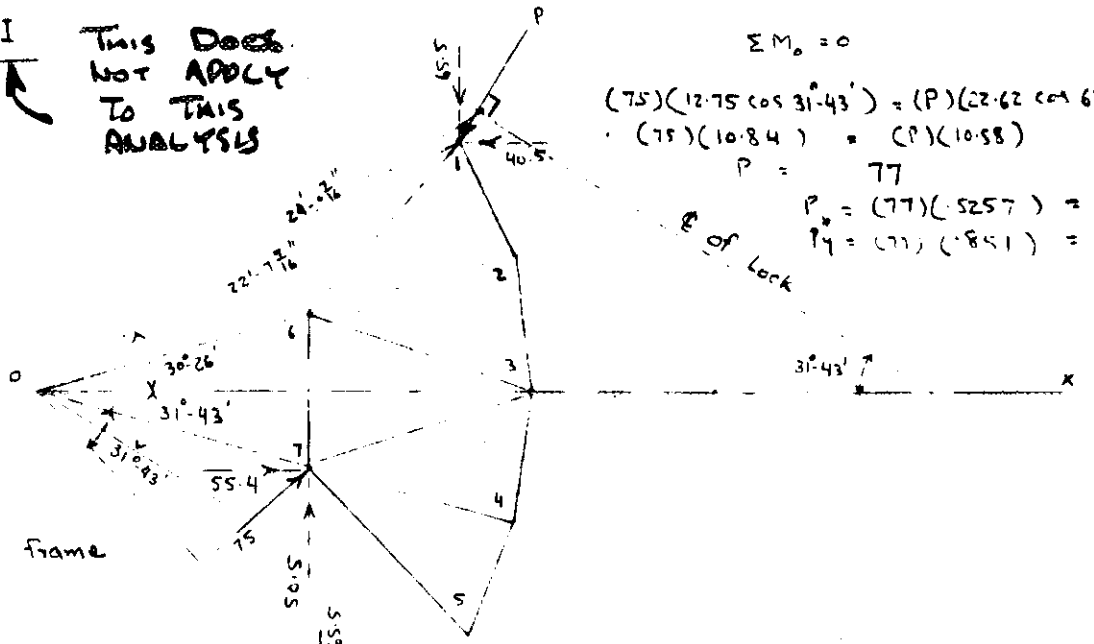
A83

Jamming Force

NOTE: THE GATE CAN JAM IN ANY POSITION HOWEVER THE MAX FORCE IS 75k

(1) The gate is jammed by debris and trash as it closes. Maximum possible force that can be exerted on the strut as the gate closes is 75 k per sh. M-16 of M-20 (MECHANICAL DEPT.)
(2) This force is applied @ El. 116 and for computation purposes @ Jt. 1 neglecting ecc. Direction would be perpendicular to the ℄ of lock
(3) U-frame takes full load Case I
(4) This loading condition is additive to that of DL

~~Case I~~ THIS DOES NOT APPLY TO THIS ANALYSIS



"U" frame

$\Sigma M_o = 0$

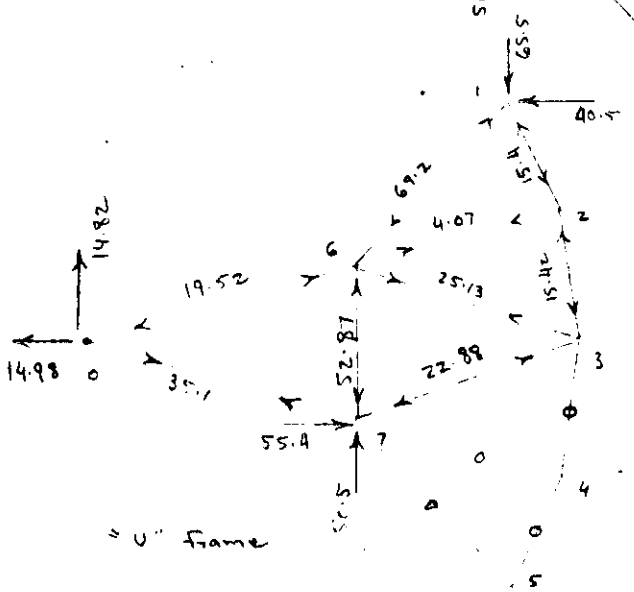
$(75)(12.75 \cos 31°-43') = (P)(22.62 \cos 62°9')$

$(75)(10.84) = (P)(10.58)$

$P = 77$

$P_x = (77)(.5257) = 40.5$

$P_y = (77)(.851) = 65.5$



"U" frame

Check Σx 55.4 − 40.5 = 14.9
Σy 65.5 − 50.5 = 15

PROJECT Charles River Dam ACC. NO. 1956.31
SUBJECT Large Lock gates - Tide End SHEET NO. 4 OF
Jamming Force DATE Sept. 1973
COMP. AD CHECK CONT. NO.

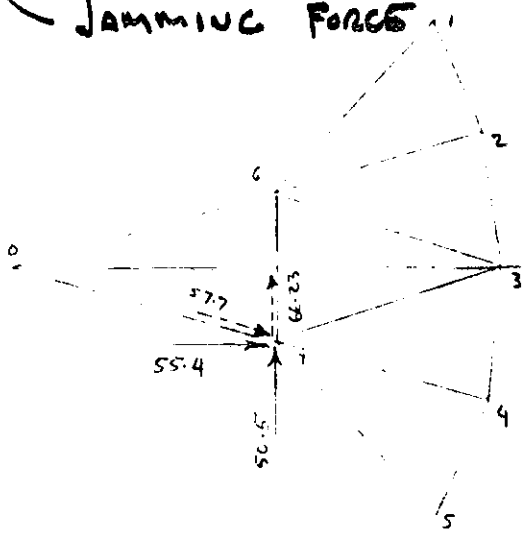
A 84

Jamming Force ~~[illegible]~~ DOES NOT APPLY TO THIS ANALYSIS

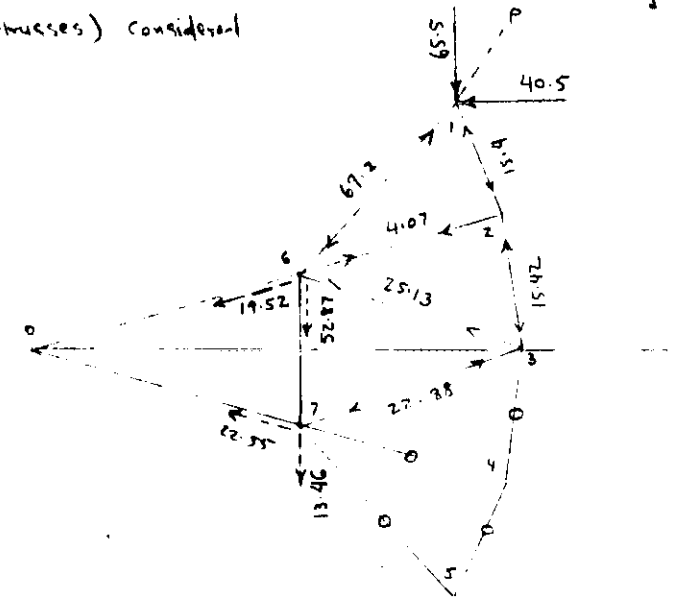
Submerged Loading - Assume forces taken by Upper and Lower frames only. (i.e. vertical and diagonal members of trusses B, C and partly A are not working)

$\Sigma M_o = 0$ Upper and lower frames (trusses) considered together

JAMMING FORCE

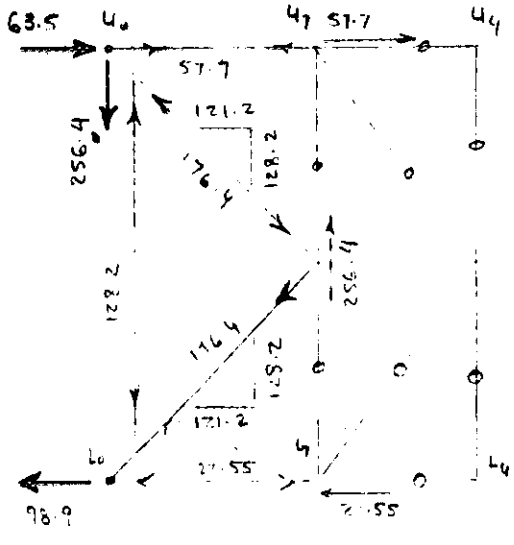


Upper Frame

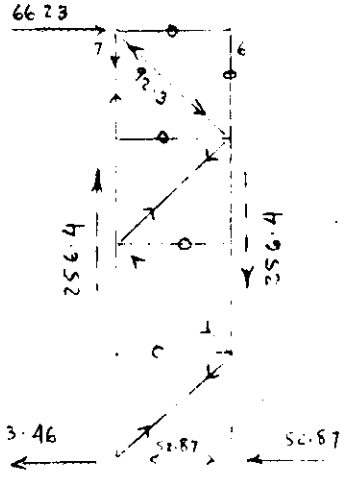


Lower Frame

dashed lines show resultants on trusses A and D



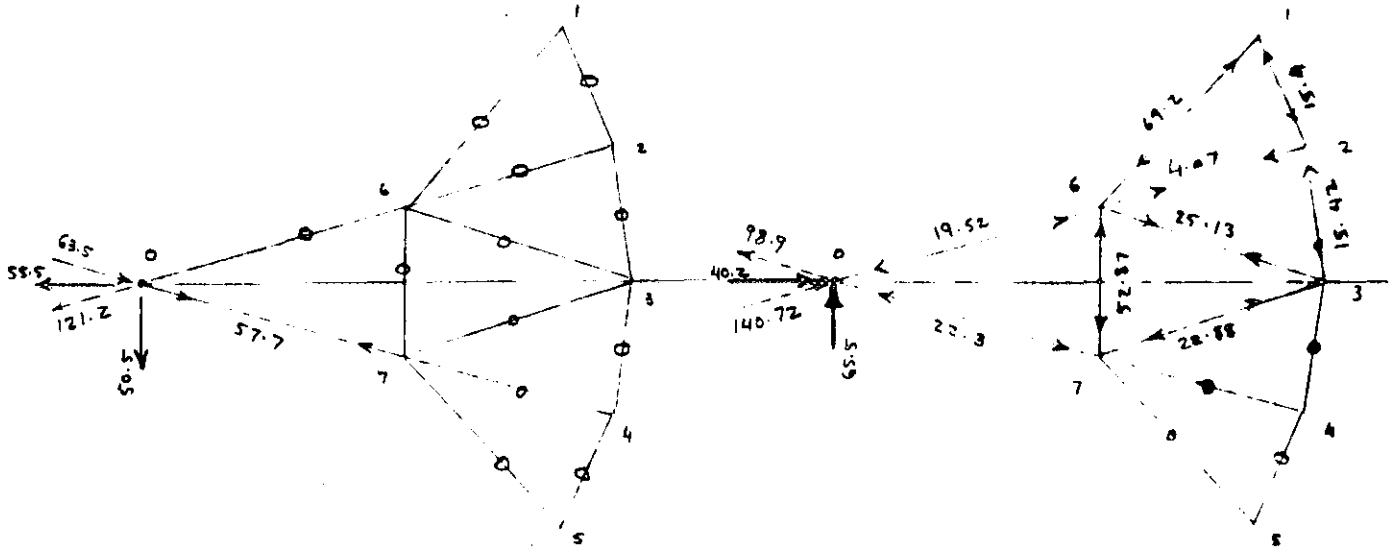
Truss A



Truss D

PROJECT Charles River Dam. ACC. NO. 1956.31
SUBJECT Large Lock gates - Tide End SHEET NO. 48 OF
Jamming force DATE Sept. 1973
COMP. AD CHECK RR CONT. NO.

A 85



Jamming Force Case III

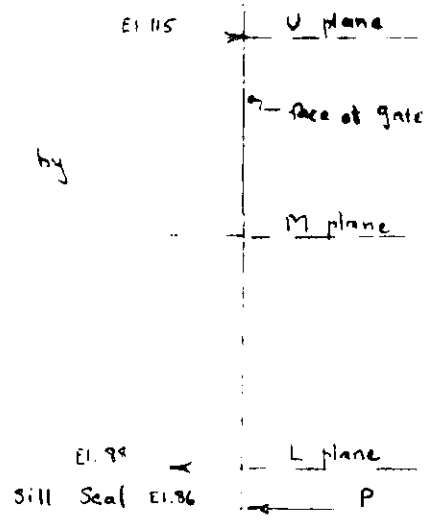
Check Jamming @ Sill Seal El 86.0

Jamming force @ $L_1 = P\left(\frac{29}{27}\right) = 1.074\ P$
$U_1 = P\left(\frac{2}{27}\right) = .074\ P$

Shear @ Jt. 2 $(75)(10.84) \div 22.62 = 36$ k
Torsion between upper and lower frames is resisted by the shear keys @ Jt. 2

Shear @ $L_2 = .074 \times 36 = 2.66$
$U_2 = 1.074 \times 36 = 38.63$

P = 77 k (Sh. 40)
Jamming force @ $L_1 = 77 \times 1.074 = 82.7$
$U_1 = 77 \times .074 = 5.7$



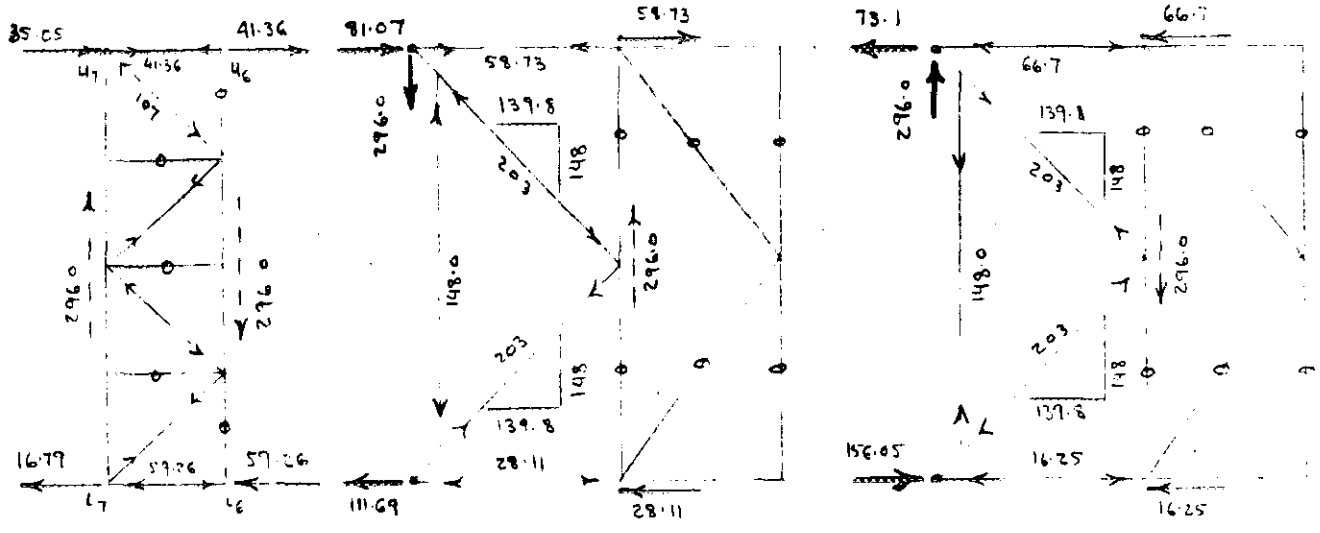
Torsion between the upper and lower frames

$(5.7)(10.8) + (38.63)(22.62) = 934.3$
$(82.7)(10.58) + (2.66)(22.62) = 934.2$ } balanced

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 43 OF
Jamming Force DATE Sept. 1972
COMP. AD CHECK RE CONT. NO.

A 86

@ Jt. 6 and 7 resultants (and not balancing forces) are shown in dashed line



Truss D Truss A @ 7-4 Truss A @ 6-2

PROJECT Charles River Dam
SUBJECT Large Lock Gate · Tide End Jamming Force
COMP. AD CHECK RB

ACC. NO. 1856.31
SHEET NO. 4 OF
DATE Sept. 1972
CONT. NO.

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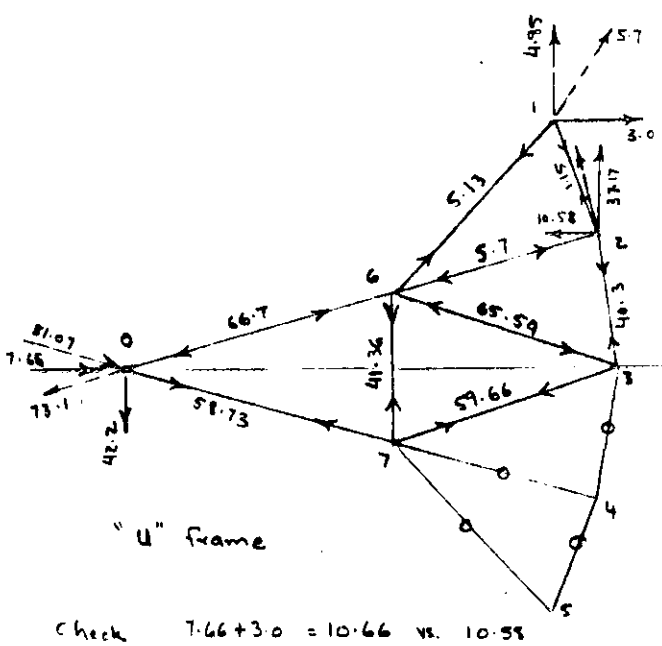
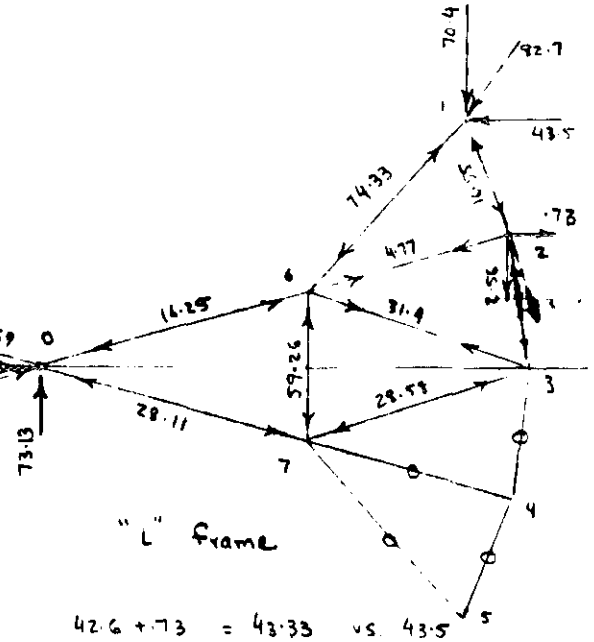


"U" frame



"L" frame

Check 7.66 + 3.0 = 10.66 vs. 10.58
37.17 + 4.95 = 42.02 vs. 42.2

42.6 + .73 = 43.33 vs. 43.5
70.4 + 2.56 = 72.96 vs. 73.13

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SUBJECT Large Lock gates - Tide End SHEET NO. 45 OF
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COMP. AD CHECK RB CONT. NO.

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NOTE: D.L. INCLUDED ONLY WHEN INDICATED

Upper Horizontal Frame "U"

Member	DL	Hydrostatic Load Case I	Case II	Case III	Operating Load Case I	Case II	Stop load closed ms	Jamming Force ~~Case I~~	~~Case II~~	~~Case III~~
		Non op.	oper.	oper.	oper	oper.	Non op.	with	DL	only
	Sh. 18	Sh. 20,21	Sh. 24,25	Sh. 28,29	Sh. 36		Sh. 39	Sh. 40	Sh. 42	Sh. 44
U_6U_1	0	+3.42	+5.1	+.03	0	-5.91	+2.99	-69.2	0	+5.13
U_7U_5	0	+3.42	+5.1	+.03	0	0	0	0	0	0
U_6U_3	0	+3.46	+5.16	+.03	0	-10.98	+37.61	+25.13	0	-65.54
U_7U_3	0	+3.46	+5.16	+.03	0	+10.0	-34.24	-22.88	0	+59.66
U_6U_2	0	+6.55	+9.77	+.05	0	-1.79	+6.5	+4.07	0	-5.7
U_7U_4	0	+6.55	+9.77	+.05	0	0	0	0	0	0
U_6U_0	+10.41	+109.61	+82.0	-64.46	±2.32	-15.32	+45.7	-19.52	0	-66.7
U_7U_0	+10.41	+109.61	+82.0	-64.46	∓26.26	+1.07	+1.58	+35.1	+57.7	+58.73
U_6U_7	+1.63	-1.37	-1.04	+.78	∓1.24	+4.3	-20.48	-52.87	0	+41.36
U_1U_2	0	-1.03	-1.54	-.01	0	+6.73	-23.1	-15.4	0	+1.15
U_5U_4	0	-1.03	-1.54	-.01	0	0	0	0	0	0
U_2U_3	0	-1.03	-1.54	-.01	0	+6.75	-23.21	-15.42	0	+40.3
U_4U_3	0	-1.03	-1.54	-.01	0	0	0	0	0	0

Tension +
Compression −

As per notes on sh. 36 operating loads under case I in this table are twice as much. Operating load case I and Jamming force Case II (submerged loading) are reversible.
DL and all hydrostatic cases are symm. @ ℄ plane thr' gate

PROJECT Charles River Dam — ACC. NO. 1956.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 46 OF

Tabulation of Stresses — DATE Sept. 1972

COMP. AD — CHECK JB/RB — CONT. NO.

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Lower Horizontal Frame "L"

Member	DL	Hydrostatic Load			Operation Load		Stop Load	Jamming Force			
		Case I	Case II	Case III	Case I	Case II	closed pos.	~~Case I~~	~~Case II~~	~~Case III~~	
	Sh. 18	Non op.	Oper.	Oper.	oper.	oper.	Non op.	with	DL	only	
		Sh. 20,21	Sh. 24,25	Sh. 28,29	Sh. 36		Sh. 39	Sh. 40	Sh. 42	Sh. 44	
L_6L_1	0	+50.0	+18.35	-27.2	∓ .92	0	0	0	-69.2	-74.33	
L_7L_5	0	+50.0	+18.35	-27.2	± .92	0	0	0	0	0	
L_6L_3	0	+50.5	+18.54	-27.4	∓ 28.0	0	0	0	+25.13	+31.4	
L_7L_3	0	+50.5	+18.54	-27.4	± 28.0	0	0	0	-22.88	-28.58	
L_6L_2	0	+95.67	+35.2	-52.0	∓ 1.68	0	0	0	+4.07	+4.77	
L_7L_4	0	+95.67	+35.2	-52.0	± 1.68	0	0	0	0	0	
L_6L_0	-10.41	+267.05	+129.87	-162.67	∓ 27.56	0	0	0	-19.52	-16.25	
L_7L_0	-10.41	+267.05	+129.87	-162.67	± 27.56	0	0	0	-22.3	-28.11	
L_6L_7	-1.63	-.56	-1.63	+2.0	± 14.74	0	0	0	-52.87	-59.26	
L_1L_2	0	-15.0	-5.53	+8.17	± 2.66	0	0	0	-15.4	-16.55	
L_5L_4	0	-15.0	-5.53	+8.17	∓ 2.66	0	0	0	0	0	
L_2L_3	0	-15.0	-5.53	+8.17	± 6.98	0	0	0	-15.42	-19.28	
L_4L_3	0	-15.0	-5.53	+8.17	∓ 6.98	0	0	0	0	0	

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 47 OF

Tabulation of Stresses — DATE Oct. 1972

COMP. AD — CHECK [illegible] — CONT. NO.

A 90

Mid Horizontal Frame "M"

Member	DL	Hydrostatic Load			Operating Load		Stop Load	Jamming Force			
		Case I	Case II	Case III	Case I	Case II	Closed Pos.	~~Case I~~	~~Case II~~	Case III	
		Non op.	Oper.	Oper.	Oper.	Oper.	Non op.	With DL only			
	Sh. 16,17	Sh. 20,21	Sh. 24,25	Sh. 28,29	Sh. 33,34		Sh. 39	Sh. 40	Sh. 41	Sh. 43	
M_1M_2	0	-16.23	-10.62	+10.78	∓ .42	0	0	0	0	0	
M_5M_4	0	-16.23	-10.62	+10.78	± .42	0	0	0	0	0	
M_2M_3	0	-16.23	-10.62	+10.78	∓ 1.08	0	0	0	0	0	
M_4M_3	0	-16.23	-10.62	+10.78	± 1.08	0	0	0	0	0	

Diagonals and Other Secondary Members

U_6M_1, U_7M_5	+8.9	+43.27	+28.22	-28.73	± .12	0	0	0	0	0	
L_6M_1, L_7M_5	-8.9	+43.27	+28.22	-28.73	± .12	0	0	0	0	0	
U_6M_3, U_7M_3	+3.84	+43.31	+28.38	-28.77	± 1.73	0	0	0	0	0	
L_6M_3, L_7M_3	-3.84	+43.31	+28.38	-28.77	± 3.46	0	0	0	0	0	
U_6M_2, U_7M_4	+7.03	+87.43	+57.15	-58.15	± .22	0	0	0	0	0	
L_6M_2, L_7M_4	-7.03	+87.43	+57.15	-58.15	± .22	0	0	0	0	0	
U_6M_6, U_6M_7	+36.23	0	0	0	∓ 80.2	0	0	0	∓ 176.4	∓ 203	
L_6M_6, L_6M_7	-36.23	0	0	0	± 80.2	0	0	0	± 176.4	± 203	
U_7U_6'	0	0	0	0	± 41.86	0	0	0	∓ 92.3	-107	
M_7U_6'	0	0	0	0	∓ 41.86	0	0	0	± 92.3	+ 107	
M_7L_6'	0	0	0	0	± 41.86	0	0	0	∓ 92.3	-107	
L_7L_6'	0	0	0	0	∓ 41.86	0	0	0	± 92.3	+ 107	
$U_6'U_7'$, M_6M_7, $L_6'L_7$	0	0	0	0	0	0	0	0	0	0	

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 48 OF
Tabulation of Stresses DATE Oct. 1972
COMP. AD CHECK [illegible] CONT. NO.

A 91

Vertical Members

Member	DL	Hydrostatic Load Case I Non op	Case II Oper.	Case III Oper.	Operating Load Case I Oper.	Case II Oper.	Stop Load closed pos. Non op.	Jamming Force with DL only Case I	Case II	Case III
	Sh. 17, 18	Sh. 20, 21	Sh. 24, 25	Sh. 28, 29	Sh. 35, 36	Sh. 37	Sh. 39	Sh. 40	Sh. 41	Sh. 43
* $U_6M_6L_6$	-45.67	-138.0	-90.2	+91.7	±58.24	0	0	0	±256.4	-296.0
$U_7M_7L_7$	-45.67	-138.0	-90.2	+91.7	±58.24	0	0	0	±256.4	+296.0
U_0L_0	+31.23	0	0	0	±58.24	0	0	0	±128.2	±148.0

Bearing Reactions

	V				H		H	H	H	H
U_0	68.0 ← ↑ 125.32	← 211.85	← 157.75	→ 124.0	22.2 ↑ → 23.0		45.4 ← ↓ 12.03	14.82 ↑ ← 14.98	55.5 ← ↓ 50.5	7.66 → ↓ 42.2
L_0	→ 68.0	← 516.15	← 249.84	→ 312.94	↓ 14.90	0	0	0	40.2 → ↑ 65.5	42.6 → ↑ 73.13

DL - $U_6M_6L_6$ (also $U_7M_7L_7$) = 22.77 T + 22.90 C = 45.67 say C

U_0L_0 - One member each for two trusses A

V - reactions in vertical plane
H - " " Horiz. "

* - Jt. Analysis shows unreal values of stress carried in $U_6M_6L_6$, however a conservative assumption is that entire shear is carried by that members. Same is true for $U_7M_7L_7$

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock gates : Tide End — SHEET NO. 49 OF
Design of Members — DATE Oct. 1972
COMP. AD — CHECK RS — CONT. NO.

A92

Design Criteria

(1) Design of members to be in accordance with AISC Specs 1970 Seventh Edition ✓

(2) Allowable Stresses as per C.O.E. Engineer Manual EM 1110-1-2101 ✓

(3) Check Structure under hydrodynamic Condition in Conformance with C.O.E. manual EM 1110-2-2200 chapter 3. ✓

(4) When hydrodynamic force is included in the Design the Allowable working stress should be increased by 33⅓ % ✓

(5) Zone 3 Seismic requirements ✓

(6) Normal pool El. 110.2 (tide end) for hydrodynamic Loads ✓

(7) Maximum L/r = for tension and compression members as per AISC 1970 specs. ✓

(8) minimum thickness of metal used as per 1.7.14 AASHO 1969 ✓

5/16" for plates .23" for rolled Sections

Notes: In order to accord with the details sometimes heavier sections may seem to have been used.
Connections are not designed.

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 52 OF
Design of Members — DATE Oct 1972
COMP. AD — CHECK RB — CONT. NO.

A93

Load Grouping

Upper Horiz. Frame "U"

Mem.	Load	Non op. case	Oper. Case		Jamming Case	
U_6U_1	D	0	0	0	0	0
	H	+3.42	+5.1	+.03	0	0
	L	+2.99	0	-3.91	0	0
	J	0	0	0	-69.2	+5.13
		+6.41	+5.1	-3.88	-69.2	+5.13
U_6U_3	D	0	0	0	0	0
	H	+3.46	+5.16	+.03	0	0
	L	+37.61	0	-10.98	0	0
	J	0	0	0	+25.13	-65.54
		41.07	+5.16	-10.95	+25.13	-65.54
U_6U_2	D	0	0	0	0	0
	H	+6.55	+9.77	+.05	0	0
	L	+6.5	0	-1.79	0	0
	J	0	0	0	+4.07	-5.7
		+13.05	+9.77	-1.74	+4.07	-5.7
U_6U_0	D	+10.41	+10.41	+10.41	+10.41	+10.41
	H	+109.61	+82.0	-64.46	0	0
	L	+45.70	±2.32	-15.32	0	0
	J	0	0	0	-19.52	-66.7
		+164.72	+94.73	-69.37	-9.11	-56.29
U_7U_0	D	+10.41	+10.41	+10.41	+10.41	+10.41
	H	+107.61	+82.0	-64.46	0	0
	L	+1.58	∓26.26	+1.07	0	0
	J	0	0	0	+35.1	+58.73
		+121.60	+118.67	52.98	+45.51	+69.14
U_6U_7	D	+1.63	+1.63	+1.63	+1.63	+1.63
	H	-1.37	-1.04	+.78	0	0
	L	-20.48	∓1.24	+4.3	0	0
	J	0	0	0	-52.87	+41.36
		-23.48	+1.83	+6.71	-51.24	+42.99
U_1U_2	D	0	0	0	0	0
	H	-1.03	-1.54	-.01	0	0
	L	-23.1	0	+6.73	0	0
	J	0	0	0	-15.4	+1.15
		-24.13	-1.54	+6.72	15.4	+1.15
U_2U_3	H	-1.03	-1.54	-.01	0	0
	L	-23.21	0	+6.75	0	0
	J	0	0	0	-15.42	+40.3
		-24.24	-1.54	+6.74	-15.42	+40.3

(data from sh. 45 thr' 48)

Design Critical Members:

U_6U_1 and U_7U_5

Design load = 69.2 ᵏ comp.

l = 10.77 x 12 = 129"

Try W 8x28

A = 8.23 r_x = 3.45 r_y = 1.62

t_w = .285

Kl/r_y → K is unity in trusses (AISC 1.8.2)

$l/r_y = \frac{129}{1.62} = 80 \rightarrow F_a = 11.5$

(Appendix II EM 1110-1-2101)

Compr. stress

$\frac{69.2}{8.23} = 8.42 < 11.5$ ok

tensile stress ok

U_6U_3 and U_7U_3

Max. comp. = 65.54 ᵏ U_6U_3

Max. tension = 59.66 U_7U_3 (computed as U_6U_3)

l = 10.93 x 12 = 131

On inspection W 8x28 ok

U_6U_0 and U_7U_0

Max. Comp. = 69.37 U_6U_0

Max Tension = 164.72 U_7U_0

l = 12.75 x 12 = 153"

A = 10.3 sq in. r_y = 2.03 for W 8x35

$l/r_y = \frac{153}{2.03} = 75.5 \rightarrow F_a = 11.85$

$\frac{69.37}{10.3} = 6.74 < 11.85$ ok

$\frac{164.72}{10.3} = 16.0 < 16.2$ ok

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 51 OF
Design of Members — DATE Oct. 1972
COMP. AD — CHECK RB — CONT. NO.

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Lower horiz. frame "L"

Mem.	L	Non op. Case	Oper. Case I	Oper. Case II	Jamming Case I	Jamming Case II	Jamming Case III
L_6L_1	D	0	0	0	0	0	0
	H	+50.0	+18.35	-27.2	0	0	0
	L	0	∓ .92	0	0	0	0
	J	0	0	0	0	-69.2	-74.33
		+50	+17.43	-27.2	0	-69.2	-74.33
L_6L_3	D	0	0	0	0	0	0
	H	+50.5	+18.54	-27.4	0	0	0
	L	0	∓28.0	∓28.0	0	0	0
	J	0	0	0	0	+25.13	+31.4
		+50.5	+46.54	-55.4	0	+25.13	+31.4
L_6L_2	D	0	0	0	0	0	0
	H	+95.67	+35.2	-52.0	0	0	0
	L	0	∓1.68	∓1.68	0	0	0
	J	0	0	0	0	+4.07	+4.77
		+95.67	+33.52	-53.68	0	+4.07	+4.77
L_6L_0	D	-10.41	-10.41	-10.41	-10.41	-10.41	-10.41
	H	+267.05	+129.87	-167.67	0	0	0
	L	0	±27.56	±27.6	0	0	0
	J	0	0	0	0	-19.52	-16.25
		+256.64	+91.9	-200.68	-10.41	-29.93	-26.66
L_7L_0	D	-10.41	-10.41	-10.41	-10.41	-10.41	-10.41
	H	+267.05	+129.87	-167.67	0	0	0
	L	0	±27.56	±27.56	0	0	0
	J	0	0	0	0	-22.3	-28.11
		+256.64	+91.9	-200.64	-10.41	-32.71	-38.52
L_6L_7	D	-1.63	-1.63	-1.63	-1.63	-1.63	-1.63
	H	-.56	-1.63	+2.0	0	0	0
	L	0	±14.74	±14.74	0	0	0
	J	0	0	0	0	-52.87	-59.26
		-2.19	-18	+15.11	-1.63	-54.50	-60.89
L_1L_2	D	0	0	0	0	0	0
	H	-15.0	-5.53	+8.17	0	0	0
	L	0	±2.66	±2.66	0	0	0
	J	0	0	0	0	15.4	-16.55
		-15.0	-2.87	+10.83	0	-15.4	-16.55
L_2L_3	D	0	0	0	0	0	0
	H	-15.0	-5.53	+8.17	0	0	0
	L	0	±6.98	±6.98	0	0	0
	J	0	0	0	0	-15.42	-19.25
		-15.0	-12.51	+15.15	0	-15.42	-19.28

Design Critical Members:

L_6L_1

Max. Compression 74.33 k
Max. Tension 50
ℓ = 129"
Try W 10x29
A = 8.54 r_y = 1.38"

$\ell/r_y = \frac{129}{1.38} = 93.5 \longrightarrow F_a = 10.35$ ksi

Compr. Stress $\frac{74.33}{8.54} = 8.71 < 10.35$

tens. Stress $\frac{50}{8.54} = 5.86 < 16.2$
ok

L_6L_2

Max Comp. 53.68
Max. Tension 95.67

tens. Stress $\frac{95.67}{8.54} = 11.22 < 16.2$
ok
(using W 10x29)

L_6L_0

Max. Compr. 200.68
Max. Ten 256.64
ℓ = 153"
Try W 10x66
A = 19.4 r_y = 2.58"

$\ell/r_y = \frac{153}{2.58} = 59.4 \longrightarrow F_a = 13.1$

Compr. Stress $\frac{200.68}{19.4} = 10.33 < 13.1$

tens. Stress $\frac{256.64}{19.4} = 13.22 < 16.2$

ok

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SUBJECT Large Lock Gates - Tide End SHEET NO. 52 OF
Design of Members DATE Oct. 1972
COMP. AP CHECK [illegible] CONT. NO.

A95

Mid Horiz Frame "M"

Memb.	L	Non op. Case	Oper. Case I	Oper. Case II	Jamming Case I	Jamming Case II	Jamming Case III
M_1M_2 & M_5M_4	D	0	0	0	0	0	0
	H	-16.23	-10.62	+10.78	0	0	0
	L	0	± .42	± .42	0	0	0
	J	0	0	0	0	0	0
		-16.23	-11.04	+11.20	0	0	0
M_2M_3 & M_4M_3	D	0	0	0	0	0	0
	H	-16.23	-10.62	+10.78	0	0	0
	L	0	± 1.08	± 1.08	0	0	0
	J	0	0	0	0	0	0
		-16.23	-11.70	+11.86	0	0	0

For all the horizontal ties Try ST 5 x 12.7 (tried before in earlier comps)

$A = 3.73$ $r_{min} = r_y = .954''$ $t_w = .311$

Max. Compression = -24.24 k U_2U_3
Max Tension = 40.3 U_2U_3
$l = 6.24 \times 12 = 74.7''$

$l/r_y = \frac{74.7}{.954} = 78.5 \longrightarrow F_a = 11.63$

compr. stress $\frac{24.24}{3.73} = 6.5 < 11.63$

tens stress $\frac{40.3}{3.73} = 10.8 < 16.2$ ok

For U_1U_2, U_5U_4, U_2U_3, U_4U_3 and similarly all other ties @ M plane and L plane.

Explaination

D Dead Load
H Hydrostatic Loads
L Friction and Stop Loads are Combined and Called Link Loads
J Jamming Forces

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates · Tide End — SHEET NO. 53 OF
Design of Members — DATE Oct. 1972
COMP. AD — CHECK — CONT. NO.

A 96

Diagonals

Mem.	L	Non Op. Case	Oper. Case I	Oper. Case II	Jamming Case I	Jamming Case II	Jamming Case III
U_6M_1	D	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9
	H	+43.27	+28.22	-28.73	0	0	0
	L	0	±.12	±.12	0	0	0
	J	0	0	0	0	0	0
		+52.17	+37.0	-19.95	+8.9	+8.9	+8.9
L_6M_1	D	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9
	H	+43.27	+28.22	-28.73	0	0	0
	L	0	±.12	±.12	0	0	0
	J	0	0	0	0	0	0
		+34.37	+19.44	-37.75	-8.9	-8.9	-8.9
U_6M_3	D	+3.84	+3.84	+3.84	+3.84	+3.84	+3.84
	H	+43.31	+28.38	-28.77	0	0	0
	L	0	±1.73	±1.73	0	0	0
	J	0	0	0	0	0	0
		+47.15	+33.95	-26.66	+3.84	+3.84	+3.84
L_6M_3	D	-3.84	-3.84	-3.84	-3.84	-3.84	-3.84
	H	+43.31	+28.38	-28.77	0	0	0
	L	0	±3.46	±3.46	0	0	0
	J	0	0	0	0	0	0
		+39.47	+21.08	-35.68	-3.84	-3.84	-3.84
U_6M_2	D	+7.03	+7.03	+7.03	+7.03	+7.03	+7.03
	H	+84.73	+57.15	-58.15	0	0	0
	L	0	±.22	±.22	0	0	0
	J	0	0	0	0	0	0
		+91.76	+64.40	-51.34	+7.03	+7.03	+7.03
L_6M_2	D	-7.03	-7.03	-7.03	-7.03	-7.03	-7.03
	H	+87.43	+51.15	-53.16	0	0	0
	L	0	±.22	±.22	0	0	0
	J	0	0	0	0	0	0
		+77.7	+50.34	-65.40	-7.03	-7.03	-7.03
U_6M_6 and U_6M_7	D	+36.23	+36.23	+36.23	+36.23	+36.23	+36.23
	H	0	0	0	0	0	0
	L	0	±80.2	±80.2	0	0	0
	J	0	0	0	0	±176.4	±203
		+36.23	-116.43	-43.97	+36.23	+212.63 -140.17	+239.23 -166.77
L_6M_6 and L_6M_7	D	-36.23	-36.23	-36.23	-36.23	-36.23	-36.23
	H	0	0	0	0	0	0
	L	0	±80.2	±80.2	0	0	0
	J	0	0	0	0	±176.4	±203
		-36.23	-116.43	+43.97	-36.23	+140.17	+166.77 -239.23

CHARLES A. MAGUIRE & ASSOCIATES INC. ENGINEERS

U_6M_1 and L_6M_1

Max. Compr. = 37.75 L_6M_1
Max. tension = 52.17 U_6M_1
$l = 17.27 \times 12 = 207''$
Try WT 5 × 16.5
$A = 4.85$ $r_{min} = r_y = 1.94$

$l/r_y = \frac{207}{1.94} = 106.6 \rightarrow F_a =$ ksi

Compr. Stress $\frac{37.75}{4.85} = 7.78 < 9.04$

tens. Stress $\frac{52.17}{4.85} = 10.77 < 16.2$ OK

(Same for U_6M_3 and L_6M_3)

U_6M_2 and L_6M_2

Max. Compr. 65.4 L_6M_2
Max. Tension 91.76 U_6M_2
$l = 16.72 \times 12 = 201''$
Try WT 5×19.5
$A = 5.74$ $r_y = 1.98$

$l/r_y = \frac{201}{1.98} = 101.5 \rightarrow F_a = 9.55$

Compr. Stress $\frac{65.4}{5.74} = 11.4 > 9.55$ N.G.

Try WT 5 × 22.5

$A = 6.62$ $r_y = 2.0$

$l/r_y = \frac{201}{2} = 100.5 \rightarrow F_a = 9.65$

Compr. Stress $\frac{65.4}{6.62} = 9.89 > 9.65$ N.G.

Try WT 5 × 24.5
$A = 7.20$ $r_y = 2.54$

$l/r_y = \frac{201}{2.54} = 79.4 \rightarrow F_a = 11.55$

Compr Stress $\frac{65.4}{7.20} = 9.1 < 11.55$

tens. stress $\frac{91.76}{7.20} = 12.73 < 16.2$ OK

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 54 OF
Design of Members — DATE Oct. 1972
COMP. AD — CHECK — CONT. NO.

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Diagonals (contd..)

Mem.	L	Non op. Case	Oper. Case I	Oper. Case II	Jamming case I	Jamming case II	Jamming case III
L_7U_6', M_7U_6', M_7L_6' and L_7L_6'	D	0	0	0	0	0	0
	H	0	0	0	0	0	0
	L	0	±41.86	±41.86	0	0	0
	J	0	0	0	0	±92.3	±107
	T	0	±41.86	±41.86	0	±92.3	±107

Vertical Members

$U_6M_6L_6$ and $U_7M_7L_7$	D	-45.67	-45.67	-45.67	-45.67	-45.67	-45.67
	H	-138.0	-90.2	+91.7	0	0	0
	L	0	±58.24	±58.24	0	0	0
	J	0	0	0	0	±256.4	±296.0
	T	-183.67	-194.11	+104.27 -12.21	-45.67	+210.73 -302.07	+250.33 -341.67
U_0L_0	D	+31.23	+31.23	+31.23	+31.23	+31.23	+31.23
	H	0	0	0	0	0	0
	L	0	±58.24	±58.24	0	0	0
	J	0	0	0	0	±129.2	±148.0
	T	+31.23	-27.01	+89.47	+31.23	+159.43	+179.23 -116.77

U_0M_6 and L_0M_6

(also U_0M_7 and L_0M_7)

Max. Compr. 239.23
Max. Tension 239.23
$\ell = 18.57 \times 12 = 223$
Try W 10x60
$A = 17.7$ $r_y = 2.57$

$\ell/r_y = \frac{223}{2.57} = 87 \rightarrow F_a = 10.5$

Compr. Stress $= \frac{239.23}{17.7} = 13.5 > 10.5$ N.G.

Try W 10x72
$A = 21.2$ $r_y = 2.59$
$\ell/r_y = \frac{223}{2.59} = 86 \rightarrow F_a = 11$

Compr. Stress $= \frac{239.23}{21.2} = 11.3 > 11$ N.G.

Try W 10x77
$A = 22.7$ $r_y = 2.6$
$\ell/r_y = \frac{223}{2.6} = 86 \rightarrow F_a = 11$
Compr. Stress $= \frac{239.23}{22.7} = 10.53 < 11$ OK

U_7U_6'

Max Compr. = 107
Max Ten = 107
$\ell = 9.7 \times 12 = 116.3$

Try W 6x25 $A = 7.35$ $r_y = 1.53$

$\ell/r_y = \frac{116.3}{1.53} = 76 \rightarrow F_a = 11.8$

Compr Stress $= \frac{107}{7.35} = 14.6 < 11.8$ N.G.

Try W 8x31 $A = 9.12$ $r_y = 2.01$ $\ell/r_y = 58 \rightarrow F_a = 13.2$

Compr Stress $= \frac{107}{9.12} = 11.85 < 13.2$ OK

Similarly use W 8x31 for M_7U_6', M_7L_6' and L_7L_6'

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 55 OF
Design of Members — DATE Oct. 1972
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$U_6M_6L_6$ and $U_7M_7L_7$

Max. Compr. = 341.67 — Try W 10x77
Max. Tension = 250.33 — A = 22.7 — r_y = 2.60
l = 13.5 x 12 = 162

$l/r_y = \frac{162}{2.6} = 62.5 \rightarrow F_a = 12.9$

Compr Stress $= \frac{341.67}{22.7} = 15 > 12.9$ N.G.

Try W 10x100 — A = 29.4 — r_y = 2.65

$l/r_y = \frac{162}{2.65} = 61.3 \rightarrow F_a = 13$

Compr. Stress $\frac{341.67}{29.4} = 11.62 < 13$ OK

U_0L_0 (One for each truss A)

Max. Compr = 116.77
Max Ten = 179.23
l = 27 2x1.6 = 23.9 x12 = 286

Try W 8x48 — A = 14.1 — r_y = 2.04

$l/r_y = \frac{286}{2.04} = 140 \rightarrow F_a = 5.7$

Compr. Stress $\frac{116.77}{14.1} = 8.78 > 5.7$ N.G.

Try W 8x67 — A = 19.7 — r_y = 2.12

$l/r_y = \frac{286}{2.12} = 135 \rightarrow F_a = 6.1$

Compr Stress $= \frac{116.77}{19.7} = 5.94 < 6.1$

tens Stress $\frac{179.23}{19.7} = 9.11 < 16.2$

Lighter section can be used ... try W 10x49

A = 14.4 — r_y = 2.54 — $l/r_y = \frac{286}{2.54} = 112.7 \rightarrow F_a = 8.43$

Compr. Stress $= \frac{116.77}{14.4} = 8.11 < 8.43$

tens. Stress $= \frac{179.23}{14.4} = 12.47 < 16.2$ OK

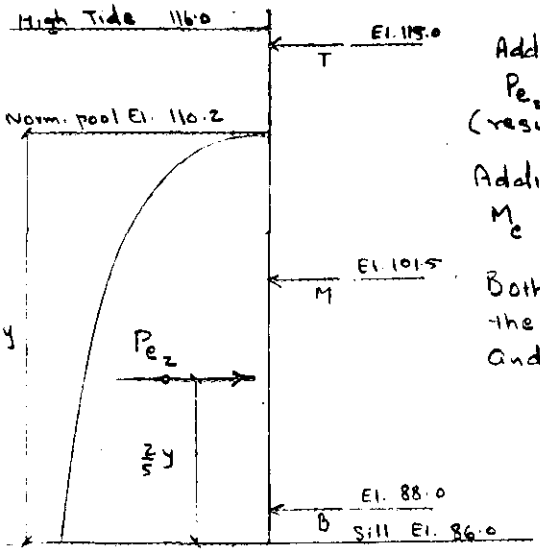
PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End — SHEET NO. 56 OF
Hydrodynamic Forces — DATE Oct. 11 1972
COMP. AD — CHECK — CONT. NO.

A 99

Check Effect of Hydrodynamic Force

The effect of Earthquake on the gates is to increase water press. due to earthquake acceleration

Use Westergaard Formula to estimate additional water press. and additional moment (EM 1110-2-2200)



Additional water press

$P_{e_z} = \frac{2}{3} C_e \alpha y \sqrt{hy}$ # / foot width of structure
(resultant of parabolic press. distr.)

Additional Mom. @ depth y

$M_e = \frac{4}{15} C_e \alpha y^2 \sqrt{hy}$ #ft / foot width of structure

Both these formulae are based on assumption that the structure is cantilever fixed @ bottom sill and applicable for $0 \leq y \leq 24.2$

For earthquake zone 3 $\alpha = .1$
(ratio of earthquake acc. 'a' to g)

h = ht. of structure = 31
t_e = 1 sec.

$$C_e = \frac{51}{\sqrt{1 - .72\left(\frac{h}{1000 t_e}\right)^2}} = \frac{51}{\sqrt{1 - .72\left(\frac{31}{1000 \times 1}\right)^2}} \simeq 51$$

Front Vertical Beams

Max. moments occur @ support M and lower midspan however this will call for an exact analysis so for simplification face beams will be assumed conservatively to be cantilever fixed @ plane where moment is investigated.

@ plane M $y = 110.2 - 101.5 = 8.7$

additional moment $M_e = \left(\frac{4}{15}\right)(51)(.1)(8.7)^2\sqrt{31 \times 8.7}$ (6.6' width)

$= 11150$ 1# $= 11.15$ 'k

Mom due to hydrostatic load case I @ M = 129.9 'k int. beam (sh. 4)

% increase 8.6 < 33⅓ % increase in allowable stresses

PROJECT Charles River Dam ACC. NO. 1856.31
SUBJECT Large Lock Gates - Tide End SHEET NO. 57 OF
Hydrodynamic Forces DATE Oct. 1972
COMP. AD CHECK CONT. NO.

A 100

@ plane where max. pos. mom. occurs due to hydrostatic load Case I (Sh.6)

$y = 8.7 + 7.25 = 15.95'$

additional moment $M_e = (\frac{4}{15})(51)(.1)(15.95)^2\sqrt{(31)(15.95)}$ (6.6' width)

$= 50,500 = 50.5$ 'k

Mom. due to hyd. load @ this plane $= 132$ 'k (Sh. 6)

total mom. $= 132 + 50.5 = 182.5$ 'k

$f_b = \frac{182.5 \times 12}{10.4} = 21.1 < 1.33 \times 16.2 = 21.6$

Effect of Hydrodynamic loads on Truss members

total additional load will be estimated and compared with total hydrostatic load If the increase is very small then it does not warrant any rigorous analysis

$P_{e_2} = (\frac{2}{3})(51)(.1)(24.2)(\sqrt{(31)(24.2)})(6.6)$ ← total increase/front vert. beam

$= 14,920$ # $= 14.92$ k

Total hydrostatic load / front vert. beam $= 196.28$ k Case I (Sh. 5)

% increase $= 7.6$ % as against $33\frac{1}{3}$% increase allowed for final design load

with Case II $\frac{14.92}{107.78} = 13.75$ % (Sh. 23)

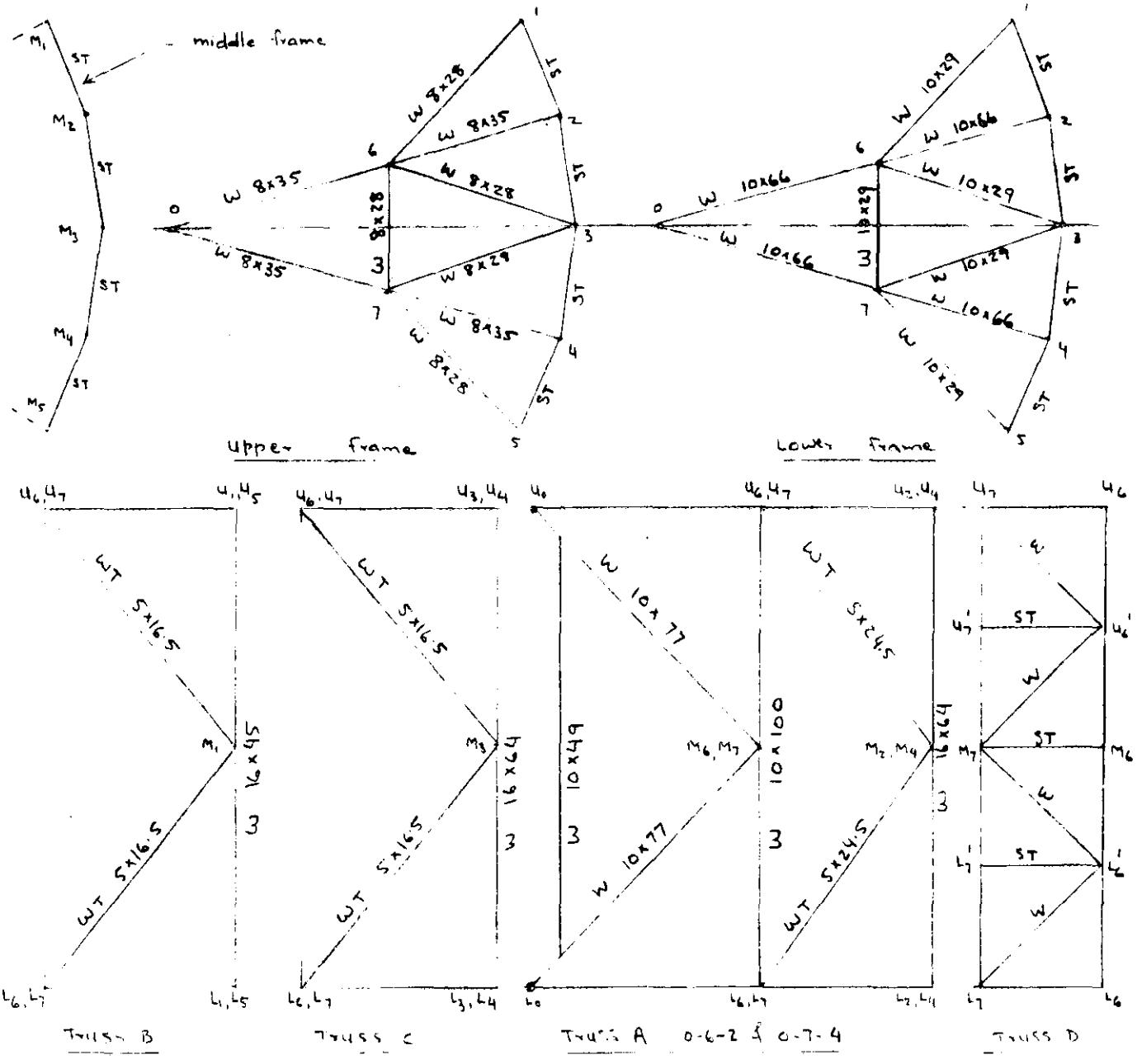
Thus effect of Hydrodynamic loads on this structure is not very significant and certainly well within allowable. ✓

Ref: ASCE Transactions Vol. 98 1933 pp. 418-433

PROJECT Charles River Dam ACC. NO. 195631
SUBJECT Large Lock Gates - Tide End SHEET NO. 58 OF
Design Summary DATE Oct. 1972
COMP. AD CHECK CONT. NO.

A101

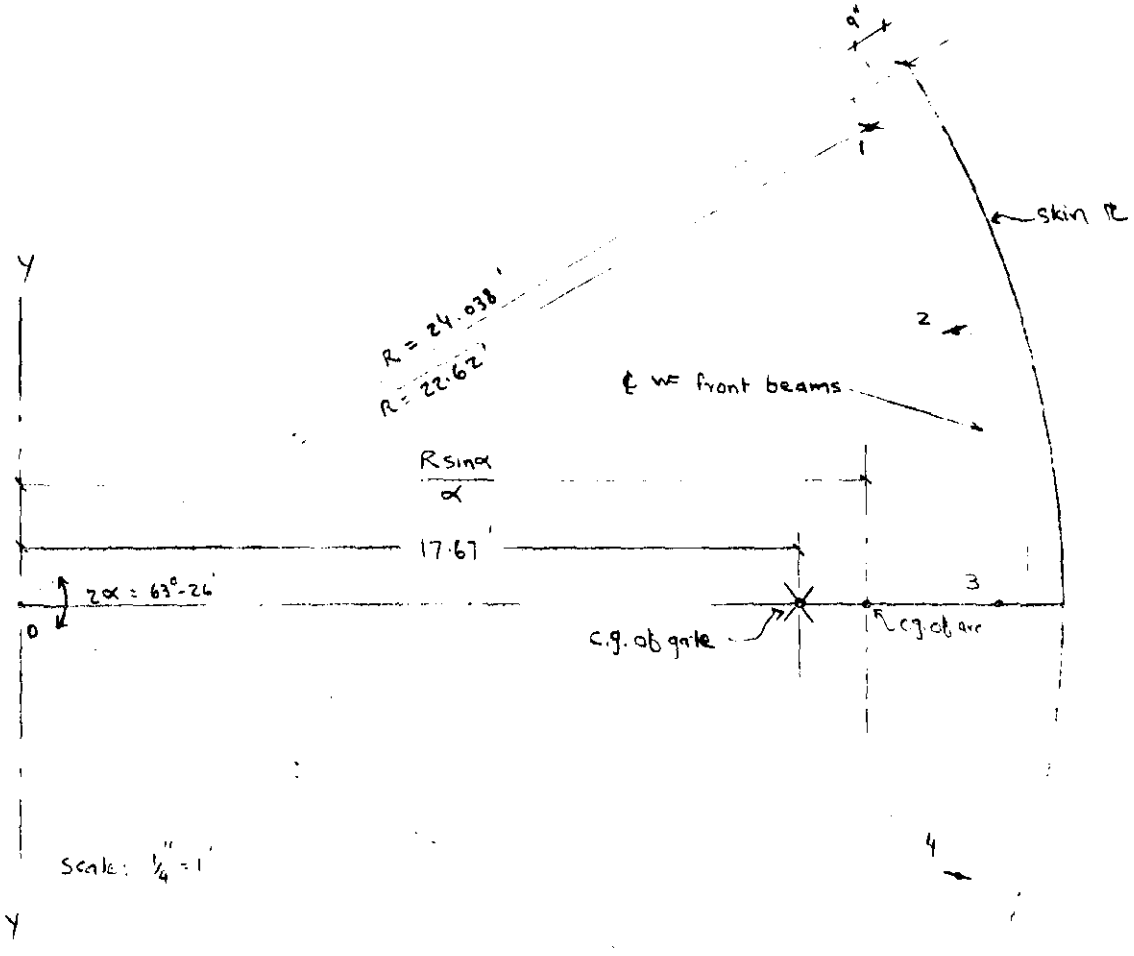
ST = ST 5x12.7
W = W 8x31



PROJECT Charles River Dam
SUBJECT Large Lock Gates - Tide End
C.g. of Gate
COMP. AD CHECK

ACC. NO. 1856.31
SHEET NO. 59 OF
DATE Oct. 16 1972
CONT. NO.

A102



c.g. of any symm. arc of radius R
$= \frac{R \sin\alpha}{\alpha}$ from center of circle

PROJECT Charles River Dam — ACC. NO. 1856.31

SUBJECT Large Lock Gates - Tide End — SHEET NO. 60 OF ____

Wgt. and c.g. of gate — DATE Oct. 16 1972

COMP. AD — CHECK RE — CONT. NO. ____

A 103

Summary Table

(data from sh. 10, 11, 14, 50 thru 53 and 57)

Truss	Member	Design load	Control case	Size	total length ft.	Wgt. lb	Arm ft.	M_{xx} ft lb.
	U_6U_1 and U_7U_5	69.2 C	Jamm.	W 8x28	2x10.77 = 21.54	603.12	15.884	9579.96
	U_6U_3 and U_7U_3	65.54 C	"	W 8x28	2x10.93 = 21.86	612.08	17.442	10,675.90
U	U_6U_7	51.24 C	"	W 8x28	6.97	195.16	12.264	2393.44
	U_6U_0 and U_7U_0	164.72 T	Hyd.	W 8x35	2x12.75 = 25.50	892.50	6.132	5472.81
	U_6U_2 and U_7U_4	13.05 T	"	W 8x35	2x9.87 = 19.74	690.90	17.011	11,752.90
	U_1U_2 and U_4U_5	24.13 C	H	ST 5x12.7	2x5.73 = 11.46	145.54	20.628	3,002.20
	U_2U_3 and U_3U_4	24.24 C	H	ST 5x12.7	2x6.24 = 12.48	158.50	22.187	3516.96
	L_6L_1 and L_7L_5	74.33 C	Jamm.	W 10x29	2x10.77 = 21.54	624.66	15.884	9922.10
	L_6L_3 and L_7L_3	55.4 C	Hyd	W 10x29	2x10.93 = 21.86	633.94	17.442	11,057.18
L	L_6L_7	60.89 C	Jamm	W 10x29	6.97	202.13	12.264	2479.32
	L_6L_0 and L_7L_0	257 T, 701 C	Hyd.	W 10x66	2x12.75 = 25.50	1683.00	6.132	10,320.16
	L_6L_2 and L_7L_4	95.67 T	"	W 10x66	2x9.87 = 19.74	1302.84	17.011	22,162.61
	L_1L_2 and L_4L_5	16.55 C	Jamm.	ST 5x12.7	2x5.73 = 11.46	145.54	20.628	3002.20
	L_2L_3 and L_3L_4	19.28 C	"	ST 5x12.7	2x6.24 = 12.48	158.50	22.187	3516.96
M	M_1M_2 and M_4M_5	16.23 C	Hyd.	ST 5x12.7	2x5.73 = 11.46	145.54	20.628	3002.20
	M_2M_3 and M_3M_4	16.23 C	"	ST 5x12.7	2x6.24 = 12.48	158.50	22.187	3516.96
B	U_6M_1, L_6M_1, U_7M_5 & L_7M_5	37.15 C	Hyd	WT 5x16.5	4x17.21 = 69.08	1139.82	15.884	18,104.70
C	U_6M_3, L_6M_3, U_7M_3 & L_7M_3	35.68 C	"	WT 5x16.5	4x17.37 = 69.48	1146.42	17.442	19,995.86
A	U_6M_2, L_6M_2, U_7M_4 & L_7M_4	65.4 C, 91.8 T	"	WT 5x24.5	4x16.72 = 66.88	1639.56	17.011	27,973.54
A	U_6M_6, L_6M_6, U_0M_7 & L_0M_7	239.22 C	Jamm.	W 10x77	4x18.51 = 74.28	5719.56	6.132	35,072.34
D	U_7U_6', M_7U_6', M_7L_6' & L_7L_6'	107 C	"	W 8x31	4x7.7 = 38.8	1207.80	12.264	14,751.14
	$U_7'U_6'$, M_7M_6 & $L_7'L_6'$	0	—	ST 5x12.7	3x6.77 = 20.91	265.56	12.264	3256.83
A	$U_6M_6L_6$ and $U_7M_7L_7$	341.67 C	"	W 10x100	2x27 = 54	5400.0	12.264	66,225.60
	U_0L_0	116.77 C	"	W 10x49	2x23.8 = 47.6	2332.4	1.50	3,498.60
						27,197.57		304,152.27
	U_1L_1 and U_5L_5	—	—	W 16x45	2x31 = 62	2790.0	19.503	54,413.37
	U_2L_2 and U_4L_4	—	—	W 16x64	2x31 = 62	3968.0	21.758	86,335.74
	U_3L_3	—	—	W 16x64	31	1984.0	22.62	44,878.08
	Vert. stiffners	—	—	ST 9x27.35	2x31 = 62	1695.7	20.203	34,2[illegible].22
	"			ST 9x27.35	2x31 = 62	1695.7	22.758	38,57[illegible].74
	"			ST 9x27.35	31	847.85	23.66	20,06[illegible].13
	face beams	—	—	ST 9x27.35	17x26.61 = 452.37	12,372.3	22.59	279,490.26
	3/8" Skin PL	—	—	—	31x26.61 = 824.91	12,621.1	22.95	289,654.25
						65,172.22	—	1,151,833.06

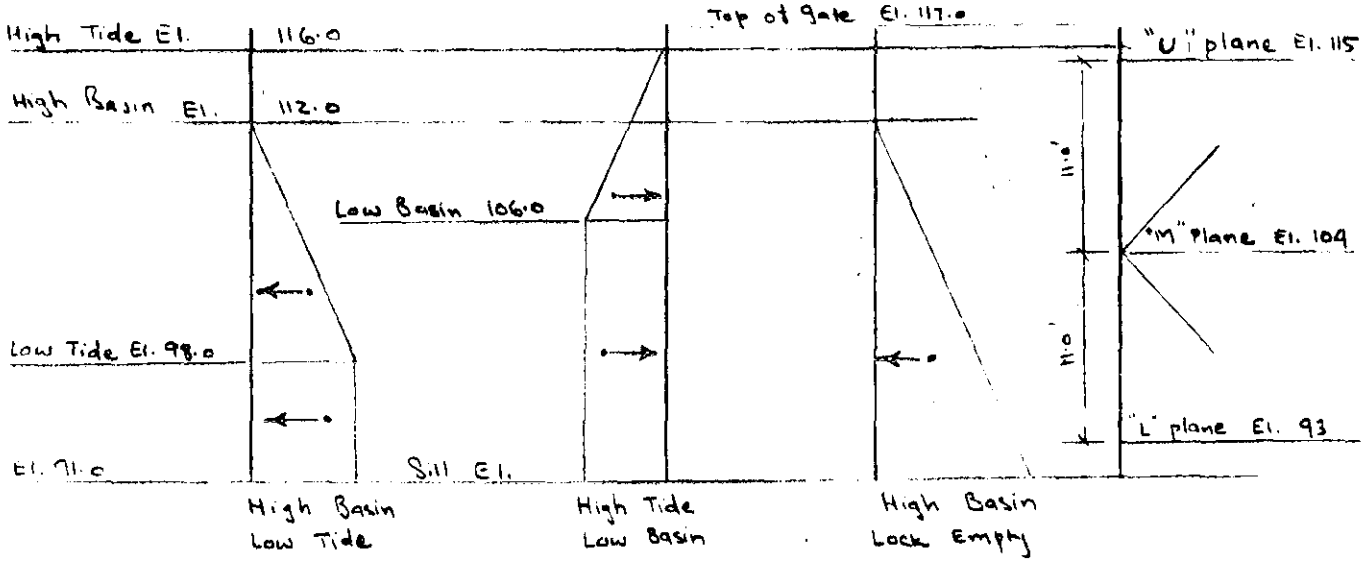
Wgt. of gate = 65.17 + 10% Misc. 71.68 Say 72 K.

(trusses, skin PL, front beams, face beams included; trash rack, walkway, seals excluded)

c.g. of gate = $\frac{1,151,833.06}{65,172.22}$ = 17.67' from hinge located on ℄ of gate

PROJECT Charles River Dam — ACC. NO. 1856.31
SUBJECT Large Lock Gates - Basin End — SHEET NO. 61 OF
Design — DATE Oct. 1972
COMP. AD — CHECK RE — CONT. NO.

A104



Compare these hydrostatic cases with that @ tide end & can be seen that Tide End is critical one so for the basin end same design is adopted.

However spacing of free beams (horiz. Tees) may be increased

water pressure @ Sill $w = .064 \times 21 = 1.345$ k/ft/ft (Sh. 7)

Try spacing 2'

$M = \frac{1.345 \times (1.75)^2}{10} = .41$ $\qquad f_b = \frac{.41 \times 12}{.281} = 17.55 > 16.2$ N.G.

Try spacing 1'-9"

$M = \frac{1.345 \times (1.5)^2}{10} = .303$ $\qquad f_b = \frac{.303 \times 12}{.281} = 12.9 < 16.2$

use 4 sp. @ 1'-9" = 7'

water pressure @ 7' up from Sill $\qquad w = .064 \times 14 = .895$ k/ft

Try 2' spacing

$M = \frac{(.895)(1.75)^2}{10} = .274$ $\qquad f_b = \frac{.274 \times 12}{.281} = 11.7 < 16.2$

use 4 sp. @ 2' = 8'

PROJECT Charles River Dam — ACC. NO. 19-6.31
SUBJECT Large Lock Gates - Basin End Design — SHEET NO. 62 OF
DATE Oct. 1972
COMP. AD — CHECK — CONT. NO.

A105

water pressure @ 15' up from sill $w = .064 \times 6 = .385$ k/ft

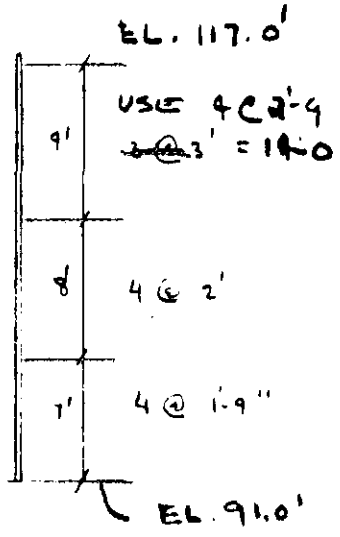
Try Spacing 2'-6"

$M = \frac{(.385)(2.25)^2}{10} = .195$ $\quad f_b = \frac{.195 \times 12}{.281} = 8.4 < 16.2$

Try Spacing 3'-0

$M = \frac{(.385)(2.75)^2}{10} = .291$ $\quad f_b = \frac{.291 \times 12}{.281} = 12.4 < 16.2$

Use 3 sp. @ 3' = 9



NOTE USING THIS SPACING THERE IS TWO FEET OF GATE LEFT OUT. ?

3 @ 3'-0" = 9-0
4 @ 2-0 = 8-0
4 @ 1-9 = 7-0
24-0

TOP OF GATE EL. 117.0'
BOT OF GATE EL. 91.0
26.0

FOR TOP SPACING USE 4 @ 2'-9'

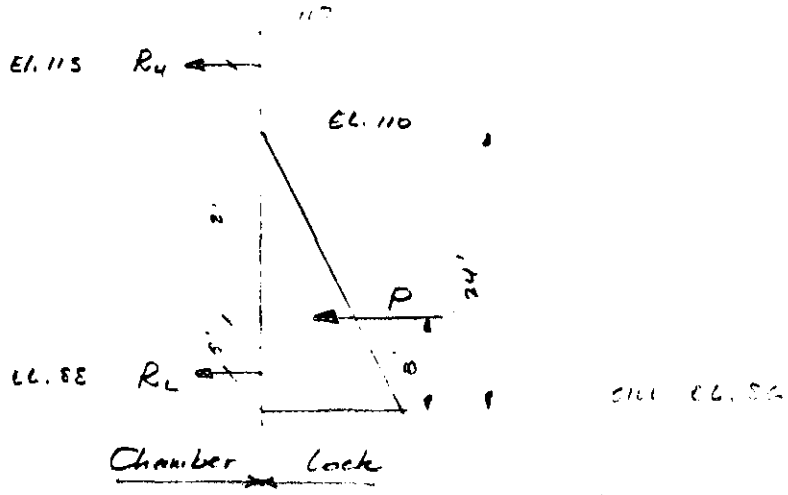
USING 4 @ 2-9 = 11-0
4 @ 2-0 = 8-0
4 @ 1-9 = 7-0
26-0

JAB 11-22

PROJECT CHARLES RIVER DAM – LARGE LOCK GATE ACC. NO.
SUBJECT BEARING LOADS SHEET NO. 63 OF
DATE 10/27 1972
COMP. CE CHECK CONT. NO. 1856.31

A106

Determine Bearing load for the non operating maintenance condition with stop logs in place, gate chambers empty and water in lock at El. 110 (mean high tide).



$P = \frac{1}{2} \times 0.0[illegible] \times 24^2 (24.34') = 450^k$

$R_u = \frac{6}{27} \times 450 = 100^k$

$R_L = \frac{21}{27} \times 450 = 350^k$

Compression on support

PROJECT CHARLES RIVER DAM — ACC. NO.
SUBJECT GATE BEARING REACTIONS LARGE LOCK — SHEET NO. 64 OF
DATE 10/27 19 72
COMP. L.E. CHECK JR — CONT. NO. 1856.31

A 106 A

LARGE LOCK GATES - TIDE END

Ref.: sh. 48 "Tabulation of Stresses" Oct. 1972 by A.D.

REACTIONS AT EL. 115 (Upper Bearing) $R_v = 125^k$ (Vertical Dead Load)

MAX. COMPR. (PUSH) →

D.L. Hydrost. (Non-Op.)	68 ←		32^k
	100 →		
	32 →		
D.L. Hydrost. (Oper.) Link	68 ←		82^k *
	124 →	↑ 22	
	23 →		
	79 →		
D.L. Jamming	68 ←		0
	56 →	↑ 15	
	12 ← (tension)		

MAX. TENSION (PULL) ←

D.L. Hydrost. (Non-Op.) Stop	68 ←		325^k
	212 ←	↓ 22	
	45 ←		
	325 ←		
D.L. Hydrost. (Oper.) Link	68 ←		250^k
	158 ←	↓ 22	
	23 ←		
	249 ←		
D.L. Jamming	68 ←		134^k
	56 ←	↓ 15	
	124 ←		

REACTIONS AT EL. 88 (Lower Bearing) $R_v = 0$

D.L. Hydrost. (Non-Op.)	68 →		418^k
	350 →		
	418 →		
D.L. Hydrost. (Oper.)	68 →		382^k
	313 →	↑ 15 (Link)	
	381 →		
D.L. Jamming	68 →		133^k
	43 →	↑ 73 (Jam)	
	111 →		

D.L. Hydrost. (Non-op.)	68 →		448^k
	516 ←		
	448 ←		
D.L. Hydrost. (Oper.)	68 →		183^k
	250 ←	↓ 15 (Link)	
	182 ←		
D.L. Jamming	68 →		0
	43 ←	↓ 73 (Jam)	
	25 → (tension)		

* Operating Force also equals non-operating

INDEX

1) STAGE 1 - No Earthquake p. A108 - A114

2) STAGE 1 - With Earthquake p. A115 - A121

3) STAGE 2 - Fill Concrete Neglected
no earthquake, summary sheet p. A122

4) STAGE 2 - Fill Concrete Neglected
with earthquake, summary sheet p. A123

5) STAGE 2 - Fill Concrete Included
no earthquake, summary sheet p. A124

6) STAGE 2 - Fill Concrete Included
with earthquake, summary sheet p. A125

CHAR TS RIVER LOCKS 1579.60 L.E. DEC. 8, 1971 STAGE 1

NUMBER OF NODAL POINTS = 44
NUMBER OF LOADING CASES = 2

NODAL POINT COORDINATES

NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE
1	0.00000E 00	2	0.25000E 01	3	0.44928E 01	4	0.72857E 01	5	0.96735E 01	6	0.12071E 02
7	0.14464E 02	8	0.16857E 02	9	0.19250E 02	10	0.21642E 02	11	0.24035E 02	12	0.26428E 02
13	0.28821E 02	14	0.31214E 02	15	0.33607E 02	16	0.36000E 02	17	0.38500E 02	18	0.41000E 02
19	0.43500E 02	20	0.46000E 02	21	0.48500E 02	22	0.51000E 02	23	0.53500E 02	24	0.56000E 02
25	0.58500E 02	26	0.61000E 02	27	0.63500E 02	28	0.66000E 02	29	0.68500E 02	30	0.71000E 02
31	0.73500E 02	32	0.76000E 02	33	0.78458E 02	34	0.80916E 02	35	0.83375E 02	36	0.85833E 02
37	0.88291E 02	38	0.90749E 02	39	0.93208E 02	40	0.95666E 02	41	0.98124E 02	42	0.10058E 03
43	0.10304E 03	44	0.10550E 03								

ELEMENT PROPERTIES

ELMT	LENGTH(L)	THICKNESS(B)	HEIGHT(H)	MODULUS(E)	SUBGRADE MODULUS(KS)
1	0.25000E 01	0.10000E 01	0.14000E 02	0.50400E 06	0.17280E 03
2	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
3	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
4	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
5	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
6	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
7	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
8	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
9	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
10	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
11	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
12	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
13	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
14	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
15	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
16	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
17	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
18	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
19	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
20	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
21	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
22	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
23	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
24	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
25	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
26	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
27	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
28	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
29	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
30	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
31	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
32	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
33	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
34	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
35	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
36	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03

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37    24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.1728    03
38    24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.1728    03
39 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
40 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
41 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
42 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
43 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
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DISTRIBUTED WINKLER SPRINGS
ITERATIONS TO REMOVE TENSION

```
CHARI   RIVER LOCKS  1579.60  L.E.  DEC. 8, 1971   STAGE 1
LOAD .  DEAD LOAD OF LARGE LOCK ONLY  - NO WATER


FOR LOADING NUMBER     1 THERE ARE
             0 POINT LOADS
             4 DISTRIBUTED LOADS
             0 POINT MOVENTS
DISTRIBUTED LOAD = -0.12000E 01 FROM X =  0.00000E 00 TO X =  0.25000E 01
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.25000E 01 TO X =  0.36000E 02
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.76000E 02 TO X =  0.10550E 03
DISTRIBUTED LOAD = -0.90000E 00 FROM X =  0.00000E 00 TO X =  0.10550E 03
```

CHAR RIVER LOCKS 1579.60 L.E. DEC. 8, 1971 STAGE 1
LOAD DEAD LOAD OF LARGE LOCK ONLY - NO WATER

DISPLACEMENTS FORCES AND MOMENTS

NODE	SETTLEMENT (Y)	ROTATION THETA	SOIL REACTIONS LEFT	SOIL REACTIONS RIGHT	SHEARS LEFT	SHEARS RIGHT	MOMENTS LEFT	MOMENTS RIGHT
1	-0.14953E-01	0.76276E-04		-0.25839E 01		0.13515E 01		0.59960E 00
2	-0.14762E-01	0.76293E-04	-0.25510E 01	-0.25510E 01	-0.13535E 01	0.34750E 01	0.22792E 01	0.59252E 01
3	-0.14580E-01	0.76301E-04	-0.25194E 01	-0.25194E 01	-0.11601E 02	0.20500E 02	0.22538E 02	0.70190E 01
4	-0.14397E-01	0.76316E-04	-0.24879E 01	-0.24879E 01	-0.20626E 02	0.16801E 02	0.41600E 02	-0.10670E 02
5	-0.14214E-01	0.76343E-04	-0.24563E 01	-0.24563E 01	-0.16927E 02	0.14212E 02	0.52721E 02	-0.34513E 02
6	-0.14032E-01	0.76393E-04	-0.24247E 01	-0.24247E 01	-0.14339E 02	0.22329E 02	0.76722E 02	-0.54403E 02
7	-0.13849E-01	0.76469E-04	-0.23931E 01	-0.23931E 01	-0.22518E 02	0.25379E 02	0.11506E 03	-0.95200E 02
8	-0.13666E-01	0.76580E-04	-0.23615E 01	-0.23615E 01	-0.25568E 02	0.20315E 02	0.15716E 03	-0.13572E 03
9	-0.13482E-01	0.76730E-04	-0.23298E 01	-0.23298E 01	-0.20503E 02	0.16980E 02	0.19343E 03	-0.18426E 03
10	-0.13298E-01	0.76915E-04	-0.22980E 01	-0.22980E 01	-0.17169E 02	0.15330E 02	0.22902E 03	-0.21751E 03
11	-0.13114E-01	0.77130E-04	-0.22662E 01	-0.22662E 01	-0.15518E 02	0.11441E 02	0.26246E 03	-0.24969E 03
12	-0.12929E-01	0.77364E-04	-0.22342E 01	-0.22342E 01	-0.11629E 02	0.47324E 01	0.27561E 03	-0.25399E 03
13	-0.12744E-01	0.77600E-04	-0.22022E 01	-0.22022E 01	-0.49213E 01	-0.60908E 01	0.27301E 03	-0.25987E 03
14	-0.12558E-01	0.77827E-04	-0.21701E 01	-0.21701E 01	0.59023E 01	-0.67949E 01	0.24925E 03	-0.23804E 03
15	-0.12372E-01	0.78037E-04	-0.21378E 01	-0.21378E 01	0.66684E 01	-0.19965E 02	0.23309E 03	-0.21351E 03
16	-0.12185E-01	0.78214E-04	-0.21055E 01	-0.21055E 01	0.19839E 02	-0.25711E 02	0.18222E 03	-0.16594E 03
17	-0.11939E-01	0.11508E-03	-0.20631E 01	-0.20631E 01	0.25711E 02	-0.22832E 02	0.10163E 03	-0.10162E 03
18	-0.11623E-01	0.13522E-03	-0.20085E 01	-0.20085E 01	0.22832E 02	-0.20042E 02	0.44535E 02	-0.44543E 02
19	-0.11275E-01	0.14059E-03	-0.19484E 01	-0.19484E 01	0.20041E 02	-0.17424E 02	-0.55778E 01	0.55849E 01
20	-0.10931E-01	0.13304E-03	-0.18889E 01	-0.18889E 01	0.17424E 02	-0.14952E 02	-0.49186E 02	0.49214E 02
21	-0.10620E-01	0.11433E-03	-0.18351E 01	-0.18351E 01	0.14952E 02	-0.12631E 02	-0.86612E 02	0.86663E 02
22	-0.10367E-01	0.86099E-04	-0.17915E 01	-0.17915E 01	0.12615E 02	-0.10404E 02	-0.11822E 03	0.11826E 03
23	-0.10195E-01	0.49928E-04	-0.17618E 01	-0.17618E 01	0.10404E 02	-0.82482E 01	-0.14425E 03	0.14428E 03
24	-0.10123E-01	0.73241E-05	-0.17493E 01	-0.17493E 01	0.82325E 01	-0.61273E 01	-0.16491E 03	0.16495E 03
25	-0.10163E-01	-0.40249E-04	-0.17562E 01	-0.17562E 01	0.61271E 01	-0.39976E 01	-0.18031E 03	0.18037E 03
26	-0.10327E-01	-0.91330E-04	-0.17846E 01	-0.17846E 01	0.39976E 01	-0.17857E 01	-0.19035E 03	0.19040E 03
27	-0.10621E-01	-0.14441E-03	-0.18354E 01	-0.18354E 01	0.17857E 01	0.56519E 00	-0.19484E 03	0.19487E 03
28	-0.11049E-01	-0.19792E-03	-0.19094E 01	-0.19094E 01	-0.56519E 00	0.30836E 01	-0.19350E 03	0.19357E 03
29	-0.11610E-01	-0.25020E-03	-0.20063E 01	-0.20063E 01	-0.30836E 01	0.58615E 01	-0.18585E 03	0.18593E 03
30	-0.12298E-01	-0.29942E-03	-0.21251E 01	-0.21251E 01	-0.58615E 01	0.89151E 01	-0.17130E 03	0.17137E 03
31	-0.13103E-01	-0.34358E-03	-0.22642E 01	-0.22642E 01	-0.89151E 01	0.12332E 02	-0.14911E 03	0.14921E 03
32	-0.14010E-01	-0.38046E-03	-0.24209E 01	-0.24209E 01	-0.12332E 02	0.14863E 02	-0.11840E 03	0.11540E 03
33	-0.14945E-01	-0.38055E-03	-0.25826E 01	-0.25826E 01	-0.14992E 02	0.18873E 02	-0.80441E 02	0.10131E 03
34	-0.15881E-01	-0.38061E-03	-0.27443E 01	-0.27443E 01	-0.19126E 02	0.27148E 02	-0.39367E 02	0.61121E 02
35	-0.16817E-01	-0.38064E-03	-0.29059E 01	-0.29059E 01	-0.27527E 02	0.16796E 02	-0.87578E 01	0.33392E 02
36	-0.17752E-01	-0.38066E-03	-0.30676E 01	-0.30676E 01	-0.17175E 02	0.44785E 01	0.15156E 01	0.20460E 02
37	-0.18688E-01	-0.38067E-03	-0.32294E 01	-0.32294E 01	-0.48574E 01	0.80683E 01	0.39218E 01	0.17031E 02
38	-0.19624E-01	-0.38067E-03	-0.33911E 01	-0.33911E 01	-0.83222E 01	0.10230E 02	-0.43750E 00	0.10425E 02
39	-0.20560E-01	-0.38067E-03	-0.35528E 01	-0.35528E 01	-0.10609E 02	0.25097E 01	0.17101E 02	-0.19472E 01
40	-0.21496E-01	-0.38067E-03	-0.37145E 01	-0.37145E 01	-0.28906E 01	0.96113E 01	-0.31445E 01	0.17171E 02
41	-0.22432E-01	-0.38068E-03	-0.38762E 01	-0.38762E 01	-0.98571E 01	0.40878E 01	0.15937E 01	0.24601E 02
42	-0.23367E-01	-0.38069E-03	-0.40379E 01	-0.40379E 01	-0.43437E 01	0.39277E 01	-0.65468E 01	0.15847E 02
43	-0.24303E-01	-0.38070E-03	-0.41996E 01	-0.41996E 01	-0.43066E 01	0.93730E 01	-0.43046E 01	0.16005E 02
44	-0.25239E-01	-0.38070E-03	-0.43614E 01		-0.96269E 01		0.13011E 02	

A-111

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CHA   S RIVER LOCKS  1579.60  L.E.  DEC. 8, 1971   STAGE 1
LOAD _  WATER AT 98 IN LARGE LOCK WITH UPLIFT

FOR LOADING NUMBER    2 THERE ARE
              0 POINT LOADS
              5 DISTRIBUTED LOADS
              2 POINT MOMENTS
DISTRIBUTED LOAD = -0.12000E 01 FROM X =  0.00000E 00 TO X =  0.25000E 01
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.25000E 01 TO X =  0.36000E 02
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.76000E 02 TO X =  0.10550E 03
DISTRIBUTED LOAD = -0.90000E 00 FROM X =  0.36000E 02 TO X =  0.76000E 02
DISTRIBUTED LOAD =  0.38000E 00 FROM X =  0.00000E 00 TO X =  0.10550E 03
MOMENT =  0.48000E 02 AT X =  0.36000E 02
MOMENT = -0.48000E 02 AT X =  0.76000E 02
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CHAR RIVER LOCKS 1579.60 L.E. DEC. 8, 1971 STAGE 1
LOAD , WATER AT 98 IN LARGE LOCK WITH UPLIFT

DISPLACEMENTS FORCES AND MOMENTS

NODE	SETTLEMENT (Y)	ROTATION THETA	SOIL REACTIONS LEFT	SOIL REACTIONS RIGHT	SHEARS LEFT	SHEARS RIGHT	MOMENTS LEFT	MOMENTS RIGHT
1	-0.11197E-01	0.80211E-04		-0.19348E 01		0.18739E 01		0.11062E 01
2	-0.10996E-01	0.80241E-04	-0.19002E 01	-0.19002E 01	-0.18759E 01	0.28261E 01	0.39526E 01	-0.55327E 01
3	-0.10804E-01	0.80250E-04	-0.18670E 01	-0.18670E 01	-0.29521E 01	0.12315E 02	0.16122E 02	-0.11696E 02
4	-0.10612E-01	0.80269E-04	-0.18338E 01	-0.18338E 01	-0.12504E 02	0.95981E 01	0.33668E 02	-0.21838E 02
5	-0.10420E-01	0.80302E-04	-0.18006E 01	-0.18006E 01	-0.97871E 01	0.16663E 02	0.52286E 02	-0.40705E 02
6	-0.10228E-01	0.80355E-04	-0.17674E 01	-0.17674E 01	-0.16851E 02	0.16386E 02	0.76963E 02	-0.67212E 02
7	-0.10035E-01	0.80431E-04	-0.17341E 01	-0.17341E 01	-0.20575E 02	0.19636E 02	0.10557E 03	-0.95349E 02
8	-0.98432E-02	0.80537E-04	-0.17009E 01	-0.17009E 01	-0.19762E 02	0.23563E 02	0.14367E 03	-0.12720E 03
9	-0.96503E-02	0.80675E-04	-0.16675E 01	-0.16675E 01	-0.23689E 02	0.14253E 02	0.18084E 03	-0.16978E 03
10	-0.94571E-02	0.80840E-04	-0.16341E 01	-0.16341E 01	-0.14442E 02	0.13232E 02	0.20204E 03	-0.19818E 03
11	-0.92634E-02	0.81030E-04	-0.16007E 01	-0.16007E 01	-0.13359E 02	0.14360E 02	0.22780E 03	-0.21532E 03
12	-0.90693E-02	0.81235E-04	-0.15671E 01	-0.15671E 01	-0.14486E 02	0.83196E 01	0.24684E 03	-0.22900E 03
13	-0.88747E-02	0.81443E-04	-0.15335E 01	-0.15335E 01	-0.85087E 01	0.48828E-02	0.23749E 03	-0.22906E 03
14	-0.86795E-02	0.81645E-04	-0.14998E 01	-0.14998E 01	-0.19384E 00	-0.34116E 01	0.22387E 03	-0.22101E 03
15	-0.84839E-02	0.81836E-04	-0.14660E 01	-0.14660E 01	0.32226E 01	-0.95043E 01	0.20759E 03	-0.19924E 03
16	-0.82879E-02	0.82001E-04	-0.14321E 01	-0.14321E 01	0.93154E 01	-0.19212E 02	0.17051E 03	-0.11288E 03
17	-0.80495E-02	0.10649E-03	-0.13909E 01	-0.13909E 01	0.19212E 02	-0.17024E 02	0.64874E 02	-0.64636E 02
18	-0.77659E-02	0.11849E-03	-0.13419E 01	-0.13419E 01	0.17024E 02	-0.14981E 02	0.22278E 02	-0.22266E 02
19	-0.74662E-02	0.11946E-03	-0.12901E 01	-0.12901E 01	0.14981E 02	-0.13068E 02	-0.15187E 02	0.15182E 02
20	-0.71765E-02	0.11078E-03	-0.12401E 01	-0.12401E 01	0.13068E 02	-0.11264E 02	-0.47837E 02	0.47841E 02
21	-0.69193E-02	0.93722E-04	-0.11956E 01	-0.11956E 01	0.11264E 02	-0.95772E 01	-0.76003E 02	0.76007E 02
22	-0.67139E-02	0.69477E-04	-0.11601E 01	-0.11601E 01	0.95772E 01	-0.79733E 01	-0.99954E 02	0.99947E 02
23	-0.65769E-02	0.39185E-04	-0.11365E 01	-0.11365E 01	0.79732E 01	-0.64330E 01	-0.11989E 03	0.11990E 03
24	-0.65221E-02	0.39285E-05	-0.11270E 01	-0.11270E 01	0.64330E 01	-0.49244E 01	-0.13598E 03	0.13600E 03
25	-0.65606E-02	-0.35247E-04	-0.11336E 01	-0.11336E 01	0.49243E 01	-0.33761E 01	-0.14831E 03	0.14835E 03
26	-0.67008E-02	-0.77295E-04	-0.11578E 01	-0.11578E 01	0.33761E 01	-0.17840E 01	-0.15681E 03	0.15684E 03
27	-0.69485E-02	-0.12113E-03	-0.12007E 01	-0.12007E 01	0.17838E 01	-0.79963E-01	-0.16131E 03	0.16134E 03
28	-0.73070E-02	-0.16562E-03	-0.12626E 01	-0.12626E 01	0.79715E-01	0.17727E 01	-0.16154E 03	0.16159E 03
29	-0.77762E-02	-0.20954E-03	-0.13437E 01	-0.13437E 01	-0.17727E 01	0.38286E 01	-0.15717E 03	0.15723E 03
30	-0.83531E-02	-0.25155E-03	-0.14434E 01	-0.14434E 01	-0.38291E 01	0.61454E 01	-0.14763E 03	0.14771E 03
31	-0.90311E-02	-0.29013E-03	-0.15605E 01	-0.15605E 01	-0.61454E 01	0.87439E 01	-0.13233E 03	0.13245E 03
32	-0.97996E-02	-0.32361E-03	-0.16933E 01	-0.16933E 01	-0.87439E 01	0.95546E 01	-0.11054E 03	0.62703E 02
33	-0.10595E-01	-0.32356E-03	-0.18308E 01	-0.18308E 01	-0.96835E 01	0.13357E 02	-0.32593E 02	0.44457E 02
34	-0.11390E-01	-0.32368E-03	-0.19683E 01	-0.19683E 01	-0.13485E 02	0.94824E 01	-0.10085E 02	0.20095E 02
35	-0.12186E-01	-0.32369E-03	-0.21058E 01	-0.21058E 01	-0.76113E 01	0.66542E 01	0.84414E 01	0.11414E 02
36	-0.12982E-01	-0.32368E-03	-0.22433E 01	-0.22433E 01	-0.69101E 01	0.81230E 01	0.18328E 02	0.98046E 00
37	-0.13778E-01	-0.32367E-03	-0.23808E 01	-0.23808E 01	-0.82539E 01	0.15097E 01	0.17710E 02	-0.11855E 01
38	-0.14573E-01	-0.32367E-03	-0.25183E 01	-0.25183E 01	-0.16386E 01	0.20527E 01	0.11128E 02	-0.53730E 01
39	-0.15369E-01	-0.32366E-03	-0.26558E 01	-0.26558E 01	-0.21816E 01	-0.78125E-02	0.15253E 02	0.43574E 01
40	-0.16165E-01	-0.32365E-03	-0.27933E 01	-0.27933E 01	-0.37304E 00	0.69492E 01	0.13714E 02	0.12433E 02
41	-0.16960E-01	-0.32365E-03	-0.29308E 01	-0.29308E 01	-0.72050E 01	0.17498E 02	0.11117E 02	0.27453E 02
42	-0.17756E-01	-0.32366E-03	-0.30683E 01	-0.30683E 01	-0.17876E 02	0.18945E 02	0.64062E 01	0.17443E 02
43	-0.18552E-01	-0.32367E-03	-0.32058E 01	-0.32058E 01	-0.19199E 02	0.12724E 02	0.58867E 01	0.15054E 02
44	-0.19347E-01	-0.32367E-03	-0.33433E 01		-0.12980E 02		0.10859E 02	

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CHARLE RIVER LOCKS 1579.60 L.E. DEC. 8, 1971 STAGE 1

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR				LEFT MOMENT				RIGHT MOMENT				RESISTING MOMENT	
	LEFT		RIGHT		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		LEFT	RIGHT
1			1.87	2			1.10	2			0.00	0		3941.94
2	-1.87	2	3.47	1	3.95	2	0.00	0	5.92	1	-5.53	2	3941.94	34012.55
3	-2.95	2	20.50	1	22.53	1	0.00	0	7.01	1	-11.69	2	34012.55	34012.55
4	-12.50	2	16.80	1	41.60	1	0.00	0	0.00	0	-21.88	2	34012.55	34012.55
5	-9.78	2	16.66	2	52.72	1	0.00	0	0.00	0	-40.70	2	34012.55	34012.55
6	-16.85	2	22.32	1	76.96	2	0.00	0	0.00	0	-67.21	2	34012.55	34012.55
7	-20.57	2	25.37	1	115.06	1	0.00	0	0.00	0	-95.34	2	34012.55	34012.55
8	-19.76	2	23.56	2	157.16	1	0.00	0	0.00	0	-135.72	1	34012.55	34012.55
9	-23.68	2	16.98	1	198.43	1	0.00	0	0.00	0	-184.26	1	34012.55	34012.55
10	-14.44	2	15.33	1	229.02	1	0.00	0	0.00	0	-217.51	1	34012.55	34012.55
11	-13.35	2	14.36	2	262.46	1	0.00	0	0.00	0	-249.69	1	34012.55	34012.55
12	-14.48	2	8.31	2	275.61	1	0.00	0	0.00	0	-253.99	1	34012.55	34012.55
13	-8.50	2	0.00	2	273.01	1	0.00	0	0.00	0	-259.87	1	34012.55	34012.55
14	5.90	1	-3.41	2	249.25	1	0.00	0	0.00	0	-238.04	1	34012.55	34012.55
15	6.66	1	-9.50	2	233.09	1	0.00	0	0.00	0	-213.51	1	34012.55	34012.55
16	19.83	1	-19.21	2	182.22	1	0.00	0	0.00	0	-165.94	1	34012.55	642.99
17	25.71	1	-17.02	2	101.63	1	0.00	0	0.00	0	-101.62	1	642.99	642.99
18	22.83	1	-14.98	2	44.53	1	0.00	0	0.00	0	-44.54	1	642.99	642.99
19	20.04	1	-13.06	2	0.00	0	-15.18	2	15.18	2	0.00	0	642.99	642.99
20	17.42	1	-11.26	2	0.00	0	-49.19	1	49.21	1	0.00	0	642.99	642.99
21	14.95	1	-9.57	2	0.00	0	-86.61	1	86.66	1	0.00	0	642.99	642.99
22	12.61	1	-7.97	2	0.00	0	-118.22	1	118.26	1	0.00	0	642.99	642.99
23	10.40	1	-6.43	2	0.00	0	-144.25	1	144.28	1	0.00	0	642.99	642.99
24	8.23	1	-4.92	2	0.00	0	-164.91	1	164.95	1	0.00	0	642.99	642.99
25	6.12	1	-3.37	2	0.00	0	-180.31	1	180.37	1	0.00	0	642.99	642.99
26	3.99	1	-1.78	2	0.00	0	-190.35	1	190.40	1	0.00	0	642.99	642.99
27	1.78	1	0.56	1	0.00	0	-194.84	1	194.87	1	0.00	0	642.99	642.99
28	0.07	2	3.08	1	0.00	0	-193.50	1	193.57	1	0.00	0	642.99	642.99
29	-1.77	2	5.86	1	0.00	0	-185.85	1	185.93	1	0.00	0	642.99	642.99
30	-3.82	2	8.91	1	0.00	0	-171.30	1	171.37	1	0.00	0	642.99	642.99
31	-6.14	2	12.33	1	0.00	0	-149.11	1	149.21	1	0.00	0	642.99	642.99
32	-8.74	2	14.86	1	0.00	0	-118.40	1	115.40	1	0.00	0	642.99	34012.55
33	-9.68	2	18.87	1	0.00	0	-80.44	1	101.31	1	0.00	0	34012.55	34012.55
34	-13.48	2	27.14	1	0.00	0	-39.36	1	61.12	1	0.00	0	34012.55	34012.55
35	-9.61	2	16.79	1	8.44	2	-8.75	1	33.38	1	0.00	0	34012.55	34012.55
36	-6.91	2	8.12	2	18.32	2	0.00	0	20.46	1	0.00	0	34012.55	34012.55
37	-8.25	2	8.06	1	17.71	2	0.00	0	17.03	1	-1.18	2	34012.55	34012.55
38	-1.63	2	10.23	1	11.12	2	-0.43	1	10.42	1	-5.37	2	34012.55	34012.55
39	-2.18	2	2.50	1	17.10	1	0.00	0	4.35	2	-1.94	1	34012.55	34012.55
40	-0.37	2	9.61	1	13.71	2	-3.14	1	17.17	1	0.00	0	34012.55	34012.55
41	-7.20	2	17.49	2	11.11	2	0.00	0	27.45	2	0.00	0	34012.55	34012.55
42	-17.87	2	18.94	2	6.40	2	-6.54	1	17.44	2	0.00	0	34012.55	34012.55
43	-19.19	2	12.72	2	5.88	2	-4.30	1	16.00	1	0.00	0	34012.55	34012.55
44	-12.98	2			13.01	1			0.00	0			34012.55	

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C.F . DEC8, 1971 L.E. WITH EARTHQUAKE STAGE 1

NUMBER OF NODAL POINTS = 44
NUMBER OF LOADING CASES = 2

NODAL POINT COORDINATES

NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE	NODE	COORDINATE
1	0.00000E 00	2	0.25000E 01	3	0.48928E 01	4	0.72857E 01	5	0.96785E 01	6	0.12071E 02
7	0.14464E 02	8	0.16857E 02	9	0.19250E 02	10	0.21642E 02	11	0.24035E 02	12	0.26428E 02
13	0.28821E 02	14	0.31214E 02	15	0.33607E 02	16	0.36000E 02	17	0.38500E 02	18	0.41000E 02
19	0.43500E 02	20	0.46000E 02	21	0.48500E 02	22	0.51000E 02	23	0.53500E 02	24	0.56000E 02
25	0.58500E 02	26	0.61000E 02	27	0.63500E 02	28	0.66000E 02	29	0.68500E 02	30	0.71000E 02
31	0.73500E 02	32	0.76000E 02	33	0.78458E 02	34	0.80916E 02	35	0.83375E 02	36	0.85833E 02
37	0.88291E 02	38	0.90749E 02	39	0.93208E 02	40	0.95666E 02	41	0.98124E 02	42	0.10058E 03
43	0.10304E 03	44	0.10550E 03								

ELEMENT PROPERTIES

ELMT	LENGTH(L)	THICKNESS(B)	HEIGHT(H)	MODULUS(E)	SUBGRADE MODULUS(KS)
1	0.25000E 01	0.10000E 01	0.14000E 02	0.50400E 06	0.17280E 03
2	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
3	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
4	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
5	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
6	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
7	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
8	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
9	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
10	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
11	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
12	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
13	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
14	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
15	0.23928E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
16	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
17	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
18	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
19	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
20	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
21	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
22	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
23	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
24	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
25	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
26	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
27	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
28	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
29	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
30	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
31	0.25000E 01	0.10000E 01	0.60000E 01	0.50400E 06	0.17280E 03
32	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
33	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
34	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
35	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03
36	0.24583E 01	0.10000E 01	0.40000E 02	0.50400E 06	0.17280E 03

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 37  24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280    3
 38    4583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
 39 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
 40 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
 41 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
 42 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03
 43 0.24583E 01 0.10000E 01 0.40000E 02 0.50400E 06 0.17280E 03

DISTRIBUTED WINKLER SPRINGS
ITERATIONS TO REMOVE TENSION
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C.R.   DEC8, 1971 L.E. WITH EARTHQUAKE STAGE 1
LOAD .  DEAD LOAD OF LARGE LOCK ONLY  - NO WATER

FOR LOADING NUMBER     1 THERE ARE
              0 POINT LOADS
              4 DISTRIBUTED LOADS
              4 POINT MOMENTS
DISTRIBUTED LOAD = -0.12000E 01 FROM X =  0.00000E 00 TO X =  0.25000E 01
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.25000E 01 TO X =  0.36000E 02
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.76000E 02 TO X =  0.10550E 03
DISTRIBUTED LOAD = -0.90000E 00 FROM X =  0.00000E 00 TO X =  0.10550E 03
MOMENT =  0.13300E 03 AT X =  0.25000E 01
MOMENT =  0.13300E 03 AT X =  0.36000E 02
MOMENT =  0.11900E 03 AT X =  0.76000E 02
MOMENT =  0.11900E 03 AT X =  0.10550E 03
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C.R.L. 29, 1971 L.E. WITH EARTHQUAKE STAGE 1
LOAD 1 DAD LOAD OF LARGE LOCK ONLY - NO WATER

DISPLACEMENTS FORCES AND MOMENTS

NODE	SETTLEMENT (Y)	ROTATION THETA	SOIL REACTIONS LEFT	SOIL REACTIONS RIGHT	SHEARS LEFT	SHEARS RIGHT	MOMENTS LEFT	MOMENTS RIGHT
1	-0.16227E-01	0.12327E-03		-0.28040E 01		0.14687E 01		0.84179E 00
2	-0.15918E-01	0.12330E-03	-0.27507E 01	-0.27507E 01	-0.14727E 01	0.21035E 02	0.28242E 01	0.14856E 03
3	-0.15624E-01	0.12319E-03	-0.26998E 01	-0.26998E 01	-0.21225E 02	0.18308E 02	-0.10062E 03	0.12777E 03
4	-0.15329E-01	0.12309E-03	-0.26489E 01	-0.26489E 01	-0.18499E 02	0.25256E 02	-0.93695E 02	0.11970E 03
5	-0.15034E-01	0.12301E-03	-0.25980E 01	-0.25980E 01	-0.25384E 02	0.29919E 02	-0.59218E 02	0.84321E 02
6	-0.14740E-01	0.12296E-03	-0.25471E 01	-0.25471E 01	-0.30110E 02	0.25846E 02	-0.31982E 02	0.41291E 02
7	-0.14446E-01	0.12294E-03	-0.24963E 01	-0.24963E 01	-0.26037E 02	0.33582E 02	0.10332E 02	-0.30468E 00
8	-0.14152E-01	0.12297E-03	-0.24455E 01	-0.24455E 01	-0.33772E 02	0.27800E 02	0.70765E 02	-0.58202E 02
9	-0.13857E-01	0.12306E-03	-0.23946E 01	-0.23946E 01	-0.27991E 02	0.25873E 02	0.12434E 03	-0.10813E 03
10	-0.13563E-01	0.12318E-03	-0.23437E 01	-0.23437E 01	-0.26062E 02	0.22523E 02	0.17936E 03	-0.16716E 03
11	-0.13268E-01	0.12336E-03	-0.22927E 01	-0.22927E 01	-0.22713E 02	0.16509E 02	0.21805E 03	-0.19562E 03
12	-0.12972E-01	0.12356E-03	-0.22417E 01	-0.22417E 01	-0.16700E 02	0.12390E 02	0.25961E 03	-0.23008E 03
13	-0.12676E-01	0.12378E-03	-0.21905E 01	-0.21905E 01	-0.12518E 02	0.28105E 01	0.26533E 03	-0.24689E 03
14	-0.12380E-01	0.12400E-03	-0.21393E 01	-0.21393E 01	-0.29384E 01	-0.62500E 00	0.25495E 03	-0.24345E 03
15	-0.12083E-01	0.12422E-03	-0.20880E 01	-0.20880E 01	0.49707E 00	-0.14193E 02	0.25021E 03	-0.23917E 03
16	-0.11785E-01	0.12442E-03	-0.20366E 01	-0.20366E 01	0.14003E 02	-0.19740E 02	0.21339E 03	-0.65952E 02
17	-0.11457E-01	0.13579E-03	-0.19799E 01	-0.19799E 01	0.19740E 02	-0.17048E 02	0.16569E 02	-0.16561E 02
18	-0.11117E-01	0.13448E-03	-0.19211E 01	-0.19211E 01	0.17048E 02	-0.14497E 02	-0.26075E 02	0.26087E 02
19	-0.10794E-01	0.12230E-03	-0.18652E 01	-0.18652E 01	0.14497E 02	-0.12087E 02	-0.62307E 02	0.62331E 02
20	-0.10513E-01	0.12096E-03	-0.18167E 01	-0.18167E 01	0.12087E 02	-0.97892E 01	-0.92543E 02	0.92564E 02
21	-0.10295E-01	0.72081E-04	-0.17791E 01	-0.17791E 01	0.97890E 01	-0.76039E 01	-0.11737E 03	0.11738E 03
22	-0.10158E-01	0.37190E-04	-0.17553E 01	-0.17553E 01	0.76037E 01	-0.54542E 01	-0.13613E 03	0.13615E 03
23	-0.10113E-01	-0.22084E-05	-0.17476E 01	-0.17476E 01	0.54541E 01	-0.33216E 01	-0.14979E 03	0.14985E 03
24	-0.10171E-01	-0.44651E-04	-0.17576E 01	-0.17576E 01	0.33215E 01	-0.11925E 01	-0.15817E 03	0.15827E 03
25	-0.10338E-01	-0.88680E-04	-0.17864E 01	-0.17864E 01	0.11924E 01	0.10089E 01	-0.16126E 03	0.16137E 03
26	-0.10615E-01	-0.13280E-03	-0.18343E 01	-0.18343E 01	-0.10091E 01	0.33504E 01	-0.15883E 03	0.15890E 03
27	-0.11001E-01	-0.17543E-03	-0.19009E 01	-0.19009E 01	-0.33506E 01	0.58548E 01	-0.15052E 03	0.15059E 03
28	-0.11499E-01	-0.21491E-03	-0.19854E 01	-0.19854E 01	-0.58550E 01	0.85592E 01	-0.13594E 03	0.13603E 03
29	-0.12071E-01	-0.24945E-03	-0.20859E 01	-0.20859E 01	-0.85592E 01	0.11520E 02	-0.11465E 03	0.11470E 03
30	-0.12731E-01	-0.27710E-03	-0.21999E 01	-0.21999E 01	-0.11520E 02	0.14776E 02	-0.85923E 02	0.85996E 02
31	-0.13449E-01	-0.29570E-03	-0.23240E 01	-0.23240E 01	-0.14776E 02	0.18310E 02	-0.49047E 02	0.49144E 02
32	-0.14200E-01	-0.30294E-03	-0.24538E 01	-0.24538E 01	-0.18310E 02	0.20378E 02	-0.33439E 01	0.11775E 03
33	-0.14945E-01	-0.30302E-03	-0.25825E 01	-0.25825E 01	-0.20507E 02	0.25687E 02	-0.70230E 02	0.83460E 02
34	-0.15690E-01	-0.30307E-03	-0.27112E 01	-0.27112E 01	-0.25941E 02	0.25923E 02	-0.20578E 02	0.37097E 02
35	-0.16435E-01	-0.30307E-03	-0.28400E 01	-0.28400E 01	-0.26179E 02	0.24828E 02	0.30175E 02	-0.61816E 01
36	-0.17180E-01	-0.30304E-03	-0.29687E 01	-0.29687E 01	-0.24958E 02	0.12656E 02	0.56396E 02	-0.38757E 02
37	-0.17925E-01	-0.30299E-03	-0.30975E 01	-0.30975E 01	-0.13037E 02	0.13207E 02	0.66734E 02	-0.51115E 02
38	-0.18670E-01	-0.30293E-03	-0.32262E 01	-0.32262E 01	-0.13585E 02	0.19697E 02	0.83269E 02	-0.67119E 02
39	-0.19414E-01	-0.30285E-03	-0.33548E 01	-0.33548E 01	-0.19953E 02	0.13248E 02	0.11151E 03	-0.84630E 02
40	-0.20159E-01	-0.30276E-03	-0.34835E 01	-0.34835E 01	-0.13628E 02	0.14148E 02	0.11173E 03	-0.77080E 02
41	-0.20903E-01	-0.30267E-03	-0.36121E 01	-0.36121E 01	-0.14404E 02	0.62578E 01	0.11658E 03	-0.92703E 02
42	-0.21647E-01	-0.30258E-03	-0.37406E 01	-0.37406E 01	-0.65117E 01	0.15669E 02	0.10359E 03	-0.88242E 02
43	-0.22391E-01	-0.30249E-03	-0.38691E 01	-0.38691E 01	-0.15923E 02	0.60625E 01	0.12101E 03	-0.10877E 03
44	-0.23134E-01	-0.30238E-03	-0.39976E 01		-0.64414E 01		0.12695E 03	

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C.R.L  DECR. 1971 L.E. WITH EARTHQUAKE STAGE 1
LOAD     WATER AT 9A IN LARGE LOCK WITH UPLIFT
1

FOR LOADING NUMBER     2 THERE ARE
                 0 POINT LOADS
                 5 DISTRIBUTED LOADS
                 6 POINT MOMENTS
DISTRIBUTED LOAD = -0.17000E 01 FROM X =  0.00000E 00 TO X =  0.25000E 01
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.25000E 01 TO X =  0.36000E 02
DISTRIBUTED LOAD = -0.40000E 01 FROM X =  0.76000E 02 TO X =  0.10550E 03
DISTRIBUTED LOAD = -0.90000E 00 FROM X =  0.36000E 02 TO X =  0.76000E 02
DISTRIBUTED LOAD =  0.38000E 00 FROM X =  0.00000E 00 TO X =  0.10550E 03
MOMENT =  0.49000E 02 AT X =  0.36000E 02
MOMENT = -0.48000E 02 AT X =  0.76000E 02
MOMENT =  0.13300E 03 AT X =  0.25000E 01
MOMENT =  0.13300E 03 AT X =  0.36000E 02
MOMENT =  0.11900E 03 AT X =  0.76000E 02
MOMENT =  0.11900E 03 AT X =  0.10550E 03
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C.R.L. DEC8, 1971 L.E. WITH EARTHQUAKE STAGE 1
LOAD WATER AT 98 IN LARGE LOCK WITH UPLIFT

DISPLACEMENTS FORCES AND MOMENTS

NODE	SETTLEMENT (Y)	ROTATION THETA	SOIL REACTIONS LEFT	SOIL REACTIONS RIGHT	SHEARS LEFT	SHEARS RIGHT	MOMENTS LEFT	MOMENTS RIGHT
1	-0.12470E-01	0.12721E-03		-0.21549E 01		0.22214E 01		0.83367E 00
2	-0.12152E-01	0.12724E-03	-0.21000E 01	-0.21000E 01	-0.22235E 01	0.71640E 01	0.42181E 01	0.13434E 03
3	-0.11848E-01	0.12714E-03	-0.20474E 01	-0.20474E 01	-0.72919E 01	0.13277E 02	-0.10619E 03	0.11954E 03
4	-0.11544E-01	0.12704E-03	-0.19948E 01	-0.19948E 01	-0.13466E 02	0.17372E 02	-0.91404E 02	0.10700E 03
5	-0.11240E-01	0.12697E-03	-0.19423E 01	-0.19423E 01	-0.21500E 02	0.19625E 02	-0.61367E 02	0.76648E 02
6	-0.10936E-01	0.12692E-03	-0.18898E 01	-0.18898E 01	-0.19753E 02	0.28013E 02	-0.29453E 02	0.45408E 02
7	-0.10632E-01	0.12691E-03	-0.18373E 01	-0.18373E 01	-0.28140E 02	0.23927E 02	0.13566E 02	0.50683E 00
8	-0.10329E-01	0.12693E-03	-0.17848E 01	-0.17848E 01	-0.24117E 02	0.26761E 02	0.58013E 02	-0.45788E 02
9	-0.10025E-01	0.12700E-03	-0.17323E 01	-0.17323E 01	-0.26888E 02	0.27171E 02	0.11042E 03	-0.92694E 02
10	-0.97214E-02	0.12711E-03	-0.16798E 01	-0.16798E 01	-0.27362E 02	0.20911E 02	0.15311E 03	-0.14159E 03
11	-0.94170E-02	0.12726E-03	-0.16272E 01	-0.16272E 01	-0.21101E 02	0.15540E 02	0.18943E 03	-0.17720E 03
12	-0.91123E-02	0.12743E-03	-0.15746E 01	-0.15746E 01	-0.15729E 02	0.12401E 02	0.21558E 03	-0.19891E 03
13	-0.88072E-02	0.12762E-03	-0.15218E 01	-0.15218E 01	-0.12590E 02	0.93496E 01	0.23179E 03	-0.21393E 03
14	-0.85015E-02	0.12782E-03	-0.14690E 01	-0.14690E 01	-0.95390E 01	0.35771E 01	0.23149E 03	-0.22302E 03
15	-0.81954E-02	0.12802E-03	-0.14161E 01	-0.14161E 01	-0.37675E 01	-0.69765E 01	0.22781E 03	-0.22139E 03
16	-0.78888E-02	0.12821E-03	-0.13632E 01	-0.13632E 01	0.67871E 01	-0.13236E 02	0.20083E 03	-0.12894E 02
17	-0.75677E-02	0.12720E-03	-0.13077E 01	-0.13077E 01	0.13236E 02	-0.11253E 02	-0.20200E 02	0.20205E 02
18	-0.72598E-02	0.11775E-03	-0.12545E 01	-0.12545E 01	0.11263E 02	-0.94295E 01	-0.48363E 02	0.48348E 02
19	-0.69848E-02	0.10118E-03	-0.12069E 01	-0.12069E 01	0.94294E 01	-0.77105E 01	-0.71933E 02	0.71920E 02
20	-0.67588E-02	0.78708E-04	-0.11679E 01	-0.11679E 01	0.77104E 01	-0.60978E 01	-0.91205E 02	0.91206E 02
21	-0.65952E-02	0.51473E-04	-0.11396E 01	-0.11396E 01	0.60978E 01	-0.45564E 01	-0.10645E 03	0.10644E 03
22	-0.65045E-02	0.20568E-04	-0.11239E 01	-0.11239E 01	0.45563E 01	-0.30389E 01	-0.11784E 03	0.11783E 03
23	-0.64946E-02	-0.12951E-04	-0.11222E 01	-0.11222E 01	0.30389E 01	-0.15301E 01	-0.12543E 03	0.12544E 03
24	-0.65706E-02	-0.48047E-04	-0.11354E 01	-0.11354E 01	0.15300E 01	0.87909E-02	-0.12927E 03	0.12931E 03
25	-0.67353E-02	-0.83679E-04	-0.11638E 01	-0.11638E 01	-0.89149E-02	0.16215E 01	-0.12928E 03	0.12933E 03
26	-0.69885E-02	-0.11876E-03	-0.12076E 01	-0.12076E 01	-0.16215E 01	0.33427E 01	-0.12530E 03	0.12534E 03
27	-0.73277E-02	-0.15215E-03	-0.12662E 01	-0.12662E 01	-0.33427E 01	0.52005E 01	-0.11699E 03	0.11703E 03
28	-0.77469E-02	-0.18261E-03	-0.13386E 01	-0.13386E 01	-0.52007E 01	0.72528E 01	-0.10402E 03	0.10408E 03
29	-0.82372E-02	-0.20979E-03	-0.14233E 01	-0.14233E 01	-0.72531E 01	0.95128E 01	-0.85945E 02	0.86016E 02
30	-0.87861E-02	-0.22922E-03	-0.15182E 01	-0.15182E 01	-0.95128E 01	0.11996E 02	-0.62230E 02	0.62310E 02
31	-0.93772E-02	-0.24225E-03	-0.16203E 01	-0.16203E 01	-0.11996E 02	0.14745E 02	-0.32276E 02	0.32354E 02
32	-0.99897E-02	-0.24609E-03	-0.17262E 01	-0.17262E 01	-0.14745E 02	0.16253E 02	0.45095E 01	0.63572E 02
33	-0.10594E-01	-0.24613E-03	-0.18307E 01	-0.18307E 01	-0.16382E 02	0.13228E 02	-0.23105E 02	0.28115E 02
34	-0.11199E-01	-0.24614E-03	-0.19353E 01	-0.19353E 01	-0.13357E 02	0.13314E 02	0.10980E 02	-0.10298E 02
35	-0.11804E-01	-0.24612E-03	-0.20399E 01	-0.20399E 01	-0.13445E 02	0.15587E 02	0.41902E 02	-0.34640E 02
36	-0.12409E-01	-0.24607E-03	-0.21444E 01	-0.21444E 01	-0.15716E 02	0.93593E 01	0.71468E 02	-0.48999E 02
37	-0.13014E-01	-0.24600E-03	-0.22489E 01	-0.22489E 01	-0.96152E 01	0.78300E 01	0.90800E 02	-0.67693E 02
38	-0.13619E-01	-0.24593E-03	-0.23534E 01	-0.23534E 01	-0.80839E 01	0.12546E 02	0.97113E 02	-0.76406E 02
39	-0.14223E-01	-0.24584E-03	-0.24579E 01	-0.24579E 01	-0.12677E 02	0.36035E 01	0.11693E 03	-0.94814E 02
40	-0.14828E-01	-0.24574E-03	-0.25623E 01	-0.25623E 01	-0.77324E 01	0.83886E 01	0.11287E 03	-0.10005E 03
41	-0.15432E-01	-0.24565E-03	-0.26666E 01	-0.26666E 01	-0.85175E 01	0.44433E 01	0.10839E 03	-0.89216E 02
42	-0.16036E-01	-0.24555E-03	-0.27710E 01	-0.27710E 01	-0.46992E 01	0.72128E 01	0.11756E 03	-0.10600E 03
43	-0.16639E-01	-0.24545E-03	-0.28753E 01	-0.28753E 01	-0.74687E 01	0.17910E 02	0.11273E 03	-0.10521E 03
44	-0.17242E-01	-0.24535E-03	-0.29795E 01		-0.18291E 02		0.12982E 03	

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C.R.L ECB. 1971 L.E. WITH EARTHQUAKE STAGE 1

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR				LEFT MOMENT				RIGHT MOMENT				RESISTING MOMENT	
	LEFT		RIGHT		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		LEFT	RIGHT
1			2.22	2			0.84	1			0.00	0		3941.94
2	-2.22	2	21.03	1	4.21	2	0.00	0	148.56	1	0.00	0	3941.94	34012.55
3	-7.29	2	18.30	1	0.00	0	-106.19	2	127.77	1	0.00	0	34012.55	34012.55
4	-13.46	2	25.25	1	0.00	0	-93.69	1	119.70	1	0.00	0	34012.55	34012.55
5	-21.50	2	29.91	1	0.00	0	-61.36	2	84.32	1	0.00	0	34012.55	34012.55
6	-19.75	2	28.01	2	0.00	0	-31.98	1	45.40	2	0.00	0	34012.55	34012.55
7	-28.14	2	33.58	1	13.56	2	0.00	0	0.50	2	-0.30	1	34012.55	34012.55
8	-24.11	2	27.80	1	70.76	1	0.00	0	0.00	0	-58.20	1	34012.55	34012.55
9	-26.88	2	27.17	2	124.34	1	0.00	0	0.00	0	-108.13	1	34012.55	34012.55
10	-27.36	2	22.52	1	179.36	1	0.00	0	0.00	0	-167.16	1	34012.55	34012.55
11	-21.10	2	16.50	1	218.05	1	0.00	0	0.00	0	-199.62	1	34012.55	34012.55
12	-15.72	2	12.40	2	259.61	1	0.00	0	0.00	0	-230.08	1	34012.55	34012.55
13	-12.59	2	9.34	2	265.33	1	0.00	0	0.00	0	-246.89	1	34012.55	34012.55
14	-9.53	2	3.57	2	254.95	1	0.00	0	0.00	0	-243.45	1	34012.55	34012.55
15	-3.76	2	-6.97	2	250.21	1	0.00	0	0.00	0	-239.17	1	34012.55	34012.55
16	14.00	1	-13.23	2	213.39	1	0.00	0	0.00	0	-65.95	1	34012.55	642.99
17	19.74	1	-11.26	2	16.56	1	-20.20	2	20.20	2	-16.56	1	642.99	642.99
18	17.04	1	-9.42	2	0.00	0	-48.36	2	48.34	2	0.00	0	642.99	642.99
19	14.49	1	-7.71	2	0.00	0	-71.93	2	71.92	2	0.00	0	642.99	642.99
20	12.08	1	-6.09	2	0.00	0	-92.54	1	92.56	1	0.00	0	642.99	642.99
21	9.78	1	-4.55	2	0.00	0	-117.07	1	117.08	1	0.00	0	642.99	642.99
22	7.60	1	-3.03	2	0.00	0	-136.13	1	136.15	1	0.00	0	642.99	642.99
23	5.45	1	-1.53	2	0.00	0	-149.79	1	149.85	1	0.00	0	642.99	642.99
24	3.32	1	0.00	2	0.00	0	-158.17	1	158.27	1	0.00	0	642.99	642.99
25	1.19	1	1.62	2	0.00	0	-161.26	1	161.37	1	0.00	0	642.99	642.99
26	-1.62	2	3.35	1	0.00	0	-158.83	1	158.90	1	0.00	0	642.99	642.99
27	-3.34	2	5.85	1	0.00	0	-150.52	1	150.59	1	0.00	0	642.99	642.99
28	-5.20	2	8.55	1	0.00	0	-135.94	1	136.03	1	0.00	0	642.99	642.99
29	-7.25	2	11.52	1	0.00	0	-114.65	1	114.70	1	0.00	0	642.99	642.99
30	-9.51	2	14.77	1	0.00	0	-85.92	1	85.99	1	0.00	0	642.99	642.99
31	-11.99	2	18.31	1	0.00	0	-49.04	1	49.14	1	0.00	0	642.99	642.99
32	-14.74	2	20.37	1	4.50	2	-3.34	1	117.75	1	0.00	0	642.99	34012.55
33	-16.38	2	25.68	1	0.00	0	-70.23	1	83.46	1	0.00	0	34012.55	34012.55
34	-13.35	2	25.92	1	10.98	2	-20.57	1	37.08	1	-10.29	2	34012.55	34012.55
35	-13.44	2	24.82	1	41.90	2	0.00	0	0.00	0	-34.64	2	34012.55	34012.55
36	-15.71	2	12.65	1	71.46	2	0.00	0	0.00	0	-48.59	2	34012.55	34012.55
37	-9.61	2	13.20	1	90.80	2	0.00	0	0.00	0	-67.69	2	34012.55	34012.55
38	-8.08	2	19.69	1	97.11	2	0.00	0	0.00	0	-76.40	2	34012.55	34012.55
39	-12.67	2	13.24	1	116.93	2	0.00	0	0.00	0	-94.81	2	34012.55	34012.55
40	-7.73	2	14.14	1	112.87	2	0.00	0	0.00	0	-100.05	2	34012.55	34012.55
41	-8.51	2	6.25	1	116.58	1	0.00	0	0.00	0	-92.70	1	34012.55	34012.55
42	-4.69	2	15.66	1	117.56	2	0.00	0	0.00	0	-106.00	2	34012.55	34012.55
43	-7.46	2	17.91	2	121.01	1	0.00	0	0.00	0	-108.77	1	34012.55	34012.55
44	-18.29	2			129.82	2			0.00	0			34012.55	

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CHARL RIVER LOCKS 1579.60 L.F. DEC. 8, 1971 STAGE 2 FILL C RETE NEGLECTED

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR				LEFT MOMENT				RIGHT MOMENT				RESISTING MOMENT	
	LEFT		RIGHT		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		LEFT	RIGHT
1			2.00	8			2.89	8			-325.10	1		18944.85
2	-2.02	8	1.45	7	321.39	2	0.00	0	0.00	0	-319.65	2	18944.85	18944.85
3	5.88	3	-0.00	8	311.11	2	0.00	0	0.00	0	-309.78	2	18944.85	18944.85
4	10.13	3	-3.72	8	291.70	2	0.00	0	0.00	0	-291.34	2	18944.85	18944.85
5	14.69	1	-7.68	8	264.21	2	-12.73	8	14.47	8	-263.51	2	18944.85	18944.85
6	19.34	1	-7.85	8	226.77	2	-47.34	7	53.67	8	-91.24	6	18944.85	256.01
7	18.48	6	-1.94	8	16.94	5	-86.38	8	86.18	8	-16.99	5	256.01	256.01
8	11.41	6	3.43	8	0.00	0	-94.98	7	94.89	7	0.00	0	256.01	256.01
9	4.65	6	8.69	8	0.00	0	-81.76	7	81.78	7	0.00	0	256.01	256.01
10	-8.69	8	14.18	8	0.00	0	-47.25	7	47.36	7	0.00	0	256.01	256.01
11	-14.18	8	20.07	8	15.31	8	-14.83	2	14.87	2	-15.18	8	256.01	256.01
12	-20.08	8	20.68	8	98.85	8	0.00	0	0.00	0	-194.03	2	256.01	18944.85
13	-20.69	8	15.33	8	219.83	2	0.00	0	0.00	0	-218.98	2	18944.85	18944.85
14	-15.34	8	10.11	8	250.33	8	0.00	0	0.00	0	-247.84	8	18944.85	18944.85
15	-10.12	8	4.99	8	291.01	8	0.00	0	0.00	0	-289.36	8	18944.85	18944.85
16	-5.00	8	-0.16	8	309.94	8	0.00	0	0.00	0	-309.31	8	18944.85	18944.85
17	3.74	5	-4.90	8	309.53	8	0.00	0	0.00	0	-305.59	8	18944.85	18944.85
18	6.07	5	-9.24	8	286.44	8	0.00	0	0.00	0	-283.99	8	18944.85	18944.85
19	9.50	7	-13.72	8	245.22	8	0.00	0	0.00	0	-243.74	8	18944.85	18944.85
20	13.71	8	-17.14	8	198.56	2	0.00	0	0.00	0	-196.98	2	18944.85	18944.85
21	17.37	7	-16.78	8	175.35	2	0.00	0	12.18	2	-103.25	8	18944.85	256.01
22	16.78	8	-8.56	8	27.73	8	-39.90	5	39.90	5	-27.79	8	256.01	256.01
23	8.56	8	6.39	2	0.00	0	-56.87	5	56.95	5	0.00	0	256.01	256.01
24	0.58	8	14.91	6	13.03	4	-32.99	5	33.15	5	-12.95	4	256.01	256.01
25	-7.17	8	24.84	5	65.17	4	0.00	0	0.00	0	-65.16	4	256.01	256.01
26	-14.73	8	31.94	5	168.04	6	0.00	0	0.00	0	-171.19	6	256.01	3941.94
27	-21.44	8	30.09	5	250.12	6	0.00	0	0.00	0	-386.71	2	3941.94	34012.55
28	-22.43	8	22.55	3	483.88	2	0.00	0	0.00	0	-480.86	2	34012.55	34012.55
29	-17.93	8	14.84	5	557.35	2	0.00	0	0.00	0	-554.03	2	34012.55	34012.55
30	-13.57	8	8.86	8	602.47	2	0.00	0	0.00	0	-600.04	2	34012.55	34012.55
31	-8.87	8	2.85	8	623.72	2	0.00	0	0.00	0	-620.06	2	34012.55	34012.55
32	12.85	4	-3.21	8	617.02	2	0.00	0	0.00	0	-613.75	2	34012.55	34012.55
33	21.43	4	-9.30	8	583.74	2	0.00	0	0.00	0	-579.68	2	34012.55	34012.55
34	31.13	6	-11.89	8	520.40	2	0.00	0	0.00	0	-203.36	6	34012.55	642.99
35	34.24	6	-9.08	8	51.18	6	-52.76	8	52.63	8	-51.36	6	642.99	642.99
36	27.06	6	-6.69	8	0.00	0	-96.48	4	96.29	4	0.00	0	642.99	642.99
37	20.54	6	-4.57	8	0.00	0	-171.03	4	170.90	4	0.00	0	642.99	642.99
38	14.57	6	-2.52	8	0.00	0	-224.76	6	224.73	6	0.00	0	642.99	642.99
39	8.90	6	3.52	1	0.00	0	-264.29	6	264.38	6	0.00	0	642.99	642.99
40	3.15	6	10.80	1	0.00	0	-278.40	6	278.62	6	0.00	0	642.99	642.99
41	-2.32	8	18.90	1	0.00	0	-264.84	6	265.21	6	0.00	0	642.99	642.99
42	-5.63	8	28.06	1	0.00	0	-219.35	6	219.83	6	0.00	0	642.99	642.99
43	-9.85	8	28.49	1	63.34	1	-135.73	6	130.37	6	-377.78	2	642.99	34012.55
44	-10.16	8	21.25	1	423.79	2	-30.25	6	36.01	6	-419.77	2	34012.55	34012.55
45	-5.76	8	14.63	1	448.57	2	0.00	0	0.00	0	-440.22	2	34012.55	34012.55
46	-2.45	8	9.30	1	457.55	2	0.00	0	0.00	0	-456.29	2	34012.55	34012.55
47	-0.85	8	4.73	1	456.16	2	0.00	0	0.00	0	-453.48	2	34012.55	34012.55
48	-0.90	8	1.13	1	456.40	2	0.00	0	0.00	0	-449.10	2	34012.55	34012.55
49	0.04	7			457.43	1			0.00	0			34012.55	

C.R. DEC8. 1971 L.E. WITH EARTHQUAKE STAGE 2 FILL CONC. EGLECTED

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR LEFT		SHEAR RIGHT		LEFT MOMENT POSITIVE		LEFT MOMENT NEGATIVE		RIGHT MOMENT POSITIVE		RIGHT MOMENT NEGATIVE		RESISTING MOMENT LEFT	RESISTING MOMENT RIGHT
1			2.66	7			49.35	7			-278.82	1		18944.85
2	-2.51	8	3.08	7	277.51	2	-38.83	8	40.87	7	-276.47	2	18944.85	18944.85
3	4.16	3	2.60	7	275.39	2	-29.92	8	30.19	7	-273.74	2	18944.85	18944.85
4	7.61	3	0.22	7	267.16	2	-21.29	8	23.74	8	-266.46	2	18944.85	18944.85
5	11.76	1	-4.14	8	252.51	2	-23.21	7	26.30	8	-251.71	2	18944.85	18944.85
6	16.23	1	-4.73	8	229.18	2	-44.45	8	97.27	8	-47.64	6	18944.85	256.01
7	15.37	6	0.96	8	0.00	0	-117.00	8	116.77	8	0.00	0	256.01	256.01
8	8.50	6	6.12	8	0.00	0	-113.45	7	113.37	7	0.00	0	256.01	256.01
9	-6.12	8	11.22	8	0.00	0	-89.06	7	89.11	7	0.00	0	256.01	256.01
10	-11.22	8	16.66	8	0.00	0	-44.03	7	44.16	7	0.00	0	256.01	256.01
11	-16.66	8	22.60	8	28.85	8	-1.29	2	1.35	2	-28.70	8	256.01	256.01
12	-22.60	8	23.52	8	122.89	8	0.00	0	0.00	0	-142.24	2	256.01	18944.85
13	-23.53	8	17.70	8	178.84	2	0.00	0	0.00	0	-177.92	2	18944.85	18944.85
14	-17.71	8	12.56	8	220.10	8	0.00	0	0.00	0	-218.73	8	18944.85	18944.85
15	-12.57	8	7.90	8	271.19	8	0.00	0	0.00	0	-270.41	8	18944.85	18944.85
16	-7.91	8	2.73	8	302.44	8	0.00	0	0.00	0	-302.63	8	18944.85	18944.85
17	-2.74	8	-1.74	8	311.90	8	0.00	0	0.00	0	-308.43	8	18944.85	18944.85
18	3.70	5	-6.16	8	302.09	8	0.00	0	0.00	0	-298.60	8	18944.85	18944.85
19	6.60	5	-10.37	8	271.45	8	0.00	0	0.00	0	-269.49	8	18944.85	18944.85
20	10.35	8	-15.21	8	236.73	2	0.00	0	0.00	0	-235.07	2	18944.85	18944.85
21	15.20	8	-14.24	8	222.65	2	0.00	0	39.94	2	-75.49	8	18944.85	256.01
22	14.24	8	-6.03	8	11.41	8	-56.22	5	56.26	5	-11.43	8	256.01	256.01
23	6.03	8	9.03	2	0.00	0	-61.90	5	62.03	5	0.00	0	256.01	256.01
24	-2.05	8	17.84	6	19.84	4	-26.19	5	26.39	5	-19.70	4	256.01	256.01
25	-10.10	8	28.19	5	85.11	4	0.00	0	0.00	0	-85.07	4	256.01	256.01
26	-18.08	8	35.63	5	203.02	6	0.00	0	0.00	0	-206.20	6	256.01	3941.94
27	-25.34	8	34.02	5	294.63	6	0.00	0	0.00	0	-298.53	2	3941.94	34012.55
28	-26.13	8	27.53	5	414.37	2	0.00	0	0.00	0	-412.86	2	34012.55	34012.55
29	-22.45	8	19.93	5	506.58	2	0.00	0	0.00	0	-505.06	2	34012.55	34012.55
30	-18.41	8	12.86	8	574.30	2	0.00	0	0.00	0	-572.04	2	34012.55	34012.55
31	-12.88	8	7.80	8	617.68	2	0.00	0	0.00	0	-614.03	2	34012.55	34012.55
32	7.99	4	1.70	8	633.75	2	0.00	0	0.00	0	-631.43	2	34012.55	34012.55
33	16.58	4	-4.45	8	621.38	2	0.00	0	0.00	0	-618.96	2	34012.55	34012.55
34	26.53	6	-7.40	8	591.47	2	0.00	0	71.65	8	-131.63	6	34012.55	642.99
35	29.75	6	-4.75	8	0.00	0	-104.55	8	104.43	8	0.00	0	642.99	642.99
36	22.74	6	-2.46	8	0.00	0	-129.06	4	128.90	4	0.00	0	642.99	642.99
37	16.31	6	-0.31	8	0.00	0	-184.84	4	184.76	4	0.00	0	642.99	642.99
38	10.32	6	1.89	8	0.00	0	-219.72	6	219.73	6	0.00	0	642.99	642.99
39	4.48	6	8.10	1	0.00	0	-239.65	6	239.77	6	0.00	0	642.99	642.99
40	-4.41	8	15.79	1	0.00	0	-232.80	6	233.04	6	0.00	0	642.99	642.99
41	-7.44	8	24.30	1	0.00	0	-196.49	6	196.84	6	0.00	0	642.99	642.99
42	-11.17	8	33.77	1	30.70	1	-126.39	6	126.82	6	-30.70	1	642.99	642.99
43	-15.70	8	34.84	1	180.82	1	-16.72	6	127.82	6	-377.19	2	642.99	34012.55
44	-15.91	8	26.68	1	454.17	2	-2.72	6	5.89	6	-450.83	2	34012.55	34012.55
45	-11.94	8	19.38	1	504.75	2	0.00	0	0.00	0	-498.43	2	34012.55	34012.55
46	-7.22	8	13.40	1	537.93	2	0.00	0	0.00	0	-536.52	2	34012.55	34012.55
47	-3.97	8	7.93	1	558.76	2	0.00	0	0.00	0	-555.41	2	34012.55	34012.55
48	-2.77	8	3.06	3	569.67	2	0.00	0	0.00	0	-564.81	2	34012.55	34012.55
49	-1.14	8			576.62	1			0.00	0			34012.55	

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CHA S RIVER LOCKS 1579.60 L.E. DEC. 8, 1971 STAGE 2 FILL NCRETE INCLUDED

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR				LEFT MOMENT				RIGHT MOMENT				RESISTING MOMENT	
	LEFT		RIGHT		POSITIVE		NEGATIVE		POSITIVE		NEGATIVE		LEFT	RIGHT
1			2.04	8			2.95	8			-324.16	3		34012.55
2	-2.09	8	0.29	8	322.11	4	0.00	0	8.63	8	-319.51	2	34012.55	34012.55
3	7.13	3	-6.18	8	309.71	4	-18.07	7	22.47	7	-307.74	4	34012.55	34012.55
4	12.03	3	-9.15	8	288.02	4	-47.76	7	52.13	7	-286.66	4	34012.55	34012.55
5	17.20	3	-13.69	8	257.98	4	-96.75	7	98.96	7	-256.19	4	34012.55	34012.55
6	22.72	3	-13.87	8	214.96	4	-170.00	7	178.20	7	-79.70	6	34012.55	3941.94
7	22.03	3	-6.05	8	25.22	4	-243.87	7	243.98	7	-25.07	4	3941.94	3941.94
8	15.00	3	1.44	8	1.21	4	-278.05	7	278.03	7	-1.15	4	3941.94	3941.94
9	7.96	3	8.84	8	0.00	0	-281.18	7	281.24	7	0.00	0	3941.94	3941.94
10	-8.84	8	16.14	8	1.05	4	-253.88	7	254.10	7	-0.92	4	3941.94	3941.94
11	-16.14	8	23.27	8	24.97	4	-196.36	7	196.75	7	-24.77	4	3941.94	3941.94
12	-23.27	8	25.78	8	64.80	4	-109.10	7	104.89	7	-211.15	4	3941.94	34012.55
13	-25.81	8	21.72	8	258.54	4	-9.96	7	13.36	7	-256.39	4	34012.55	34012.55
14	-21.73	8	18.20	8	295.84	4	0.00	0	0.00	0	-294.08	4	34012.55	34012.55
15	-18.22	8	13.22	8	329.94	4	0.00	0	0.00	0	-326.97	4	34012.55	34012.55
16	-13.25	8	9.78	8	359.87	4	0.00	0	0.00	0	-356.40	4	34012.55	34012.55
17	-9.80	8	5.25	7	380.03	4	0.00	0	0.00	0	-378.65	4	34012.55	34012.55
18	5.93	5	0.61	7	395.48	4	0.00	0	0.00	0	-393.01	4	34012.55	34012.55
19	8.63	5	-5.72	8	404.91	4	0.00	0	0.00	0	-403.10	4	34012.55	34012.55
20	10.81	5	-9.41	8	406.60	4	-34.99	5	37.81	5	-405.99	4	34012.55	34012.55
21	13.12	5	-10.80	8	403.37	4	-93.21	5	100.22	5	-254.92	4	34012.55	3941.94
22	10.80	8	5.64	2	256.45	4	-148.30	5	148.34	5	-256.44	4	3941.94	3941.94
23	4.26	8	10.29	2	276.61	4	-153.34	5	153.33	5	-276.62	4	3941.94	3941.94
24	-2.08	8	18.10	5	314.99	4	-115.18	5	115.26	5	-314.93	4	3941.94	3941.94
25	-8.27	8	27.79	5	371.14	4	-33.75	5	33.81	5	-371.11	4	3941.94	3941.94
26	-14.23	8	34.36	5	444.50	4	0.00	0	0.00	0	-445.56	4	3941.94	3941.94
27	-19.89	8	31.81	5	490.84	4	0.00	0	0.00	0	-638.67	4	3941.94	34012.55
28	-20.44	8	24.38	5	706.99	4	0.00	0	0.00	0	-704.98	4	34012.55	34012.55
29	-14.87	8	16.74	5	733.99	4	0.00	0	0.00	0	-732.54	4	34012.55	34012.55
30	-10.21	8	9.00	5	726.61	2	0.00	0	0.00	0	-724.25	2	34012.55	34012.55
31	10.19	4	-1.26	8	734.36	2	0.00	0	0.00	0	-732.57	2	34012.55	34012.55
32	18.77	4	-7.15	8	713.53	2	0.00	0	0.00	0	-711.04	2	34012.55	34012.55
33	27.99	4	-13.57	8	665.83	2	0.00	0	0.00	0	-561.97	2	34012.55	34012.55
34	36.97	4	-15.97	8	584.75	2	0.00	0	0.00	0	-286.80	6	34012.55	642.99
35	38.87	6	-12.63	8	114.04	6	0.00	0	0.00	0	-114.17	6	642.99	642.99
36	31.11	6	-9.63	8	0.00	0	-54.39	8	54.30	8	0.00	0	642.99	642.99
37	23.90	6	-6.88	8	0.00	0	-135.44	4	135.31	4	0.00	0	642.99	642.99
38	17.23	6	-4.24	8	0.00	0	-206.68	6	206.64	6	0.00	0	642.99	642.99
39	10.88	6	-1.49	8	0.00	0	-255.02	6	255.09	6	0.00	0	642.99	642.99
40	4.52	6	10.03	1	0.00	0	-275.21	6	275.40	6	0.00	0	642.99	642.99
41	-1.60	8	18.46	1	0.00	0	-265.35	6	265.69	6	0.00	0	642.99	642.99
42	-5.30	8	27.87	1	0.00	0	-221.58	6	222.03	6	0.00	0	642.99	642.99
43	-9.84	8	28.84	1	59.23	1	-138.07	6	130.91	6	-376.00	2	642.99	34012.55
44	-9.70	8	20.95	1	422.99	2	-34.66	6	39.23	6	-420.96	2	34012.55	34012.55
45	-5.59	8	14.71	1	445.43	2	0.00	0	0.00	0	-440.91	2	34012.55	34012.55
46	-2.50	8	9.35	1	457.04	2	0.00	0	0.00	0	-450.73	2	34012.55	34012.55
47	-0.91	8	5.86	1	458.78	2	0.00	0	0.00	0	-449.38	2	34012.55	34012.55
48	-1.71	8	1.85	1	458.10	2	0.00	0	0.00	0	-449.55	2	34012.55	34012.55
49	-0.07	8			451.97	1			0.00	0			34012.55	

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C.R.L DEC8. 1971 L.F. WITH EARTHQUAKE STAGE 2 FILL CONC. LUDED

SUMMARY TABLE
MAXIMUM FORCES MOMENTS AND LOADING CONDITIONS

NODE	SHEAR LEFT		SHEAR RIGHT		LEFT MOMENT POSITIVE		LEFT MOMENT NEGATIVE		RIGHT MOMENT POSITIVE		RIGHT MOMENT NEGATIVE		RESISTING MOMENT LEFT	RESISTING MOMENT RIGHT
1			2.11	7			52.07	7			-277.97	3		34012.55
2	-1.05	8	0.28	8	277.21	2	-41.73	8	50.93	8	-274.87	4	34012.55	34012.55
3	6.31	3	-3.13	8	267.62	4	-60.51	7	62.23	7	-265.65	4	34012.55	34012.55
4	10.97	3	-5.60	8	251.46	4	-86.65	7	91.66	7	-249.56	4	34012.55	34012.55
5	15.71	3	-11.93	8	227.33	4	-125.94	7	130.86	7	-226.50	4	34012.55	34012.55
6	21.10	3	-11.91	8	190.59	4	-191.14	7	247.80	7	-10.29	6	34012.55	3941.94
7	20.10	3	-3.92	8	0.00	0	-305.16	7	305.48	7	0.00	0	3941.94	3941.94
8	12.86	3	3.81	8	0.00	0	-330.51	7	330.72	7	0.00	0	3941.94	3941.94
9	5.58	3	11.44	8	0.00	0	-323.65	7	324.05	7	0.00	0	3941.94	3941.94
10	-11.44	8	18.87	8	0.00	0	-286.03	7	286.22	7	0.00	0	3941.94	3941.94
11	-18.88	8	26.10	8	3.88	4	-217.44	7	217.76	7	-3.78	4	3941.94	3941.94
12	-26.10	8	27.49	8	55.50	4	-118.44	7	190.80	7	-125.64	4	3941.94	34012.55
13	-29.51	8	24.48	8	185.16	4	-81.72	7	85.95	7	-183.21	4	34012.55	34012.55
14	-24.50	8	21.96	8	236.38	4	-5.88	3	9.31	3	-233.78	4	34012.55	34012.55
15	-21.99	8	18.34	8	283.24	4	0.00	0	0.00	0	-281.34	4	34012.55	34012.55
16	-18.36	8	11.69	7	326.67	4	0.00	0	0.00	0	-323.70	4	34012.55	34012.55
17	-11.47	8	8.28	4	362.51	4	0.00	0	0.00	0	-359.92	4	34012.55	34012.55
18	-8.10	8	6.79	4	392.90	4	0.00	0	0.00	0	-389.96	4	34012.55	34012.55
19	4.91	5	-1.02	8	416.72	4	0.00	0	0.00	0	-414.35	4	34012.55	34012.55
20	7.60	5	-6.60	8	435.09	4	-6.57	5	9.00	5	-433.73	4	34012.55	34012.55
21	9.39	5	-6.89	8	447.93	4	-49.60	5	132.43	5	-222.68	4	34012.55	3941.94
22	6.89	8	9.68	2	241.84	4	-162.96	5	163.01	5	-241.83	4	3941.94	3941.94
23	0.30	8	14.37	2	279.89	4	-149.99	5	150.05	5	-279.91	4	3941.94	3941.94
24	-6.25	8	22.25	5	336.54	4	-93.63	5	93.78	5	-336.50	4	3941.94	3941.94
25	-12.41	8	31.96	5	411.18	4	0.00	0	0.00	0	-411.18	4	3941.94	3941.94
26	-18.38	8	39.63	5	503.31	4	0.00	0	0.00	0	-504.26	4	3941.94	3941.94
27	-24.03	8	36.43	5	560.37	4	0.00	0	0.00	0	-575.73	4	3941.94	34012.55
28	-24.37	8	28.68	5	662.77	4	0.00	0	0.00	0	-660.14	4	34012.55	34012.55
29	-19.24	8	21.41	5	711.98	4	0.00	0	0.00	0	-709.69	4	34012.55	34012.55
30	-14.41	8	13.37	5	724.60	2	0.00	0	0.00	0	-721.60	2	34012.55	34012.55
31	-8.52	8	3.56	8	750.74	2	0.00	0	0.00	0	-749.35	2	34012.55	34012.55
32	15.01	4	-3.04	8	751.05	2	0.00	0	0.00	0	-749.29	2	34012.55	34012.55
33	23.71	4	-9.53	8	720.48	2	0.00	0	0.00	0	-718.66	2	34012.55	34012.55
34	33.41	4	-12.15	8	659.64	2	0.00	0	0.00	0	-228.63	6	34012.55	642.99
35	35.09	6	-8.91	8	72.84	6	-39.56	8	39.47	8	-72.96	6	642.99	642.99
36	27.39	6	-5.92	8	0.00	0	-79.10	8	79.05	8	0.00	0	642.99	642.99
37	20.20	6	-3.07	8	0.00	0	-143.74	4	143.65	4	0.00	0	642.99	642.99
38	13.42	6	-0.16	8	0.00	0	-198.06	6	198.06	6	0.00	0	642.99	642.99
39	6.80	6	6.81	1	0.00	0	-228.33	6	228.43	6	0.00	0	642.99	642.99
40	-2.97	8	14.97	1	0.00	0	-228.68	6	228.90	6	0.00	0	642.99	642.99
41	-6.54	8	23.88	1	0.00	0	-196.88	6	197.20	6	0.00	0	642.99	642.99
42	-10.72	8	33.66	1	28.26	1	-128.99	6	129.39	6	-28.00	1	642.99	642.99
43	-15.63	8	34.50	1	177.62	1	-19.68	6	132.81	6	-377.01	2	642.99	34012.55
44	-16.66	8	26.86	1	449.47	2	-6.11	6	9.98	6	-448.04	2	34012.55	34012.55
45	-11.56	8	19.66	1	502.97	2	0.00	0	0.00	0	-500.12	2	34012.55	34012.55
46	-7.71	8	14.01	1	536.55	2	0.00	0	0.00	0	-534.49	2	34012.55	34012.55
47	-4.55	8	8.05	1	557.50	2	0.00	0	0.00	0	-552.44	2	34012.55	34012.55
48	-2.87	8	2.97	1	571.53	2	0.00	0	0.00	0	-566.00	2	34012.55	34012.55
49	-1.69	8			572.69	1			0.00	0			34012.55	

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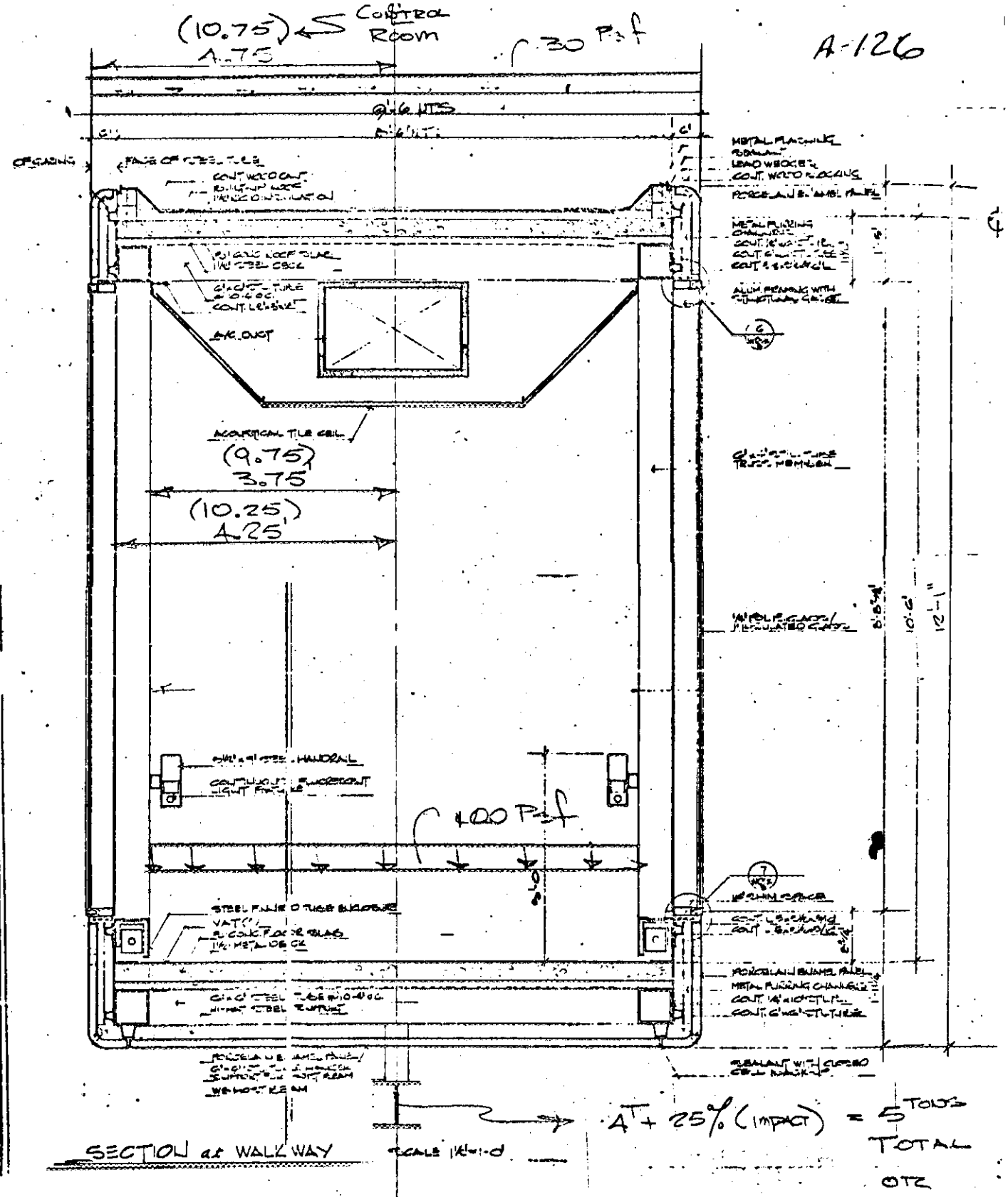


TYPICAL SECTION

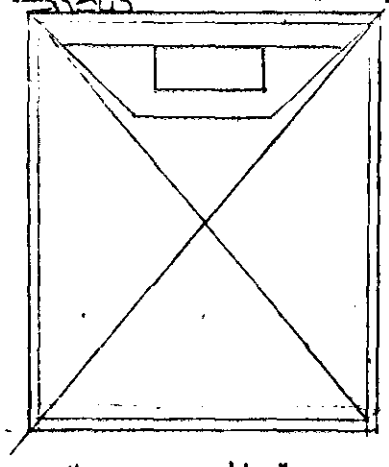
PROJECT C. PIER DAM ACC. NO. 195627
SUBJECT LOADS ON TRUSS SHEET NO. ___ OF 1
DATE ___ 19__
COMP. W.H.R. CHECK ___ CONT. NO. ___

A-127

(A) LOADS ON TRUSS

WEIGHT of TRUSS

Roof
ARCH & MECH + ELEC = 10 psf
3" Conc + 1½" Dk = 50 psf
SNOW = 30 psf

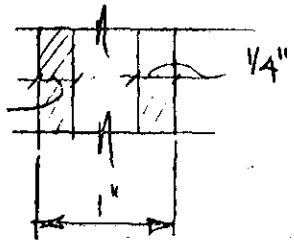


6×6 = 34.49 #/1 · 81 × 2 = 5585.76
6×4 = 21.94 #/1 · 16 × 1165 = 4089.62
21.94 #/1 · 2 · 10 = 439.80
10,114.18

$\bar{w}_{TRUSS} = \frac{10114.2}{81} \approx 125\ ^{\#}/FT$

(B) ARCH GLASS

13-15 #/FT² for 1" thick



∴ = 15/2 = 7.5

CONSIDER 10 #/FT² FOR GLASS, RAIL SIDE PANEL

∴ W_{ARCH} = 10 #/FT² × 12

$W = 120\ ^{\#}/FT$

FLR. 3" Conc + 1½" = 50 psf
ARCH + MECH + ELEC = 10 psf

LL FLR = 100 psf

LOADS @ WALKWAY

					w (#/FT)	
Roof	DL - Conc & Dk	- 50 psf	× 4.25'	=	212.5	
	ARCH, MECH, ELEC	- 10 psf	× 4.75'	=	47.5	
					260.0	→ DL
	LL - Snow	- 30 psf	× 4.75'	=	142.5	
					402.5	D+L
Floor	DL - Conc & Dk	- 50 Psf	× 4.25'	=	212.5	
	ARCH, etc	- 10 Psf	× 4.75'	=	47.5	
					260.0	→ D
	LL =	100 Psf	× 3.75'	=	375.0	
					635.0	→ D+

½ CRANE RAIL = $\frac{4^T \times 2}{2}$ + 25% IMPACT = 5^K LOAD

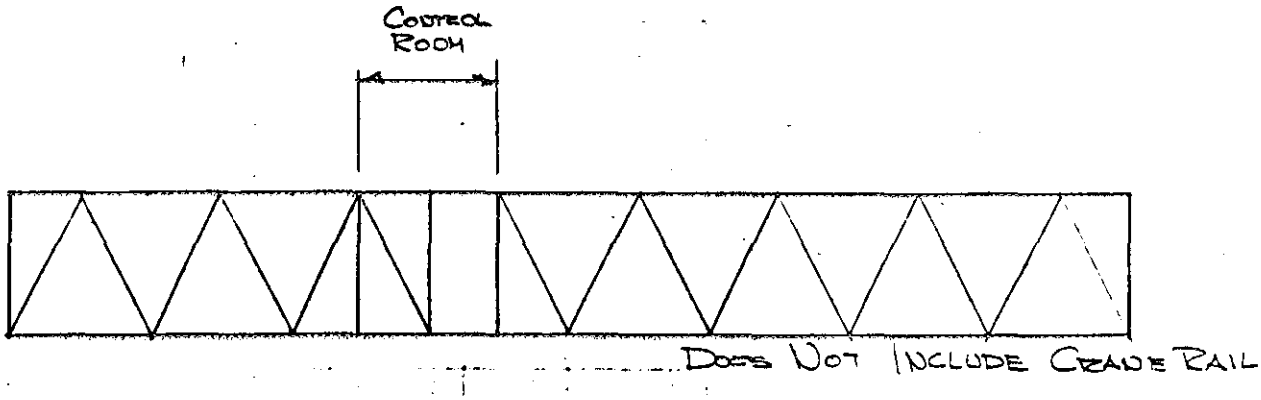
PROJECT Charles River Dam ACC. NO. 1856
SUBJECT Computer Set-up Loads SHEET NO. ___ OF 2
DATE ___ 19__
COMP. WHR CHECK ___ CONT. NO. ___

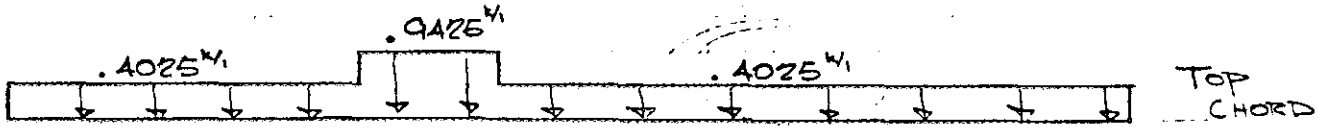
@C.R 6' overhang [illegible] 21.5

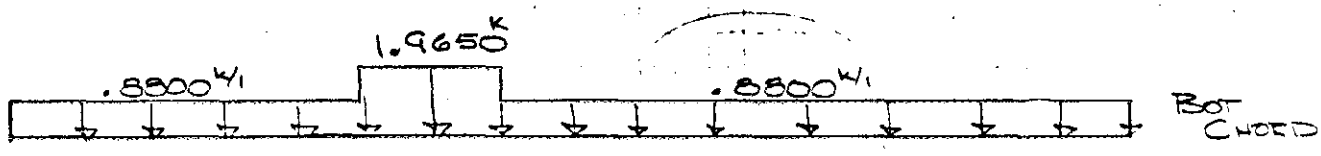
LOADS @ Control Room

A 128

Roof	DL - Conc & Dk	-	50 × 10.25 =	512.5	
	Arch, etc	-	10 × 10.75 =	107.5	
				620.0	D.L
	LL - Snow	-	30 × 10.75 =	322.5	
				942.5	D+L
FLOOR	DL - Conc & Dk		50 × 10.25 =	512.5	
	Arch, etc		10 × 10.75 =	107.5	
				620.0	D.L
	LL	-	100 × 9.75 =	975.0	
				1595	D+L







Roof = Walk = .4025 k/1
Cont = .9425 k/1

FLR = Walk = .6350 k/1 + .125 + .120 = .880 k/1
Cont = 1.595 + .125 + .120 + .125 = 1.965 k/1

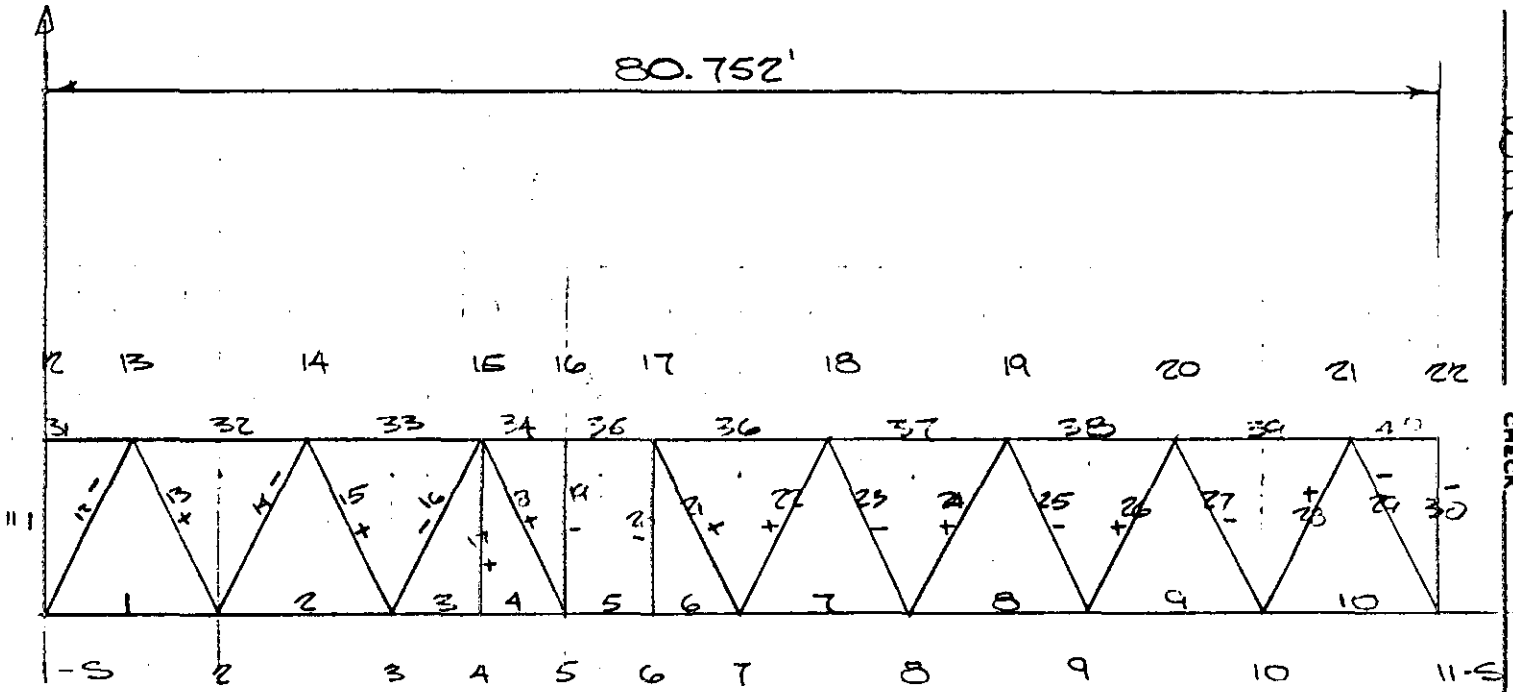
CE MAGUIRE, INC.
ARCHITECTS · ENGINEERS · PLANNERS

11-72B

PROJECT C.R.D.
SUBJECT Computer Set-Up
COMP. WHP
CHECK
ACC. NO. 1856
SHEET NO. ___ OF 3
DATE ___ 19__
CONT. NO. ___

A129

1ST RUN



TOP CHORD - 6×6 TUBE 31 TO 40

BOT. CHORD - 6×6 TUBE 1 TO 10

ALL WEB MEMBERS - 6×4×TUBE 11 TO 30

CE MAGUIRE, INC.
ARCHITECTS · ENGINEERS · PLANNERS

11-72B

PROJECT C.P.D. ACC. NO. 1956
SUBJECT DEFLECTIONS SHEET NO. ___ OF 4
See Computer Run DATE ___ 19__
COMP. Wattell CHECK ___ CONT. NO. ___

A130

For T & B Chord 6×6×1/2 P = 123.56^k
M =

#1 δ_{max} = .92in (D+L)

P = 126.0^k
M =

#2 δ_{max} = .93in (D+L)

Design Case

#3 δ_{max} = 1.00in (D+L) P = 132.95^k

	T.L	L.L.	D.L
Roof	.4025	.1425	.2600
Floor	.8800	.3750	.5050
	1.2825	.5175	.7650

Crane Load @ Midspan

∴ For

(A) DL $\delta_{max} = \frac{.7650}{1.2825}(1.00) = .596''$

(B) LL $\delta_{max} = \frac{.5175}{1.2825}(1.00) = .404''$ (100psf)

(C) or $\frac{40}{100}(.404) = .1616$ (40psf)

(D) Wind Load = 30psf × 9.5 = 285plf./2 = 143plf each Truss

δ for 1282.5plf = 1.00"

∴ $\delta_w = \frac{143}{1282.5}(1) = .111''$

Difference in Deflection Under Changing Wind Loads

$\delta = 2 \times .111 = .222''$

CE MAGUIRE, INC.
ARCHITECTS · ENGINEERS · PLANNERS

11-72B

FINAL COMPUTER — C.K.D.

A 131

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STRUCTURE-WALKWAY-TRUSS-CHARLES RIVER DAM B. RODGER DECEMBER,1972
TYPE PLANE FRAME
NUMBER OF JOINTS    22
NUMBER OF SUPPORTS   2
NUMBER OF MEMBERS   40
NUMBER OF LOADINGS   3
TABULATE ALL
JOINT COORDINATES
1    0.000   0.000 S
2   10.094   0.000
3   20.188   0.000
4   25.235   0.000
5   30.282   0.000
6   35.329   0.000
7   40.376   0.000
8   50.470   0.000
9   60.564   0.000
10  70.658   0.000
11  80.752   0.000 S
12   0.000  10.500
13   5.047  10.500
14  15.141  10.500
15  25.235  10.500
16  30.282  10.500
17  35.329  10.500
18  45.423  10.500
19  55.517  10.500
20  65.611  10.500
21  75.705  10.500
22  80.752  10.500
MEMBER PROPERTIES PRISMATIC
1   AX .070139 IZ .002344
2   AX .070139 IZ .002344
3   AX .070139 IZ .002344
4   AX .070139 IZ .002344
5   AX .070139 IZ .002344
6   AX .070139 IZ .002344
7   AX .070139 IZ .002344
8   AX .070139 IZ .002344
9   AX .070139 IZ .002344
10  AX .070139 IZ .002344
11  AX .044792 IZ .000733
12  AX .044792 IZ .000733
13  AX .044792 IZ .000733
14  AX .044792 IZ .000733
15  AX .044792 IZ .000733
16  AX .044792 IZ .000733
17  AX .044792 IZ .000733
18  AX .044792 IZ .000733
19  AX .044792 IZ .000733
20  AX .044792 IZ .000733
21  AX .044792 IZ .000733
22  AX .044792 IZ .000733
23  AX .044792 IZ .000733
24  AX .044792 IZ .000733
25  AX .044792 IZ .000733
26  AX .044792 IZ .000733
27  AX .044792 IZ .000733
28  AX .044792 IZ .000733
29  AX .044792 IZ .000733
```

A132
2

```
30 AX .044792 IZ .000733
31 AX .070139 IZ .002344
32 AX .070139 IZ .002344
33 AX .070139 IZ .002344
34 AX .070139 IZ .002344
35 AX .070139 IZ .002344
36 AX .070139 IZ .002344
37 AX .070139 IZ .002344
38 AX .070139 IZ .002344
39 AX .070139 IZ .002344
40 AX .070139 IZ .002344
MEMBER INCIDENCES
1  1  2
2  2  3
3  3  4
4  4  5
5  5  6
6  6  7
7  7  8
8  8  9
9  9  10
10 10 11
11 1  12
12 1  13
13 2  13
14 2  14
15 3  14
16 3  15
17 4  15
18 5  15
19 5  16
20 6  17
21 7  17
22 7  18
23 8  18
24 8  19
25 9  19
26 9  20
27 10 20
28 10 21
29 11 21
30 11 22
31 12 13
32 13 14
33 14 15
34 15 16
35 16 17
36 17 18
37 18 19
38 19 20
39 20 21
40 21 22
CONSTANTS E 4320000.00 ALL
JOINT RELEASES
1  MOMENT Z
11 MOMENT Z FORCES X
LOADING 1 (FULL DEAD + LIVE)
MEMBER LOADS
1  FORCE Y UNIFORM -.8[illegible]
2  FORCE Y UNIFORM -.8[illegible]
3  FORCE Y UNIFORM -.[illegible]
```

A133
3

```
4  FORCE Y UNIFORM -1.965
5  FORCE Y UNIFORM -1.965
6  FORCE Y UNIFORM -.8800
7  FORCE Y UNIFORM -.8800
8  FORCE Y UNIFORM -.8800
9  FORCE Y UNIFORM -.8800
10 FORCE Y UNIFORM -.8800
31 FORCE Y UNIFORM -.4025
32 FORCE Y UNIFORM -.4025
33 FORCE Y UNIFORM -.4025
34 FORCE Y UNIFORM -.9425
35 FORCE Y UNIFORM -.9425
36 FORCE Y UNIFORM -.4025
37 FORCE Y UNIFORM -.4025
38 FORCE Y UNIFORM -.4025
39 FORCE Y UNIFORM -.4025
40 FORCE Y UNIFORM -.4025
LOADING 2 (FULL DEAD + LIVE) WITH CRANE LOAD NEAR SUPPORT
JOINT LOADS
2 FORCE Y -5.000
MEMBER LOADS
1  FORCE Y UNIFORM -.8800
2  FORCE Y UNIFORM -.8800
3  FORCE Y UNIFORM -.8800
4  FORCE Y UNIFORM -1.965
5  FORCE Y UNIFORM -1.965
6  FORCE Y UNIFORM -.8800
7  FORCE Y UNIFORM -.8800
8  FORCE Y UNIFORM -.8800
9  FORCE Y UNIFORM -.8800
10 FORCE Y UNIFORM -.8800
31 FORCE Y UNIFORM -.4025
32 FORCE Y UNIFORM -.4025
33 FORCE Y UNIFORM -.4025
34 FORCE Y UNIFORM -.9425
35 FORCE Y UNIFORM -.9425
36 FORCE Y UNIFORM -.4025
37 FORCE Y UNIFORM -.4025
38 FORCE Y UNIFORM -.4025
39 FORCE Y UNIFORM -.4025
40 FORCE Y UNIFORM -.4025
LOADING 3 (FULL DEAD + LIVE) WITH CRANE LOAD AT MIDSPAN
JOINT LOADS
7 FORCE Y -5.000
MEMBER LOADS
1  FORCE Y UNIFORM -.8800
2  FORCE Y UNIFORM -.8800
3  FORCE Y UNIFORM -.8800
4  FORCE Y UNIFORM -1.965
5  FORCE Y UNIFORM -1.965
6  FORCE Y UNIFORM -.8800
7  FORCE Y UNIFORM -.8800
8  FORCE Y UNIFORM -.8800
9  FORCE Y UNIFORM -.8800
10 FORCE Y UNIFORM -.8800
31 FORCE Y UNIFORM -.4025
32 FORCE Y UNIFORM -.4025
33 FORCE Y UNIFORM -.4025
34 FORCE Y UNIFORM -.9425
35 FORCE Y UNIFORM -.9425
36 FORCE Y UNIFORM -.4025
```

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4

```
37 FORCE Y UNIFORM -.4025
38 FORCE Y UNIFORM -.4025
39 FORCE Y UNIFORM -.4025
40 FORCE Y UNIFORM -.4025
SOLVE
PROBLEM CORRECTLY SPECIFIED, EXECUTION TO PROCEED.
```

A135
5

STRUCTURE-WALKWAY-TRUSS-CHARLES RIVER DAM B. RODGER DECEMBER,1972

LOADING 1 (FULL DEAD + LIVE)

MEMBER FORCES

MEMBER	JOINT	AXIAL FORCE	SHEAR FORCE	MOMENT
1	1	-27.956	4.154	4.57
1	2	27.956	4.728	-7.47
2	2	-75.323	4.860	8.78
2	3	75.323	4.021	-4.55
3	3	-110.123	3.427	4.81
3	4	110.123	1.014	1.27
4	4	-110.197	2.620	-0.76
4	5	110.197	7.296	-11.03
5	5	-123.153	9.609	14.53
5	6	123.153	0.307	8.94
6	6	-123.557	-0.210	-6.94
6	7	123.557	4.651	-5.32
7	7	-118.590	4.338	5.94
7	8	118.590	4.544	-6.98
8	8	-100.111	4.373	6.28
8	9	100.111	4.509	-6.96
9	9	-69.421	4.202	5.93
9	10	69.421	4.680	-8.34
10	10	-25.992	4.722	7.34
10	11	25.992	4.160	-4.50
11	1	1.304	-0.416	-2.49
11	12	-1.304	0.416	-1.87
12	1	62.920	-0.314	-2.07
12	13	-62.920	0.314	-1.58
13	2	-59.738	-0.139	-0.66
13	13	59.738	0.139	-0.96
14	2	49.084	-0.107	-0.64
14	14	-49.084	0.107	-0.60
15	3	-44.252	-0.065	-0.18
15	14	44.252	0.065	-0.57
16	3	35.953	0.007	-0.07
16	15	-35.953	-0.007	0.16
17	4	-3.634	-0.073	-0.50
17	15	3.634	0.073	-0.26
18	5	-28.536	-0.156	-1.15
18	15	28.536	0.156	-0.67
19	5	8.747	-0.452	-2.34
19	16	-8.747	0.452	-2.40
20	6	-0.096	-0.403	-1.99
20	17	0.096	0.403	-2.24
21	7	0.840	-0.196	-0.67

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21	17	-0.840	0.196	-1.61
22	7	-10.931	0.048	0.05
22	18	10.931	-0.048	0.51
23	8	16.255	0.080	0.51
23	18	-16.255	-0.080	0.42
24	8	-26.132	0.048	0.18
24	19	26.132	-0.048	0.38
25	9	30.409	0.074	0.56
25	19	-30.409	-0.074	0.30
26	9	-40.083	0.093	0.47
26	20	40.083	-0.093	0.61
27	10	44.691	0.075	0.46
27	20	-44.691	-0.075	0.42
28	10	-55.145	0.120	0.53
28	21	55.145	-0.120	0.87
29	11	58.420	0.310	2.06
29	21	-58.420	-0.310	1.55
30	11	1.252	0.403	2.44
30	22	-1.252	-0.403	1.78
31	12	0.413	1.304	1.87
31	13	-0.413	0.726	-0.41
32	13	53.962	2.065	2.96
32	14	-53.962	1.997	-2.62
33	14	94.553	2.339	3.80
33	15	-94.553	1.723	-0.69
34	15	122.700	1.396	1.47
34	16	-122.700	3.360	-6.43
35	16	123.153	5.386	8.83
35	17	-123.153	-0.629	6.34
36	17	123.370	1.374	-2.48
36	18	-123.370	2.688	-4.14
37	18	111.475	2.094	3.20
37	19	-111.475	1.968	-2.56
38	19	86.870	1.874	1.88
38	20	-86.870	2.188	-3.46
39	20	49.991	1.972	2.42
39	21	-49.991	2.090	-3.02
40	21	0.403	0.778	0.59
40	22	-0.403	1.252	-1.78

APPLIED JOINT LOADS, FREE JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
2	-0.000	0.000	-0.00
3	-0.000	0.000	0.00
4	-0.000	0.000	0.00
5	-0.000	0.001	0.00
6	-0.000	0.000	0.00
7	0.000	0.001	0.00
8	-0.000	0.001	0.00
9	-0.000	0.000	0.00
10	-0.000	0.000	-0.00
12	-0.002	0.000	0.00
13	0.000	-0.000	0.00
14	-0.000	-0.000	0.00
15	0.000	-0.000	0.00
16	0.000	-0.001	0.00
17	0.001	-0.001	0.00

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18	-0.000	-0.001	0.00
19	0.000	-0.000	0.00
20	0.000	-0.000	-0.00
21	0.000	0.000	-0.00
22	-0.000	0.000	-0.00

REACTIONS,APPLIED LOADS SUPPORT JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
1	0.001	62.032	-0.00
11	0.000	57.931	-0.00

FREE JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
2	0.0009	-0.0274	-0.0022
3	0.0034	-0.0496	-0.0014
4	0.0052	-0.0580	-0.0013
5	0.0071	-0.0638	-0.0018
6	0.0091	-0.0764	-0.0011
7	0.0112	-0.0765	0.0001
8	0.0151	-0.0691	0.0011
9	0.0185	-0.0527	0.0019
10	0.0208	-0.0288	0.0023
12	0.0205	-0.0000	-0.0026
13	0.0205	-0.0140	-0.0027
14	0.0187	-0.0393	-0.0021
15	0.0155	-0.0578	-0.0009
16	0.0135	-0.0643	-0.0019
17	0.0114	-0.0764	-0.0015
18	0.0073	-0.0739	0.0009
19	0.0036	-0.0618	0.0015
20	0.0007	-0.0415	0.0022
21	-0.0008	-0.0147	0.0029
22	-0.0009	-0.0000	0.0027

$\delta_m = .92'$ (D+L

SUPPORT JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
1	0.0000	0.0000	-0.0036
11	0.0216	0.0000	0.0038

STRUCTURE-WALKWAY-TRUSS-CHARLES RIVER DAM B. RODGER DECEMBER,1972

LOADING 2 (FULL DEAD + LIVE) WITH CRANE LOAD NEAR SUPPORT

MEMBER FORCES

MEMBER	JOINT	AXIAL FORCE	SHEAR FORCE	MOMENT
1	1	-30.047	4.190	4.72
1	2	30.047	4.692	-7.25
2	2	-79.213	4.844	8.63
2	3	79.213	4.038	-4.56
3	3	-113.443	3.408	4.80
3	4	113.443	1.033	1.18
4	4	-113.522	2.758	-0.65
4	5	113.522	7.158	-10.44
5	5	-125.999	9.279	13.65
5	6	125.999	0.638	8.14
6	6	-126.363	-0.073	-6.35
6	7	126.363	4.514	-5.21
7	7	-120.678	4.324	5.82
7	8	120.678	4.558	-7.00
8	8	-101.613	4.374	6.28
8	9	101.613	4.508	-6.96
9	9	-70.320	4.199	5.90
9	10	70.320	4.683	-8.34
10	10	-26.292	4.719	7.33
10	11	26.292	4.163	-4.52
11	1	1.353	-0.434	-2.59
11	12	-1.353	0.434	-1.96
12	1	67.685	-0.324	-2.13
12	13	-67.685	0.324	-1.64
13	2	-64.549	-0.146	-0.69
13	13	64.549	0.146	-1.00
14	2	48.404	0.111	-0.68
14	14	-48.404	0.111	-0.61
15	3	-43.595	0.063	-0.16
15	14	43.595	0.063	-0.57
16	3	35.300	0.007	-0.07
16	15	-35.300	0.007	0.15
17	4	-3.791	0.078	-0.52
17	15	3.791	0.078	-0.29
18	5	-27.535	0.145	-1.05
18	15	27.535	0.145	-0.64
19	5	8.319	0.416	-2.16
19	16	-8.319	0.416	-2.21
20	6	-0.564	0.363	-1.79
20	17	0.564	0.363	-2.02
21	7	1.748	0.182	-0.62
21	17	-1.748	0.182	-1.50

A139
9

22	7	-11.663	0.043	0.02
22	18	11.663	-0.043	0.48
23	8	16.919	0.080	0.51
23	18	-16.919	-0.080	0.41
24	8	-26.814	0.051	0.19
24	19	26.814	-0.051	0.40
25	9	31.103	0.076	0.57
25	19	-31.103	-0.076	0.31
26	9	-40.773	0.095	0.48
26	20	40.773	-0.095	0.62
27	10	45.380	0.077	0.47
27	20	-45.380	-0.077	0.43
28	10	-55.834	0.122	0.54
28	21	55.834	-0.122	0.88
29	11	59.105	0.312	2.06
29	21	-59.105	-0.312	1.56
30	11	1.257	0.405	2.45
30	22	-1.257	-0.405	1.80
31	12	0.432	1.353	1.96
31	13	-0.432	0.677	-0.26
32	13	58.143	2.071	2.91
32	14	-58.143	1.991	-2.51
33	14	98.157	2.321	3.70
33	15	-98.157	1.741	-0.78
34	15	125.581	1.530	1.55
34	16	-125.581	3.225	-5.83
35	16	125.998	5.091	8.04
35	17	-125.998	-0.335	5.64
36	17	125.770	1.424	-2.11
36	18	-125.770	2.638	-4.00
37	18	113.276	2.082	3.10
37	19	-113.276	1.980	-2.59
38	19	88.070	1.873	1.87
38	20	-88.070	2.189	-3.46
39	20	50.591	1.970	2.41
39	21	-50.591	2.092	-3.03
40	21	0.405	0.773	0.58
40	22	-0.405	1.257	-1.80

APPLIED JOINT LOADS, FREE JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
2	-0.000	-4.999	-0.00
3	-0.000	0.000	-0.00
4	-0.000	0.000	0.00
5	-0.000	0.001	0.00
6	-0.000	0.000	0.00
7	0.000	0.001	0.00
8	-0.000	0.001	0.00
9	-0.000	0.001	0.00
10	-0.000	0.000	-0.00
12	-0.002	0.000	0.00
13	0.000	-0.000	0.00
14	-0.000	-0.000	0.00
15	-0.000	-0.000	0.00
16	0.000	-0.001	0.00
17	0.001	-0.001	0.00
18	-0.000	-0.000	0.00

A140
10

19	0.000	-0.000	0.00
20	0.000	-0.000	0.00
21	0.000	0.000	-0.00
22	-0.000	0.000	-0.00

REACTIONS•APPLIED LOADS SUPPORT JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
1	0.001	66.407	-0.00
11	0.000	58.556	-0.00

FREE JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
2	0.0010	-0.0288	-0.0023
3	0.0036	-0.0514	-0.0014
4	0.0055	-0.0600	-0.0014
5	0.0074	-0.0658	-0.0017
6	0.0095	-0.0776	-0.0010
7	0.0116	-0.0776	0.0001
8	0.0156	-0.0701	0.0011
9	0.0190	-0.0534	0.0020
10	0.0213	-0.0292	0.0023
12	0.0213	-0.0000	-0.0027
13	0.0213	-0.0147	-0.0029
14	0.0194	-0.0409	-0.0022
15	0.0161	-0.0598	-0.0010
16	0.0140	-0.0662	-0.0018
17	0.0119	-0.0776	-0.0014
18	0.0077	-0.0750	0.0009
19	0.0039	-0.0627	0.0015
20	0.0010	-0.0420	0.0022
21	-0.0006	-0.0149	0.0029
22	-0.0006	-0.0000	0.0028

$\delta_{max} = .93''$ (L

SUPPORT JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
1	0.0000	0.0000	-0.0038
11	0.0222	0.0000	0.0039

STRUCTURF-WALKWAY-TRUSS-CHARLES RIVER DAM B. RODGER DECEMBER,1972

LOADING 3 (FULL DEAD + LIVE) WITH CRANE LOAD AT MIDSPAN

MEMBER FORCES

MEMBER	JOINT	AXIAL FORCE	SHEAR FORCE	MOMENT
1	1	-29.154	4.169	4.65
1	2	29.154	4.712	-7.39
2	2	-78.933	4.860	8.78
2	3	78.933	4.021	-4.54
3	3	-116.041	3.539	4.89
3	4	116.041	0.901	1.76
4	4	-116.098	2.061	-1.34
4	5	116.098	7.855	-13.28
5	5	-130.972	10.920	17.88
5	6	130.972	-1.002	12.19
6	6	-131.533	-0.721	-9.37
6	7	131.533	5.163	-5.47
7	7	-127.030	4.358	6.07
7	8	127.030	4.523	-6.90
8	8	-106.103	4.356	6.14
8	9	106.103	4.526	-6.99
9	9	-73.022	4.196	5.87
9	10	73.022	4.686	-8.35
10	10	-27.192	4.708	7.27
10	11	27.192	4.174	-4.58
11	1	1.328	-0.425	-2.54
11	12	-1.328	0.425	-1.92
12	1	65.653	-0.319	-2.10
12	13	-65.653	0.319	-1.61
13	2	-62.498	-0.145	-0.69
13	13	62.498	0.145	-0.99
14	2	51.862	-0.115	-0.69
14	14	-51.862	0.115	-0.65
15	3	-46.974	-0.076	-0.24
15	14	46.974	0.076	-0.64
16	3	38.544	0.010	-0.09
16	15	-38.544	-0.010	0.21
17	4	-2.963	-0.056	-0.42
17	15	2.963	0.056	-0.17
18	5	-32.542	-0.200	-1.52
18	15	32.542	0.200	-0.81
19	5	10.469	-0.594	-3.08
19	16	-10.469	0.594	-3.15
20	6	1.724	-0.561	-2.81
20	17	-1.724	0.561	-3.07
21	7	-2.756	-0.245	-0.79
21	17	2.756	0.245	-2.06

A142

12

22	7	-13.508	0.074	0.19
22	18	13.508	-0.074	0.67
23	8	19.086	0.094	0.57
23	18	-19.086	-0.094	0.52
24	8	-28.916	0.050	0.18
24	19	28.916	-0.050	0.40
25	9	33.149	0.079	0.60
25	19	-33.149	-0.079	0.32
26	9	-42.835	0.101	0.51
26	20	42.835	-0.101	0.66
27	10	47.454	0.082	0.50
27	20	-47.454	-0.082	0.45
28	10	-57.899	0.127	0.57
28	21	57.899	-0.127	0.91
29	11	61.157	0.316	2.08
29	21	-61.157	-0.316	1.59
30	11	1.274	0.412	2.49
30	22	-1.274	-0.412	1.84
31	12	0.423	1.328	1.92
31	13	-0.423	0.702	-0.34
32	13	56.361	2.064	2.96
32	14	-56.361	1.998	-2.62
33	14	99.352	2.390	3.92
33	15	-99.352	1.672	-0.30
34	15	130.376	0.864	1.06
34	16	-130.376	3.892	-8.70
35	16	130.971	6.575	11.86
35	17	-130.971	-1.819	9.31
36	17	132.949	1.164	-4.17
36	18	-132.949	2.897	-4.56
37	18	118.676	2.119	3.37
37	19	-118.676	1.943	-2.48
38	19	91.671	1.858	1.75
38	20	-91.671	2.204	-3.50
39	20	52.390	1.965	2.37
39	21	-52.390	2.097	-3.04
40	21	0.412	0.757	0.53
40	22	-0.412	1.274	-1.84

APPLIED JOINT LOADS, FREE JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
2	0.000	0.000	-0.00
3	-0.000	0.001	0.00
4	-0.000	0.000	0.00
5	-0.000	0.001	0.00
6	-0.000	0.000	0.00
7	-0.000	-4.998	0.00
8	-0.000	0.001	0.00
9	-0.000	0.001	0.00
10	-0.001	0.000	-0.00
12	-0.002	0.000	0.00
13	0.000	-0.000	0.00
14	-0.000	-0.000	0.00
15	-0.000	-0.001	0.00
16	0.000	-0.000	0.00
17	0.000	-0.001	0.00
18	0.000	-0.000	0.00

19	0.000	-0.000	0.00
20	0.000	-0.000	0.00
21	0.000	0.000	-0.00
22	-0.000	0.000	-0.00

REACTIONS,APPLIED LOADS SUPPORT JOINTS

JOINT	FORCE X	FORCE Y	MOMENT Z
1	0.001	64.532	-0.00
11	0.000	60.431	-0.00

FREE JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
2	0.0009	-0.0296	-0.0023
3	0.0036	-0.0517	-0.0015
4	0.0055	-0.0605	-0.0013
5	0.0074	-0.0666	-0.0022
6	0.0096	-0.0828	-0.0016
7	0.0118	-0.0831	0.0002
8	0.0160	-0.0746	0.0012
9	0.0196	-0.0565	0.0021
10	0.0220	-0.0309	0.0025
12	0.0213	-0.0000	-0.0027
13	0.0213	-0.0146	-0.0028
14	0.0194	-0.0409	-0.0022
15	0.0161	-0.0603	-0.0009
16	0.0139	-0.0672	-0.0024
17	0.0118	-0.0829	-0.0020
18	0.0073	-0.0800	0.0011
19	0.0034	-0.0665	0.0016
20	0.0003	-0.0444	0.0024
21	-0.0013	-0.0157	0.0031
22	-0.0013	-0.0000	0.0029

δ_{max} = 1.00" D+L

SUPPORT JOINT DISPLACEMENTS

JOINT	X-DISPLACEMENT	Y-DISPLACEMENT	ROTATION
1	0.0000	0.0000	-0.0037
11	0.0229	0.0000	0.0040

PROJECT C.B.D. ACC. NO. 1865
SUBJECT DESIGN WALKWAY TRUSS SHEET NO. 1
DATE DEC.
COMP. WHR CHECK CONT. NO.

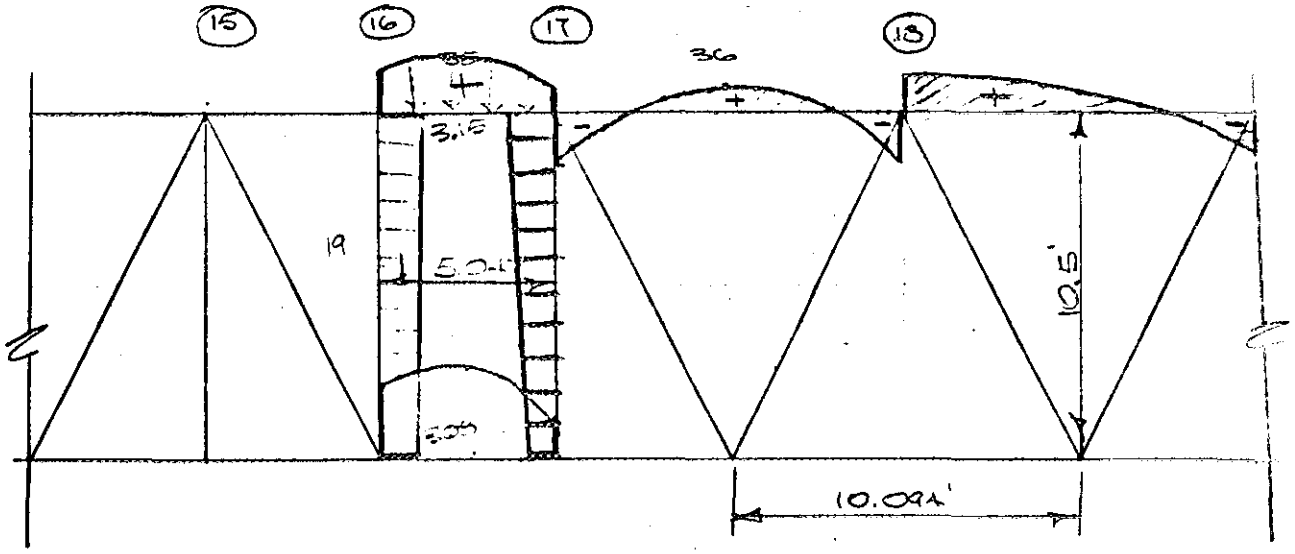
A 144

CONSIDER TYPICAL TOP CHORD COMP. MEMBER

(A) MEMBER 35 CASE III LOADING $\omega = .9425$ $P = 130.971^{k}$ $M_{16} = 11.86^{1-k}$ $M_{17} = 9.31^{1-k}$ COND (+)

(B) MEMBER 36 CASE III LOADING $\omega = .4025$ $P = 132.949^{k}$ $M_{17} = -4.17$ $M_{18} = -4.56$

CONSIDER PORTION of TRUSS



CASE III LOADING (SEE COMP SHEET)

Check	MEMBER 35	$M_{MAX} = +13.722^{1-k}$	$P = -130.97^{k}$ S=0.58
	MEMBER 36	$M_{MAX} = -4.560^{1-k}$	$P = -132.95^{k}$
	MEMBER 5	$M_{MAX} = +21.60^{1-k}$	$P = +130.97$ S=109
	MEMBER 6	$M_{MAX} = -9.37^{1-k}$	$P = +131.533$
	MEMBER 19	$M_{AX} = -3.15^{1-k}$	$P = -10.47$
	MEMBER 20	$M_{MAX} = -3.07^{1-k}$	$P = -1.724$
CASE II	MEMBER 12	$M_{MAX} = .324^{1-k}$	$P = 67.69$

CASE III

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

11-72B

PROJECT CHARLES RIVER DAM ACC. NO. 185628
SUBJECT WALKWAY TRUSS SHEET NO. ___ OF 2TD
DATE DEC 19 72
COMP. W.H.R. CHECK CONT. NO.

A145

MEMBER 5

LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
1.965
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
1.965
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
-17.880
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
12.190
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
3.831
RIGHT REACTION =
6.086
DIST TO L SPT =
0.000
MAX POS SHEAR =
3.831
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-6.086
DIST TO L SPT =
2.019
MAX POS MOM =
21.610
DIST TO L SPT =
0.000
MAX NEG MOM =
0.000

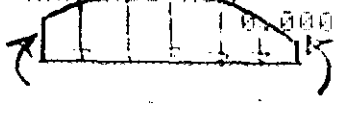
MEMBER 6
JTS 6-7

LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
.880
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.880
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
9.370
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-5.470
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
2.993
RIGHT REACTION =
1.448
DIST TO L SPT =
0.000
MAX POS SHEAR =
2.993
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-1.448
DIST TO L SPT =
0.000
MAX POS MOM =
0.000
DIST TO L SPT =
0.000
MAX NEG MOM =
-5.370

MEMBER 35
JTS 16 to 17

$M_{\oplus}$ =
6×6×1/2

LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
.943
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.943
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
-11.860
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
9.310
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
1.874
RIGHT REACTION =
2.885
DIST TO L SPT =
0.000
MAX POS SHEAR =
1.874
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-2.885
DIST TO L SPT =
2.019
MAX POS MOM =
13.722 1-K
DIST TO L SPT =
0.000
MAX NEG MOM =
0.000



CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

ALLE

11-72B

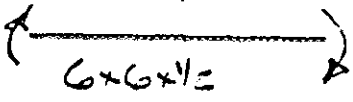
PROJECT Charles River Dam ACC. NO. 1456.28
SUBJECT Walkway Trusses SHEET NO. ___ OF 31D
DATE Dec. 19 72
COMP. W.H.R CHECK ___ CONT. NO. ___

A146

Member 36

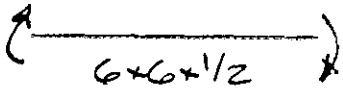
LENGTH (FT) =
10.094
UNI WA (KIP/FT)=
.403 ✓
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.403 ✓
DIST B (FT) =
10.094
MOM M (FT-KIPS)=
4.170 ✓
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-4.560 ✓
DIST A (FT) =
10.094
END OF LOADING
LEFT REACTION =
1.995
RIGHT REACTION =
2.073
DIST TO L SPT =
0.000
MAX POS SHEAR =
1.995
DIST TO L SPT =
10.094
MAX NEG SHEAR =
-2.073
DIST TO L SPT =
5.047
MAX POS MOM =
.768
DIST TO L SPT =
10.094
MAX NEG MOM =
→ 0

#34



LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
.880
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.880
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
-1.060
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-8.700
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
.287
RIGHT REACTION =
4.155
DIST TO L SPT =
0.000
MAX POS SHEAR =
.287
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-4.155
DIST TO L SPT =
.252
MAX POS MOM =
1.104
DIST TO L SPT =
5.047
MAX NEG MOM =
→ -8.700

#37



LENGTH (FT) =
10.094
UNI WA (KIP/FT)=
.403
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.403
DIST B (FT) =
10.094
MOM M (FT-KIPS)=
-3.370
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-2.480
DIST A (FT) =
10.094
END OF LOADING
LEFT REACTION =
1.454
RIGHT REACTION =
2.613
DIST TO L SPT =
0.000
MAX POS SHEAR =
1.454
DIST TO L SPT =
10.094
MAX NEG SHEAR =
-2.613
DIST TO L SPT =
3.533
MAX POS MOM =
→ 5.993
DIST TO L SPT =
10.094
MAX NEG MOM =
-2.480

PROJECT Charles River DAM ACC. NO. 1456.29
SUBJECT WALKWAY TRUSS SHEET NO. ___ OF 4TD
DATE Dec 1972
COMP. W.H.R. CHECK CONT. NO.

A 147

#33

6x6x3/8

```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .403
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .403
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -3.920
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
           -.300
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           1.616
RIGHT REACTION =
           2.452
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           1.616
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -2.452
DIST TO L SPT =
           4.038
MAX POS MOM =
           7.159
DIST TO L SPT =
          10.094
MAX NEG MOM =
           -.300
```

#38

6x6x3/8

```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .403
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .403
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -1.750
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -3.510
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           1.510
RIGHT REACTION =
           2.553
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           1.510
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -2.553
DIST TO L SPT =
           3.533
MAX POS MOM =
           4.574
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -3.510
```

#32

6x6x3/8

```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .403
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .403
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -2.960
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -2.620
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           1.481
RIGHT REACTION =
           2.587
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           1.481
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -2.587
DIST TO L SPT =
           3.533
MAX POS MOM =
           5.679
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -2.620
```

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

11-72B

PROJECT C. R. DAM
SUBJECT WALKWAY SUPPORT
COMP. W.H.R. CHECK
ACC. NO. 145628
SHEET NO. OF STD
DATE DEC. 19 72
CONT. NO.

A148

#39

6x6x3/3

LENGTH (FT) =
10.094
UNI WA (KIP/FT)=
.403
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.403
DIST B (FT) =
10.094
MOM M (FT-KIPS)=
-2.370
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-3.040
DIST A (FT) =
10.094
END OF LOADING
LEFT REACTION =
1.498
RIGHT REACTION =
2.570
DIST TO L SPT =
0.000
MAX POS SHEAR =
1.498
DIST TO L SPT =
10.094
MAX NEG SHEAR =
-2.570
DIST TO L SPT =
3.533
MAX POS MOM =
5.147
DIST TO L SPT =
10.094
MAX NEG MOM =
-3.040

#31

6x6x3/3

LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
.403
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.403
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
-1.920
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-.340
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
.569
RIGHT REACTION =
1.465
DIST TO L SPT =
0.000
MAX POS SHEAR =
.569
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-1.465
DIST TO L SPT =
1.514
MAX POS MOM =
2.320
DIST TO L SPT =
5.047
MAX NEG MOM =
-.340

#40

END MOMENTS TYPICAL

M 6x6x3/3 M

LENGTH (FT) =
5.047
UNI WA (KIP/FT)=
.403
DIST A (FT) =
0.000
UNI WB (KIP/FT)=
.403
DIST B (FT) =
5.047
MOM M (FT-KIPS)=
-.530
DIST A (FT) =
0.000
MOM M (FT-KIPS)=
-1.840
DIST A (FT) =
5.047
END OF LOADING
LEFT REACTION =
.547
RIGHT REACTION =
1.487
DIST TO L SPT =
0.000
MAX POS SHEAR =
.547
DIST TO L SPT =
5.047
MAX NEG SHEAR =
-1.487
DIST TO L SPT =
1.262
MAX POS MOM =
.900
DIST TO L SPT =
5.047
MAX NEG MOM =
-1.840

PROJECT C.R. DAM ACC. NO. 1256 29
SUBJECT WALKWAY TRUSS SHEET NO. ___ OF 6TD
DATE DEC 19__
COMP. WHR CHECK ___ CONT. NO. A449

CONSIDER TOP CHORD (COMPRESSION MEMBER) A-36 STEEL

MEMBER #35 CASE III $A_P = -130.97^k$ $L = 5.047'$
$M_M = 13.72^{1\cdot k}$ $r = 2.19''$

$\frac{KL}{R} \leq 200$ SECT. 1.8.4 AISC. 1970 $S_x = 6.58^k$

CONSIDER HST 6x6x1/2" $t_w = t_F = .5''$ $A = 10.1 in^2$
$d = 6''$ $S = 16.2 in^3$
$A' = 6 in^2$

1 - @ UNBRACED POINT

$$\frac{f_a}{F_A} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}}\right) F_{bx}} \leq 1.0 \quad (1.6\text{-}1a)$$

K = .65 FULL PENE. WELDS. FULL FIXITY @ SUPT

(A) $\frac{KL}{r_x} = \frac{KL}{r_y} = \frac{.65 \times 5.047 \times 12}{2.19} = 18$ $\therefore F_A = 20.72^{KSI}$

$f_A = \frac{130.97^k}{10.1 in^2} = 12.97^{KSI}$

$\therefore f_A / F_A = 12.97/20.72 = .626$

(B) $C_m = .85$ (p 5-23 AISC) MIN.;
$S_x = 16.2 in^3$

$\frac{KL}{r_b} = \frac{KL}{r_x} = 18$ $F'_{ex} = \frac{12\pi^2 E}{23(18)^2} = 460.9$

$C_m = .85$ (END RESTRAINED) SEE PG 5-23

$f_{bx} = \frac{13.72 \times 12}{16.2} = 10.16^{KSI}$ $b/2t = \frac{6}{2 \cdot .5} = 6 < 9.7$
$F_{bx} = 24^{KSI}$ $b/t = 12 < 31.7$
$d/t = 6/.5 = 12 < 42.8$

$$\frac{C_m \cdot f_{bx}}{\left(1 - \frac{12.97}{460.9}\right) 24} = \frac{.85 \times 10.16}{23.32} = .370$$

$$\therefore \frac{f_a}{F_A} + \frac{C_m f_{bx}}{\left(1 - \frac{f_a}{F'_e}\right) F_b} = .996 < 1.0 \quad \text{OK} \checkmark$$

2 - @ A BRACED POINT USE FORM 1.6-1b $M_B = 11.96$
$f_{bx} = 8.79$

$$\frac{f_a}{.6F_y} + \frac{f_{bx}}{F_{bx}} = \frac{12.97}{22} + \frac{8.79}{24} =$$
$$.590 + .366 = .9563 < 1.0 \quad \text{OK} \checkmark$$

(3) $F_y = \frac{6.58}{6 in^2} = 1.1^{KSI} < 14.4$ OK

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USE 6x6x1/2 HST

11-728

PROJECT C.R.D ACC. NO. 195628
SUBJECT WALKWAY TRUSS SHEET NO. ___ OF ___
DATE DEC 19 72
COMP. W.HR CHECK CONT. NO.

A150

MEMBER 36 CONSIDER 6×6×1/2 HST

$A = 10.1 \text{ in}^2$ $M_x = 4.56^{1\text{-}k}$ $L = 10.094 \text{ ft}$
$S = 16.2 \text{ in}^3$ $A_P = -132.95^k$
$r = 2.19 \text{ in}$
$k = .65$

$\frac{KL}{r} = \frac{.65 \times 10.1 \times 12}{2.19} = 36 < 200$

$F_A = 19.50^{ksi}$, $f_A = \frac{132.95}{10.1} = 13.16$

(form 1.6-1a) $f_a/F_A = \frac{13.16}{19.50} = .675$

$f_{bx} = \frac{4.56 \times 12}{16.2} = 3.37$, $C_{m_x} = .85$, $\frac{KL}{R_b} = 36$

$\therefore F'_{ex} = 115.22$ (Pg 5-94 AISC)

$\therefore \frac{.85(3.37)}{\left(1 - \frac{13.16}{115.22}\right)24} = .135$

$\therefore$ STRESS RATIO $= .675 + .135 = .810 < 1.0$ ✓ OK

(form 1.6-1b) @ BRACED POINT M_B

$\frac{f_a}{.6F_y} + \frac{f_b}{F_B} = \frac{13.16}{22} + \frac{3.37}{24}$ USE 6×6×1/2 HST

$.60 + .14 = .74 < 1.0$ OK

for MEMBERS 34 & 37 TRY 6×6×3/8" HST

CONSIDER 6"×6" TUBES FOR #31, #32, #33, #38, #39, & #40 ALSO

MEMBER 34
$P_A = 130.4^k$, $M_M = 8.7^{1\text{-}k}$

& $A = 7.95 \text{ in}^2$, $S = 13.5 \text{ in}^3$, $r = 2.26"$ (FOR 6×6×3/8 HST)

MEMBER 37
$P_A = 118.7^k$ $M_M = 6.00^{1\text{-}k}$

$\frac{KL}{r_b} = \frac{KL}{r} = \frac{.65 \times 5.047 \times 12}{2.26} = 17.42$

$F_A = 20.76$ $f_a = 16.4$

$F_B = 24^{ksi}$ $f_b = \frac{8.7 \times 12}{13.5} = 7.73$

$F'_e = \frac{12\pi^2 E}{23(17.42)^2} = 492.1$

$\frac{16.4}{20.76} + \frac{.85(7.73)}{\left(1 - \frac{16.4}{492.1}\right)24} =$

$.790 + .283 = 1.073 > 1$ NG

$\therefore$ USE 6×6×1/2 HST

$\frac{KL}{r} = \frac{.65 \times 10.094 \times 12}{2.26} = 34.84$

$F_A = 19.59$ ← Pg 5-84 (AISC)

$f_a = 14.93$ $f_b = \frac{6 \times 12}{13.5} = 5.33$

$F_B = 22^{ksi}$

F'_e (pg 5-94) $= 123$

$\frac{14.93}{19.59} + \frac{.85(5.33)}{\left(1 - \frac{14.93}{123}\right)24} =$

$.762 + .215 = .977 < 1$ OK

STILL CHANGE

$\therefore$ USE 6×6×1/2 HST

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11-72B

PROJECT C.R.D. ACC. NO. 185628
SUBJECT WALKWAY TRUSS SHEET NO. ___ OF 27D
DATE DEC 1972
COMP. W.H.R. CHECK CONT. NO.

A/51

CONSIDER MEMBERS #39 & #33

#33 $P_A = 99.4^K$, $M_H = 7.159$ #39 $P_A = 91.7^K$, $M = 4.57^{1-K}$

USE SAME SIZE TRY 6×6×3/8" A = 7.95, S = 13.5, r = 2.26

$f_A = \frac{99.4}{7.95} = 12.5$ $\frac{KL}{r} = 34.8$

∴ $F_A = 19.59$ $F'_c = 123.3$

$F_B = 24^{KSI}$ $f_b = \frac{7.16 \times 12}{13.5} = 6.36$

AISC (1.6-1a) ∴ $\frac{12.50}{19.59} + \frac{.85(6.36)}{(1-\frac{12.5}{123})24} = .638 + .25 = .889 < 1.0$ OK

(1.6-1b) $\frac{12.5}{22} + \frac{6.36}{24} = .83 < 1.0$ OK

USE 6×6×3/8" HST FOR MEMBER #39 & #33

6"×6"×3/8" WILL BE SET AS A MINIMUM SIZE FOR TOP & BOTTOM CHORDS.

USE 6×6×3/8" HST FOR ALL OTHER TOP CHORD MEMBERS

PROJECT C.R.D. ACC. NO. 1956 26
SUBJECT TENSION CHORDS SHEET NO. ___ OF 9TD
WALKWAY TRUSS DATE [illegible] 19[illegible]
COMP. W.H.R. CHECK CONT. NO.

A152

#4

```
LENGTH (FT) =
          5.047
UNI WA (KIP/FT)=
          1.965
DIST A (FT) =
          0.000
UNI WB (KIP/FT)=
          1.965
DIST B (FT) =
          5.047
MOM M (FT-KIPS)=
          1.340
DIST A (FT) =
          0.000
MOM M (FT-KIPS)=
        -13.280
DIST A (FT) =
          5.047
END OF LOADING
LEFT REACTION =
          2.593
RIGHT REACTION =
          7.324
DIST TO L SPT =
          0.000
MAX POS SHEAR =
          2.593
DIST TO L SPT =
          5.047
MAX NEG SHEAR =
         -7.324
DIST TO L SPT =
          1.262
MAX POS MOM =
           .367
DIST TO L SPT =
          5.047
MAX NEG MOM =
        -13.280
```

#8

```
LENGTH (FT) =
         10.094
UNI WA (KIP/FT)=
           .880
DIST A (FT) =
          0.000
UNI WB (KIP/FT)=
           .880
DIST B (FT) =
         10.094
MOM M (FT-KIPS)=
         -6.140
DIST A (FT) =
          0.000
MOM M (FT-KIPS)=
         -6.990
DIST A (FT) =
         10.094
END OF LOADING
LEFT REACTION =
          3.141
RIGHT REACTION =
          5.742
DIST TO L SPT =
          0.000
MAX POS SHEAR =
          3.141
DIST TO L SPT =
         10.094
MAX NEG SHEAR =
         -5.742
DIST TO L SPT =
          3.533
MAX POS MOM =
         11.741
DIST TO L SPT =
         10.094
MAX NEG MOM =
         -6.990
```

#3

```
LENGTH (FT) =
         10.094
UNI WA (KIP/FT)=
           .880
DIST A (FT) =
          0.000
UNI WB (KIP/FT)=
           .880
DIST B (FT) =
         10.094
MOM M (FT-KIPS)=
         -4.890
DIST A (FT) =
          0.000
MOM M (FT-KIPS)=
          1.760
DIST A (FT) =
         10.094
END OF LOADING
LEFT REACTION =
          4.131
RIGHT REACTION =
          4.751
DIST TO L SPT =
          0.000
MAX POS SHEAR =
          4.131
DIST TO L SPT =
         10.094
MAX NEG SHEAR =
         -4.751
DIST TO L SPT =
          4.542
MAX POS MOM =
         14.577
DIST TO L SPT =
          0.000
MAX NEG MOM =
          0.000
```

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11-72B

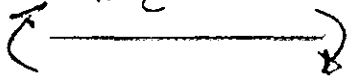
PROJECT C.R.D. ACC. NO. 1856.29
SUBJECT TENSION CHORDS SHEET NO. ___ OF 107D
WALKWAY TRUSS DATE DEC 1972
COMP. W.H.R CHECK ___ CONT. NO. ___

A 153

#7

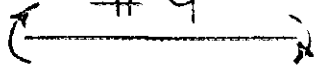
```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .880
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .880
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -6.070
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -6.900
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           3.156
RIGHT REACTION =
           5.726
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           3.156
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -5.726
DIST TO L SPT =
           3.533
MAX POS MOM =
          11.730
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -6.900
```

#2



```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .880
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .880
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -8.780
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -4.540
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           3.122
RIGHT REACTION =
           5.761
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           3.122
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -5.761
DIST TO L SPT =
           3.533
MAX POS MOM =
          14.317
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -4.540
```

#9



```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .880
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .880
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -5.870
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -8.350
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           3.033
RIGHT REACTION =
           5.850
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           3.033
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -5.850
DIST TO L SPT =
           3.533
MAX POS MOM =
          11.092
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -8.350
```

PROJECT C.R.D. ACC. NO. 185628
SUBJECT TENSION CHORDS SHEET NO. ___ OF 117
WALKWAY TENSS DATE DEC. 1971
COMP. W.H.R. CHECK CONT. NO.

A 154

#1

```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .880
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .880
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -4.650
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -7.390
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           3.249
RIGHT REACTION =
           5.634
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           3.249
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -5.634
DIST TO L SPT =
           3.533
MAX POS MOM =
          10.635
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -7.390
```

#10

```
LENGTH (FT) =
          10.094
UNI WA (KIP/FT)=
            .880
DIST A (FT) =
           0.000
UNI WB (KIP/FT)=
            .880
DIST B (FT) =
          10.094
MOM M (FT-KIPS)=
          -7.270
DIST A (FT) =
           0.000
MOM M (FT-KIPS)=
          -4.580
DIST A (FT) =
          10.094
END OF LOADING
LEFT REACTION =
           3.267
RIGHT REACTION =
           5.615
DIST TO L SPT =
           0.000
MAX POS SHEAR =
           3.267
DIST TO L SPT =
          10.094
MAX NEG SHEAR =
          -5.615
DIST TO L SPT =
           3.533
MAX POS MOM =
          13.322
DIST TO L SPT =
          10.094
MAX NEG MOM =
          -4.580
```

PROJECT C.R.D ACC. NO. 1756.[illegible]
SUBJECT TENSION CHORDS SHEET NO. ___ OF [illegible]
DATE [illegible] 19[illegible]
COMP. W.HR CHECK CONT. NO. A-55

CONSIDER TENSION CHORD (BOTTOM) A-36 Steel

CONSIDER MEMBER No 4, 5, 6, 7 6×6×1/2 HST

Where $F_T = 22^{ksi}$ FOR TENSION USE 1.6-1b

Where $\frac{f_a}{.6F_y} + \frac{f_{bx}}{F_{bx}} \leq 1.0$ (Pg 5-23 Sect 1.6.2 AISC)

MEMBER #5 (TENSION) $A_p = 130.97$ $M_u = 21.60$ $A = 10.1$ $S = 16.2$ $r = 2.19$

$f_A = 130.97/10.1 = 12.97^{ksi}$ $f_{bx} = \frac{21.6 \times 12}{16.2} = 16^{ksi}$

$F_b = 24^{ksi}$

$\therefore \frac{12.97}{22} + \frac{16}{24}$

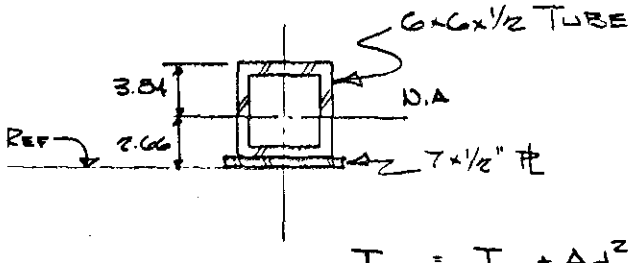
$.590 + .666 = 1.256 < 1.0$ N.G.

MEMBER #6 (TENSION) $A_p = 131.53$ $M_u = 9.37$

$f_a = 131.53/10.1 = 13.02$ $f_b = \frac{9.37 \times 12}{16.2} = 6.94$

$\therefore \frac{13.02}{22} + \frac{6.94}{24} = .592 + .30 = .89 < 1.0$ OK

CONSIDER SPECIAL BUILT-UP MEMBER FOR MEMBER #5



	A	BOT Y	AY
TUBE	10.1	3.5	35.350
PL	3.5	.25	.875
	13.6		36.225

$\bar{Y} = \frac{36.225}{13.6} = 2.66$ in

$I_{xx} = I_{o\square} + Ad_{\square}^2 + Ad_{PL}^2 = 48.6 + 10.1(.84)^2 + 3.5(2.41)^2$
$= 48.6 + 7.13 + 20.33$
$= 76.06 \text{ in}^4$

$A = 13.6 \text{ in}^2$ $S_T = \frac{76.06}{3.84} = 19.81 \text{ in}^3$ $S_B = \frac{76.06}{2.66} = 28.59 \text{ in}^3$

$f_a = 131/13.6 = 9.63^{ksi}$ $f_{bx} = \frac{21.6 \times 12}{19.81} = 13.1^{ksi}$

$\therefore \frac{9.63}{22} + \frac{13.1}{24} = .438 + .546 = .984 < 1.0$ ✓ ok

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NOTE: ALTER. BUILT UP TUBE
Too Expensive → 2 - 6" × 5/8" PL's T & B, 2 - 4.75" × 1/2" PL's Side

L1-72B

PROJECT C.R.D. ACC. NO. 195629
SUBJECT TENSION CHECKS SHEET NO. ___ OF 13TD
(DAILIGAY TENSION) DATE DEC. 1972
COMP. W.H.K. CHECK ___ CONT. NO. ___

6 × 6 × (3/8) MIN. THICKNESS

MEMBER	MAX MOM	MAX. AXIAL	t	$f_t/0.6F_y$	f_b/F_A	RATIO	REMARKS
1	10.64	30^k	3/8	.17	.39	.56	6×6×3/8
2	14.32	79.2^k	3/8	.45	.53	.98	6×6×3/8
3	14.59	116.0^k	1/2"	.52	.45	.97	6×6×1/2
4	13.28	116.1^k	1/2"	.52	.41	.93	6×6×1/2
5 w/ COVER PL	21.60	131.0^k	1/2+	.44	.55	.99	6×6×1/2 w/ 7×1/2 PL
6	9.37	131.5^k	1/2	.59	.30	.89	6×6×1/2
7	11.73	127.0^k	1/2"	.57	.36	.93	6×6×1/2
8	11.74	106.1^k	1/2"	.48	.36	.84	6×6×1/2
9	11.09	73^k	3/8	.42	.41	.83	6×6×3/8
10	13.32	27.2^k	3/8	.16	.49	.65	6×6×3/8

K = .65

6×6×1/2" HST
A = 10.1
S = 16.2
r = 2.19
F_b = 24^{KSI}
(L = 10') $\frac{KL}{r}$ = 36, F_A = 19.50
(L = 5') $\frac{KL}{r}$ = 18, F_A = 20.72
$F'_{E_{10}}$ = 115.22
F'_{E_5} = 460.90
F_T = 22^{KSI}

6×6×3/8" HST
A = 7.95
S = 13.5
r = 2.26
F_b = 24^{KSI}
(L = 10) $\frac{KL}{r}$ = 34.8, F_A = 19.59
(L = 5) $\frac{KL}{r}$ = 17.4, F_A = 20.76
$F'_{E_{10}}$ 173.0 } Pg 5-94 AISC.
F'_{E_5} 492.1 }
F_T = 22^{KSI}

A 156

PROJECT C.R.D ACC. NO. 1856.28
SUBJECT WEB MEMBERS (CONT) SHEET NO. ___ OF 14TD
DATE DEC 19 72
COMP. W.H.R CHECK CONT. NO.

CONSIDER MEMBER #19 $P_A = 10.5^k$, $M = 3.15$ 6"x4"x3/8" TUBE, $KL/R < 200$

$A = 6.45$
$r_x = 2.11$
$r_y = 1.53$
$S_y = 7.58$
$K = .65$

$\frac{KL}{r_y} = \frac{KL}{r_y} = \frac{.65 \times 10.5 \times 12}{1.53} = 53.5 \therefore F_A = 17.99$ & $F'_c = 51.21$

$\frac{KL}{r_x} = \frac{.65 \times 10.5 \times 12}{2.11} = 38.8$

WE HAVE WEAK AXIS BENDING ON TUBE

$\therefore f_A = \frac{10.5}{6.45} = 1.63$ & $F_A = 17.99$ $\therefore \frac{f_A}{F_A} = .09$

$f_{by} = \frac{3.15(12)}{7.58} = 4.98$

if $f_A/F_A < .15$ USE FORMULA 1.6-2

$\frac{f_A}{F_A} + \frac{f_{by}}{F_{bY}} = .09 + \frac{4.98}{22} = .09 + .23 = .31 < 1$ OK

Sect 1.9.2.2 $6''/.375 = 16 < 39.7$ Pg 5-74 AISC 70

$F_b = .6F_y = 22^{ksi}$ Pg 5-18 AISC 70

MEMBER #20 HAS $A_p = 1.72^k$ & $M_M = 3.07$

$\therefore$ USE 4x6x3/8" TUBE FOR #20 & #19

CONSIDER MEMBER #17 $A_p = 3.8^k$, $M_M = .52'^k$ CASE II

FOR TENSION MEMBER - USE FORMULA 1.6-1b

$f_A = 3.8/6.45 = .59$ $F_A \approx .6F_Y = 22$

$\therefore \frac{.59}{22} + \frac{.82}{22} = .03 + .04 = .07 < 1.0$

SEE NEXT SHEET FOR TABULAR DESIGN & RESULTS

A157

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11-72B

PROJECT C.R.D. A158 ACC. NO. 1956.2[illegible]
SUBJECT Web Members SHEET NO. 15 of [illegible]
Walkway Truss DATE [illegible] 19[illegible]
COMP. W.H.R. CHECK CONT. NO.

	Members	Govern Axial P.	Govern. Moment	KL/r ≤ 200 f_a/F_a	f_b/F_b	$\frac{C_m f_b}{(1-f_a/F_e)F_b}$	
Compression (−)	11 & 30	11-II 1.35	11-II 2.59	.01	.19	—	.20 6×4×3/8"
				.01	.21		.22 6×4×5/16"
	12 & 29	12-II 67.7	12-II 2.13	.60	—	.17	.77
				.70	—	.20	.90
	14 & 27	14-III 51.9	14-III .69	.46	—	.05	.51
				.53	—	.06	.59
	16 & 25	16-III 38.5	25-III .60	.34	—	.04	.37
				.40	—	.06	.46
	19 & 20	See Sht #					
	23	III 19.1	III .57	.17	—	.04	.21
				.20	—	.06	.26

Notes: For $\frac{f_a}{F_a} \le .15$ Use Form 1.6-1b AISC
$\frac{f_a}{F_a} > .15$ Use Form 1.6-1a AISC

6×4×3/8"-HST

A = 6.45 in²
r_x = 2.11
r_y = 1.53
S_y = 7.53
K = .65
C_m = .85

10.5'
$\frac{KL}{r_b} = \frac{KL}{r_y} = 53.5$ ✓
$F_A = 17.99$ $F'_e = 51.21$

11.65'
$\frac{KL}{r_b} = \frac{KL}{r_y} = 59.4$ ✓
$F_A = 17.5$ $F'_e = 41.48$

For Tension
$.6 F_y = 22^{ksi}$ Pg 5-16 (AISC 1970)

6×4×5/16"-HST

A = 5.52
r_x = 2.14
r_y = 1.56
S_y = 6.74
K = .65
C_m = .85

$\frac{KL}{r_y} = 52.5$
$F_A = 18.12$ $F'_e = 54.18$

$\frac{KL}{r_y} = 58.3$
$F_A = 17.60$ $F'_e = 43.94$

For Tension
$.6F_y = 22^{ksi}$

Vert Members = 10'-6" ± = 10'.5
Diag Members = $(5.047^2 + 10.5^2)^{1/2} = 11.65'$

	Members	Govern Axial P.	Govern Moment	L/r ≤ 240 $f_a/.6F_y$	f_b/F_b		
Tension (+)	13 & 28	13-II 64.55	13-II 1.00	.45	.07	.52	6×4×3/8
				.65	.09	.74	" × 1/4
	15 & 26	15-III 47.00	26-III .66	.33	.05	.38	" × 3/8
				.47	.06	.53	" × 1/4
	17	See Sht #					
	18 & 24	18-III 32.5	18-III 1.52	.23	.11	.34	" × 3/8
				.33	.14	.47	" × 1/4
	21 & 22	22-III 13.5	21-III 2.06	.10	.15	.25	" × 3/8
				.14	.20	.34	" × 1/4

Use Form 1.6-1b Fy

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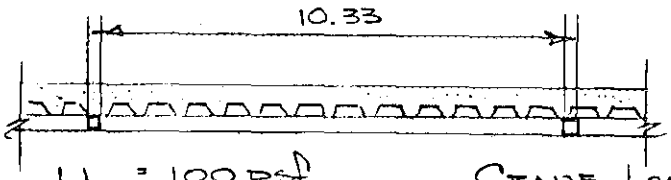
For 6×4×1/4" HST A = 4.54
S_y = 5.76

11-72B

PROJECT C.R.D. ACC. NO. 185628
SUBJECT Struts Lattice Trusses SHEET NO. ___ OF 16TD
Crane Beam DATE Dec 1972
COMP. W.H.K. CHECK ___ CONT. NO. ___

A/59



LL = 100 psf
Dk+Conc = 50 psf

Crane Load = 4^k + 25% Impact
= 5^k

Design of Tube Struts @ Panel Points
Note - Deck is Spanning In Same Direction as Strut & Is Carrying Conc & LL. As The Deck Tries To Deflect the Strut Will Start To Pick Up This Load.

∴ Conservatively

$W = .150 \times 10.33 = 1.55^{k/'}$
$.03$ Assumed Wt
$1.83^{k/'}$

$M_{MAX} = WL^2/12 + \frac{PL}{8} = \frac{1.83(7.5)^2}{12} + \frac{5(7.5)}{8}$
$= 8.6 + 4.69 = 13.29^{'k}$
$= \approx 160^{''-k}$
Assume $F_b = 22^{ksi}$

∴ $S_R = \frac{160}{22} = 7.30 \text{ in}^3$

Use 6×4×5/16" HST
$S_x = 8.46$
$f_b = 18.91$

Typically Use 6×4×5/16 HST Except @ Control Room Use 6×6×3/8"

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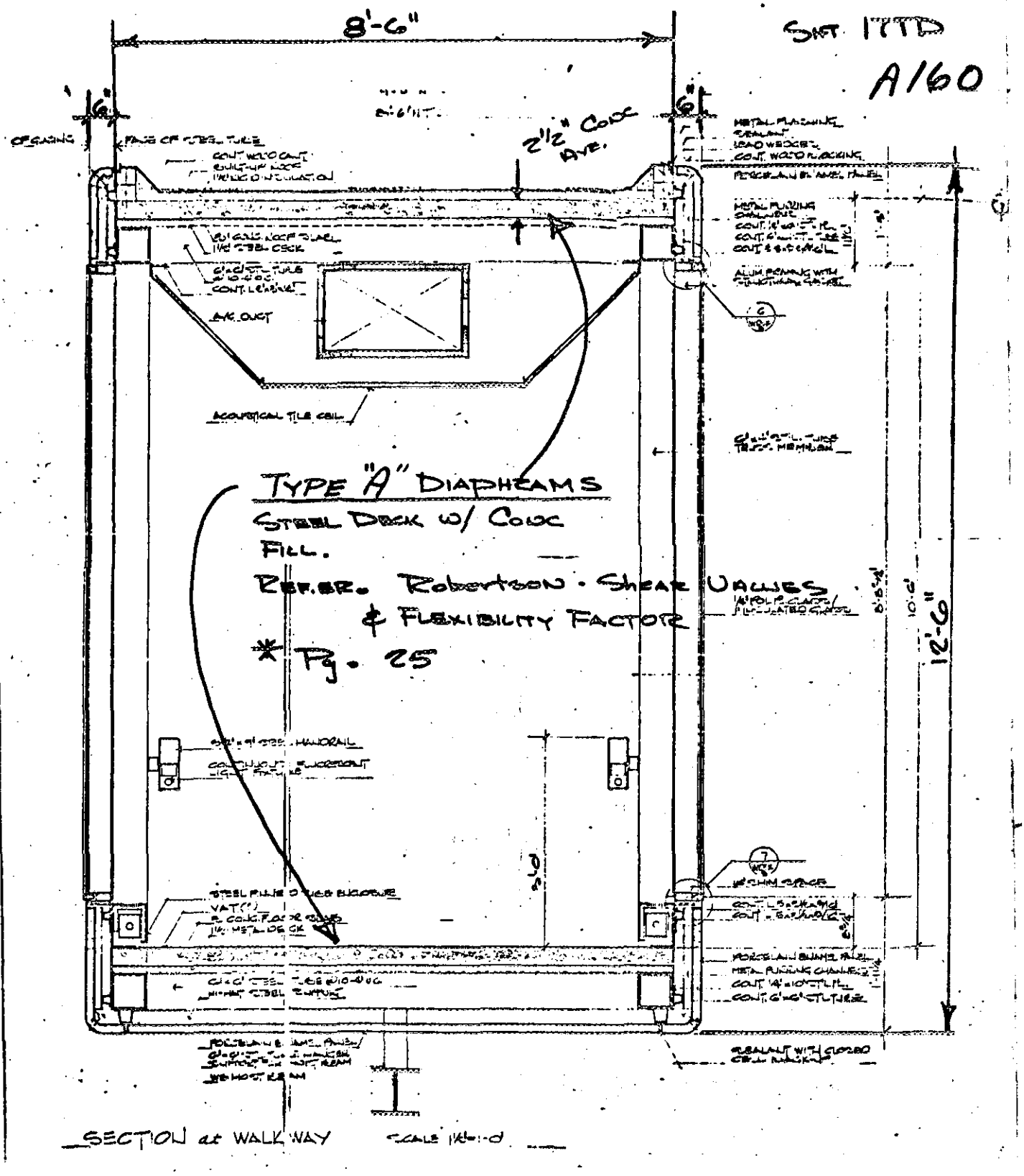
11-72B

*SKETCH FOR
SHT. 17TD
A160



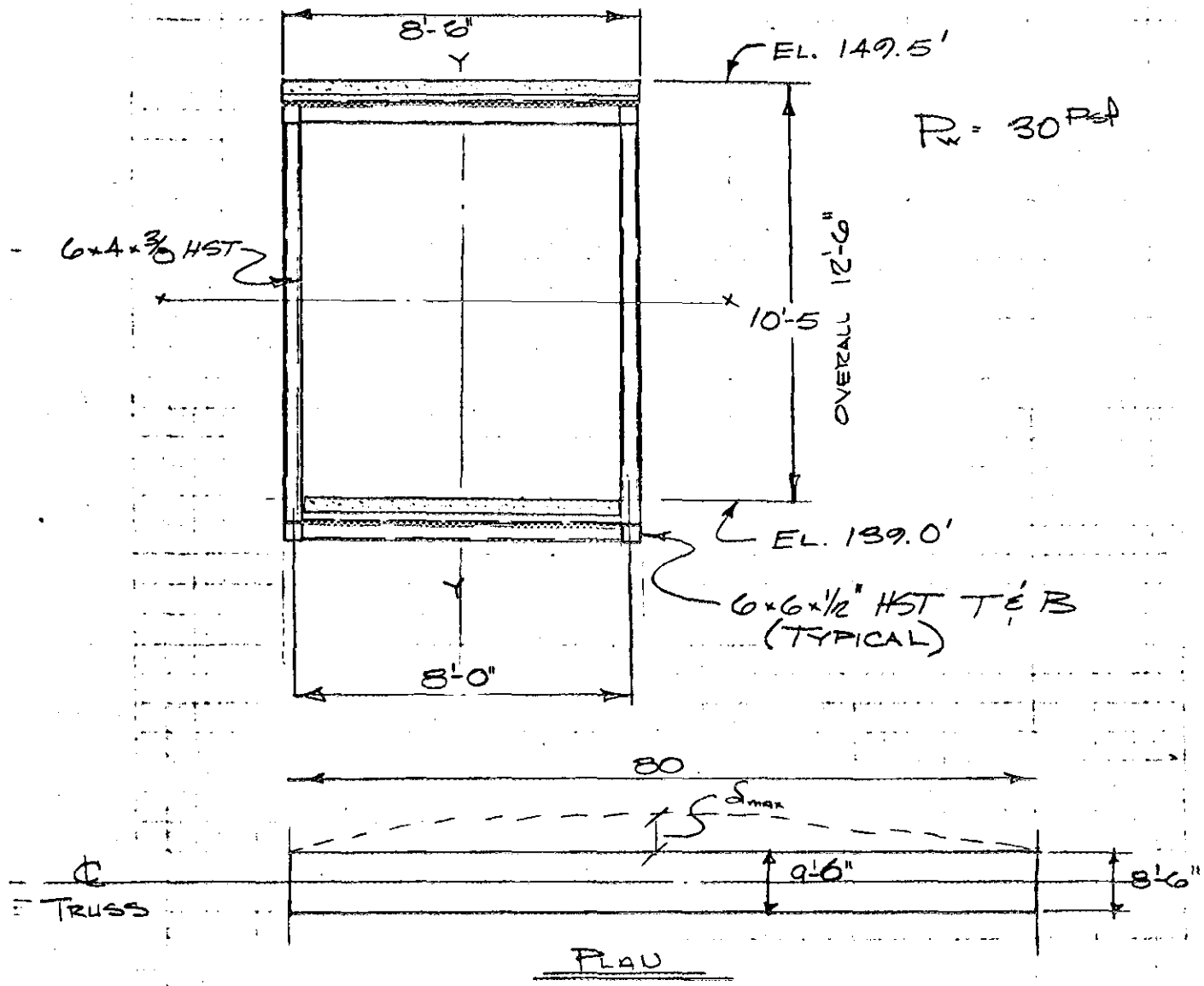
PROJECT Charles River Dam — ACC. NO. 1856.27
SUBJECT Deflection Due To Wind — SHEET NO. ___ OF 17TD
DATE 15 Oct, 1972
COMP. WHR — CHECK ___ — CONT. NO. ___

A161

Determine Horizontal Deflection Due To Wind. System Resisting Lateral Loads Is Steel Deck Used In Diaphragm Action

1½" Deck /w 2½" of Conc (Avg Topping)

(A) Truss Length 80'-0"



Plan

Reference: Robertson - Shear Values & Flexibility Factors

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PROJECT Charles River Dam ACC. NO. 1856.28
SUBJECT Deflection Due To Wind SHEET NO. 2 OF 18TD
DATE 13 Oct 19 72
COMP. W.H.E. CHECK CONT. NO.

A 162

(A) Truss 80'-0" × 8'-6"
(B) Span of Deck = 8.0'±
(C) Deck Units = 8.0'±

(d) Horizontal Force

(1) On Roof (El. 149'-6")

$P_w = 30 psf$

$W_R = .030 \times (10.5 + 1.0 + .5)/2 = .1875$ (≈12.5)

(2) on Walkway Level (El. 139'-0")

$W_w = .030 \times (12.5)/2 = .1875^{k/1}$

(e) Area of Each Long. Steel Chord
6×6×1/2" HST

(1) Max Diaphram Shear @ Walkway Supports

$$V = \frac{.1875 \times 80/2}{8.6} = .872^{k/1} < 2040^{ok}$$

(2) Try 1 1/2" Deck 20 Ga. – 2 1/2" Conc. Ave
f'c 3000, 5 Puddle Welds @ End
Button Punch @ 36" o.c. Span = 8'-0"
q = 2040
F = .83 (from Fig 25 Robertson)

Flexural Moment of Inertia

Area 6×6×1/2" HST = 10.1
Area of T/Flg = 6" × .5" = 3'

$$I = 3" \times 2 \times 4.2^2 \times 144 = 15{,}240 \text{ in}^4$$

∴

Flexural Deflection

$$\Delta_f = \frac{5wL^4}{384EI} = \frac{5(.1875)(80)^4(1728)}{384 \times 30 \times 10^3 \times 15{,}240} = .378"$$

Web Deflection

$$\Delta_w = \frac{Q_{avg} L \cdot F}{10^6} = \frac{872/2 \times 40 \times .83}{10^6} = .014$$

Total $\Delta = .392$ in

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PROJECT Charles River Dam ACC. NO. 1456.28
SUBJECT Approximate Deflection SHEET NO. 3 OF 19TD
DATE 13 Oct 1972
COMP. WHR CHECK CONT. NO.

A163

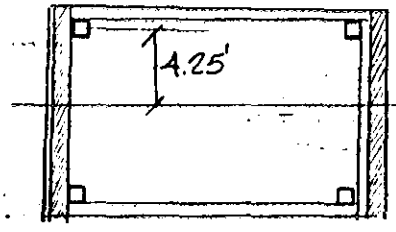
Consider Entire Structure As Built-Up Beam
Bending Occurs About The Y-Y Axis (See Pg 1)
Span 80'

δ_{max} @ Center Span

$$\delta = \frac{5wL^4}{384EI} = \frac{5(.360)(80)^4(1728)}{384(30\times10^6)\,I_{section}}$$

$$= \frac{11{,}059.2}{I} = \delta = .11$$

Determine I_{Y-Y} of Walkway



Consider I_{YY} Due To

$$I_{YY\ approx} = 4\left[(10.1)\times(4.25^2)\,144\right]$$
$$= 10{,}5{,}000$$

Alternate Diaphram - Consider Type 3 Deck
20 Gauge
8'-0" Span
3 End Welds

$\therefore$ q = 1900
F = .88

Flexural Deflection $V = .872^{k/'} < 1900^{k/'}$ OK

$$\Delta f = \frac{5(.1875)(80)^4(1728)}{384\times30\times10^6\times15240} = .378$$

Web δ

$$\Delta_w = \frac{872/2\times40\times.88}{10^6} = .015$$

.393" @ Center Span

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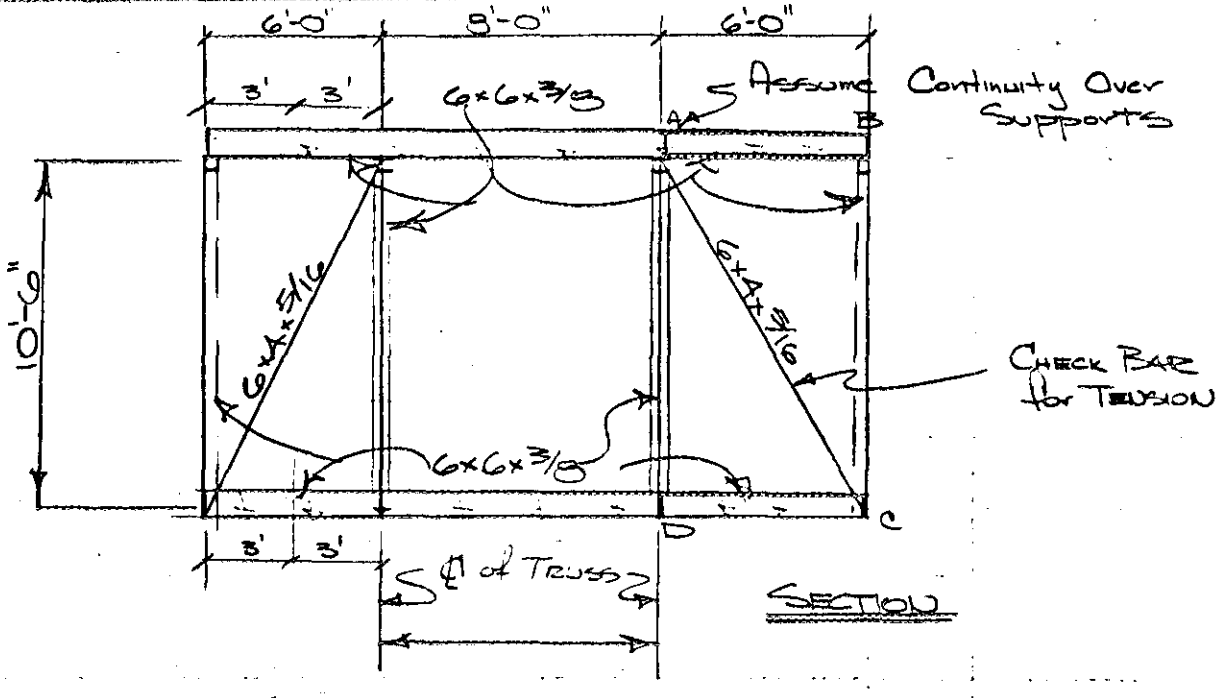
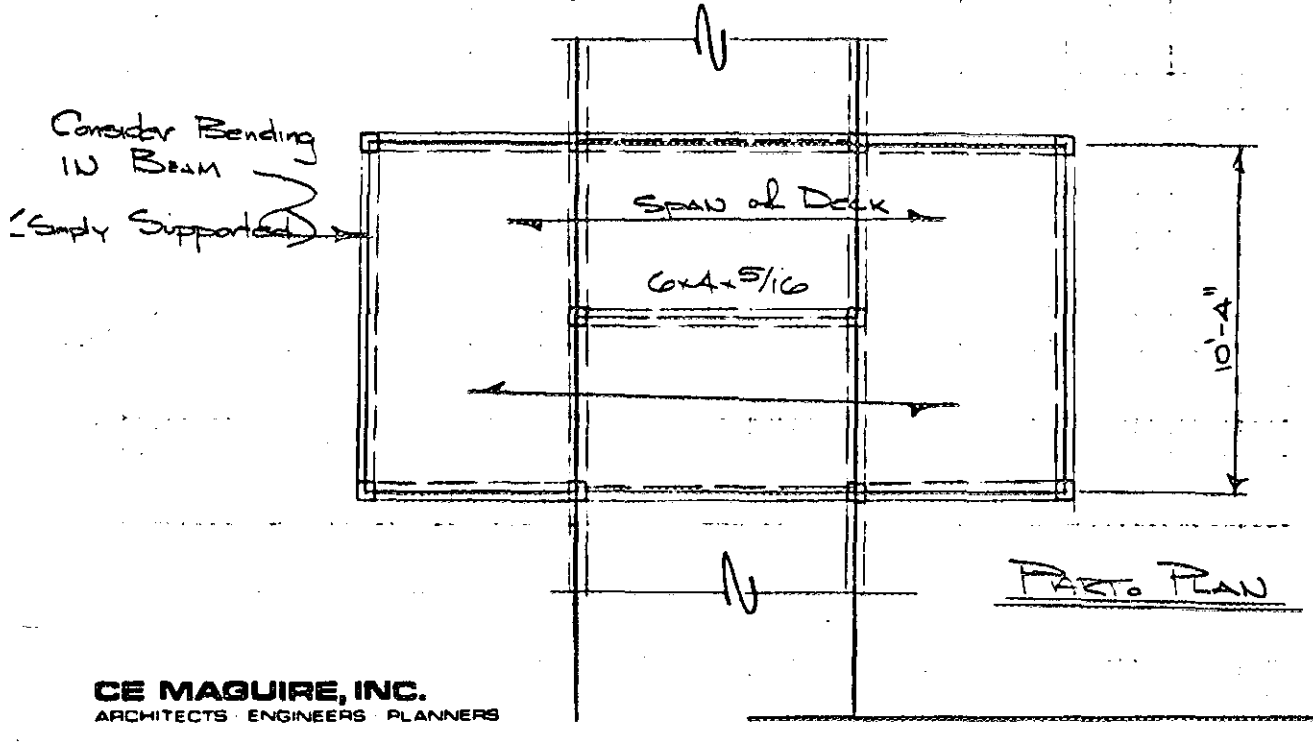
PROJECT Charles River Dam ACC. NO. 1956.78
SUBJECT Control Room SHEET NO. CT-1 OF
DATE Dec 1972
COMP. WLTR CHECK CONT. NO.

A164

Consider Control Tower



Main Truss Has Already Been Designed To Carry Addt Load @ Control Room. Investigation Here is Design Primary Supporting Elements @ Control Tower



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PROJECT Charles River Dam — ACC. NO. 1856.20
SUBJECT Control Tower — SHEET NO. ___ OF CT-2
DATE Dec 1972
COMP. WHR — CHECK ___ — CONT. NO. A-165

Loads Roof: Snow - 30 Psf; Arch, etc - 10 Psf; Conc Dk 50 Psf; 90 Psf

Flr: LL - 100 Psf; Add'l etc - 10 Psf; Conc Dk - 50 Psf; 160 Psf

(A) Consider Beam @ Roof

$w = 3'(.090^{ksf}) = .27^{k/'}$

$M_{(+)} = \frac{wL^2}{8} = \frac{.27(10.5)^2}{8} = 3.72^{'-k} = 4.092$

+Add'l M = .027 = .37

Use: 6×6×3/8 HST

A = 7.95 in² Wt = 27.04 #/'

S = 13.5 in³

$f_b = \frac{M}{S} = \frac{4.092 \times 12}{13.5} = 3.64^{ksi}$

$L_b \leq \frac{2500 \times 6}{F_y} = 69.4\,b = 69.4 \times \frac{6''}{12} = 34.7 > x$ (Pg 5-68 AISC)

$F_B = 22$ ksi > 3.64 OK

(B) Beam @ Floor

$w = 3(.160) + .027 + .120 = .627^{k/'}$

$M_{(+)} = \frac{wL^2}{8} = \frac{.627(10.5)^2}{8} = 8.64^{'-k}$

Use 6×6×3/8 HST

$f_b = \frac{8.64 \times 12}{13.5} = 7.68 < 22$ OK

$\delta = \frac{5(.627)(10.5)^4 \times 1728}{384 \times 29000 \times 45.5}$

= .146 in ≈ 5/32" Deflection

(C) End Columns

Roof Beam = .297(10.5)/2 = 1.56^k

Flr Beam = .627(10.5)/2 = 3.29^k

Col Weight = 10.5(.027) = .28

Add'l Arch = 3(.12) = .36

Beam = 3(.027) = .08

5.57^k

$\frac{KL}{r} = \frac{1(10.5)(12)}{2.26} = 55.75$

F_A = Say 17.91

$P_{ALL} = 17.91(7.95) = 141^k > 5.57$

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11-72B

PROJECT C.P.D. ACC. NO. 1856.28
SUBJECT Control Tower Deflection SHEET NO. CT-3 OF
DATE Dec 1972
COMP. W.H.R. CHECK CONT. NO.

A166

Moment Min, Use 6x6x3/8 ALL Around

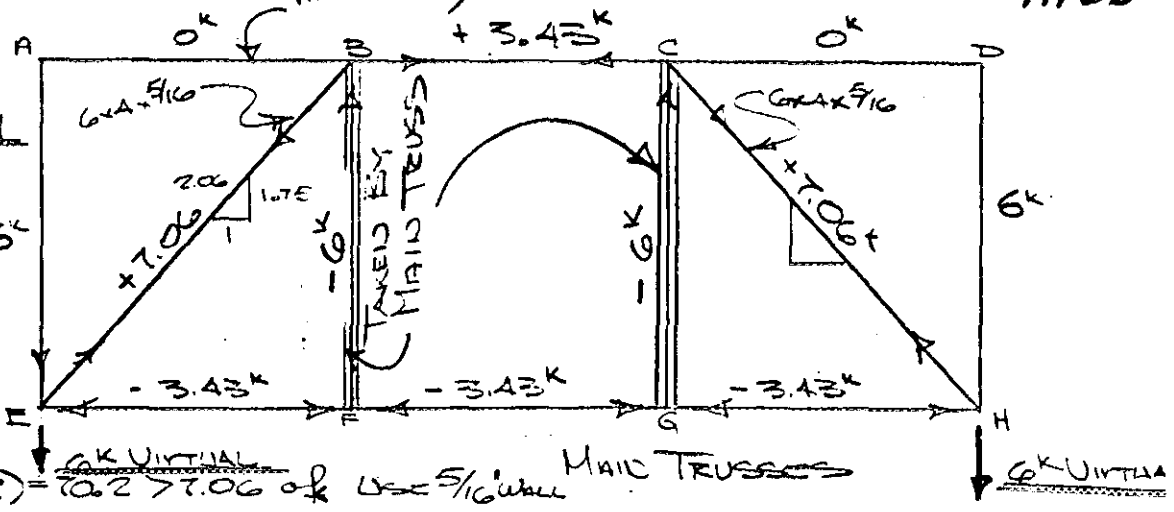
REAL DIAGRAM S_A

$\frac{L}{R} = \frac{1(12)(3.2)}{1.56}$ 6k

$\left(\begin{matrix} r_x = 2.14 \\ r_y = 1.56 \end{matrix}\right)$

= 101.54

$F_A = 12.72$



$P_A = (12.72)(5.52) = 70.2 > 7.06$ ok Use 5/16" wall

$EB = \frac{2.06}{1.75}(6) = 7.06^k$ Use 6x6x3/8" TYPICAL

$EF = \frac{1}{1.75}(6) = 3.43^k$

CONSIDER RELATIVE DEFLECTION

$(12)\delta = \sum \frac{S_Q S_A L}{AE}$ $S_Q \neq S_A$

(VIRTUAL WORK
VIRTUAL DIAG - S_Q
SIMILAR TO S_A)

MEMBER	L	A	S_Q	S_A	$\frac{S_Q S_A L}{A}$
AB	6	7.95	0	0	—
BC	8	↑	+3.43	+3.43	11.84
CD	6		0	0	—
AE	10.5		-6	0	—
BF	10.5		-6	-6	47.55
CG	10.5	↓	-6	-6	47.55
DH	10.5	7.95	-6	0	—
EB	13.2	6.45	+7.06	+7.06	102.0
CH	13.2	6.45	+7.06	+7.06	102.0
EF	6	7.95	-3.43	-3.43	8.88
FG	8	7.95	-3.43	-3.43	11.84
GH	6	7.95	-3.43	-3.43	8.88
					340.54

$\cancel{(12)}\delta = \frac{(340.54)}{29000} \times \cancel{12}^{1/1} = .0117$ in ↓ @ Points E & H Relative To Points on Main Truss

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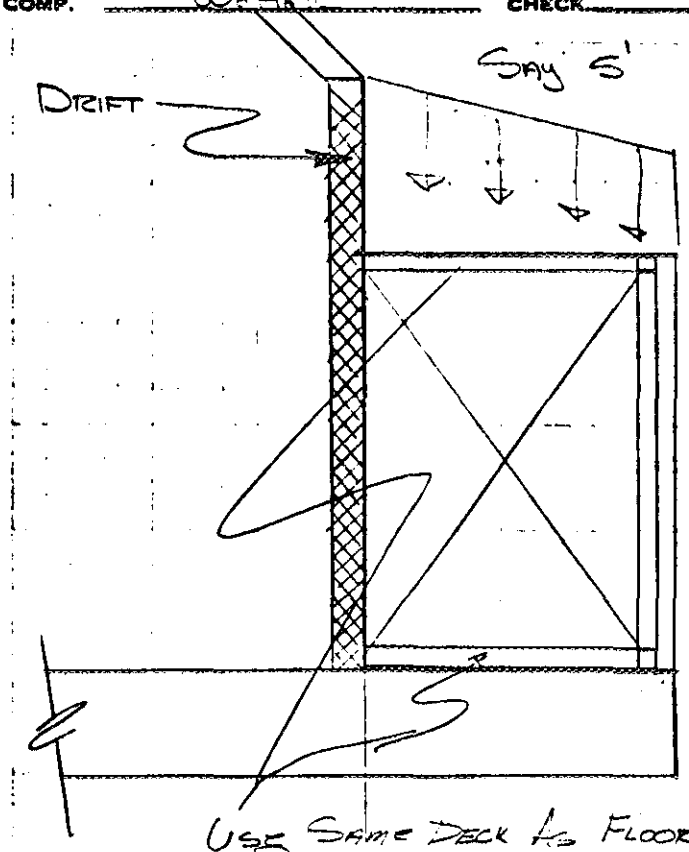
PROJECT C.R.D. ACC. NO. 1956.23
SUBJECT Truss Along Pumphouse SHEET NO. 1 OF 1
DATE DEC 19 72
COMP. W.H.T. CHECK CONT. NO. 9167



Say 5' Consider Snow = 12×5 = 60 lb/ft²

$f_a = \frac{P}{A} = \frac{60^k}{10.1} = 5.94$

$\frac{f_a}{22} = \frac{5.94}{22} = .27 \longrightarrow .27$

$f_b = \frac{M}{S} = \frac{7 \times 12}{16.2} = 5.2$

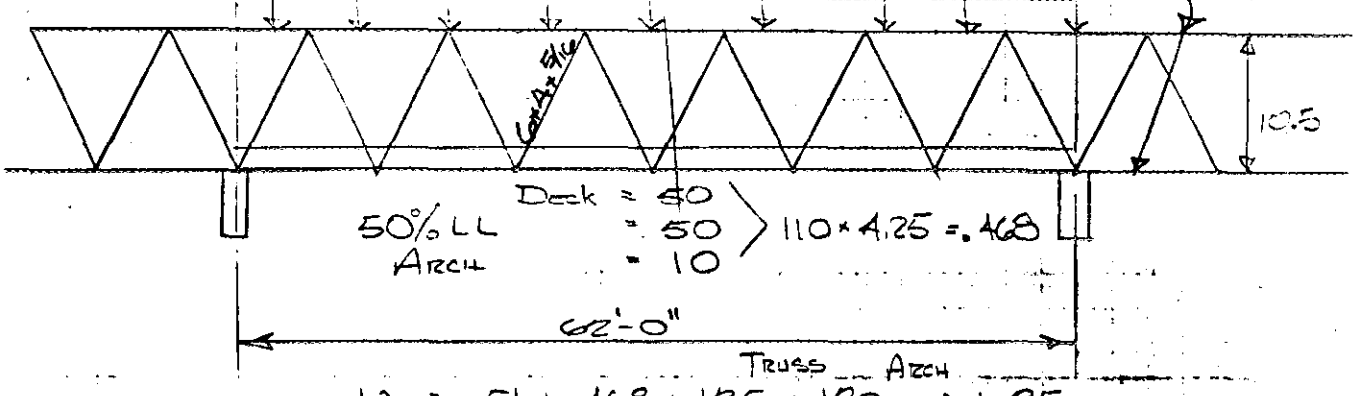
$\frac{f_b}{F_b} = \frac{5.2}{22} = .24 \longrightarrow .24$

.51

Snow = 60 #/ft²
Conc/Deck = 50 #/ft²
Arch etc = 10
4.25 × 120 #/ft² = .51

Use Same Deck As Floor
To Prevent Local Buckling of Deck
Due To High Snow Loads in Drift Areas

Use 6×6×3/8



Deck = 50
50% LL = 50 } 110 × 4.25 = .468
Arch = 10

Truss Arch

$W_T = .51 + .468 + .125 + .120 = 1.25$

As Simple Truss $R_L = R_R = 1.25 \times 31 = 38.75^k$

P_u = Stress in Bot or Top ≈ $\frac{38.75^k(31')}{10.5'} - \frac{31^2(1.25)}{2} = \frac{600.6}{10.5}$ ≈ 57.2

$M_u = \frac{wL^2}{8} = \frac{.51(10.3)^2}{8} = 6.81^{1-k}$

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11-72B

APPENDIX 8

CORROSION SURVEY

PREFACE

This report was prepared for Charles A. Maguire and Associates, Inc. to evaluate the extent of corrosion activity at the Mystic River locks and to recommend the most practical and economical method for corrosion control of the proposed Charles River dam and locks. Every effort has been made to present the information as simply and as clearly as possible for understanding of the basic principles involved.

Corrosion control recommendations outlined are the result of field tests, knowledge of other waterfront structures in the area and practical experience. The contents of this report are not applicable for use as a standard corrosion control outline for other situations due to non-symmetrical conditions.

This report or any part thereof may not be duplicated in any way for other projects, except by a written agreement with The Hinchman Company. This will assure that no information is used in such a manner as to be misleading.

CORROSION SURVEY REPORT

of

MYSTIC RIVER LOCKS
BOSTON, MASSACHUSETTS

(For Proposed Charles River Dam and Locks)
Boston, Massachusetts

Prepared for
Charles A. Maguire & Associates, Inc.
178 Tremont Street
Boston, Massachusetts

Our Job No. 271-1762
Your Letter of Authorization - March 2, 1971
March 30, 1971

Pedro C. Reyes
Project Manager

Lewis H. West, P.E.
President

The Hinchman Company
Corrosion Engineers
304 Francis Palms Building
Detroit, Michigan 48201

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5.	OTHER EVALUATIONS	19
6.	APPENDIX	31

CORROSION SURVEY REPORT
of
MYSTIC RIVER LOCKS
BOSTON, MASSACHUSETTS

1. INTRODUCTION

The purpose of the survey was to determine the extent of corrosion on the gates and other metallic structures of the Mystic River Locks. This study, together with our experience with structures such as the Boston Coast Guard and Massachusetts Port Authority piers, is the basis for our corrosion control recommendations for the proposed Charles River dam and locks.

We recommend cathodic protection for the proposed Charles River dam and locks at an estimated cost of $25,000.00, including engineering. Coating on the Mystic lock gates has significantly deteriorated within five years. Since installation (5 years), over 730 bolts have been replaced and holes in the gates have required repair, because of corrosion. This points out the need for supplementary cathodic protection. The cost of dewatering alone (approximately $50,000.) for maintenance and repairs due to corrosion will be converted into savings. In addition,

coating repair and maintenance costs will be minimized if cathodic protection is applied.

The survey included tests of water resistivity, pH, structure-to-electrolyte potential measurements, stray current investigation and visual examination of the corrosion and coating condition. Tests, evaluations, photographs and data gathered are included in this report.

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2. RECOMMENDATIONS

2.1 Cathodic Protection

We recommend cathodic protection, supplementing a protective coating, for the proposed Charles River dam and locks and the existing Mystic River locks. Structures to be protected will be the gates and their accessories in contact with the electrolyte. Piles require only coating.

Estimated costs for cathodic protection for the Charles River facilities are as follows:

Engineering	-	$ 9,200.00
Labor & Materials	-	15,800.00
Total	-	$25,000.00

2.2 Coating

Vinyl mastic may be considered an acceptable alternate to "Tarset" coal tar epoxy coating. This vinyl-based coating is used in most lock installations by the Corps of Engineers. Also, 30-month exposure tests on pilings in California made by the U.S. Naval Civil Engineering Laboratory in June, 1962 among eight (8) coating systems resulted in the vinyl mastic coating system as the most

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economical protection. Coal-tar epoxy was among the coatings tested.

Two coats of anti-fouling paint should be incorporated in the coating system.

2.3 Miscellaneous

Dissimilar metal connections (i.e., stainless steel and carbon steel on the sill and side seals, lead washers and steel washers, copper cables on steel brackets in the pipe tunnel, etc.) should be avoided. Once coating on these junctions deteriorates, galvanic corrosion occurs.

Nonmetallic materials for the floating moorings, bolt washers, ladders and the pipe tunnel should be considered where moisture is prevalent.

Where bolts are in contact with the electrolyte, we recommend 'cathodic' bolts. These are low alloy steel, normally cathodic to plain carbon steel and can be supplied by:

Dresser Manufacturing
41 Fisher Avenue
Bradford, Pennsylvania 16701

3. CONCLUSIONS

3.1 General

Results of the survey on Mystic River locks indicate the need for cathodic protection to supplement protective coatings on the proposed Charles River dam and locks. Our study of other submerged facilities in similar environments, such as Boston Coast Guard piers and four Massachusetts Port Authority piers in Boston, confirms the need for supplemental cathodic protection.

3.2 Water Resistivity

The following average resistivities were measured:

Basin Side	-	1100 ohm-centimeters
Inside Lock	-	400 ohm-centimeters
Tide Side	-	80 ohm-centimeters

The environment is highly corrosive, as indicated by low resistivity, the polluted and brackish condition of the water samples, and marine growth and corrosion product deposits on the structures.

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3.3 pH

Water pH range from 5.0 to 5.7, with majority of the samples reading 5.7. This reading shows acidic salt contamination of the fresh water-salt water mixture on the locks. pH in this range, taken alone, is not considered seriously aggressive to steel structures. However, widely varying low resistivities in the area of the locks does create a severely corrosive condition.

3.4 Structure-to-Electrolyte Potentials

The low structure-to-electrolyte potential values measured are typical for unprotected, corroding steel and aluminum structures.

3.5 Stray Current Tests

No D.C. and A.C. stray currents were noted during the survey. D.C. stray currents are caused by grounded D.C. electrical equipment in the vicinity of the tested structures using the electrolyte as a conductor. They may be variable or steady state.

3.6 Visual Inspections

3.6.1 Coating Condition

Protective coating was generally in good condition in the atmospheric zone while for the splash, tidal, and permanent-immersion zones the following coating condition was observed: (Refer to Section 5.1.6.1 for zones)

Splash, Tidal and Immersion Zones
Approximate Percent Coating Effectiveness

Location	Big Lock	Small Lock #1	Small Lock #2
Basin End			
a) Outside Lock	90%	95%	95%
b) Inside Lock	50%	55%	55%
Tide End			
a) Outside Lock	60%	70%	65%
b) Inside Lock	40%	50%	55%

3.6.2 Marine Growth

Thick formations of shell fish (barnacles) and algae have destroyed portions of the coatings, decreasing coating effectiveness. This was most evident in the permanent-immersion zone of the structures.

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3.6.3 Corrosion Product Deposits

Where coating has deteriorated, corrosion product deposits were evident and minor pitting has begun underneath corrosion products. Pitting is expected to accelerate once coating has been destroyed, unless supplemental cathodic protection is applied.

3.6.4 Harbor Contamination

Water near the Monsanto Chemicals discharge sewers was brackish and polluted with oil, chemicals and other forms of industrial wastes.

The normal corrosion rate is frequently changed radically by the effects of harbor contamination and, in this case, by the influx of fresh water which may cause extreme seasonal variations. The seasonal changes may either increase or decrease the rate of corrosion.

3.6.5 Cast-Iron Butterfly Valve

The coating on the culvert butterfly valve sampled was still in good condition. Barnacle growth and corrosion product deposits were present on approximately 20% of the valve surface. (See Picture #4)

3.6.6 Pipe Tunnel

Picture #10 shows a typical view of corrosion of metal structures in the tunnel. Damp conditions, lack of protective coatings and insulation, and the fact that copper grounding rods and steel pipes are on the same brackets contribute to corrosion.

3.7 Maintenance and Repairs

More extensive repairs are anticipated in the coming years because of deteriorated coating. Repairs, like replacement of bolts due to corrosion, can be avoided if protective coating is supplemented with cathodic protection.

3.8 Economics

Our estimated cost for cathodic protection for the Charles River locks, including engineering, is $25,000.00. This initial cost of cathodic protection will eventually result in savings, considering that dewatering of the locks for repairs and/or replacements alone, costs approximately $50,000.00. Also, maintenance costs due to corrosion will be reduced.

No coatings can remain 100% effective because of variations in application, damage after application and deteriorating

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environments. These factors result in localized corrosion at the holidays (breaks) in the coating. Cathodic protection, properly maintained, will prevent corrosion at these breaks in the coating and prevent coating deterioration from undercutting by corrosion products.

3.9 Foreign Structures Information

No foreign structures such as gas utilities, etc. are present in the river in the vicinity of the locks, except for Western Union lead-sheathed cables which have been abandoned. No stray current effects are expected on the locks.

4. TESTS AND EVALUATIONS

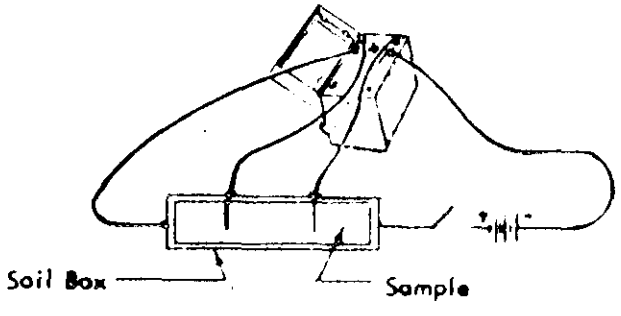
4.1 General

This study on the Mystic River locks was conducted to determine the need for corrosion control for the locks and for the proposed Charles River dam and locks.

Water samples for water resistivity and pH were taken at selected locations. Structure-to-electrolyte potentials were measured and tests conducted to determine if any stray currents existed in the vicinity of the locks.

4.2 Water Resistivities

Water resistivity was measured on samples taken from the Mystic River Locks, using a Model 293 "Vibroground" and an M.C. Miller "Soil Box", as shown below:



The 'soil box' is a plexiglas container with terminals for measuring the voltage drop through a soil or water sample

and the current, impressed by the "Vibroground" meter. The resistance (ohms) is read directly on the meter. The dimensions of the soil box are such that, when filled, the resistivity in ohm-centimeters of its contents is equal to its measured resistance. in ohms.

The locations of the water samples are shown in Figure 1 in the Appendix and the results of the tests are in Table I.

TABLE I: MYSTIC RIVER LOCKS - BOSTON, MASSACHUSETTS
Water Resistivity
Ohm-Centimeters

Sample No. (See Fig.1)	Location	Water Resistivity
1	Near Monsanto Chemicals Sewers (Tide Side)	70
2	Near end of wood piers for big lock (Basin Side)	1100
3	Big lock gate (Basin Side)	1200
4	Big lock gate (inside lock - Basin Side)	470
5	Big lock gate (inside lock - Tide Side)	300
6	Big lock gate (Tide Side)	80
7	Small lock No. 2 gate (inside lock - Basin Side)	500
8	Small lock No. 2 gate (Tide Side)	100
9	Small lock No. 1 gate (Basin Side)	1100
10	Small lock No. 1 gate (inside lock - Tide Side)	500
11	Small lock No. 1 gate (Tide Side)	86

Water resistivity, expressed in ohm-centimeters, is a measure of the resistance of the water to the flow of electric current. The lower the resistivity, the more corrosive the water.

From Table I, the following average resistivities are calculated:

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Basin side	-	1100 ohm-centimeters
Inside lock	-	400 ohm-centimeters
Tide side	-	80 ohm-centimeters

The water is highly corrosive, as indicated by the low resistivity, the polluted and brackish condition of the samples, specifically #1, and marine growth on the coatings of the metal structures.

The lower resistivities on the tide side are the result of a greater percentage of salt water, acids, chlorides and other chemicals from the sewers of different industrial plants, as compared to inside the locks and on the basin side of the locks.

4.3 pH

Electrolytes are classified as acidic, neutral or alkaline in accordance with the results of pH tests. Measurements were made with pH paper on the water samples. Table II shows the results of the pH tests on the water samples, locations of which are shown on Figure 1, found in the Appendix.

TABLE II: MYSTIC RIVER LOCKS - BOSTON, MASSACHUSETTS
pH Tests on Water Samples

Sample No. (For Locations, see Table I & Figure 1)	pH
1	5.0
2	5.5
3	5.5
4	5.7
5	5.7
6	5.7
7	5.3
8	5.7
9	5.7
10	5.7
11	5.7

Water pH range from 5.0 to 5.7, with majority of the samples reading 5.7. The lower pH of 5.0 measured on the water sample taken near the sewers' discharge of 'Monsanto Chemicals' is more acid than the average because of water pollution. pH in this range, taken alone, is not considered seriously aggressive to steel structures. However, the low resistivity plus widely varying resistivities in the area of the locks does create a severely corrosive condition.

4.4 Structure-to-Electrolyte Potentials

Structure-to-electrolyte potential measurements indicate the condition of structures with regard to corrosion. These tests are made with a potentiometer-voltmeter and a reference electrode. The electrode (half-cell) is placed near the structure in the electrolyte and the voltage measured between the half-cell and the structure.

When voltages were measured with respect to any structure, the behavior of the needle swing was observed for detection of fluctuating stray currents.

Gate-to-water potentials were measured using a 'calomel' reference electrode. Structure-to-soil potentials were taken for various types of available underground metallic structures, using a $Cu-CuSO_4$ reference electrode.

Results and test locations are shown in Table III and Figure 1.

TABLE III: MYSTIC RIVER LOCKS - BOSTON, MASSACHUSETTS
Structure-to-Electrolyte Potentials

A) Lock Gate-to-Water Potentials
Volts, Negative to 'Calomel' Reference Electrode

Test Location (See Fig. 1)	Structure	Volts
1	Lock gate	0.57
2	Lock gate	0.54
	Aluminum ladder	0.68
3	Lock gate	0.57
4	Lock gate	0.59
	Aluminum ladder	0.84
5	Lock gate	0.57
6	Lock gate	0.55
7	Lock gate	0.58
8	Lock gate	0.57
	Aluminum ladder	0.58
9	Lock gate	0.57
	Aluminum floating mooring	0.62
10	Lock gate	0.56
11	Lock gate	0.52

B) Structure-to-Soil Potentials
Volts, Negative to Cu-$CuSO_4$ Reference Electrode

12	Steel Post	0.30 (Reading over concrete)
13	Hydrant	0.52

The low potential values measured are typical for unprotected, corroding structures.

No stray current was evident.

4.5 Stray Current Tests

No D.C. and A.C. stray currents were noted during the survey. D.C. stray currents are caused by grounded D.C. electrical equipment in the vicinity of the tested structures using the electrolyte as a conductor. They may be variable or steady state.

Detection of possible stray currents is made by observing the needle behavior of the "Miller" meter whenever structure-to-electrolyte potentials are measured.

5. OTHER EVALUATIONS

5.1 Visual Inspections

5.1.1 Big Lock

5.1.1.1 Tide End

A) Inside Lock - Picture #8 shows the formation of corrosion product deposits and barnacle growth on deteriorated coating on the center seal framing of the gate. A steel washer in contact with a lead washer was completely corroded away due to a dissimilar metal galvanic cell. Rust-free iron is anodic to lead in acidic electrolytes but lead is anodic to iron corrosion products, thus causing the lead washers to also corrode.

The largest formation of corrosion product deposits (rust) among all the gates was found on the east sector gate. 60% of the gate surface was covered with barnacles (marine growth) and corrosion product deposits. Underneath these formations, bare steel was exposed since coating has deteriorated. This is true for all gates. No evidence of extensive pitting was found.

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B) Outside Lock - Compared to the small locks, less marine growth was found here but more corrosion product formation on the portions of the steel girders and plates below low tide was evident. No evidence of extensive pitting was found on the gates.

5.1.1.2 Basin End

A) Inside Lock - 50% of the coating has deteriorated on the submerged surfaces. Corrosion product scale has formed. Picture #7 shows one of five (5) portions of the gate where such formation was evident. The black spot on the picture shows chalking of the coating, revealing bare steel surface. This is common for all corrosion product formations on lock gates.

B) Outside Lock - Coating is generally in good condition on the gates. However, blisters and peeling of coating were evident on the upper bearing of the east sector gate anchorage. This is apparently due to atmospheric corrosion, possibly caused by salt sprays.

5.1.2 Small Lock #1

5.1.2.1 Tide End

A) Inside Lock - Two pit holes, as shown in Picture #9, were found on the gate. Compared to small lock #2, this gate has thicker, loose corrosion product formation.

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B) Outside Lock - As in small lock #2, no pits were visible on the accessible portions of the gates where the corrosion product formations can be scraped off. However, very thick corrosion product buildup can be seen on the submerged portions of the steel framing. The lowest rung of the east aluminum ladder (1" original diameter) is almost gone because of corrosion. No peeling of coating was evident.

5.1.2.2 Basin End

A) Inside Lock - A blister on the coating, about 1/2" diameter and 1/16" deep, was found on this gate. Probable causes of the blister are localized pitting, effect of ice-melting copper wires at the back of the gate or effect of re-welding leak holes caused by pitting or puncturing. The same barnacle-buildup and corrosion product formation was evident.

B) Outside Lock - Coating is still in good condition, with very little marine growth and corrosion product formation.

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5.1.3 Small Lock #2

5.1.3.1 Tide End

A) Inside Lock - The view from the deck revealed more marine growth and less rust cale formation than the preceding gates. Pictures #1 and 2 show corrosion of aluminum moorings taken from this lock.

B) Outside Lock - No pitting was visible but thick corrosion product and marine growth formation can be seen on the steel portions of the gate under water. Coating was peeling on scattered portions of the gate in about 1" and 2" areas. One-half inch deep pits were visible on the badly-corroded aluminum ladders. Picture #3 shows corrosion of the west aluminum ladder.

5.1.3.2 Basin End

A) Inside Lock - Picture #5 shows typical corrosion caused by marine growth from coating deterioration and eventual pitting of the steel plates. Picture #6 is a dissimilar metal galvanic cell between stainless steel and mild steel on the sill seal. (Note deteriorated coating underneath thick corrosion product deposits.) A steel washer on the center seal showed 80% metal loss, typical of marine growth and lead-iron galvanic cell corrosion.

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B) Outside Lock - The same good condition of the coatings, common to all gates on the basin side outside the locks, was found here.

5.1.4 Cast-Iron Butterfly Valve

The coating on the culvert butterfly valve sampled was still in good condition. Barnacle growth and corrosion product deposits were present on approximately 20% of the valve surface. (Refer to Picture No. 4)

5.1.5 Pipe Tunnel

Picture #10 shows a typical view of corrosion of metal structures in the tunnel. Damp conditions, lack of both protective coatings and dielectric insulation, and the fact that copper grounding rods and steel pipes are on the same brackets contribute to corrosion.

5.1.6 Evaluation of Visual Inspection

5.1.6.1 General

For purposes of this discussion, the following zones of attack will be referred to:

1) Atmospheric Zone - Portion of the structures that is not wetted directly by water, but by water spray.

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2) Splash Zone - Portion of the structures just above highest water level; exposed to water wave action and, consequently, to alternate wetting and drying.
3) Tidal Zone - Portion of the structures between normal low and high water levels. On the tide side of the locks, the tidal zone is between low and high tide levels. This area is exposed to atmospheric and splash zone corrosion for twelve hours a day. During the remaining twelve hours, the tidal zone will be partially or completely immersed and will corrode at holidays in the coating at a rate of approximately one-half of the rate of corrosion occurring in the permanently-immersed zone.
4) Permanent-Immersion Zone - Portion of the structures below normal low water level.

The visual inspections revealed pitting of bare steel underneath deteriorated coating (see next section, 5.1.7) is not yet significant. It is expected to increase, however, in the coming years. Corrosion attack due to marine growth and corrosion product deposits was less severe on the basin side (fresh water) of the locks and more severe on the tide side (salt water) and inside the locks (mixture of salt and fresh water). The rates of corrosion at the tide side and inside the locks varied depending on marine growth, water

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contamination, water velocity and variations in resistivity. Generally, where corrosion product deposits can be seen, coating underneath has deteriorated and where marine growth is seen, coating begins to deteriorate.

The world-wide average rate of uniform corrosion of bare steel in sea water is 0.005 inches per year (5 mils/yr). For contaminated sea water (marine growth, chemicals, etc.), the rate of corrosion can be 3 to 5 times greater. Unless mitigative measures (cathodic protection and coating touch-up) are applied, severe corrosion is expected to occur in the coming years.

5.1.6.2 Marine Growth

Thick formations of shell fish barnacles and algae have attached themselves to the coating, primarily in the permanently-immersed portions of the metallic structures of the locks. The effect of marine growth in such quantity is destroying the coating and exposing steel to the corrosive environment. Also, these organisms create local corrosion cells which tend to accelerate corrosion by keeping the area under the marine growth scoured clean.

Marine life, particularly shell fish, tend to seek almost pure sea water for their growth. In sea water, contaminated with pollutants (see section 5.1.6.3), an absence of shell-fish such as clams will be noted. On the other hand, limnora, barnacles and other marine life will survive and grow in slightly-contaminated sea water.

5.1.6.3 Harbor Contamination

Water near the Monsanto Chemicals discharge sewers was brackish and polluted with oil, chemicals and other forms of industrial wastes. The normal corrosion rate is frequently changed radically by the effects of harbor contamination and, in this case, by the influx of fresh water which may cause extreme seasonal variations. The seasonal changes may either increase or decrease the rate of corrosion.

Generally, when harbors are heavily contaminated with oil which coats the steel surfaces, the corrosion rate is decreased. Similar results are obtained near the surface when clean fresh water is introduced near the surface that is not highly aerated. The opposite effect is noticed in harbors excessively contaminated with sewage, industrial waste, and with flow from some turbulent rivers. Industrial sewage frequently causes excessive lowering of the pH value of the water. Highly-aerated water promotes the establishment

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of oxygen concentration cells, particularly where there is turbulent flow.

5.1.7 Coating

For the portions of the metallic structures of the locks not in direct contact with water (atmospheric zone), the coating was generally steel in good condition.

For those portions in contact with water, the following coating quality was observed:

Percent Coating Effectiveness
Areas in Contact with Water

Location	Big Lock	Small Lock #1	Small Lock #2
Basin End			
a) Outside Lock	90%	95%	95%
b) Inside Lock	50%	55%	55%
Tide End			
a) Outside Lock	60%	70%	65%
b) Inside Lock	40%	50%	55%

Abrasion (caused by water velocity, marine growth and slurries, opening and closing of gates) was common to most of the coatings in this order of the zones of attack: (see section 5.1.6.1)

Permanent-immersion (heaviest), tidal, splash, atmospheric (lightest).

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On the splash zones, very slight marine growth and corrosion was observed. The bituminous top coat provided excellent sunlight resistance and no extensive alligatoring was observed.

Observations of the tidal and permanent-immersion zones illustrate the susceptibility of bituminous coatings to fouling attack. Most of the areas were completely covered with fouling organisms, predominantly barnacles which have penetrated the coating. Coating had been removed from the steel substrate, permitting corrosion to occur. Minimal protection was being provided the lock gates and accessories by the coating in these areas.

The condition of a coating plays a vital part in the corrosion process. On a structure with good coating, pitting will be the major type of corrosion. This is usually caused by accelerated corrosion at holidays in the coating.

'Tarset' is a coal-tar epoxy coating which furnishes excellent corrosion, erosion, impact and abrasion protection. It is high-build epoxy with good adhesion when properly applied. Thus, close attention must be devoted to proper surface preparation, equipment used and coating application. Alternatives, however, should not be discounted. (Refer to our Recommendations.)

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5.2 Maintenance and Repairs

Discussions with maintenance personnel of the locks revealed that holes have occurred on the gates due to both corrosion and mechanical failures. Also, during the period from May to July of last year, approximately 740 corroded bolts have been replaced. Coating deterioration had been observed during repairs, due to marine growth and rewelding of holes on the gates. Scattered pitting beneath deteriorated coatings has occurred and is expected to increase in the coming years, requiring more extensive repairs.

5.3 Economics

Preventing water contact with submerged surfaces of metallic structures prevents corrosion. Hence, it is logical to consider coatings. However, no coatings are presently available which can remain 100% effective and holiday-free for many years, particularly in this environment. The effectiveness of the best available coating materials is too often impaired by poor application and handling. It is for this reason that cathodic protection should supplement protective coatings for maximum operating efficiency and to prevent localized corrosion in the holidays on the coating.

We estimate the cost of cathodic protection for the Charles River locks, including engineering, will be $25,000.00. This initial cost of cathodic protection will eventually result in savings, considering that dewatering of the locks for repairs and/or replacements alone, costs approximately $50,000.00. Also, maintenance costs due to corrosion will be minimized.

Detailed records of leak history and the corresponding repair costs since 1966 when the locks were installed were not available. However, typical leak charts for buried steel structures, showing savings through cathodic protection, are shown in Appendix III.

5.4 Foreign Structures Information

No foreign structures like gas utilities, etc. are present in the river in the vicinity of the locks, except for Western Union lead-sheathed cables, which have been abandoned. No stray current effects on the locks are expected.

5.5 Coast Guard and Massachusetts Port Authority Piers Corrosion Surveys

Our corrosion surveys made on the pilings of the Coast Guard and Massachusetts Port Authority piers revealed a similar highly-corrosive environment. Where cathodic protection has been operating, the piles have been protected.

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6. APPENDIX

I. PICTURES

II. "SAVINGS THROUGH CORROSION CONTROL"

III. "FIFTEEN YEARS OF CATHODIC PROTECTION ON MARINE PIPELINES"

IV. "CORROSION AND CATHODIC PROTECTION"

V. FIGURE 1

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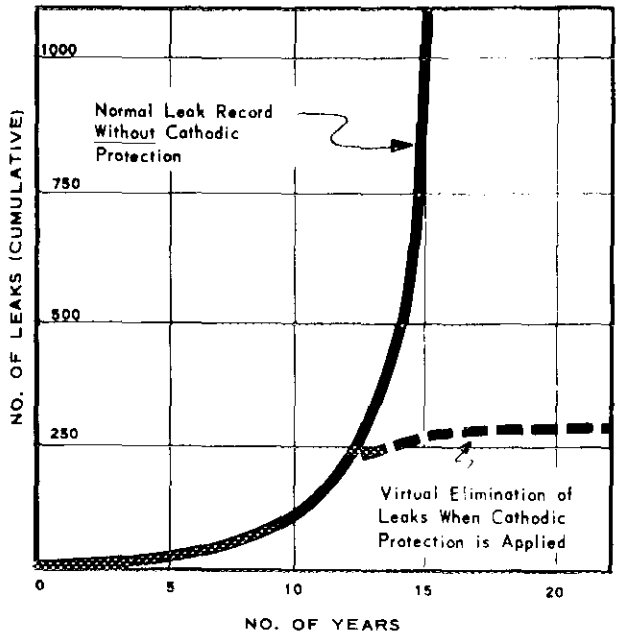
SAVINGS THROUGH CORROSION CONTROL

LEAK RECORD CHART

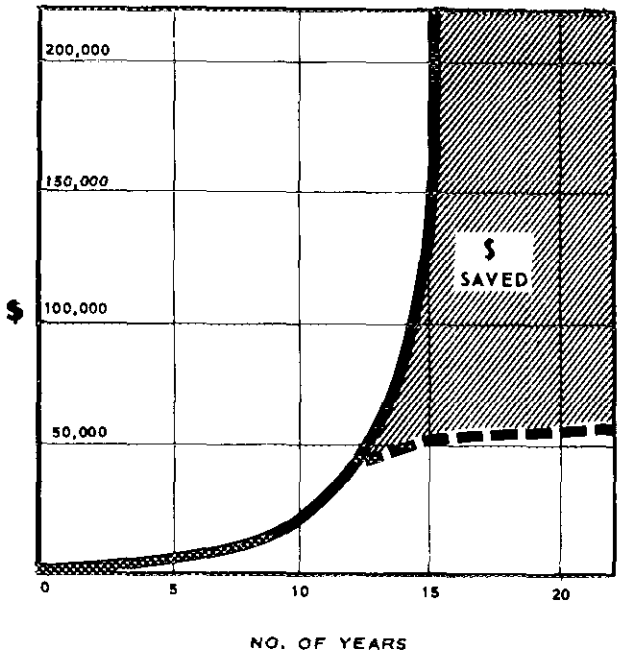
This is a typical example of a buried pipeline, taken from Leak Records on 40 miles of line.



LEAK COST CHART

This is the same chart showing the savings from applying Corrosion Control (Cathodic Protection).

$ Shown are for the cost of repairing leaks at $200 per leak, not including cost of downtime or disaster such as fire, explosion or flood.



CORROSION AND CATHODIC PROTECTION

The importance of corrosion control is illustrated by the estimate that close to ten billion dollars are lost each year from corrosion in the United States. It may seem incredible to relate, but losses of such a phenomenal magnitude are not only little noticed nor understood, they are also almost entirely unnecessary. Corrosion can usually be readily and economically prevented and the savings from corrosion control are usually in the range of $10 to $100 or more returned for each dollar spent on protection.

What is this corrosion process that destroys so much value so unnecessarily? The basic process is simple and can be readily understood by anyone. Such an understanding is necessary to appreciate how to prevent these losses.

Corrosion is the name given to the process by which metals deteriorate in the presence of moisture. We consider metals to be long lasting and stable materials, but they are not and will be quickly leveled by corrosion unless properly protected. Pure metals seldom occur in nature, and corrosion is the electrochemical process by which nature reduces them to their stable oxide or other compound form in which we find ores.

THE CORROSION PROCESS

You may recall from basic electricity that electric current flows in two ways. Primarily, and very usefully to mankind, it flows within a metal when the electrons of that metal move in response to an electrical pressure or voltage. Metal atoms characteristically exchange their electrons readily and these move freely without affecting the atoms themselves. In this type of electric current flow, the basic structure of the metal is undamaged.

There is, however, another form of electric current flow in which the structure of the metal is so radically altered that we say corrosion has taken place. This occurs when an electric current leaves its metal path or circuit and flows into a liquid. The medium by which an electric current flows in a liquid is by the movement of ions, rather than electrons, and this is primarily accomplished by the movement of metal ions. Corrosion occurs as these ions break away from the metal surface and flow into the liquid in response to the electrical pressure. The amount and duration of the corrosion is proportional to the amount and duration of electric current flow.

For example, if you bury a piece of iron in the ground where it is in contact with soil moisture (a current carrying liquid) and permit one ampere of current to flow out of the iron for one year, you will find that approximately twenty pounds of the iron will be lost through corrosion! If you bury a piece of lead, such as an electric cable, the same one ampere of current flow will destroy about 75 pounds per year! This electric current which causes corrosion is a direct current that flows quite readily and does so primarily from natural causes.

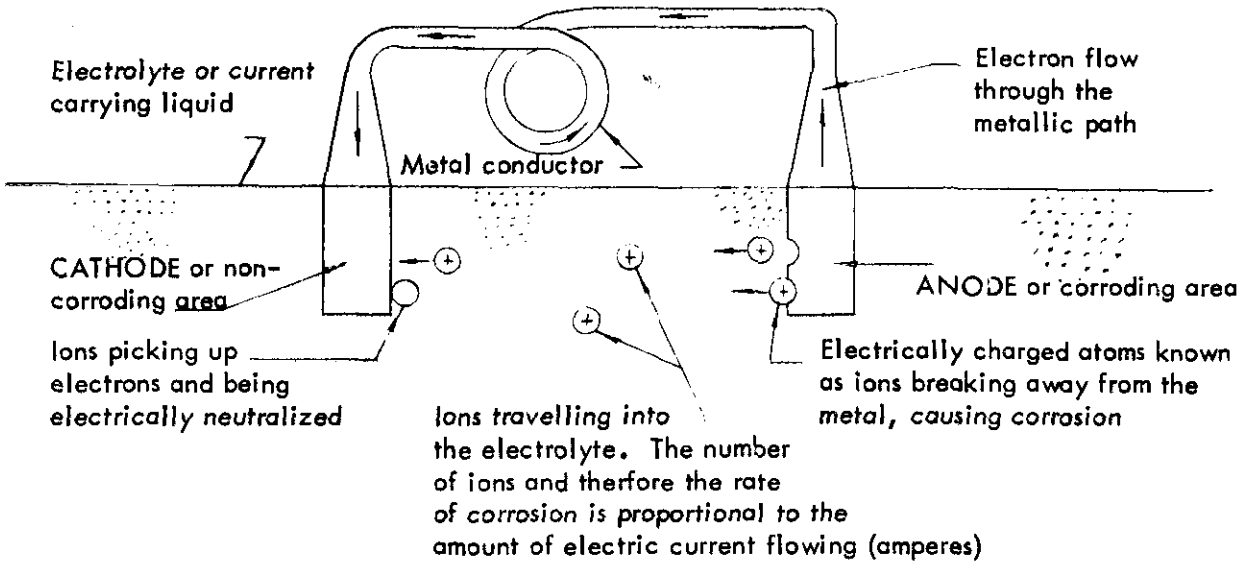


FIGURE 1: THE BASIC CORROSION CELL

Figure 1 illustrates this corrosion process, known as electrolysis. Note the necessary components of the corrosion cell. There must be a complete electric circuit composed of an external metal conductor and an internal electrolyte, and there must be a source of electrical potential to cause a current to flow. If either of these components is missing, corrosion will not occur and it is on this that we base corrosion prevention.

Anode and cathode are merely arbitrary designations for areas on the metal surface that have an electrical potential difference (voltage) between them so that a current can flow in the direction indicated. They may be microscopically close together on the same surface area, or miles apart on different parts of a pipeline system which is electrically interconnected. Any number of corrosion cells may operate on the same piece of metal, each with its own anode and cathode.

Any metal and practically any aqueous liquid, whether acid or basic, will suffice to support this corrosion cell. Being electrical in nature, it operates according to Ohm's Law; that is the amount of current flowing, and hence corrosion, decreases as the resistance of the circuit increases. It increases as the potential difference between the anode and cathode increases. You can expect the amount of corrosion to be proportional to the resistance through the electrolyte and the external metal circuit. If you break the circuit at any point, corrosion no longer occurs.

Chemical reactions take place in the electrolyte as a part of this corrosion cell. These are usually complex and not necessary to this basic illustration. However, they affect the force and duration of corrosion activity by affecting the electrical balance. The metal ions themselves seldom reach the cathode, as they enter into chemical reactions in the electrolyte. The formation of rust (usually ferric or ferrous oxide or hydroxide) when iron corrodes is due to such chemical reactions.

The potential difference between the anode and cathode can come from several sources. Almost any chemical or physical difference between the anode and cathode areas will cause a natural potential difference, whether the difference is in the electrolyte or the metal. Such common differences which cause potentials sufficient to support substantial corrosion are different metals (for example, copper and iron coupled will have a potential difference of approximately 0.6 volt), impurities in the metal, different metal surface conditions, different concentrations of chemicals within the electrolyte (especially oxygen concentration), and temperature differentials. Any direct electric current, such as stray currents from improperly grounded DC motors or generators, will support corrosion; and so, usually, will alternating current. Because of the large voltages and amperages usually involved, stray currents can cause unbelievably extensive and rapid corrosion.

It is important to remember that this corrosion process is universal for all metals. Cast iron, steel, copper, lead, concrete reinforcing steel, stainless steels, exotic metals -- all will corrode given a favorable environment. For the common metals, such as cast iron and structural steel, most environments are corrosive, and it is always necessary to consider protection against corrosion when using them. Fortunately, such protection is readily available at low cost.

CORROSION CONTROL

Corrosion may be prevented or mitigated readily, and all methods have one basic feature in common. That is: they reduce, stop or divert the flow of electric current which causes corrosion.

You can stop this corrosion current in many ways. A very common one is to put a non-conductive coating on the metal, such as plastic, coal tar or paint. This serves to break the electric circuit necessary to the corrosion process. The trouble with this method is that good coatings are expensive and there is no coating which is 100 percent effective in practice. Corrosion current can escape wherever breaks occur in the coating, even microscopic ones; and accelerated pitting often occurs because of the concentration of current flow at these breaks. However, when properly applied and maintained, coatings can be very effective. They are especially effective in reducing exposed metal area for minimizing cathodic protection current requirements.

Another type of coating serves to provide a passive chemical film at the metal surface. By passive, we mean that the film is chemically stable in the given electrolyte and will not permit an electric current to flow through it. Examples are cement coatings on iron which provide a highly-alkaline environment in which iron is usually passive, and anodizing of aluminum

which provides an aluminum oxide film which is passive in normal atmospheres. Stainless steel and many other metals automatically provide their own passive films to protect themselves against corrosion in many environments.

Stainless steel forms a tough, thin, invisible oxide film from the initial corrosion action when the steel is first introduced to moisture. This chemical film is normally impervious to further corrosion, and will repair itself when scratched or otherwise damaged. However, the introduction of an unfavorable environment, such as adding chloride ions (free chlorine) to the moisture in contact with the surface of the stainless steel, will break down this film and corrosion will ensue. This is true of all passive films -- they are corrosion resistant only in certain environments. None are universal.

Chemical treatment of the water or other electrolyte in contact with a metal surface is often a very practical method of protecting boilers, steam lines, chemical process equipment and paper mill machinery against corrosion. There are a great variety of chemical treatment methods and their action is often complex. In general, they operate either to remove free oxygen or other corrosion inducing chemicals from the electrolyte, or to create a passive film at the metal surface. Chemical treatment is not usually practical in unconfined water such as with soil moisture or marine structures.

The important fact to remember with chemical treatment is that no method is universally effective, and if improperly applied, many methods can be harmful. Each is designed to provide a certain definite chemical reaction in a certain definite environment; and, for example, just because one method works well in the boilers of one plant does not mean it will work in your plant's boilers. The only way to secure effective chemical treatment is to test the water and other factors and to design a treatment for your specific environment. This can be usually accomplished at relatively low cost, and invariably this scientific approach is far less expensive than the costly trial-and-error method often used.

Of course, a basic method of corrosion prevention is to substitute a different material -- one that will not corrode in the given environment. Plastics, stainless steel and non-ferrous metals are commonly utilized for just this reason. Platings and claddings also serve this purpose. However, the original metal was usually desired because it was inexpensive, easy to obtain, and possessed of desirable qualities. Therefore, it often pays to consider corrosion protection rather than substitution. A frequent example is with the common grades of structural steel, where a supposed lack of corrosion resistance is usually the only reason why other materials are substituted.

CATHODIC PROTECTION

This is an important and universally applicable method of corrosion control. It is unfortunate that cathodic protection is little understood, for its proper application can eliminate much of the billions of dollars lost through corrosion each year. It is a proven method, has been used to prevent corrosion on ships, the Texas Towers, the Panama Canal, the Cape Kennedy missile facilities, naval bases, industrial plants and buried utilities throughout the world for many years.

Where used, it has greatly lowered the cost of bringing water, oil, gas and electricity to your home. In fact, the intercontinental transmission of oil and gas by pipeline would not be economically feasible without cathodic protection to keep the steel lines from corroding.

Glance back to the basic corrosion process discussion (Figure 1) and note that the corroding areas on a metal surface are at the anodes where an electric current flows out of the metal, and that the protected areas are at the cathodes where the current flows into the metal. Now if the direction of current flow is reversed at the anodic areas so that the entire metal surface becomes a cathode, no corrosion occurs. This is exactly what cathodic protection, as the name signifies, does.

With cathodic protection, we do not really eliminate corrosion; we control corrosion by keeping it entirely confined to selected pieces of metal which are replaced periodically. An artificial corrosion cell is designed and manufactured by installing replaceable anodes which we expect to corrode and cause a current to flow from them through the liquid and onto the protected metal, which thus becomes the cathode of our new corrosion cell. This is illustrated in Figure 2.

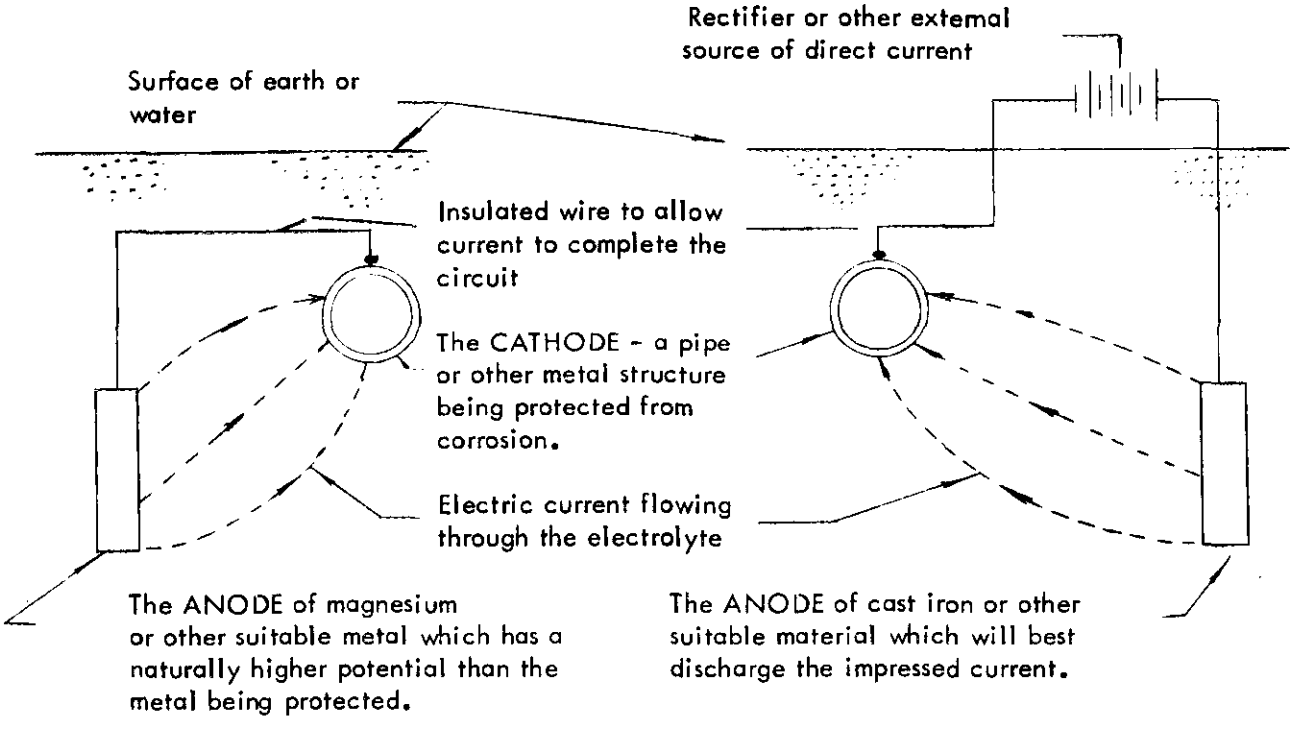


FIGURE 2: BASIC CATHODIC PROTECTION SYSTEMS

Cathodic protection is feasible wherever you have a continuous electrolyte in contact with the metal to be protected. Soils, bodies of water, and chemical solutions provide such a continuous electrolyte. It is commonly used to protect pipelines, cables, tanks and other metal structures that are underground or underwater; and to protect process equipment and tanks in contact with many liquids. A variation known as "anodic protection" is sometimes used to protect against oxidizing acids.

The two basic methods of cathodic protection illustrated differ primarily in the source of protective current. The Galvanic Anode System generates its own current. The more active or more readily corrosive metal of the anode corrodes, and in so doing impresses an electric current (i.e., stream of ions) onto the metal being protected. It is named after the galvanic cell which this action represents.

The Impressed Current System uses an external source of current which is directed through the anode in the same manner. Both systems must be designed with sufficient voltage and amperage to insure that any tendency of local corrosion cells to form on the protected structure is overcome. This requires an individual design for each installation with an accurate assessment of the specific environment through a field survey.

As the anodes are designed to corrode, they are sacrificial in nature. Therefore, they must be replaced periodically; but in a well-designed system, they normally can be expected to last for twenty years or more.

Either system may be used for most installations, but when all costs are considered, one will usually prove to be less expensive for a given application. Among the factors to consider, the galvanic anode system is simpler, but it requires more anodes because of the lower voltage and amperage output. The impressed current system is much more flexible, and a wide range of voltages and amperages can be achieved without adding components. There are many other factors which should be taken into consideration, such as the fact that galvanic anodes can usually be charged off as an expense item.

Cathodic protection serves its purpose best and is by far the most economical when it is properly coordinated with the other methods of corrosion control, especially coatings. In general, the least expensive, easiest to maintain and most practical system is to apply a good quality coating to a new structure and then to use cathodic protection to eliminate corrosion at the inevitable breaks in the coating. The reason for this is that it takes much more current and anodes to protect bare metal than it does coated metal. The amount of protective current required is proportional to the area of metal exposed to the electrolyte.

REINFORCED CONCRETE

Concrete deserves a special comment. From a corrosion standpoint, it is a type of coating over steel, whether or not the concrete is designed to serve a structural purpose. It is permeable to moisture, and an electrolyte will penetrate it to come in contact with the steel underneath. In some environments, it is a very fine coating, but if it is poorly applied or used in the wrong environments, it can lead to premature and complete structural collapse.

Moisture becomes highly alkaline when it penetrates concrete due to the chemical action of the concrete. This is beneficial to iron and steel from a corrosion standpoint, as we have noted, but it can cause accelerated corrosion of lead or aluminum. This may occur, for example, when lead cables are run through concrete ducts, or aluminum conduit is encased in concrete.

A far greater danger occurs when concrete is placed in an acid soil or water. Concrete deteriorates in an acid environment, which in general would be when the pH is below six, and especially below four. Under these circumstances, the concrete will spall away from the steel imbedded in it and corrosion ensues. This corrosion is greatly compounded by the fact that bare steel is highly anodic to concrete coated steel, and a very potent corrosion cell is set up between the areas where the concrete has spalled off and the areas which are still coated. This particular corrosion cell has a potency about equal to that of copper coupled to steel, which represents a potential difference of over 1/2 a volt, or sufficient to penetrate a 1/4 inch steel wall in a year or so!

This corrosion cell set up between concrete coated steel and bare steel causes many unsuspected losses. It should be considered and protected against wherever concrete is used, such as where concrete caps are applied to steel piles and where steel pipes are run through concrete floors into the soil below, or where cement coated pipe is connected to a steel or cast iron pipe underground.

Concrete coated pipe may have the same cathodic protection applied as other metal pipe, but it is more expensive than pipe with a good coating possessing high dielectric strength. With the latter only enough current is required to protect at the flaws in the coating, which involves usually less than one percent of the pipe's surface area. However, with concrete coated pipe, the coating will permit the ready flow of an electric current so that enough current must be provided to protect the entire surface area of the steel imbedded in the concrete. In the design of a concrete pipe system, care must also be taken to bond all encased steel and joints because an electrically continuous surface is needed for cathodic protection or stray current drainage.

RATE OF CORROSION

Once corrosion failures, such as leaks in pipes and tanks, or power outages in cables, start occurring, they will invariably continue to occur at an increasing rate. Anyone who has suffered corrosion failures knows that the nuisance and expense of repairing these failures increase until they become a major headache. When this occurs, if corrosion control is not undertaken, the structure must be replaced, usually at somewhat greater cost than the original installation. Then, the whole corrosion cycle starts over again.

A mathematical law governs the rate at which corrosion failures increase. This has been found wherever accurate corrosion leak records are kept. If you permit corrosion to proceed on any metal structure -- and we hope by now you have come to realize this is never necessary -- you will find that the rate at which failures occur increases logarithmically. That is, if you have

ten leaks in one five-year period, for example, you may expect to have approximately 100 in the next five years and 1,000 in the next!

You can install cathodic protection or other forms of corrosion control at any time in this cycle of failures, and expect to reduce or stop further corrosion. However, you cannot replace the metal already lost; and, if you have allowed corrosion to proceed so far that you have deep pitting, you may expect some of these pits to continue to fail for a few months.

CORROSION SURVEY

Progressive management and consultants are assuring against corrosion losses by having a corrosion survey made of the site in advance of the design of utilities and other buried metal and process equipment. This will tell how soon you may expect corrosion, what control measures will cost, and whether they will pay off. Necessary cathodic protection (coatings or alternate materials) can then be incorporated in the plans and specifications.

A similar survey of existing structures that are corroding will tell you whether protection is economically justified. Actual or potential corrosion can usually be determined with remarkable accuracy from electrical and chemical measurements made at the site.

MAINTENANCE

All corrosion control systems must be maintained. This is an established cost that goes with them, and it should be accepted as such. If you neglect maintenance, you will soon eliminate the usefulness of any corrosion control system. Part of maintenance is the replacement and repair of coatings, electrical components, anodes, chemical feeders and such.

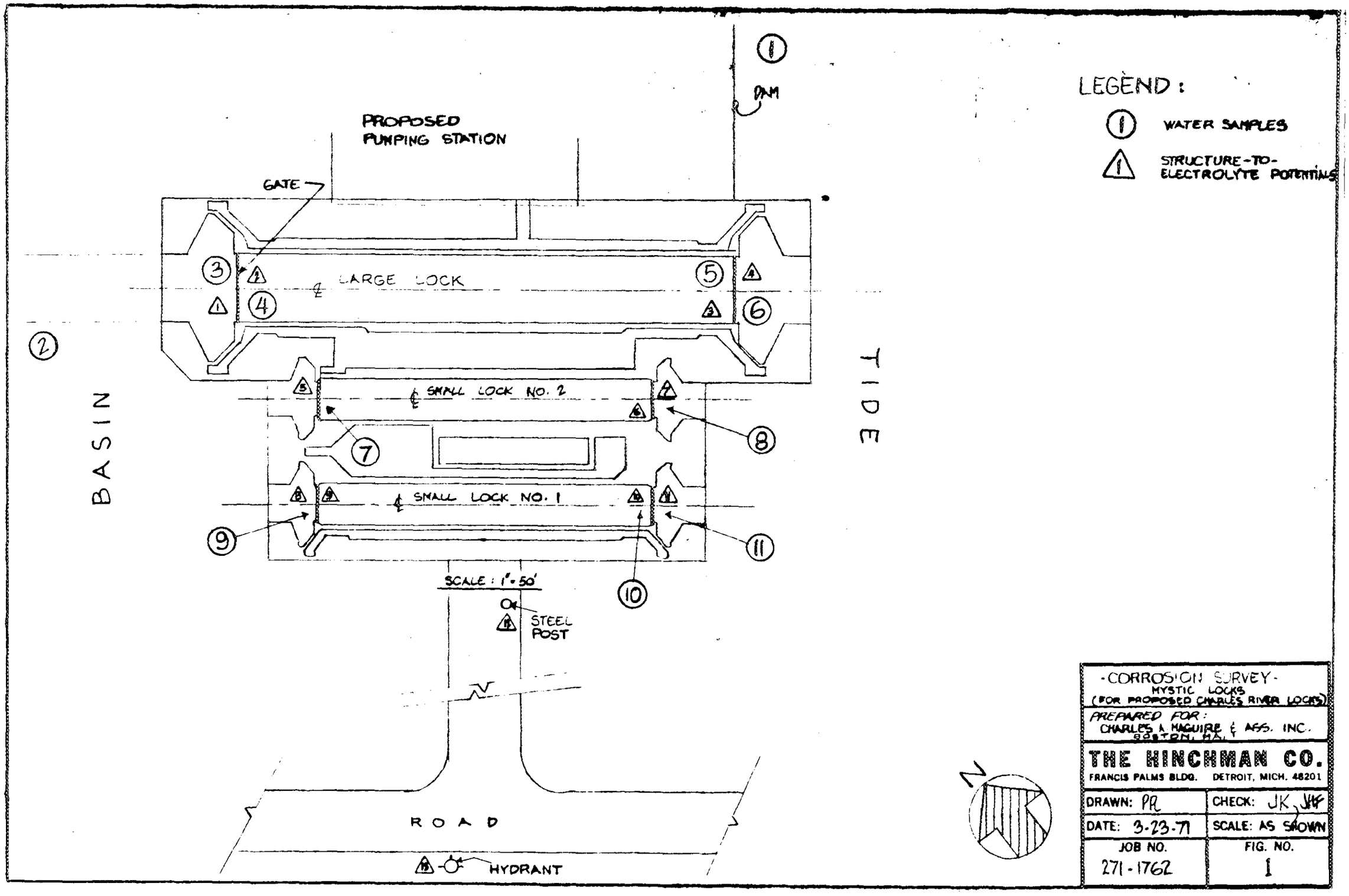
In corrosion prevention, another facet of maintenance must be considered. This is the fact that the corrosion environment of most facilities changes over the years, generally slowly but occasionally radically and rapidly. Factors which commonly change are the addition of new structures, alteration of existing ones, and the chemical composition of the electrolyte, usually for man-made reasons. An annual maintenance survey of all corrosion prevention systems should be conducted by a qualified corrosion engineer. In this survey, all components should be tested for their effectiveness, and sufficient electrical and chemical tests performed to determine the effect of any environmental changes.

Maintenance is especially important in cathodic protection systems. These are electrical systems and require the same care as any other electrical installation. Their effectiveness is especially responsive to alterations or additions to any structures in the area. These structures may shield or channel the flow of protective current.

CONCLUSION

All metals tend to corrode, and tremendous sums of money are lost each year through corrosion. However, all corrosion is due to the same basic process and it can be readily and economically prevented. Corrosion protection is based on exact science, but its application involves evaluation of a great many variables and is somewhat of an art, especially if the maximum economies are to be achieved.

The basic principles of corrosion and corrosion prevention can be readily understood. If they are, the services of a corrosion engineer can be properly evaluated. Through the use of a qualified corrosion engineer, management can achieve perhaps the greatest dollar savings available today.


LEGEND:
WATER SAMPLES
STRUCTURE-TO-ELECTROLYTE POTENTIALS
DAM
PROPOSED PUMPING STATION
GATE
LARGE LOCK
SMALL LOCK NO. 2
SMALL LOCK NO. 1
BASIN
TIDE
SCALE: 1" = 50'
STEEL POST
ROAD
HYDRANT
-CORROSION SURVEY-
MYSTIC LOCKS
(FOR PROPOSED CHARLES RIVER LOCKS)
PREPARED FOR:
CHARLES A. MAGUIRE & ASS. INC.
BOSTON, MASS.
THE HINCHMAN CO.
FRANCIS PALMS BLDG. DETROIT, MICH. 48201
DRAWN: PR
CHECK: JK
DATE: 3-23-71
SCALE: AS SHOWN
JOB NO. 271-1762
FIG. NO. 1

J. Lukacz

ENGINEERS

CHARLES A. MAGUIRE & ASSOCIATES INC.
178 TREMONT STREET · BOSTON · MASSACHUSETTS 02111
AREA CODE 617 542-5150 CABLE ADDRESS CAMAI

May 10, 1971
CAMA #1579.61

Mr. Lewis H. West, P. E., President
The Hinchman Company
Francis-Palms Building
Detroit, Michigan 48201

Reference: Corrosion Survey Report of Mystic River Locks
Boston, Massachusetts
Job No. 271-1762

Dear Mr. West:

A review of the reference survey report resulted in the following comments which we feel should be evaluated for inclusion in the report:

1. No mention has been made of the date of the corrosion tests and the level of the tide during the test. This report may be submitted to the Corps of Engineers as backup justification for possible cathodic protection. In this regard the conclusions drawn in the report, or at least the data given relative to the condition of the coating on the lock gates, could be very misleading. Neither the percentage tables given in 3.6.1 nor the write-up in Section 5 takes into consideration that the submerged areas of the basin or the tide were not dewatered and hence never inspected. Specifically, Section 5.1 makes reference to the "good condition" of the coatings on the basin side of all lock gates, but the portions inspected on the basin side were all above Elevation 107. The coating on both sides of all gates was good above this level.

2. The discussion of the economics for the recommended cathodic protection is rather brief and incomplete. It talks about the cost of dewatering ($50,000) and simply mentions that maintenance costs due to corrosion will be minimized. We realize that it is difficult to pinpoint, or accurately estimate the difference in maintenance cost with or without cathodic protection, but we feel that some economic basis for justifying cathodic protection should be provided. It must be

Mr. Lewis H. West, P. E., President
The Hinchman Company

May 10, 1971
CAMA #1579.61

kept in mind that dewatering will be essential for routine maintenance and recoating, whether or not cathodic protection is used. It is conceivable that the frequency of dewatering would be decreased by the use of cathodic protection and antifouling coatings. Information on the performance of vinyl mastic coating would be appreciated. An estimate based on your experience in similar environs seems appropriate.

Should you have any question concerning the above comments, please contact us.

Very truly yours,

CHARLES A. MAGUIRE & ASSOCIATES INC.

John Lukacz, Jr., P. E., Project Manager
Environmental Engineering Division

JL/EPD/cw

CORROSION ENGINEERS Francis Palms Building • Detroit, Mich. 48201 • Telephone [illegible]-962-5272

LEWIS H. WEST P.E. PRESIDENT

THE HINCHMAN COMPANY

May 25, 1971

Environmental Engineering Division
Charles A. Maguire & Associates, Inc.
178 Tremont Street
Boston, Massachusetts 02111

Attention: John Lukacz, P.E., Project Manager

Subject: Corrosion Survey Report of Mystic River Locks

Reference: Our Job No. 271-1762

Dear Mr. Lukacz:

We received your letter dated May 10, 1971 regarding subject report. Our comments are:

Item 1: The survey was made on March 16, 1971, starting at 7:45 AM during low tide.

We agree that visual inspections on coating conditions on the basin and tide sides of lock gates should not refer to the permanent immersion zones since no dewatering was done during the survey. Correspondingly, coating conditions referred to in Sections 3.6.1 and 5.1.7 should not apply to the permanent immersion zones of gates on the basin and tide sides. Any reference to permanent immersion zones in the report would only apply to visual inspections made inside the locks.

Item 2: A more detailed economic justification of the recommended cathodic protection for the gates cannot be made since repair costs of the gates since 1966 when the locks were installed were not available. (Refer to Section 5.3, page 30). However, cathodic protection on locks and dams is widely used by the Corps of Engineers. Among these are the Inglis lock in Florida representing the Gulf

Coast entrance to Intercoastal Waterway near Fort Myers (Sector gates) and the Kaskaskia River lock and dam in Illinois (Miter gates).

Corrosion problems are more severe with seawater on one side and fresh water on the other side, as in the Mystic and Charles River locks.

The Corps of Engineers (Cincinnati) use vinyl coating and also cathodic protection systems on locks and dams.

Attached to this letter are pertinent portions of the results of tests made in California mentioned in page 3 of the survey report and of a Department of Defense manual on protective coatings.

If you have any questions or require further information, please call.

Our best regards.

Yours very truly,

Lewis H. West, P.E.
President

W/s

Enclosures

PROTECTIVE COATINGS FOR STEEL PILING: RESULTS OF 30-MONTH TESTS

Y-R007-08-401

Type C

by

R. L. Alumbaugh

OBJECT OF TASK

T[illegible] various coatings in order to determine which coating offers maximum protection [illegible] steel piling.

ABSTRACT

Eight coating systems selected from a previous study were evaluated by the Laboratory as protective coating systems for steel piles. The systems were applied to both sheet and "H" piles. The coated piles were driven in the surf of the outer harbor at Port Hueneme and exposed for periods of 12 to 30 months.

At the conclusion of the 30-month exposure period, all eight systems showed some coating deterioration resulting either from the driving operation or the exposure condition. The most severe damage was attributed to the action of the sea-water sand slurry which caused moderate to heavy abrasion damage, just above the mudline, to all the systems.

Based on over-all protection to the three exposure zones (splash, tidal, and embedded) together with cost considerations a vinyl mastic coating system provided the most economical protection to the steel piling during the 30-month exposure period.

[illegible] available at OTS $1.50

DISCUSSION

Zone Protection

All eight systems tested showed at least some coating deterioration after 30 months of exposure in the surf at Port Hueneme. The following discussion correlates these results according to exposure zone.

Splash Zone. With the exception of the flame-sprayed zinc coating, all eight systems provided good protection to the steel piles in this zone. The zinc coating corroded and formed a white zinc salt which removed zinc from the coating and permitted rusting of the steel substrate. The coating deterioration on the remaining seven systems was principally a result of scraping, scratching or hammering during the handling and driving operation. Although rusting occurred where the coating had been broken or scraped from the metal piles, no undercutting of the coating film by rust was observed.

Tidal Zone — Area "A." The amount of fouling on the systems varied with the season of the year and was affected by water temperature. When the piles were pulled in the fall after water temperature had reached a maximum, fouling was much heavier than on piles pulled in the spring after the water temperature had reached a minimum. This was true with all eight systems.

The two bituminous coating materials (Systems 13 and 16) were the only systems tested that were subject to appreciable fouling damage. Barnacles had penetrated through these two coatings to the primer or to the steel substrate in approximately 70 percent of area "A." Because there was no inhibitive primer beneath the coal tar coating, this system showed more rust than the mica-filled asphalt emulsion system. The zinc chromate primer for the mica-filled asphalt emulsion coating was quite effective in inhibiting corrosion of the steel.

The remaining six systems provided very good protection to the steel in this area. However, System 7 (phenolic resin mastic system) and System 23 (Saran) provided the best protection.

Tidal Zone — Area "B." This area provided the most severe exposure environment for the coating systems under test. All eight systems showed some abrasion damage in this area. System 9 (neoprene) and System 20 (flame-sprayed zinc) provided the best protection to the steel substrate, and System 6 (vinyl mastic) was next best. The sea-water-sand slurry caused severe coating damage to Systems 1 (aluminum vinyl), 13 (coal tar) and 16 (mica-filled asphalt emulsion). Abrasion of these coatings from the piles in area "B" resulted in severe rusting and pitting in the top portion of the area.

Abrasion of the coatings from the steel substrate was much more severe on the sheet piles than on the "H" piles. The large flat surface of the sheet piles offered more resistance to the abrasive action of the sea-water-sand slurry than did the more compact shape of the "H" piles. Abrasion damage occurred as the slurry washed back against the concave or landward face of the sheet piles on returning to the sea. Because of this backwashing action, abrasion damage was much more severe on the concave or landward face of the sheet piles than on the convex or seaward face. System 13 (coal tar) and System 16 (mica-filled asphalt emulsion) were the only systems showing extensive coating damage on the convex face of the piles. With the remaining systems, the convex face of the piles normally showed slight removal of the topcoat from the primer and very light rusting.

The "H" piles were driven with the flanges parallel to the surfline. As a result, the principal abrasion damage occurred inside the flanges and web end on the pile edges. Light damage was observed on the outside flanges, but this consisted of abrasion of the topcoat from the primer, and light rusting.

Although "H" piles and sheet piles are driven in the surf, they are also driven in deeper water where they are not subjected to the abrasive action of the sea-water-sand slurry. Similarly, sheet piles are not usually driven individually in the surf in such a manner as to subject the landward face of the pile to the abrasive backwashing action of the sea-water-sand slurry. Sheet piling is normally driven interlocked and would thus be subjected to wave action rather than the backwash of the sea-water-sand slurry. Therefore, the abrasive condition existing in the outer harbor at Port Hueneme, although quite destructive to coating systems, is not usually encountered in actual practice and does not always constitute a serious problem.

Embedded Zone. The coated area beneath the mudline generally showed no more deterioration after 30 months of exposure than after the initial 6-month exposure. Conditions beneath the mudline varied with each pile, and the amount of cutting, scratching, and scraping of an individual coating varied with the amount of rock and debris encountered by the coated pile beneath the mudline. Most of the coating systems showed light scratching or scraping damage, but this was not serious and did not lead to additional coating deterioration. Where the coating system had been cut or scratched through to the metal pile, light rusting was evident, however, no undercutting of the coating films by rust was observed.

Although all eight systems provided very good protection to the steel substrate in this zone, System 20 (flame-sprayed zinc) and System 16 (mica-filled asphalt emulsion) provided slightly better protection than the others.

Over-all Protection

In TN-309,[3] it was suggested that System 23 (Saran) be used as a high-quality standard. Based on the resistance to rusting provided to the steel piles by the coating systems, and using Saran as the standard, the coating systems would be ranked in the following order:

Protection better than
System 23 (Saran)_ _ _ _ _ System 6 (vinyl mastic)
System 9 (neoprene)

Protection equal to
System 23 (Saran)_ _ _ _ _ System 7 (phenolic resin mastic)

Protection less than
System 23 (Saran)_ _ _ _ _ System 1 (aluminum vinyl)
System 20 (flame-sprayed zinc)
System 13 (cold-applied coal tar)
System 16 (mica-filled asphalt emulsion)

The above list is based on protection; no consideration was given to cost. Cost is an important factor because the particular coating system chosen for application to piling is often based on the cost of the system under consideration. The following list gives the total applied cost per square foot and is taken from Appendix B where a complete materials and labor cost breakdown is given:

System Number	Applied Cost per Square Foot
1 (aluminum vinyl)	$0.41
6 (vinyl mastic)	0.42
7 (phenolic mastic)	0.78
9 (neoprene)	0.83
13 (coal tar)	0.49
16 (mica-filled asphalt emulsion)	0.36
20 (flame-sprayed zinc)	0.37
23 (Saran)	0.34

On a performance basis, System 6 (vinyl mastic) and System 9 (neoprene) provided the best over-all protection to the steel piles. However, System 6 would normally be the recommended system since it provides the same degree of protection as System 9 at one-half the cost.

CONCLUSIONS

The following conclusions can be drawn concerning the protection provided steel piles by the eight coating systems, after 30 months of exposure in the surf at Port Hueneme:

1. Damage to the coating systems during the handling and driving operation was not considered a significant factor in the further deterioration of the coating systems.

2. The principal coating damage was severe abrasion by the backwashing action of the sea-water-sand slurry just above the mudline. Although this damage was more severe to the sheet piles than to the "H" piles, moderate to heavy damage was evident on all eight coating systems.

3. Fouling damage did not constitute a serious problem except in the case of the softer bituminous coatings. Cold-applied bituminous coatings do not exhibit sufficient resistance to attachment and damage by fouling organisms to warrant their use in waters where heavy fouling is prevalent.

4. In general, the least coating deterioration was shown in the embedded zone. The protection provided to this area of the piles by all eight coating systems was very good.

5. Based on the applied cost and the ability to protect steel piling against rusting, the most economical protection was provided by System 6 (vinyl mastic).

6. System 9 (neoprene) provided good protection to the steel piles in all zones of exposure. However, considering the high cost of the neoprene system, together with its tendency to blister, delaminate, peel, and promote galvanic corrosion of the steel pile, this system does not warrant further consideration.

7. If coated piles are driven in deeper water where abrasion in area "B" of the tidal zone is not a problem, the following systems should provide essentially equal protection: System 1 (aluminum vinyl); System 6 (vinyl mastic); System 7 (phenolic resin mastic); System 23 (Saran). Based on the applied cost, System 23 (Saran) would provide the most economical protection in a deep-water environment.

Table 15. Recommended Coating Systems for Exterior Iron and Steel (Continued)

Environment	*Substrate*	*Preparation**	*Type*	*Primer*	*Topcoat***	*Notes*
Marine or Moderately Corrosive.	Structural	Class 3	Vinyl + Vinyl-alkyd	MIL-P-15929 or MIL-P-15930	MIL-E-15932 MIL-E-15933 MIL-E-15934**** MIL-E-16738 MIL-E-82401	Black, semigloss. Black, flat. Gray #7. White, semigloss. Red.
	Smooth	Class 3	Chlorinated Rubber	TT-P-1046	TT-P-1046	Zinc rich.
			Chlorinated Rubber or Vinyl + Vinyl-alkyd	TT-P-1046 or MIL-P-15929 or MIL-P-15930	MIL-E-15932 MIL-E-15933 MIL-E-15934**** MIL-E-16738 MIL-E-82401	Black, semigloss. Black, flat Gray #7. White, semigloss. Red.
			Chlorinated Rubber + alkyd or silicone-alkyd	TT-P-1046	TT-E-489 or TT-E-490	High gloss, all colors. Semigloss, very durable silicone-alkyd, white and 12 colors.
Marine:	Structural	Class 4	Vinyl	VR-3, 4 coat system		See Appendix D-1, Table 4
Immersion or Highly Corrosive.			Vinyl	VR-6, 4 coat system		See Appendix D-1, Table 4
			Organic + Vinyl or Chlorinated Rubber + Vinyl.	MIL-P-26915 or TT-P-1046	VR-3 or VR-6	
			Inorganic + Urthane or Epoxy.	MIL-P-38336	MIL-C-38427	For highly corrosive and humid environments.
			Inorganic + Vinyl.	MIL-P-38336	VR-3***	

* See 4.4.2.7
** Use 2 coats on new work, then 1 or 2 coats as required.
*** Tie coat may be required.
**** See Appendix D-1, Table 4 for other gray enamels of similar formulation.

ENGINEERS

CAM

CHARLES A. MAGUIRE & ASSOCIATES INC.
Providence, R. I. Boston, Mass. Wethersfield, Conn.

MEMORANDUM OF TELECON

DATE: 5-31-71 TIME: 1345 JOB NO. 1579.61

PROJECT: CHARLES RIVER LOCKS & DAM

INITIATED BY: JOHN LUKAEZ, JR.

PERSON CALLED: PEDRO REYES, PROJECT ENGINEER, THE HINCHMAN COMPANY

SUBJECT: RESTIVITY READINGS AT THE HOOSIC PIERS.

CALLED PETER (PEDRO) TO SEE IF HE HAD RESTIVITY READING AT THE HOOSIC PIERS. TOLD HIM THE CORPS WAS PLEASED WITH THEIR STUDY, BUT THOUGHT THAT THE RESTIVITY READINGS AT MYSTIC LOCKS WOULD BE DIFFERENT FROM OUR SITE ON THE CHARLES BECAUSE OF MONSANTO'S DISCHARGE INTO THE MYSTIC. PETER SAID THE READING AT MYSTIC ARE TYPICAL OF SALT & FRESH WATER ESTUARY READINGS AND DID NOT BELIEVE MONSANTO HAD AN APPRECIABLE EFFECT ON THE RESTIVITY READINGS.

ACTION REQUIRED:

LUKAEZ – INTEND TO CALL MPA ENGINEERING TO SEE IF THEY HAVE RESTIVITY READINGS WHICH WERE TAKEN DURING THE ORIGINAL CORROSION SURVEY (BY HINCHMAN)

COPIES TO: FILE

CORROSION ENGINEERS Frances Palms Building • Detroit, Mich. 48201 • Telephone [illegible]

LEWIS H. WEST, P.E. PRESIDENT

THE HINCHMAN COMPANY

September 28, 1971

John Lukacz, P.E.
Charles A. MaGuire & Associates
178 Tremont Street
Boston, Massachusetts

Subject: Water Resistivity, Boston Harbor

Reference: Our Job Number 271-1762 - Charles River Dam

Dear Mr. Lukacz:

Here are some data on the subject resistivity. They were obtained in the summer of 1967 at the Coast Guard Piers: (Commercial Street Boston)

Resistivity	44 ohm cm - flood tide
	53 ohm cm - ebb tide
pH	5.8 both tides

The higher resistivity during ebb tide is due to the influx of fresh water from the river.

Resistivity might be higher up at the dam since there may be more fresh water there. We will be glad to test a sample if you need the information.

Our best regards, and I look forward to seeing you when I get to Boston.

Cordially,

John H. Fitzgerald

John H. Fitzgerald, III, P.E.
Vice President

F/g

CAPE CANAVERAL
(305) 783-0004

PHILADELPHIA
(215) 889-0905

APPENDIX C

GATE OPERATING MACHINERY CALCULATIONS

APPENDIX C

GATE OPERATING MACHINERY CALCULATIONS

Title	Page
Gate Machinery Mechanism	C1-C3

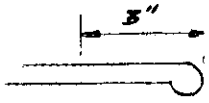
PROJECT CHARLES RIVER LOCKS ACC. NO.
SUBJECT GATE MACHINERY - MECHANISM SHEET NO. 1 OF 3
DATE 3-10 19 72
COMP. DTM CHECK EPD CONT. NO.

C-1

Large Lock - Tide End

Worst Condition - Gate Closed

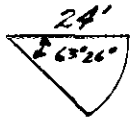
① Seal Friction - Active Sill Seal



Pressure = 10' x 64 #/ft³ = 640 #/□'
Area = 1' x 3/12 = 1/4 □'

Load / FT. of Seal = 640 / 4 = 160 #

Length of Bottom Seal



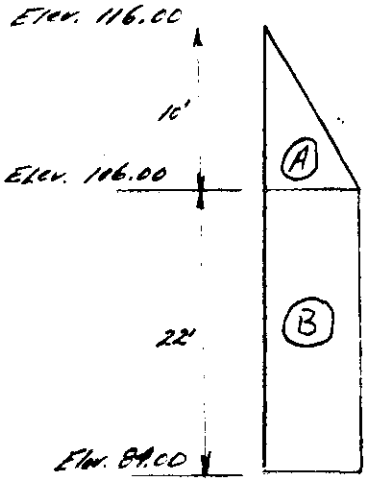
Length of Arc
C ⌒ D = 48 π = 150.8'

$\frac{63.43}{360}$ x 150.8' = 26.56'

Total Length = 26.56'

Load on Sill Seal = 26.56' x 160 #/' = 4,249.6 #

② Load on End Seal



Ⓐ P = 1/2 x 10 x 64 = 320 #/□'
A = 1/4 x 10 = 2.5 □'
Load / FT. of seal = 2.5 x 320 = 800 #

Ⓑ P = 64 x 12 = 768 #/□'
A = 1/4 x 22 = 5.5 □'
Load / FT. of seal = 5.5 x 768 = 4224 #

Total Load on Active End Seal = 5,024 #

Load on Active Seals ① & ② = 9,273.6 #
Friction = 1.1 x 9,273.6 = 10,200.96 #
Add 25% for Inactive Seals = 2,550.24 #

Total Resistance = 12,751.2 #

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C-2

OPERATING FORCE - Gate in Closed Position

Torque about pivot = 12,751.2# x 24' = 306,028.8'#

Strut Load @ Closed Position

$$F_S = \frac{T}{r \cos \theta/2} = \frac{306,028.8}{(12.75)(.8506)}$$

$$F_S = 28,218\#$$

$$F_{RACK} \times 4.00 = F_S \times 3.00$$

$$F_R = 28,218 \times \frac{3}{4}$$

$$F_R = 21,163.5\#$$

@ 1000 psi $F_R \equiv$ Area Analys x 1000

$$\text{Area Analys} = \frac{21,163.5}{1000} = 21.16\ \square''$$

Assume .8 Efficiency for Mechanism and cylinder

$$21.16/.8 = 26.5\ \square''$$

Try 8" ϕ Cylinder Area = 50.265 □"
4" ϕ Rod Area = 12.5 □"

Analys Area = 37.765 □" > 26.5 □" O.K.

Piston Force = 37765 x 1000 = 37,765# (opening)

Strut Force = .8 x 37,765 x 1/3 = 40,282.67#

Moment of Strut Force about "P"

= 40,282.67 x 10.845
= 436,871.6'#

Force Available @ Sill Line = 436,871.6/24
= 18,203# (opening)

Water Reaction Etc 18,203 - 12,751.2 = 5,451.8#

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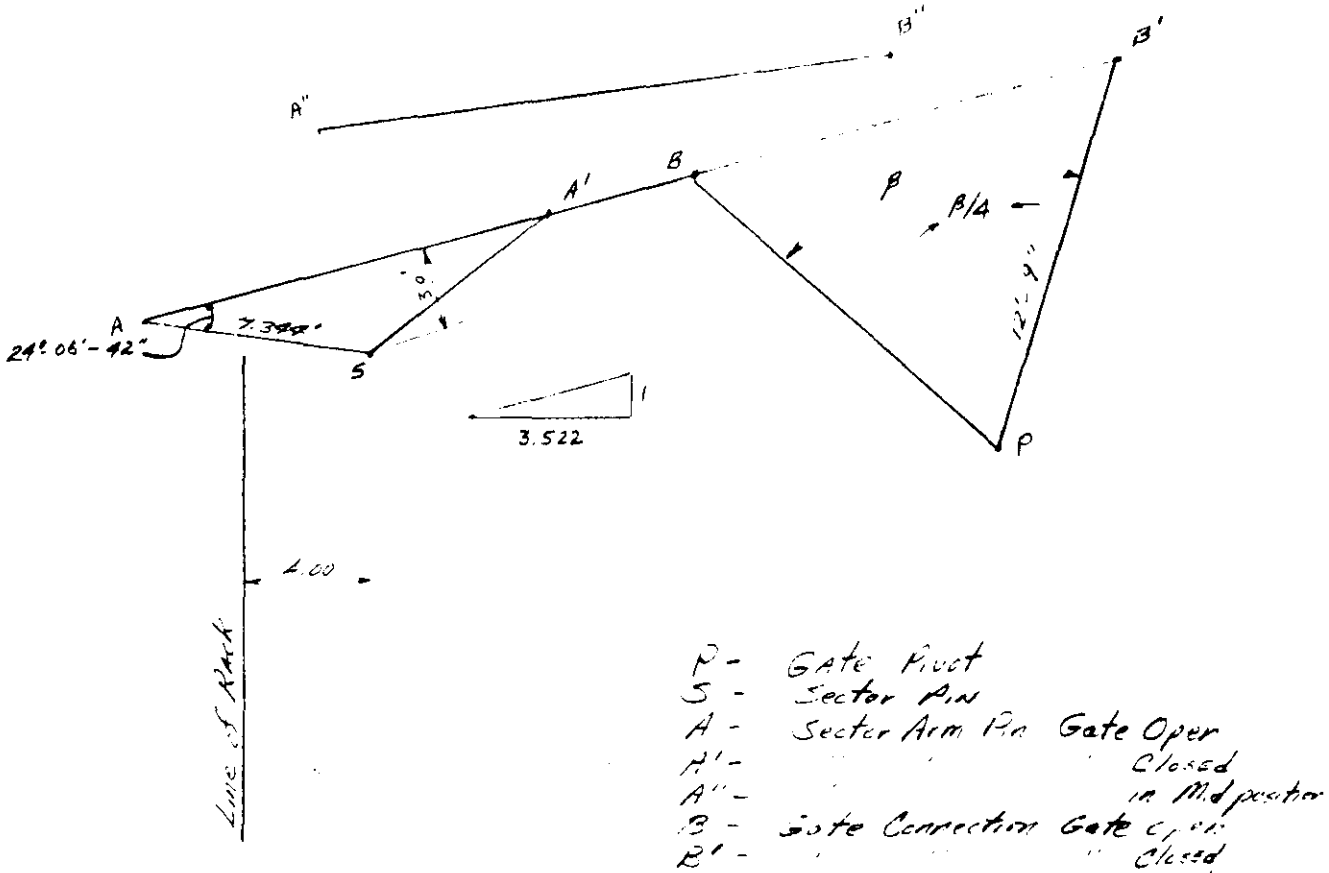
G3



P - Gate Pivot
S - Sector Pin
A - Sector Arm Pin Gate Open
A' - " " Closed
A'' - " " in Mid position
B - Gate Connection Gate Open
B' - " " Closed
B'' - " " in Mid position
β - Angle of Gate Rotation = 63°-26'