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LOCK DESIGN, BOTTOM LONGITUDINAL FILLING AND EMPTYING SYSTEM.(U)
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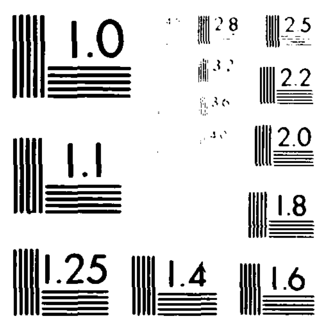

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LOCK DESIGN, BOTTOM LONGITUDINAL FILLING AND EMPTYING SYSTEM

by

Thomas E. Murphy

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents and summarizes ~~guidance~~ directions for design of bottom longitudinal filling and emptying systems for navigation locks.

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Preface

This report was prepared by Mr. Thomas E. Murphy, Consultant to the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES), to present and summarize guidance for design of bottom longitudinal filling and emptying systems for navigation locks. Chief of the Hydraulics Laboratory was Mr. H. B. Simmons. This report was reviewed and approved for publication by the Office, Chief of Engineers, U. S. Army.

Commanders and Directors of WES during the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

LOCK DESIGN, BOTTOM LONGITUDINAL FILLING AND EMPTYING SYSTEM

Introduction

1. During the 1950's, Mr. Francis Escoffier of the Mobile District was captivated by designs used for the filling and emptying systems of a series of locks on the Rhone River in France. Mr. Escoffier, with a working knowledge of the French language, corresponded with French engineers regarding details of these designs. Several times during visits to WES, Mr. Escoffier translated letters from French engineers and discussed designs of the Rhone River locks. There was general agreement at WES that the rather complicated culvert systems used in these balanced flow designs would not be directly feasible for Corps of Engineer locks, but that a less complex form of these designs could be practicable and probably would be superior to designs presently favored.

2. During a period of several years it was suggested to lock designers that a modified plan of the Rhone River locks design be considered. In each case the answer was: "looks like a good idea but not enough time to develop for this project," "probably would be too costly," or some similar brush-off. Finally, Mr. A. M. Cronenberg, Chief of the Design Section in the Mobile District, stated he was tired of hearing extolled the merits of these French designs and asked for a sketch of the system advocated. From this sketch, for locks proposed on the Alabama River, the Mobile District prepared a preliminary design suitable for determination of structural problems and preparation of cost estimates. This initial design for the longitudinal floor culvert system is shown in Figure 1.

3. Model tests of this design yielded favorable results and estimates indicated that the cost would be little if any more than other types of bottom filling systems. Development of the longitudinal floor culvert system has progressed by model studies for specific projects and a short series of general studies in the order listed below.

Project	Lock Size	Max Lift	Report
Millers Ferry	84 x 655	48	WES, TR 2-718, Mar 66
Jones Bluff	84 x 655	45	WES, TR 2-718, Mar 66
Dardanelle	110 x 670	54	WES, TR H-69-5, Apr 69
General Studies	110 x1270	100	WES, unpublished
Lower Granite	86 x 675	105	NPD, Hyd Lab, TR 126-1, Sep 79
Bankhead	110 x 670	69	WES, TR H-72-6, Sep 72
Trinity	84 x 655	41	WES, TR H-77-7, Apr 77
Bay Springs	110 x 670	92	WES, TR H-78-19, Nov 78

In the model study for each project a satisfactory design for that project was developed but testing has not been adequate for determination of optimum dimensions for all of the elements of the system.

4. In the paragraphs which follow findings of the above studies are reviewed and opinions of the author are given regarding probable improvements to the system. This discussion is concerned with that portion of the filling and emptying system between, and exclusive of, the filling and emptying valves.

Crossover Culverts

5. The portion of the system near the midpoint of the lock where flow from each wall culvert is divided and directed to the ends of the chamber has been designated the crossover culverts. Two methods of dividing the flow have been used: the side-by-side method used at Bankhead Lock (Figures 2 and 3), and the over-and-under method used at Lower Granite Lock (Figure 4), and Bay Springs Lock (Figure 6). The over-and-under crossover culvert, proposed by the designers of Lower Granite Lock, is the preferred method. It provides a more stable distribution of flow and is less likely to result in cavitation. Also, this method probably is more efficient than the side-by-side method but data are not available for a direct comparison.

6. The only reason for using the side-by-side method would be the cost advantage that may result under certain foundation conditions. However, due to the risk of cavitation, the side-by-side method should not

be considered for locks with lifts in excess of 60 ft. The Bankhead Lock with a maximum lift of 69 ft has side-by-side crossover culverts but rumbling noises indicate that cavitation may be occurring in cores of vortexes shed from the divider piers or separation piers. The divider pier, shown in Figure 3, is an important feature of the side-by-side system in that it provides a ready means for directing 50 percent of the flow to each end of the chamber and results in more stable flow conditions through the crossover culverts.

Combining Culvert

7. With either crossover culvert system flow from the two wall culverts should discharge into a common culvert in each half of the lock so that the entire distribution system will be used even though only one wall culvert is in operation. With the over-and-under crossover culvert system this combining of flow from the two wall culverts may be accomplished as for Lower Granite and Bay Springs Locks (Figures 5 and 6). With the side-by-side system, as at Bankhead Lock (Figure 2), distribution of flow in the combining culvert with only one wall culvert operating is very sensitive to the location of the trailing edge of the separation pier. If the trailing edge of this pier is too short, excessive flow passes to the side of the combining culvert opposite the active culvert; if too long, excessive flow remains on the side of the combining culvert adjacent to the active culvert.

8. It seems desirable that a relatively constant cross-sectional area be maintained from the wall culverts through the crossover culverts and the combining culvert. Since it is in this portion of the system that major foundation and structural problems are encountered, it is probable that here culvert size will have a major influence on costs. Thus it is suggested that initial studies of filling time versus cost be concerned primarily with culvert size in this portion of the system and with the assumption that culvert size will have only a minor influence on cost through other portions of the system. In the past filling valve size usually has been the first consideration but it is suggested that

valve size be determined after the wall culvert size has been selected. This will provide the designer flexibility in determining valve elevation and valve size for desired pressure conditions immediately downstream from the valve.

9. Approximate filling and emptying times can be computed using coefficients given in the model study reports listed in paragraph 3. In this system it has been found that Reynolds number differences between a 1:25-scale model and its prototype will result in prototype filling and emptying times about 16 percent less than those indicated by the model.

Distribution Culverts

10. From the combining culvert, flow should be redivided into two or four distribution culverts in each end of the lock. This separation to the distribution culverts may be accomplished as for Bankhead and Bay Springs Locks (two distribution culverts in each half of the chamber; see Figures 2 and 6) or Lower Granite Lock (four distribution culverts in each half of the chamber; see Figure 4).

11. In the 110- by 670-ft Bankhead and Bay Springs Locks two distribution culverts in each half of the chamber were adequate. In the series of general tests in a 110- by 1270-ft lock four distribution culverts in each half of the chamber were required. Thus with a length-to-width ratio of about 6.1, two distribution culverts in each half of the chamber have proved adequate, but with a length-to-width ratio of 11.5 four distribution culverts in each half of the chamber are required.

12. In the 86- by 675-ft Lower Granite Lock, with a length-to-width ratio of 7.9, four distribution culverts in each half of the chamber were used; two were not considered. Certainly this resulted in a more symmetrical flow pattern in the chamber than would have obtained with only two but it also resulted in a more costly system with increased hydraulic losses. For the 84- by 655-ft Trinity River Locks, length-to-width ratio of 7.8, two distribution culverts in each half of the chamber were deemed adequate. However, lifts were less and culverts were smaller than at Lower Granite. The exact conditions under which, in each half of the

lock chamber, two distribution culverts are adequate or four distribution culverts are needed have not been established but they probably depend upon lift and culvert size as well as length-to-width ratio.

13. It usually is feasible and desirable to provide distribution culverts with a combined cross-sectional area greater than the cross-sectional area of the wall culverts. This not only has a favorable influence on filling and emptying times but also reduces bursting pressures during filling and collapsing pressure during emptying in the crossover and combining culvert portions of the system. At Bankhead and Bay Springs Locks it was feasible to provide distribution culverts with a total cross-sectional area about 28 percent greater than the cross-sectional area of the wall culverts but data are not available for defining limits or exact benefits of various amounts of increase of distribution culvert size.

Ports

14. In the distribution culverts the manifolds of ports should extend over at least 50 percent of the length of the chamber. If four distribution culverts (one pair in each end) are used the port manifolds should be centered on the one- and three-quarter points of the chamber and each manifold should extend over at least 25 percent of the total length of the lock. If eight distribution culverts (two pairs in each end) are used the manifolds should be centered on the one-, three-, five-, and seven-eighths points of the chamber and each manifold should extend over at least 12.5 percent of the total length of the lock.

15. Ports used in studies to date have varied in size between 4.20 and 6.28 sq ft. The author favors an approximation of the 3.5-ft-high by 1.5-ft-wide port (5.25 sq ft) used in the Bay Springs Study (Figure 6). This port resulted in good distribution of turbulence and is large enough to allow access for inspection and maintenance.

16. With a long manifold such as is required in a sidewall port filling and emptying system, the total cross-sectional area of the ports should be about 95 percent of the cross-sectional area of the culvert.

In the relatively short distribution culverts used in the bottom longitudinal system, a port-to-distribution culvert cross-sectional area ratio of 1.00 is preferred.

17. The spacing of 15 ft center to center provided in the Bay Springs system was satisfactory but all of the available space should be used for the port manifold even if this requires a much different spacing. Spacings of 14 to 18 ft have been used and there is no indication that lesser or greater spaces would not be satisfactory. Certainly a particular spacing is not required, as in the sidewall port system where there is interplay between jets from opposite walls.

Diffusion Trenches

18. A large portion of the kinetic energy of the jets issuing from the ports is dissipated in turbulence in the trenches along the distribution culverts. Thus there should be a relationship between trench size and port size, with lift also a factor. Data are not available to establish such a relationship. At Bay Springs lock with a 5.25-sq-ft port, a trench 14.6 x 12.0 ft (175 sq ft) was satisfactory, as was a trench 10 x 14 ft (140 sq ft) with a 4.32-sq-ft port at Lower Granite Lock.

19. Baffles on the walls of the trenches, which prevent upwelling of the jets from the ports, are necessary features of the dissipation system. In Figures 5 and 6 are details of the baffles developed for Lower Granite and Bay Springs Locks. Opposite the ports, on the lock wall, a culvert wall, or a T-wall, a horizontal baffle wall with 2 ft of overhang has proved beneficial. With the 13- to 16-ft-wide trenches used to date, this wall has been effective when placed 1.0 to 1.5 ft higher than the top of the port. On the distribution culverts over the ports, a horizontal baffle wall also with 2 ft of overhang has been used. In several studies this wall was effective when placed about 1.5 ft higher than the similar wall opposite the ports. At Lower Granite Lock, this wall was placed at the top of the diffusion trench but a continuous wall at this location restricted the discharge and caused horizontal flow from the ends of the manifold; thus overhangs 7 ft long over each

port with 7-ft spaces between them were used.

20. At several projects, vertical walls extending from the floor of the trench to the overhang baffle wall opposite the ports have been beneficial in distributing flow equally along the lock chamber. However, in the Bankhead Lock tests, these walls caused a free tow to drift toward the lock gates and thus were undesirable. Also where such walls have been needed, unsymmetrical placement usually has been optimum.

Conclusions

21. It should be evident from the preceding paragraphs that much work needs to be done before optimum dimensions of the various elements of this system can be established. Thus, while guidance herein should be used in preparation of preliminary designs, it is imperative that a hydraulic model study be used to assist in determining final details of a new project.

22. Even though additional refinements to the system are desirable, the bottom longitudinal filling and emptying system unquestionably is the best system for intermediate- and high-lift locks used to date by the Corps of Engineers. It not only is superior when operated as planned but also is inherently safer than other systems in that it is not sensitive to faulty operation of the valves.

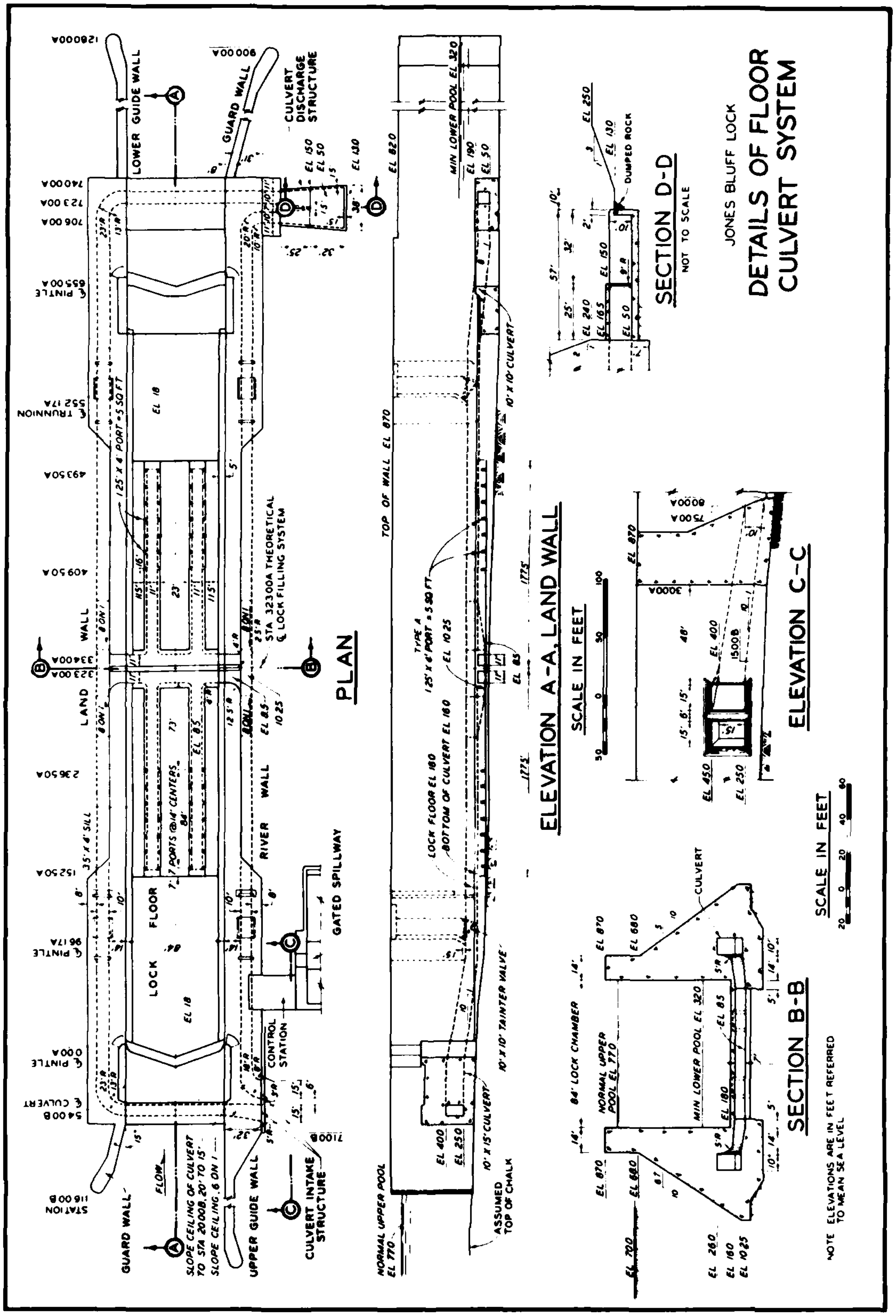

JONES BLUFF LOCK
DETAILS OF FLOOR CULVERT SYSTEM
PLAN
ELEVATION A-A, LAND WALL
SCALE IN FEET
ELEVATION C-C
SECTION D-D
NOT TO SCALE
SECTION B-B
SCALE IN FEET
NOTE ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL

FIGURE 1

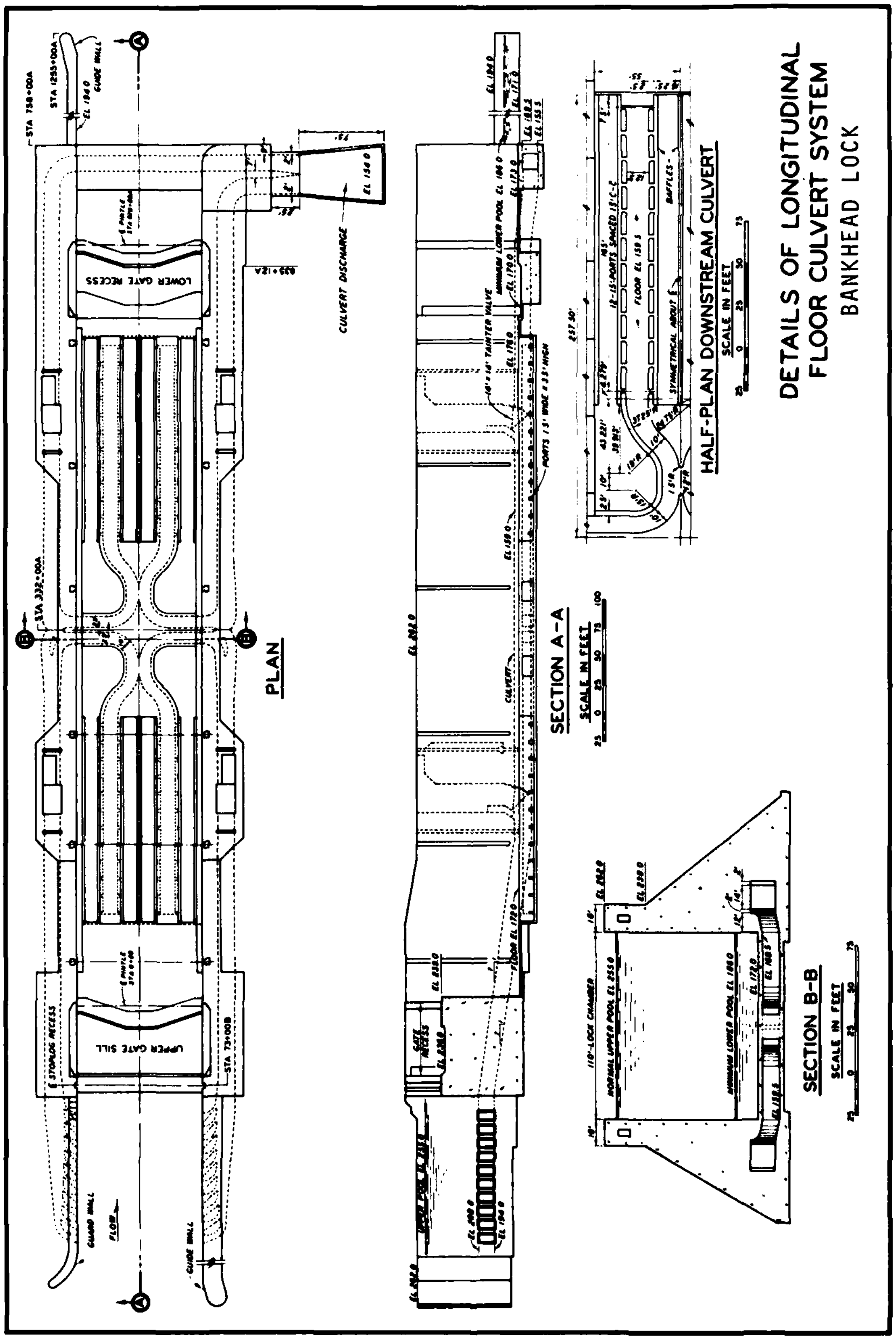
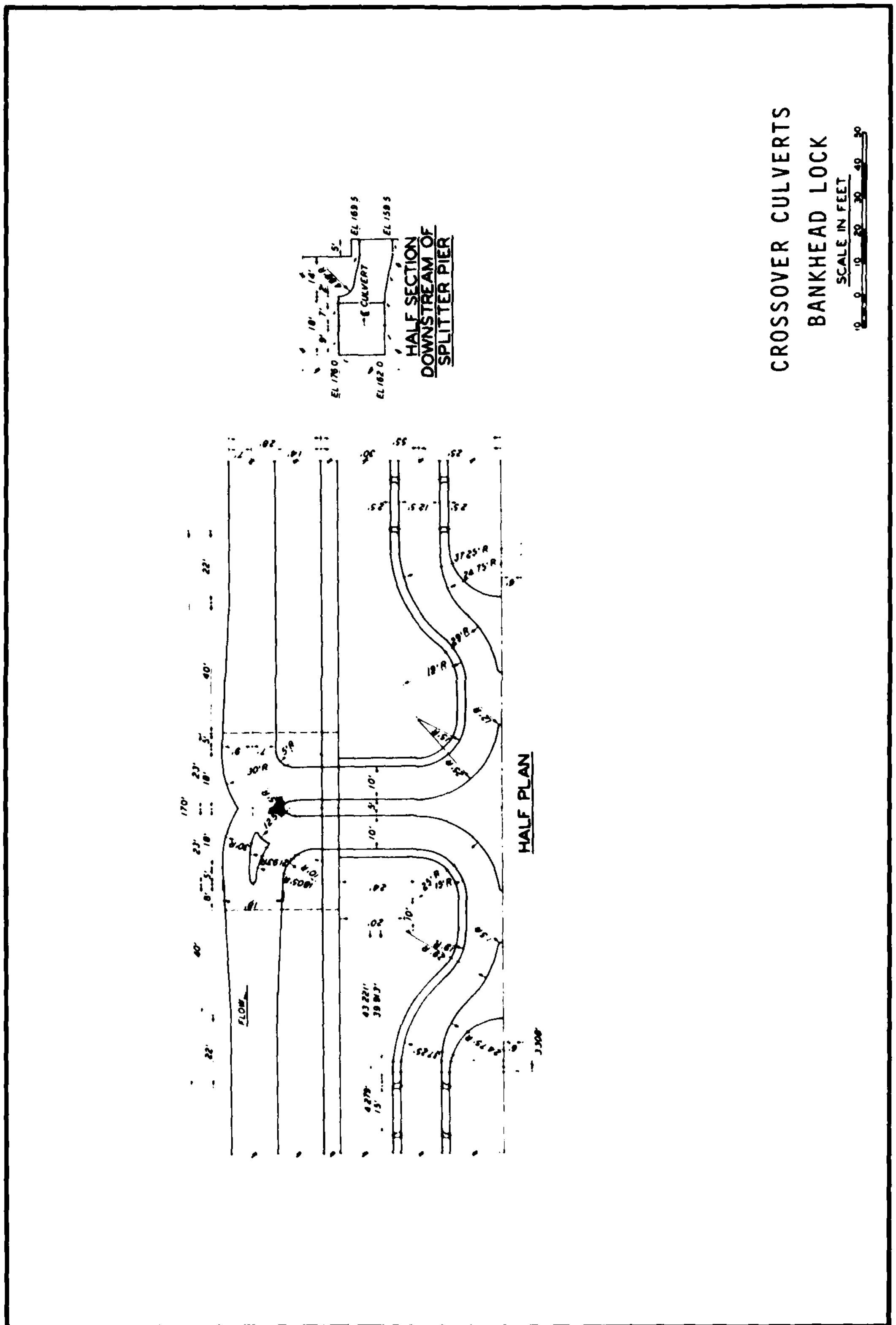
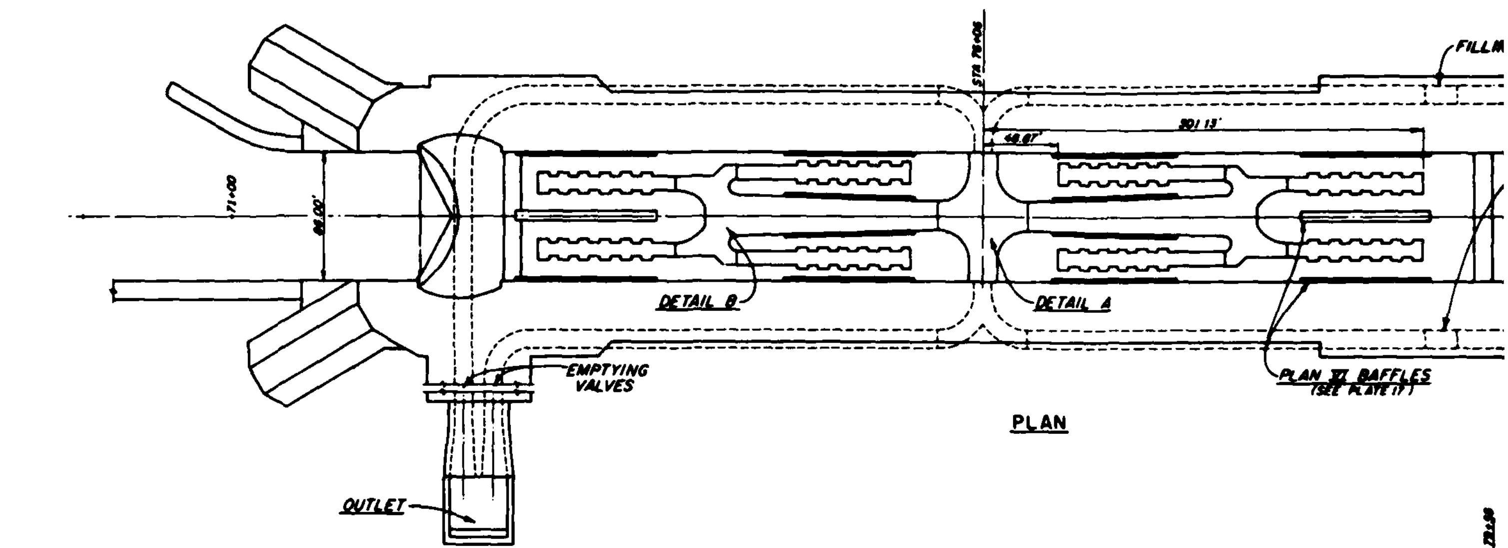

DETAILS OF LONGITUDINAL
FLOOR CULVERT SYSTEM
BANKHEAD LOCK
PLAN
SECTION A-A
SCALE IN FEET
SECTION B-B
SCALE IN FEET
HALF-PLAN DOWNSTREAM CULVERT
SCALE IN FEET
LOWER GATE RECESS
UPPER GATE SILL
CULVERT DISCHARGE

FIGURE 2

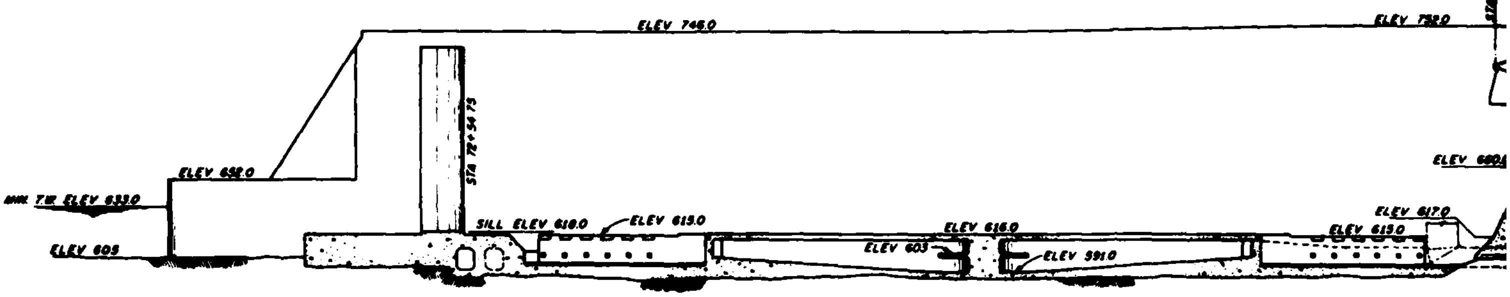


CROSSOVER CULVERTS
BANKHEAD LOCK
SCALE IN FEET
HALF SECTION
DOWNSTREAM OF
SPLITTER PIER
HALF PLAN
FLOW

FIGURE 3

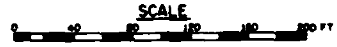


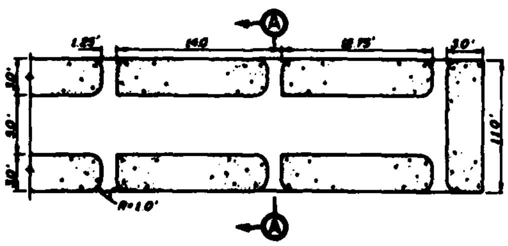
PLAN



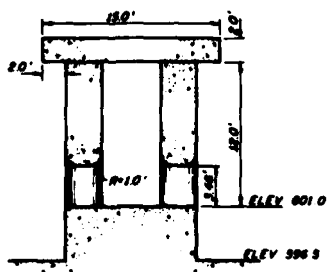
SECTION ALONG CENTER LINE OF LOCK

SCALE

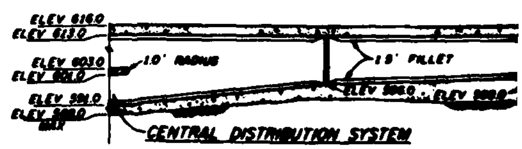




TYPICAL SECTION OF MANIFOLD



SECTION A-A



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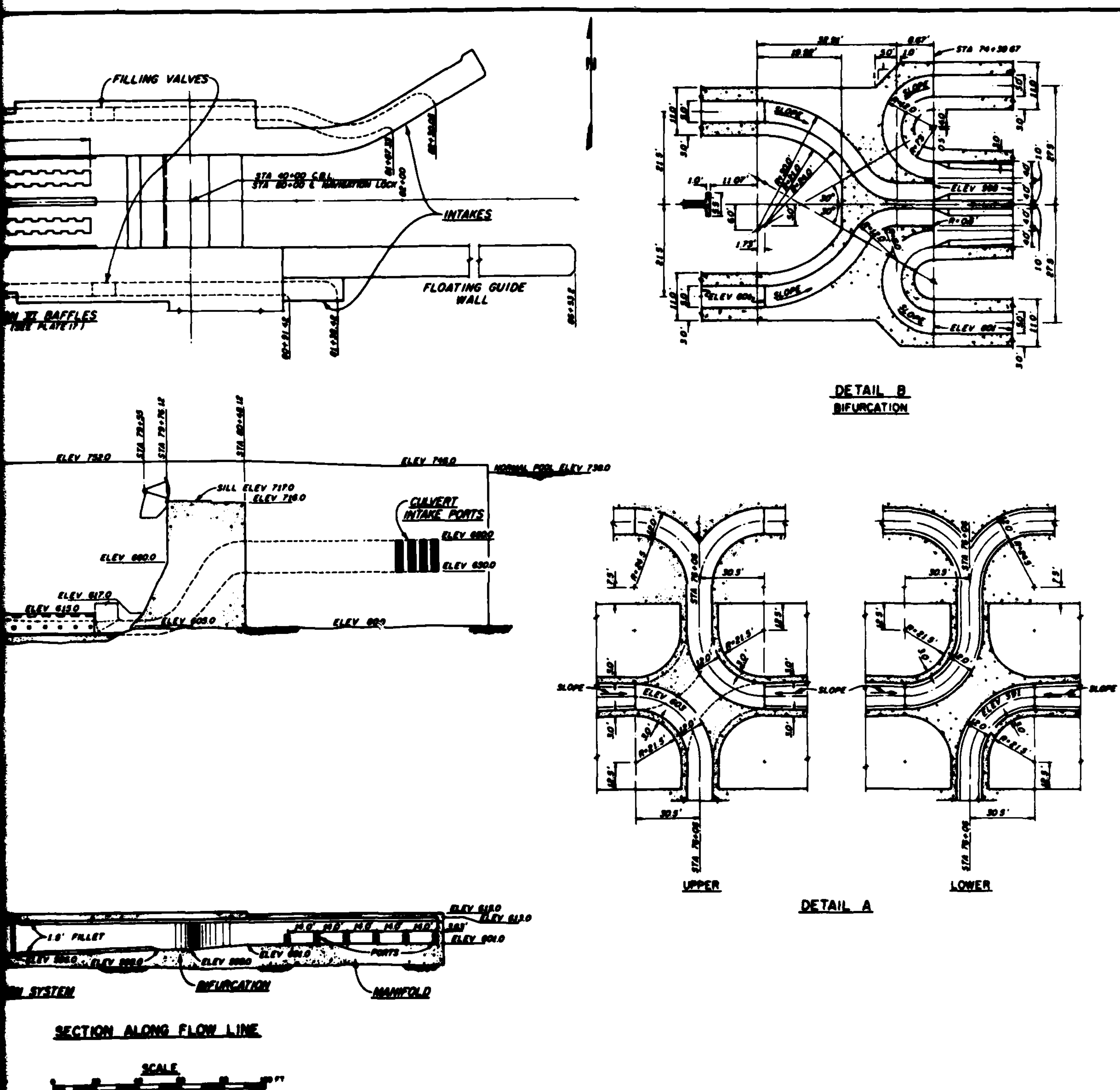


LOWER GRANITE
NAVIGATION LOCK
PLAN AND SECTIONS

FIGURE 4

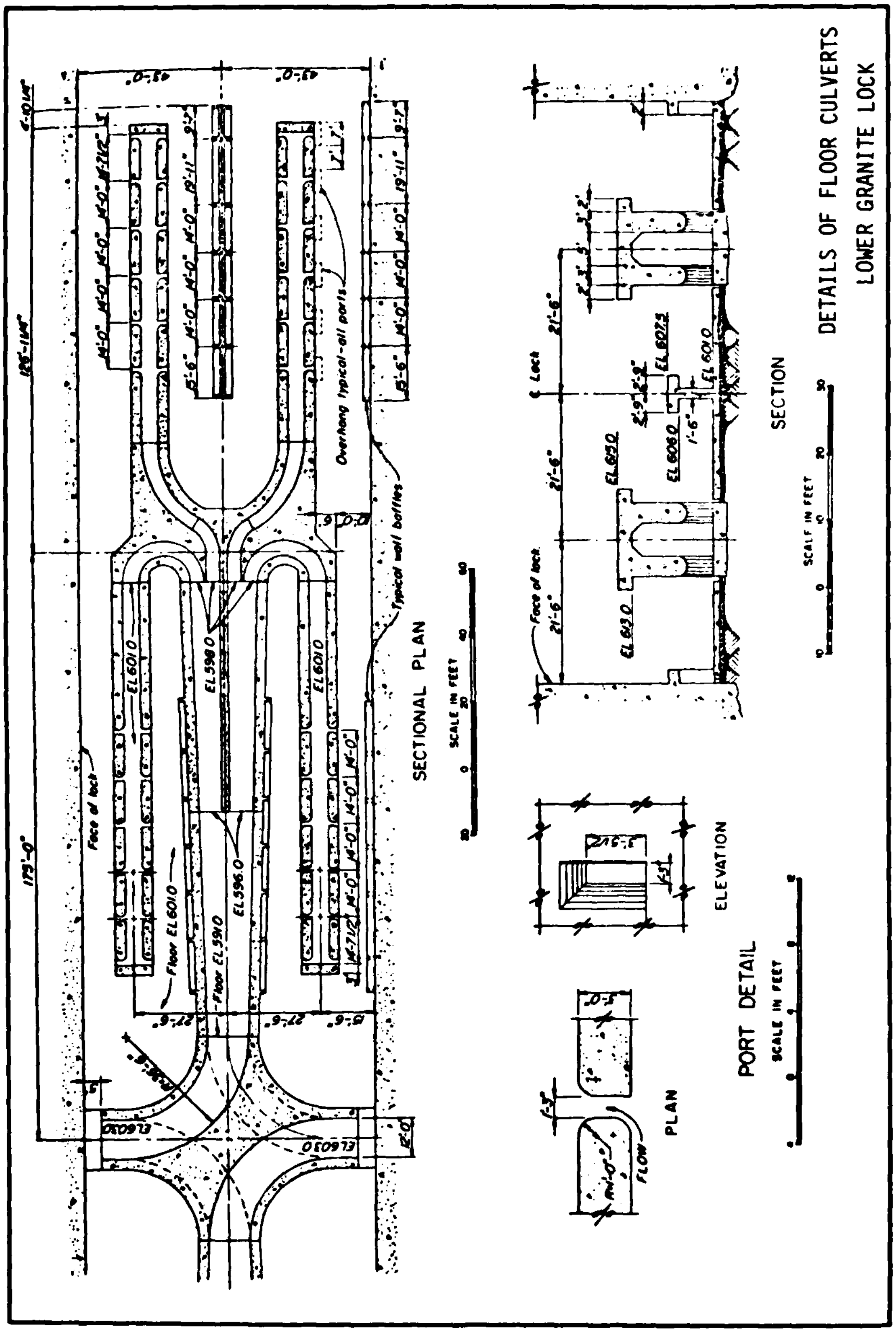
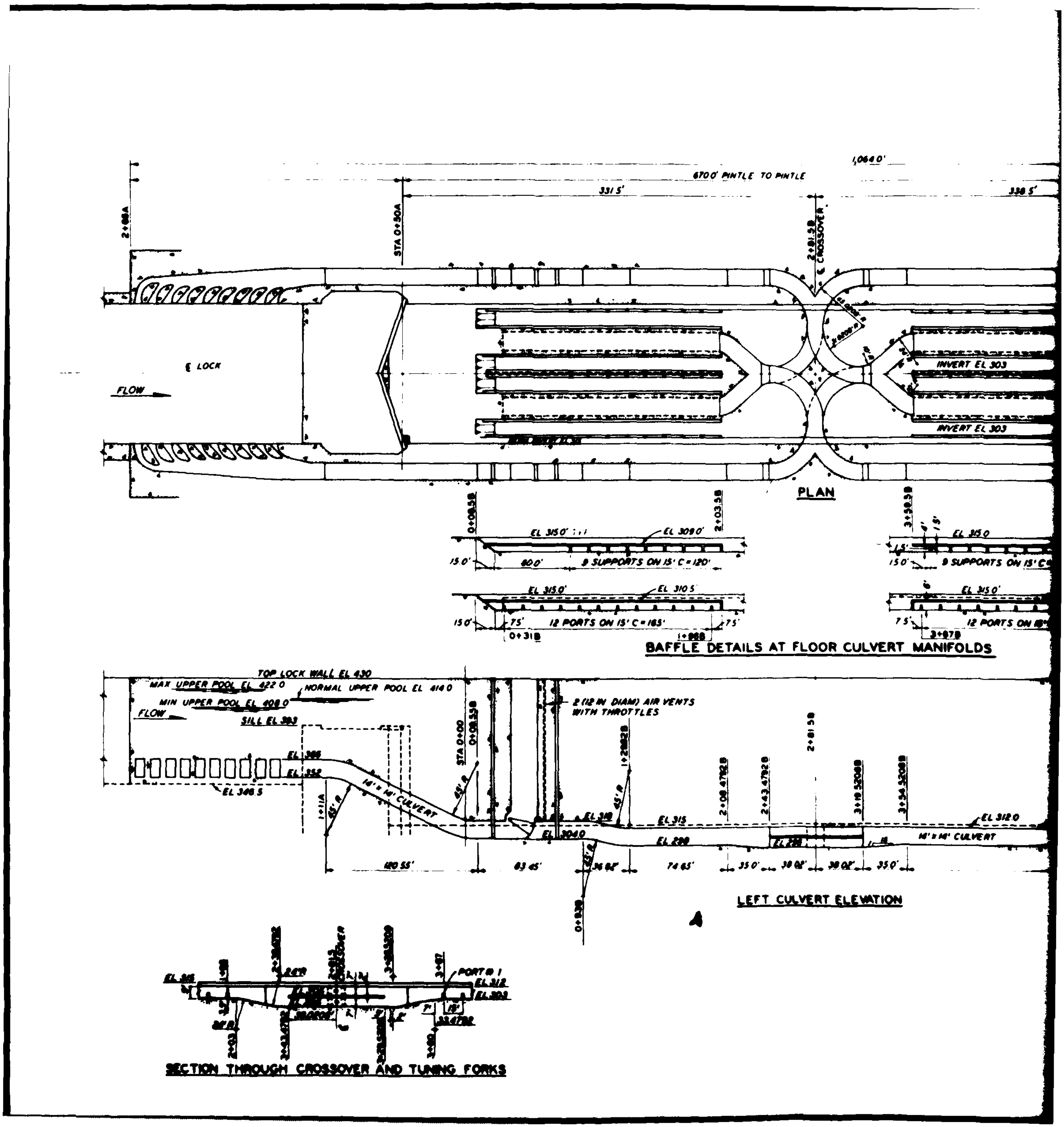
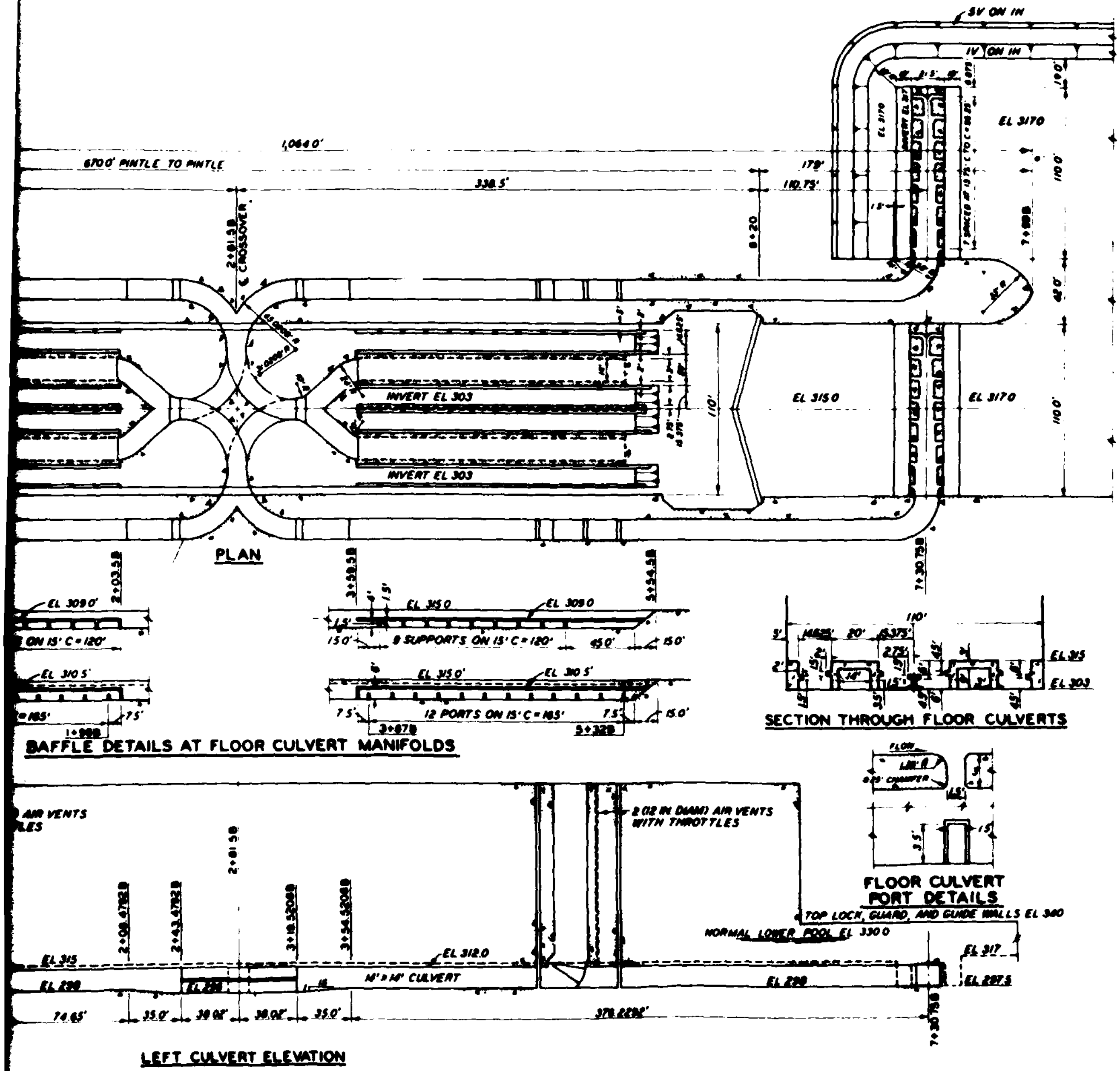

DETAILS OF FLOOR CULVERTS
LOWER GRANITE LOCK
SECTIONAL PLAN
SCALE IN FEET
SECTION
SCALE IN FEET
PORT DETAIL
SCALE IN FEET
ELEVATION
PLAN
Face of lock
Typical wall baffles
Overhang typical-all ports
Floor EL 601.0
Floor EL 591.0
EL 596.0
EL 598.0
EL 601.0
EL 603.0
EL 613.0
EL 615.0
EL 608.0
EL 602.5
FLOW

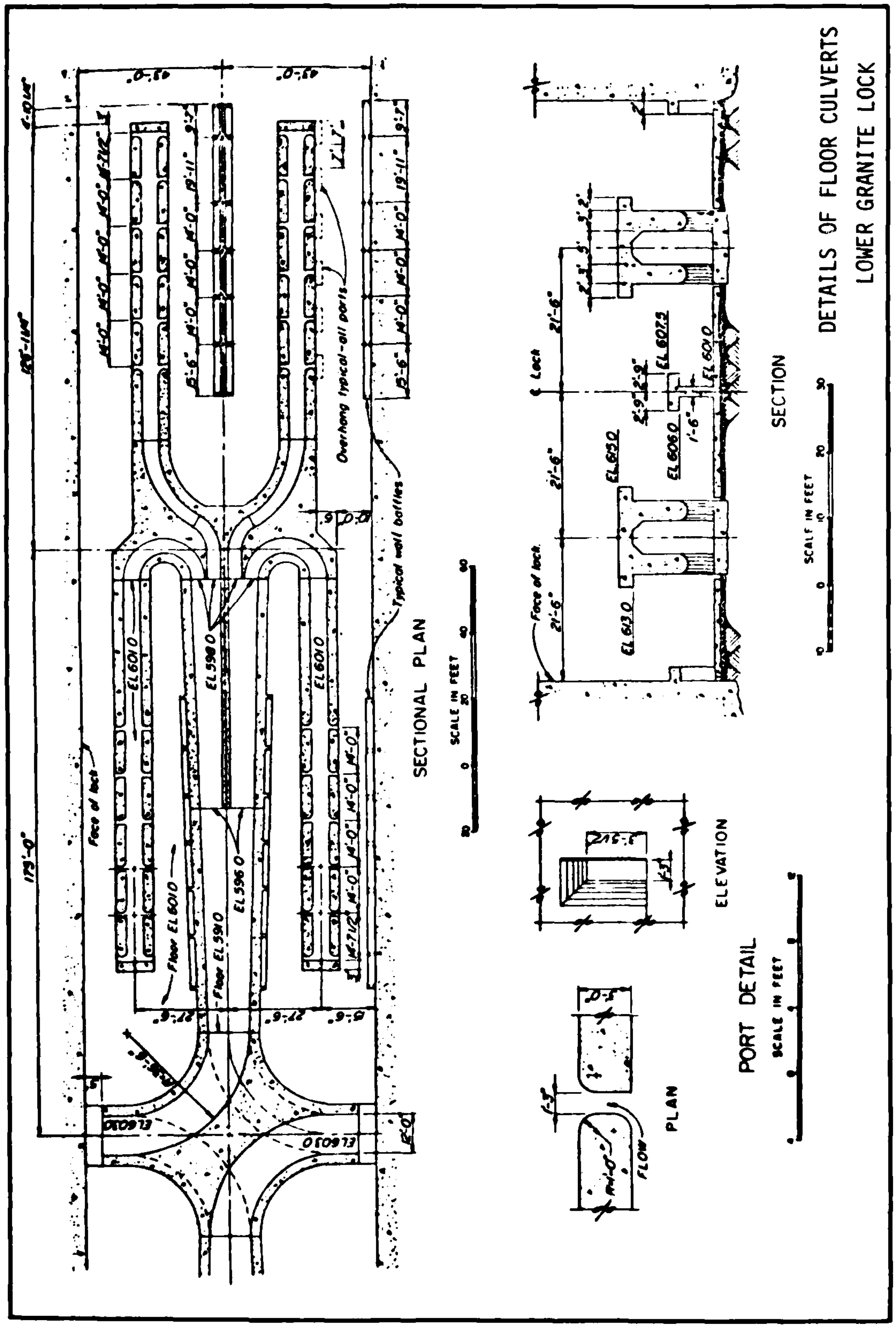
FIGURE 5


1,064.0'
670.0' PINTLE TO PINTLE
331.5'
338.5'
2+68A
STA 0+50A
2+81.5B
℄ CROSSOVER
℄ LOCK
FLOW
INVERT EL 303
PLAN
0+08.5B
2+03.5B
3+59.5B
EL 315.0'
EL 309.0'
15.0'
60.0'
9 SUPPORTS ON 15' C = 120'
EL 315.0'
EL 310.5'
7.5'
12 PORTS ON 15' C = 165'
0+31B
1+96B
EL 315.0
EL 315.0'
3+87B
BAFFLE DETAILS AT FLOOR CULVERT MANIFOLDS
TOP LOCK WALL EL 430
MAX UPPER POOL EL 422.0
NORMAL UPPER POOL EL 414.0
MIN UPPER POOL EL 408.0
FLOW
SILL EL 393
2 (12 IN DIAM) AIR VENTS
WITH THROTTLES
EL 386
EL 352
EL 348.5
14' x 14' CULVERT
STA 0+00
0+08.5B
1+28.62B
2+08.47B2B
2+43.47B2B
2+81.5B
3+19.52B8B
3+54.52B8B
EL 318
EL 315
EL 312.0
EL 304.0
EL 298
14' x 14' CULVERT
120.55'
83.45'
74.65'
35.0'
38.02'
38.02'
35.0'
0+83B
LEFT CULVERT ELEVATION
PORT # 1
EL 312
EL 303
SECTION THROUGH CROSSOVER AND TUNING FORKS



FILLING AND EMPTYING SYSTEM

BAY SPRINGS LOCK


DETAILS OF FLOOR CULVERTS
LOWER GRANITE LOCK
SECTIONAL PLAN
SCALE IN FEET
SECTION
SCALE IN FEET
PORT DETAIL
SCALE IN FEET
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Face of lock
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Overhang typical-all ports
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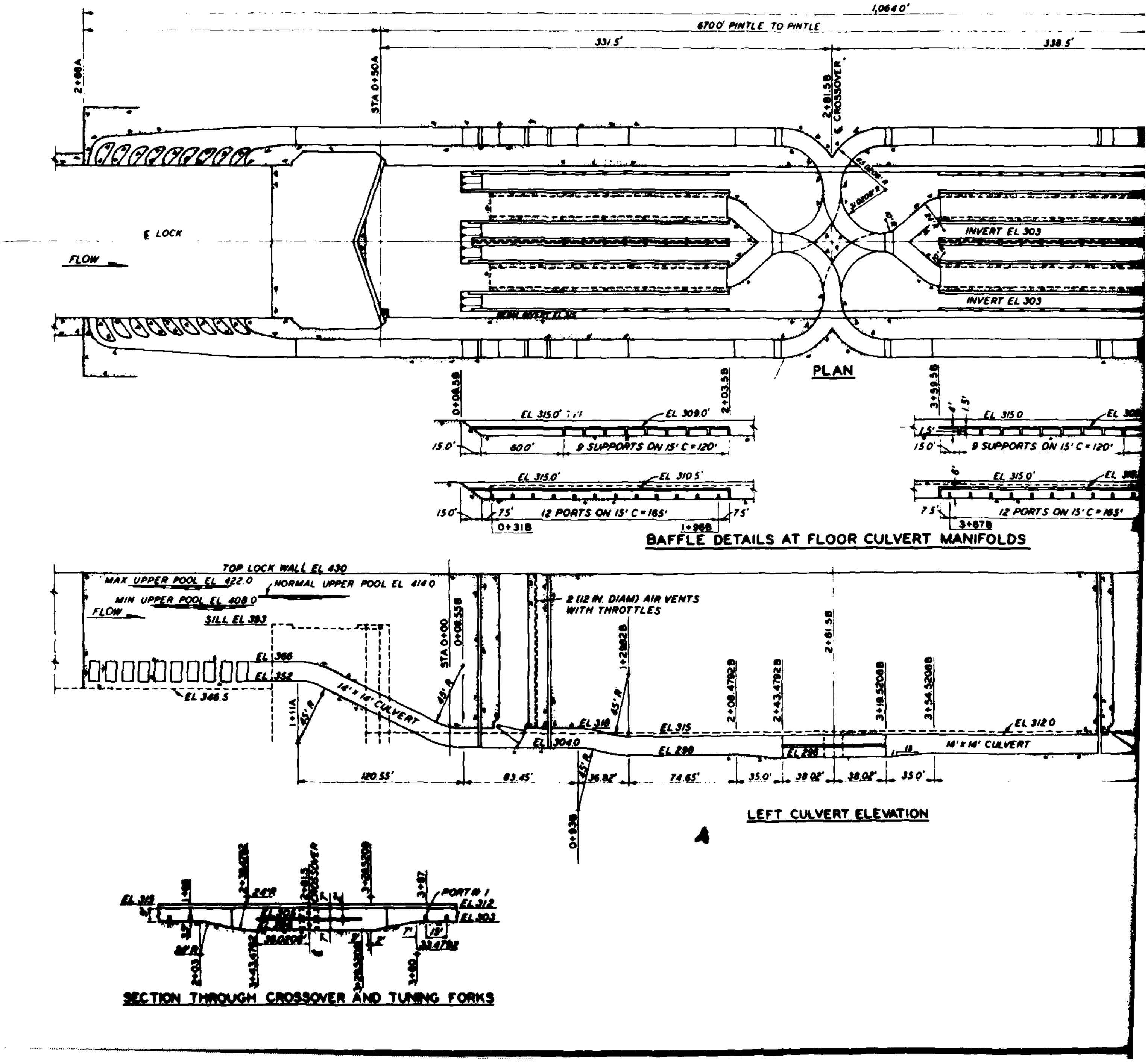
Floor EL 591.0
EL 601.0
EL 598.0
EL 596.0
EL 613.0
EL 615.0
EL 606.0
EL 607.5
EL 603.0
¢ Lock

FIGURE 5



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14' x 14' CULVERT
2 (12 IN. DIAM) AIR VENTS WITH THROTTLES
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120.55'
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35.0'
38.02'
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LEFT CULVERT ELEVATION
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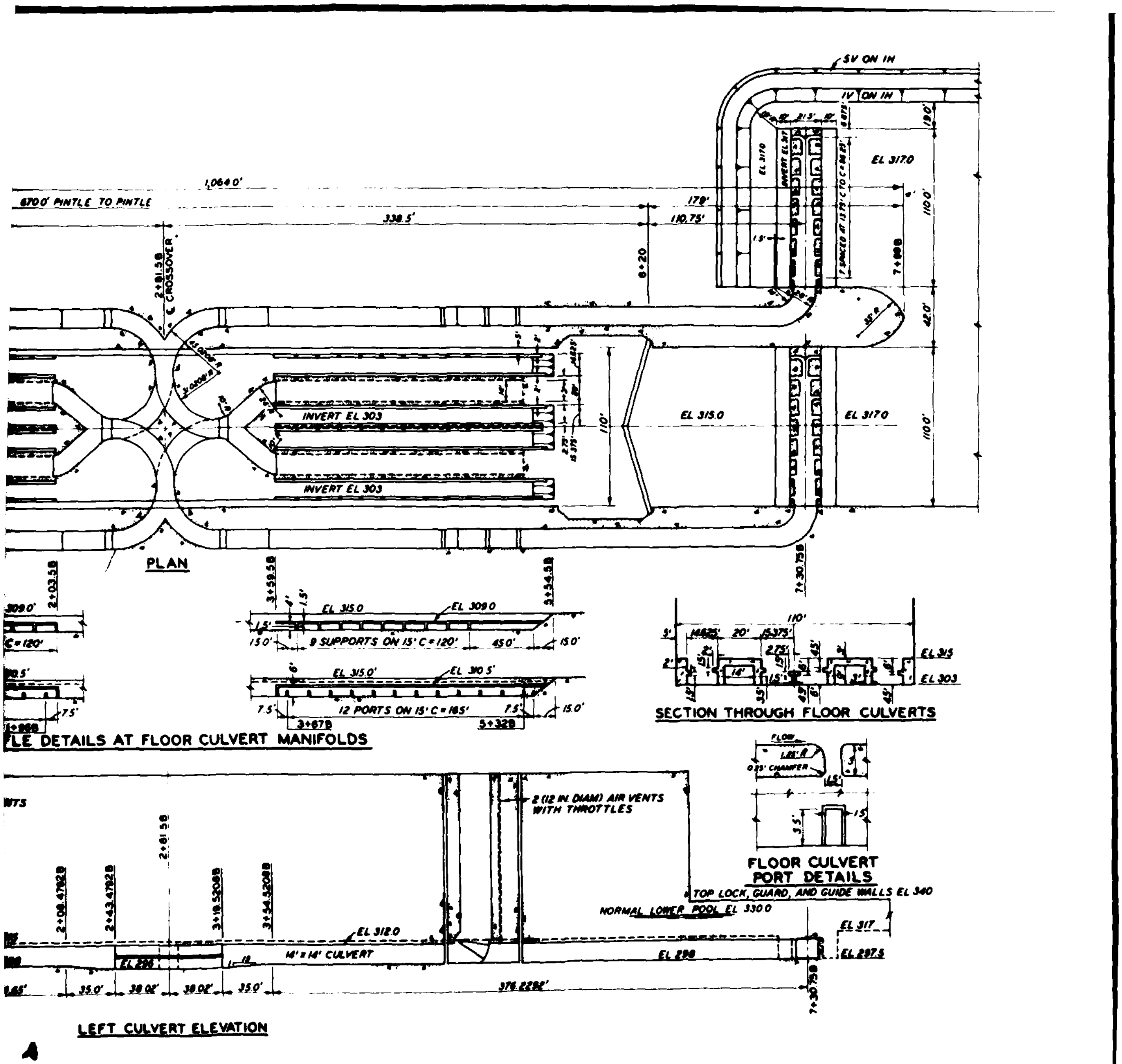
EL 312
EL 303
SECTION THROUGH CROSSOVER AND TUNING FORKS



FILLING AND EMPTYING SYSTEM

BAY SPRINGS LOCK

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