BAY SPRINGS CANAL SURGE STUDY

by

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INTRODUCTION

The Bay Springs Canal Surge Study was conducted in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) in Vicksburg to investigate the effects of releases from the proposed Bay Springs Lock on navigation in the downstream canal. During the design of the lock, the possibility for surging in the canal was recognized due to the 6.2 million cubic feet of water to be discharged over a 12-minute period.

PROJECT DESCRIPTION

The Bay Springs Lock and Dam is to be located in northeast Mississippi on the Tennessee-Tombigbee Waterway (Figure 1). The lock and dam site is west of Belmont, Mississippi, and one-half mile south of Mississippi Highway 4 on Mackey's Creek (Figure 2).

Bay Springs Lake is designed to have a maximum pool elevation (el) of 422,* however, the maximum normal pool elevation is to be 414 (summer condition). Located at the left end of the dam, the lock is to be 110 ft wide, 670 ft long (pintle to pintle), and will provide an 84-ft lift to el 414. The lock is designed to handle tows up to 600 ft long. Filling and emptying of the lock will normally occur through two culverts and a longitudinal floor culvert system. Valves located in the filling and emptying culverts will control flow (Figure 3). Discharges from the lock will enter the canal through diffusers and pass down the canal. The canal will have a normal water surface at el 330. Approximately 2.5 miles downstream, the flow will enter the headwaters of Pool E. Lock E will be located 5.2 miles downstream of Bay Springs Lock and Dam.

The canal is designed to have a base width of 300 ft and a depth of 13 ft. For approximately 1 mile downstream of the dam the canal will be an excavated rock channel with 5:1 (vertical:horizontal) side slopes (Figure 4).

MODEL CONSTRUCTION

A 1:80-scale undistorted model that was 50-ft-long was used to reproduce the lock diffuser system and 3500 ft of canal (Figure 5). Water was pumped from a sump to the model and it returned to the sump by gravity

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* All elevations cited herein are in feet referred to mean sea level unless defined otherwise.

flow. A fixed elevation vertical tailgate was used to maintain the desired water surface elevation in the canal. The approach walls and diffuser system were reproduced schematically at the correct locations.

INSTRUMENTATION

Due to the dynamic nature of the phenomenon, the model operation and data collection systems were instrumented and automated. The computed discharge hydrograph was imposed on the model by two positive displacement, variable speed, programable pumps and four actuated butterfly valves. Delay timers were used to solve timing problems between the pumps and the valves. Water surface elevations were monitored by four stationary probes which worked using capacitance as a function of water depth. Values from the probes were recorded on X-Y recorders as a function of time (Figure 6). Calibration problems occurred due to the stationary tailgate used to set the water surface. The zero and span on the probes had to be adjusted by setting the water surface to the elevations for which the calibration was required. Use of the small scale required frequent adjustment of the calibration points so the stationary tailgate was replaced by a moveable tailgate to facilitate water surface adjustments (Figure 7).

WES built load cells were used to measure forces on stationary tows in the canal. The load cells consisted of a cantilevered beam which had been straingaged for a 0- to 5-lb range. Loads in the model were less than 1 lb. A multichannel, light beam, strip chart recorder was used to record the values from the load cells.

A motorized, radio controlled towboat from the Waterways Division of the WES Hydraulic Laboratory was operated in the model (Figure 8). Documentation of the operation of the motorized tow was by time lapse photography and high speed motion pictures.

DEFINITIONS

All data herein are expressed in prototype terms. "Left" and "right" indicate directions when looking downstream. "Upstream" indicates direction toward Bay Springs Lake and "Downstream" indicates direction toward Pool E. Distances downstream are measured from the lower mitergate pintles.

PRELIMINARY TESTING

The first test run of the model showed a serious problem with the vertical tailgate. Discharge from the lock produced a surge which moved down the canal to the tailgate and was reflected upstream. The reflected wave passed through the model several times before dissipating. This was a classical example of the doubling effect on wave height due to reflection by a vertical boundary. Several types of sloping floors and porous medias were tested in an effort to dissipate the reflections without success. Success was obtained by not dissipating the surge energy but by using the energy to pass the surge through the model. A "V" shaped stationary tailgate with a 45-degree sloping face was designed with a 40-degree apex angle (Figure 7). This weir repeatedly reflected the surge downstream and out of the model with no observable upstream reflections.

ORIGINAL DESIGN

Operations for the original design (Figure 9) specified a 1-minute opening time (valve speed) on the discharge valves and a computed lock emptying time of 11.9 minutes. Water surface elevations as a function of time were recorded in the canal at various locations without the presence of a tow. This operation produced a translatory wave with a steepening leading face which when approximately 2000 ft downstream transformed into a undular wave with crests increasing to 2.6 ft above normal pool at the end of the model (Figure 10). Forces recorded for this discharge hydrograph on stationary tows at four locations (Figure 11) indicated severe conditions relative to navigation. A minimum force of 70 tons was observed on tows located between 400 ft and 1100 ft downstream of the lock. The large force of 170 tons was observed with the tow positioned 150 ft downstream and was caused by the build up of water ahead of the tow moored between the approach walls. For tow positions greater than 1100 ft downstream of the lock, the peak force increased with distance downstream.

Observations from tests using a motorized, radio-controlled tow boat indicated a tow moving upstream at approach speeds of 4 to 6 fps would be transported 60 to 120 ft downstream by the lock release even when increased power was applied during the surge.

At this point it was desired to lengthen the valve opening time, however, the inflow system of the model could not reproduce the required hydrographs. In order to impose the desired discharge hydrographs on the model a head tank was constructed which reproduced the lock head and volume. A variable speed, programable, actuated gate on the head tank was used to control flow to the model. The head tank was filled by water pumped from the tailbay and the level in the head tank was set by an overflow weir (Figure 12).

After modifing the inflow system of the model, tests were run to determine the effect of slowing the valve opening speed. Valve opening times of 2, 4, and 8 minutes were tested and showed a definite reduction in surge heights and in maximum forces exerted on stationary tows. The 2-minute valve reduced the forces to approximately one-third those produced by the original 1-minute valve for all locations. Forces for the 4- and 8 minute valves were only slightly lower than the 2-minute valve. The longer valve times lengthened the lockage time, however.

Analysis of the data for the original design yielded three significant conclusions: (1) for valve opening times greater than 1 minute the undular wave did not form in the model, (2) the slope of the water surface and not the surge height was a good indicator of the forces applied to the tow, and (3) the slope of the water surface was a function of the valve speed.

DESIGN 2

The original design with the 1-minute valve schedule was not considered to be satisfactory and a new design was tested. The new design included realigning the lock and canal to place the lock guide wall on one bank of the canal. This permits tows to use the full width of the canal when manuevering to enter the lock. Additionally, the new design provided for a uniform unit discharge across the width of the canal.

The redesigned discharge system (Figures 13 and 14) was tested with 1- and 2-minute valve schedules imposing the same release hydrographs tested with the original design. Results of these tests indicated the new design was a more efficient energy dissipater. For a 1-minute valve the maximum water surface of the surge was slightly higher near the lock than with the original design but the surge height decreased as the surge progressed downstream. Maximum forces of approximately 40 tons were measured at all points with the 1-minute valve operation. Tests with the motorized tow indicated a tow would be capable of maintaining headway through the surge. Using a 2-minute valve the maximum water surface near the lock was the same elevation as with the original design and a 1-minute valve, and again, the maximum surge height decreased as the surge progressed downstream. Maximum forces on the tow at any point in the model were reduced to approximately 20 tons. These results and those of a 1:25-scale model study of the filling and emptying system indicate the recommended use of the 2-minute valve.

The 1:25-scale model of the filling and emptying system was used to determine the lock chamber stage versus time for the 2-minute valve. Studies conducted by WES concerning the relationship of filling and emptying times between model and prototype longitudinal floor culvert systems indicate the prototype will empty 18 percent faster than the model. Accordingly the stage-time relationship generated by the lock model was adjusted and tested in the surge facility. These tests indicate the conditions which are expected to occur in the canal with the recommended design and a 2-minute valve. Forces on tows positioned anywhere in the model did not exceed 36 tons and maintained a uniform rate of loading of approximately 1 ton per second. The maximum rate of rise of the water surface was approximately one-third of the original design with the 1-minute valve and the water surface rose to 2.5 ft above normal (figures 10 and 11) in approximately 2.5 minutes rather than in one-half minute.

ADDITIONAL DESIGNS

Several modifications to design 2 were tested in an attempt to further improve design 2. These designs used the basic layout of design 2 with various diffuser pit and approach floor modifications. Widening the top of the diffuser pit was not as effective in energy dissipation as design 2. Several lower approach floor elevations were tested but they too could not improve flow conditions in the canal.

Based on the results of this study it is felt that design 2 with a 2-minute valve schedule will provide satisfactory flow conditions in the lower approach and canal downstream for safe and efficient navigation.

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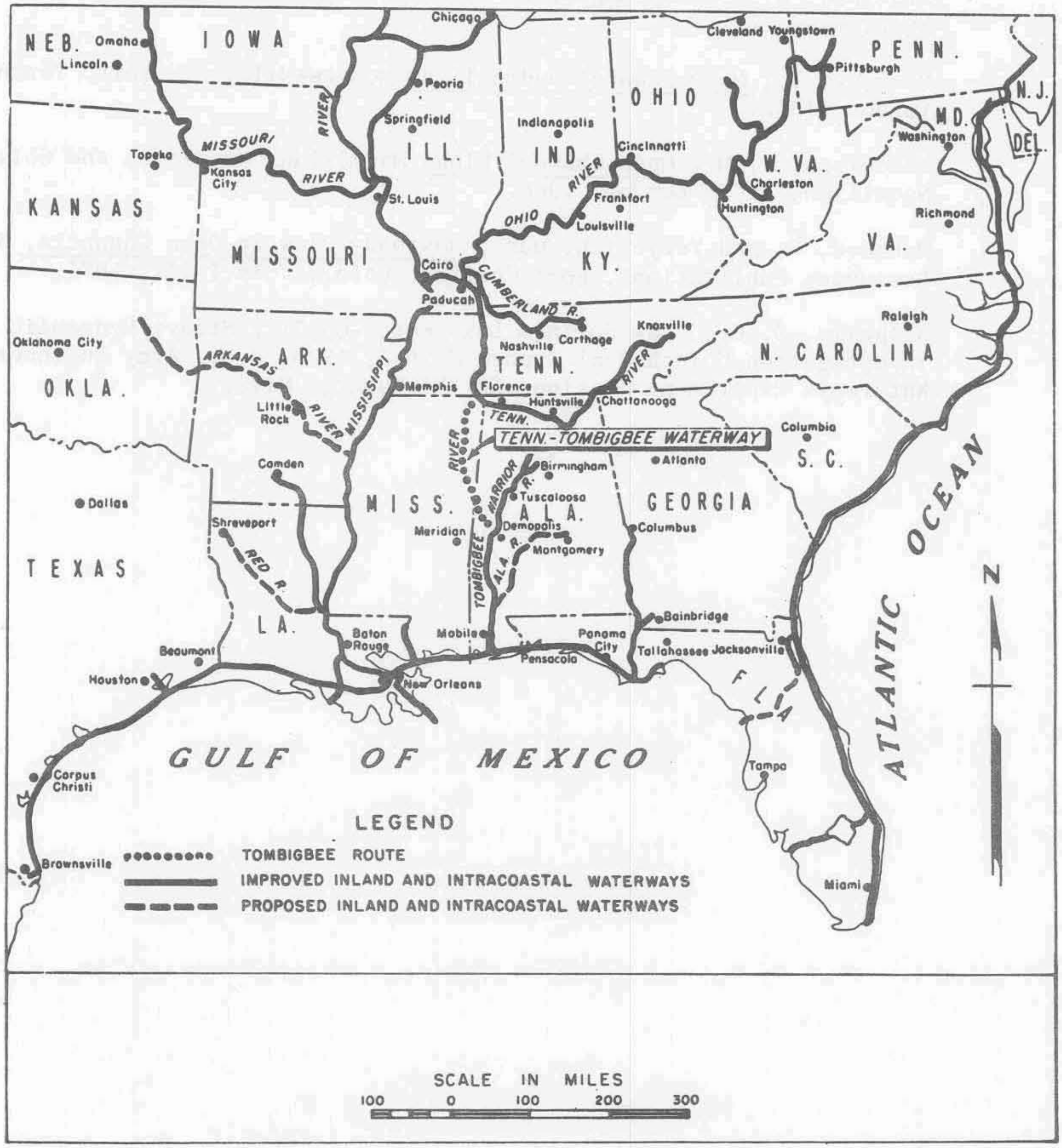


Figure 1. Location map

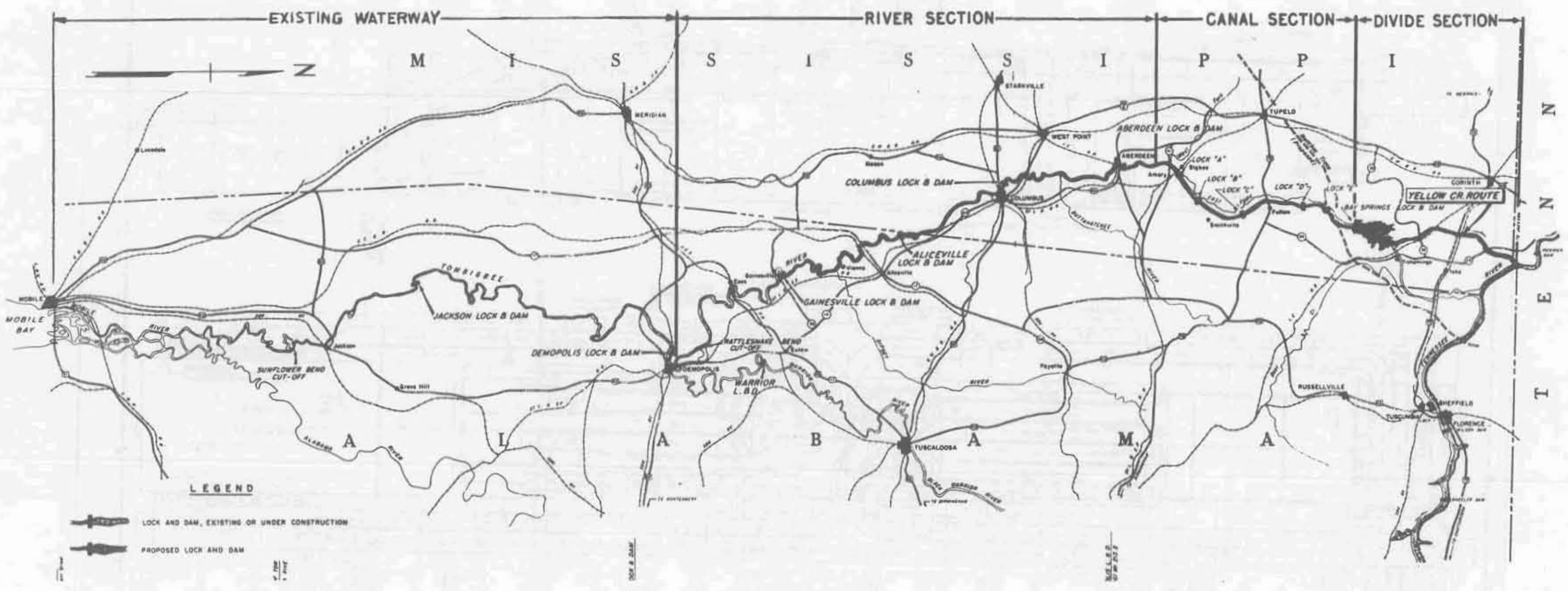


Figure 2. Vicinity map

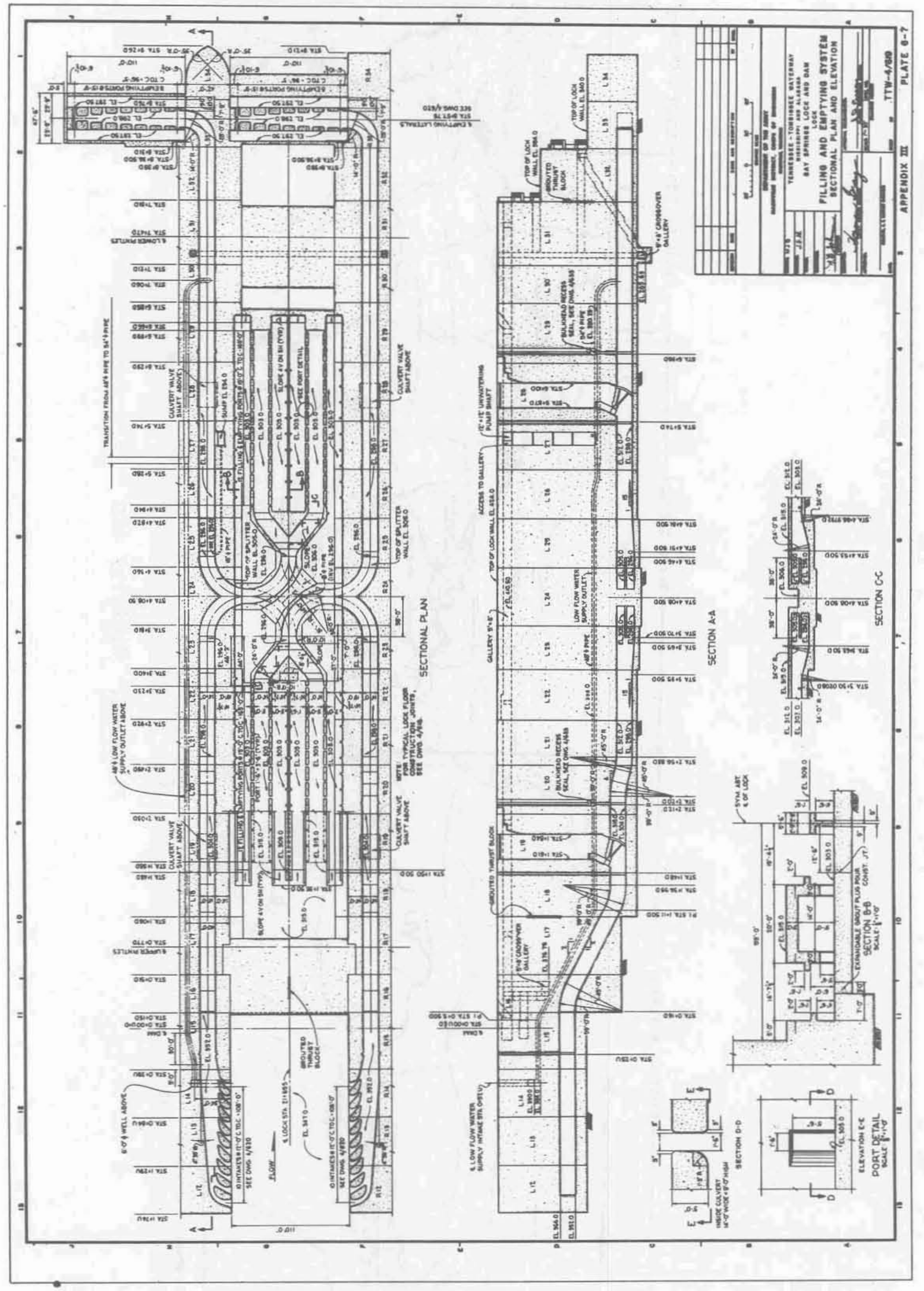


Figure 3. Filling and emptying system

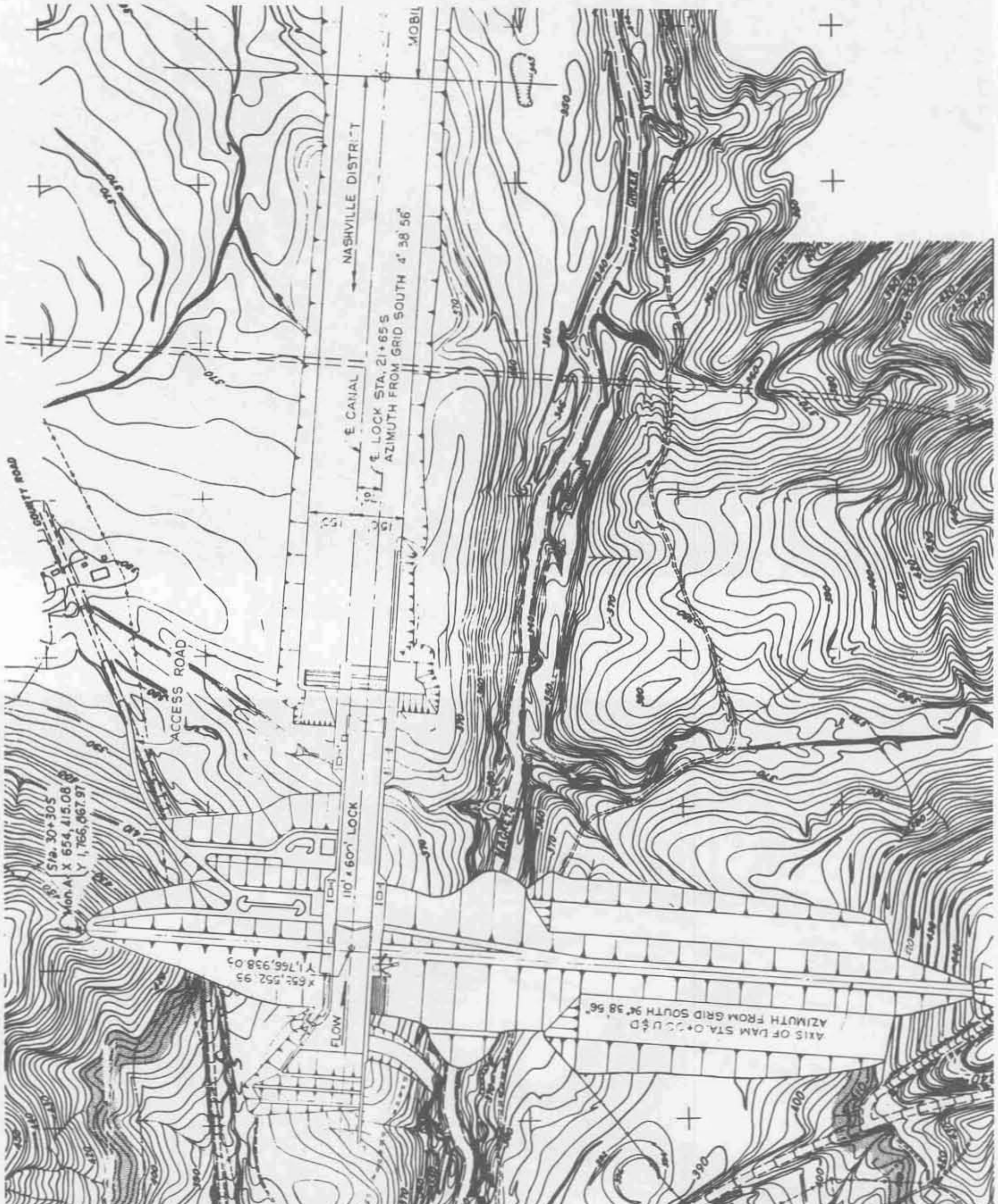


Figure 4. Area plan

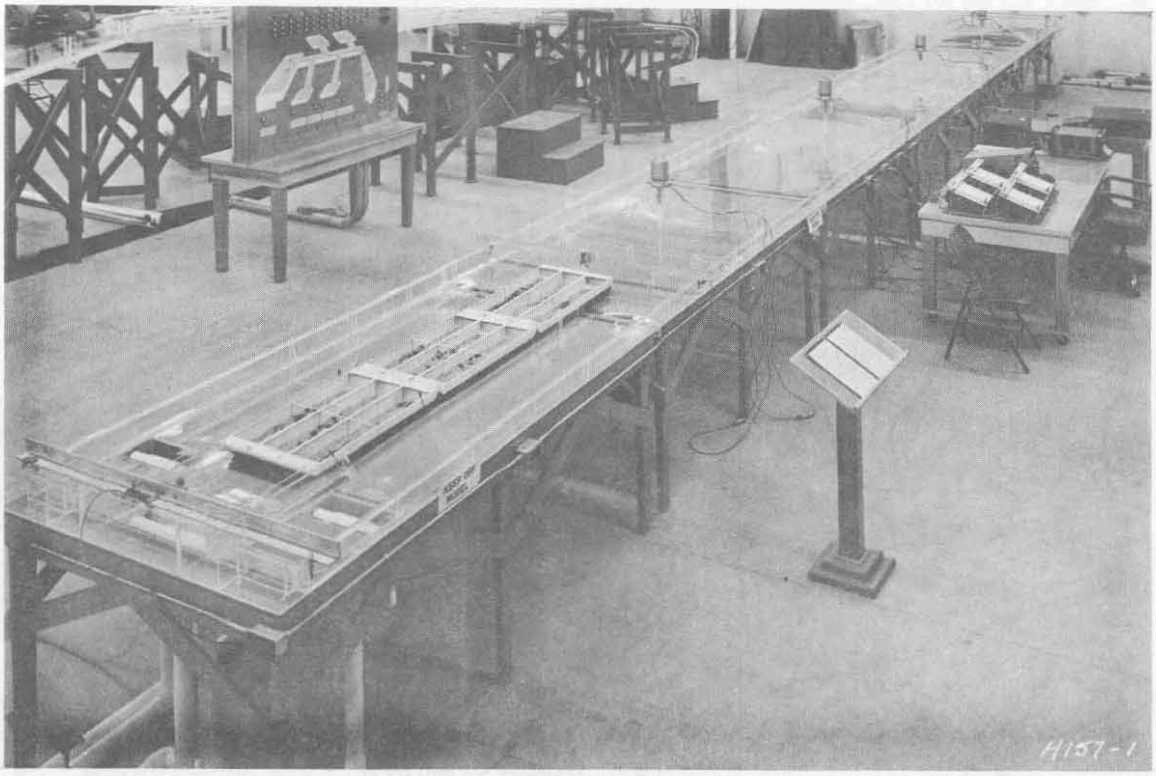


Figure 5. Overall model

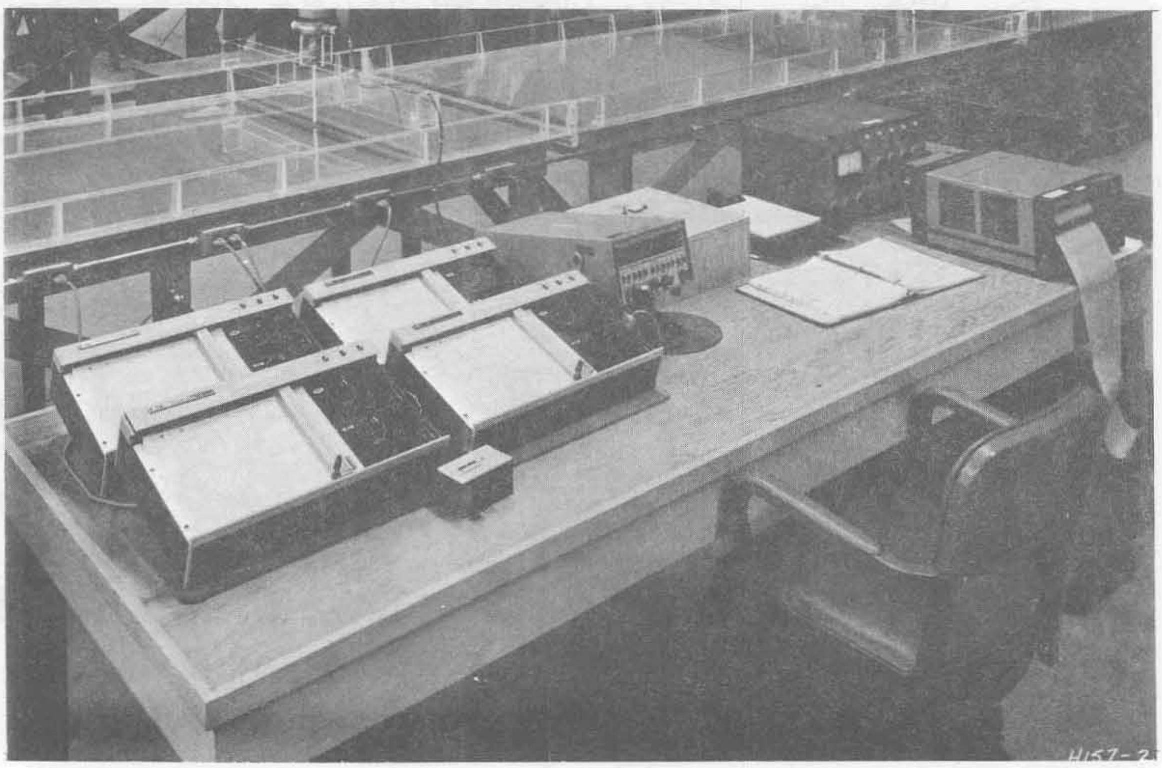


Figure 6. Instrumentation table

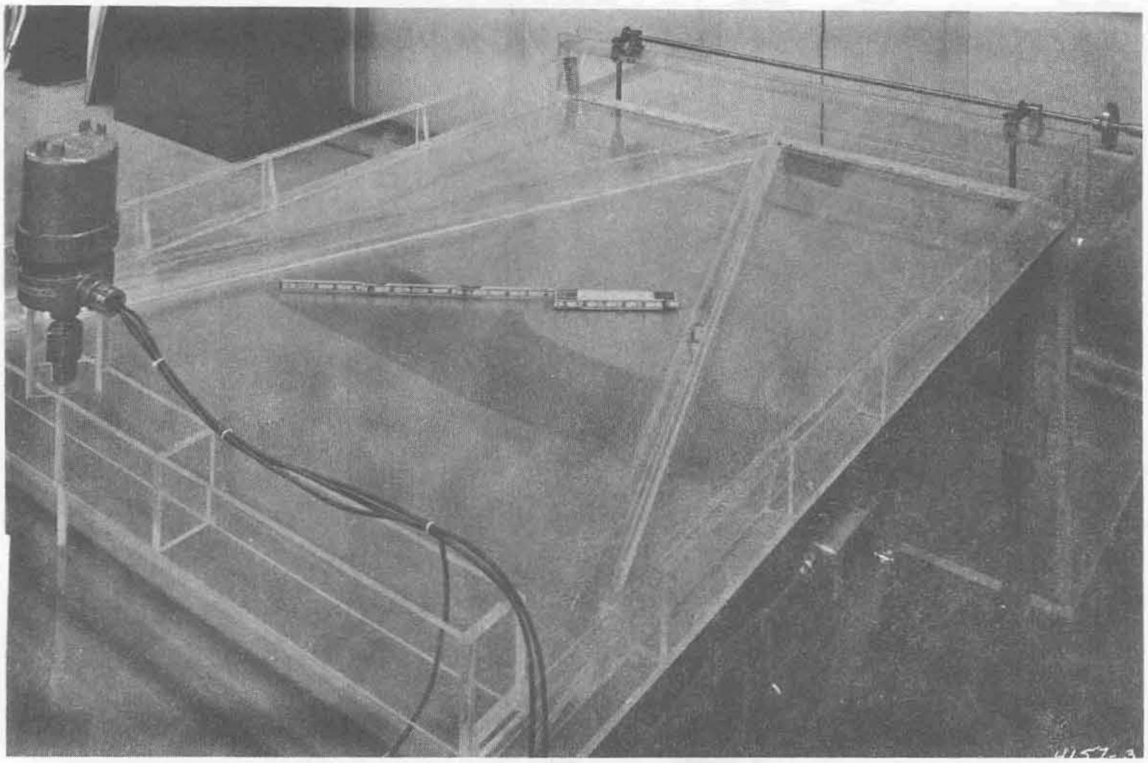


Figure 7. Antireflection weir

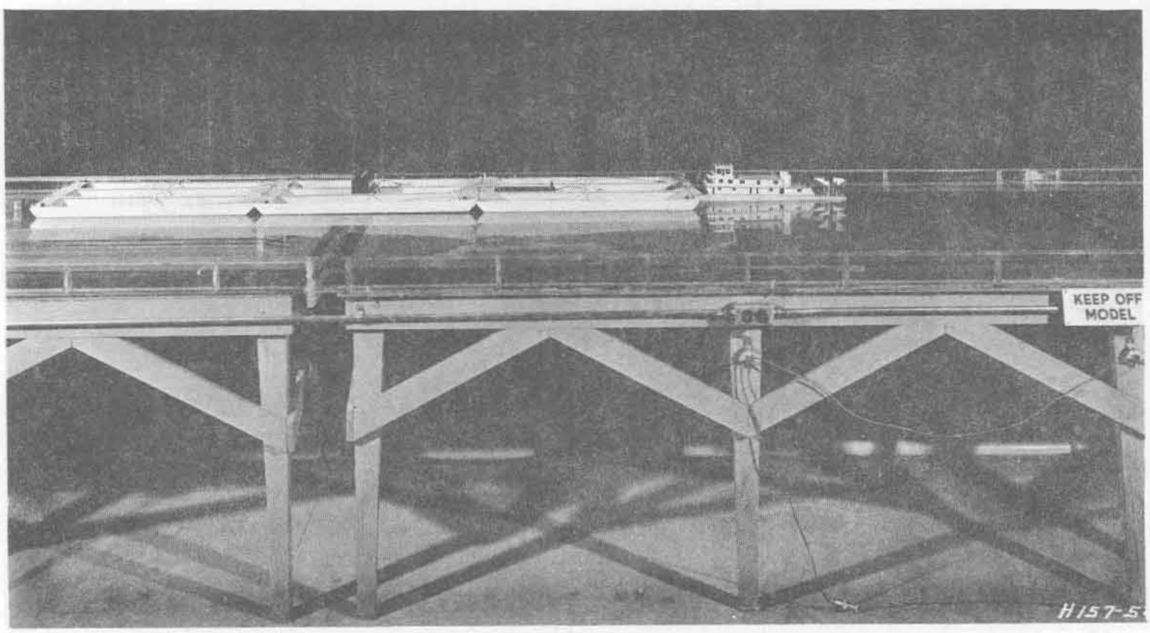


Figure 8. Motorized towboat

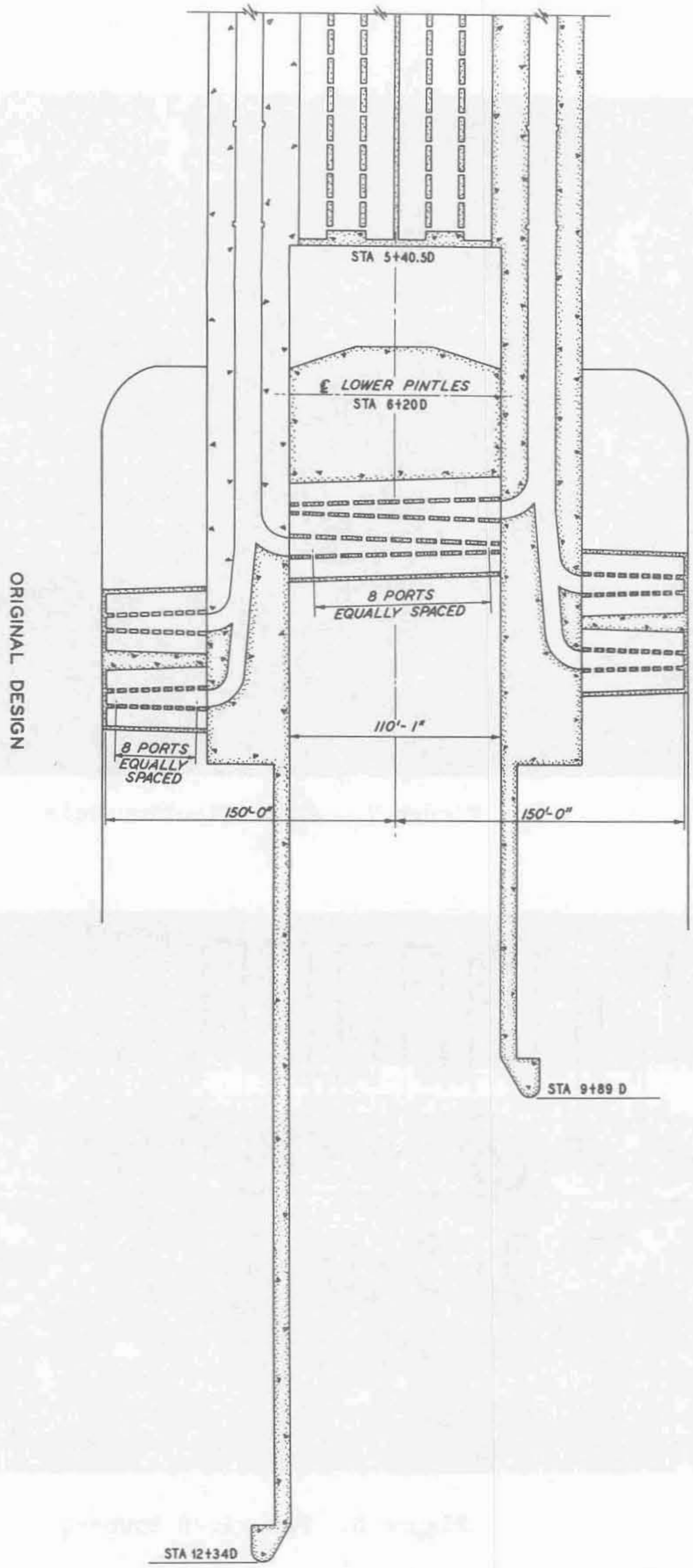


Figure 9. Original design

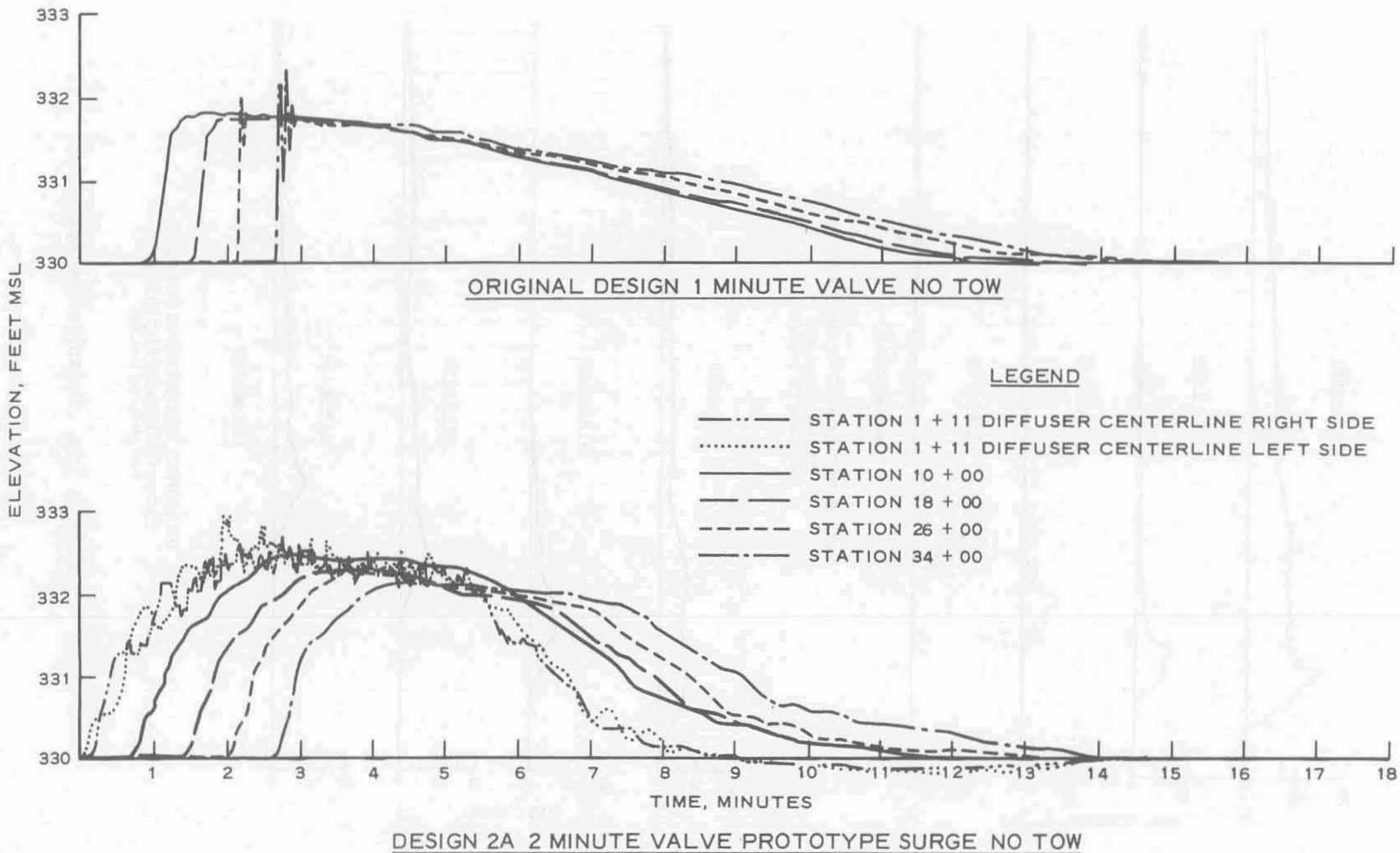


Figure 10. Water surface profiles

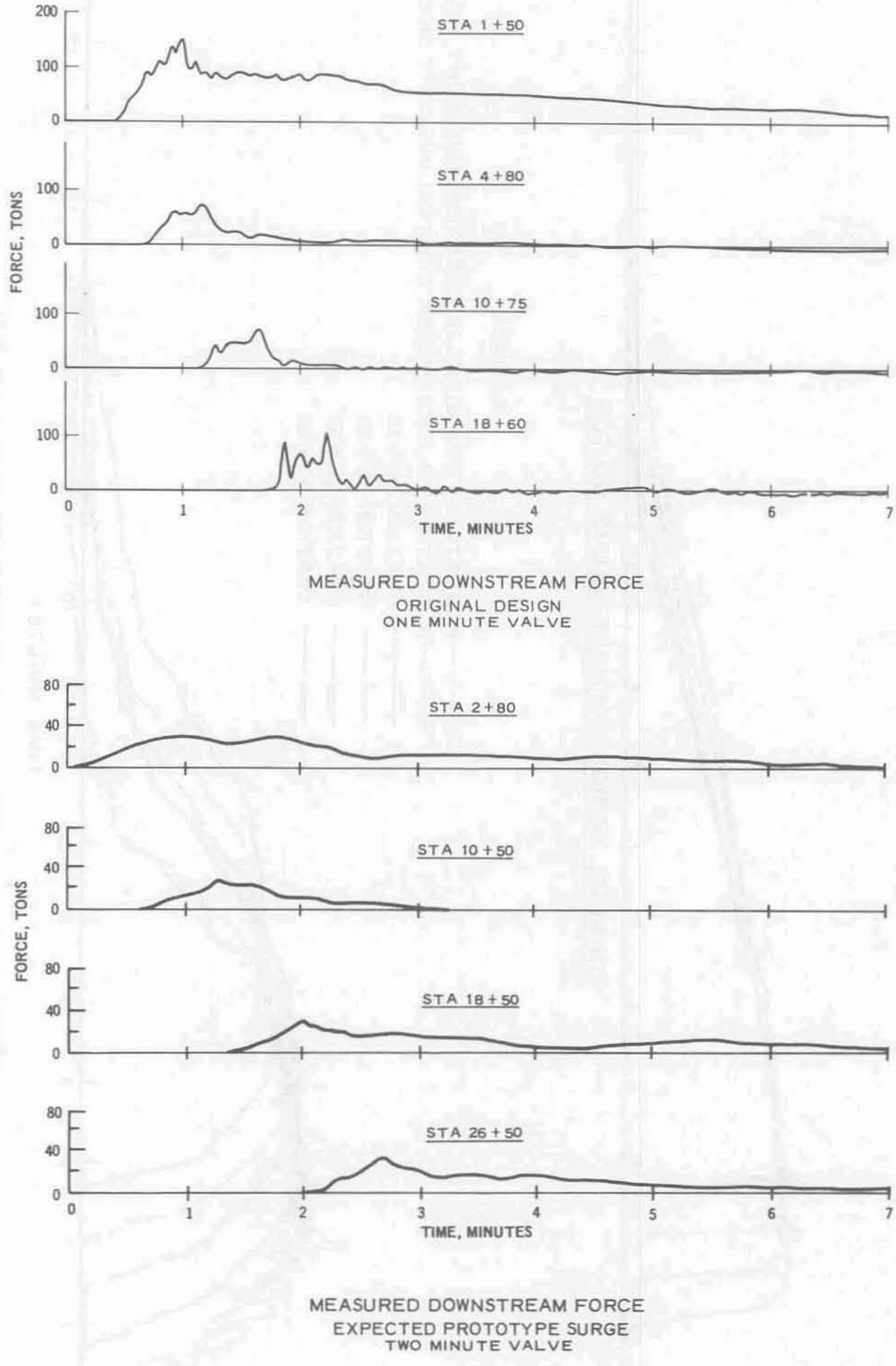


Figure 11. Downstream forces

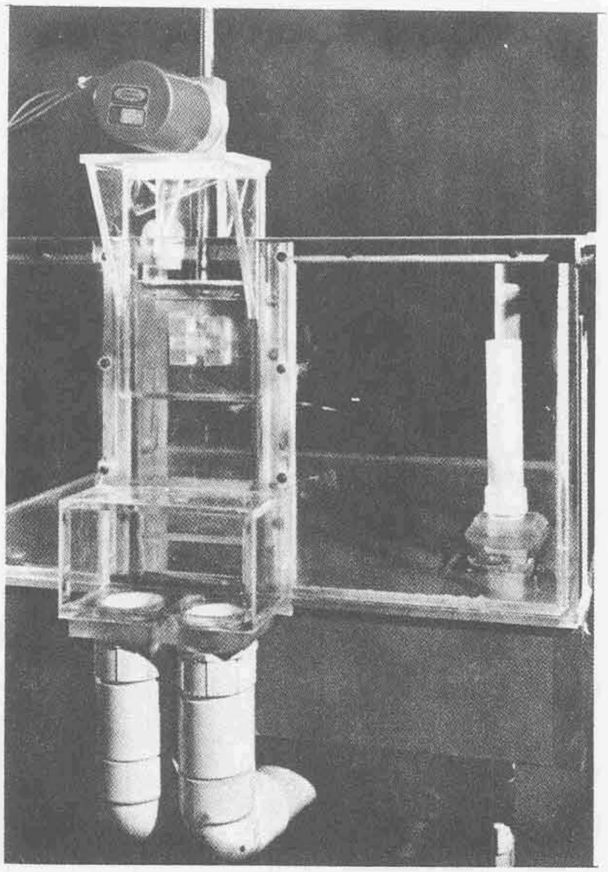


Figure 12. Head tank

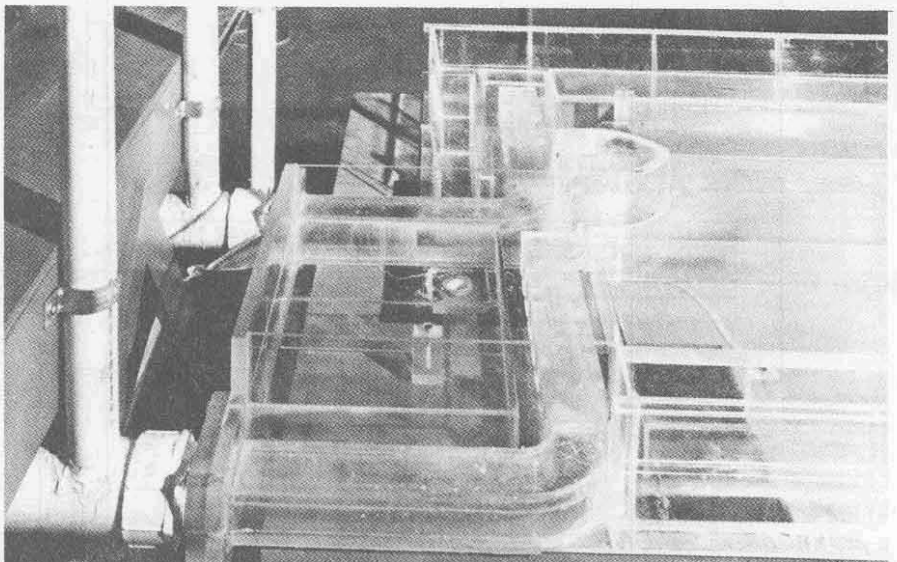
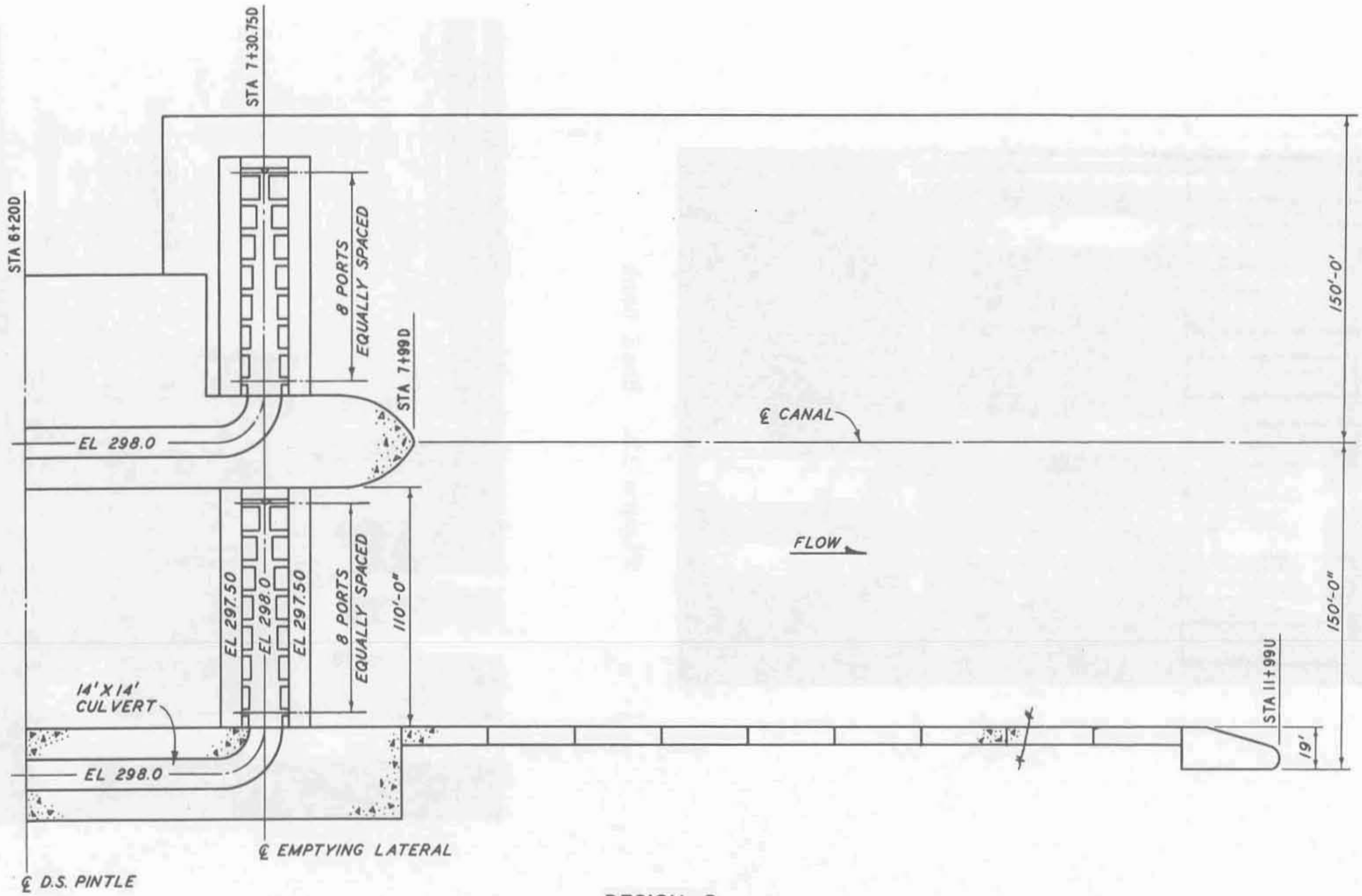


Figure 13. Design 2



DESIGN 2

Figure 14. Plan view design 2

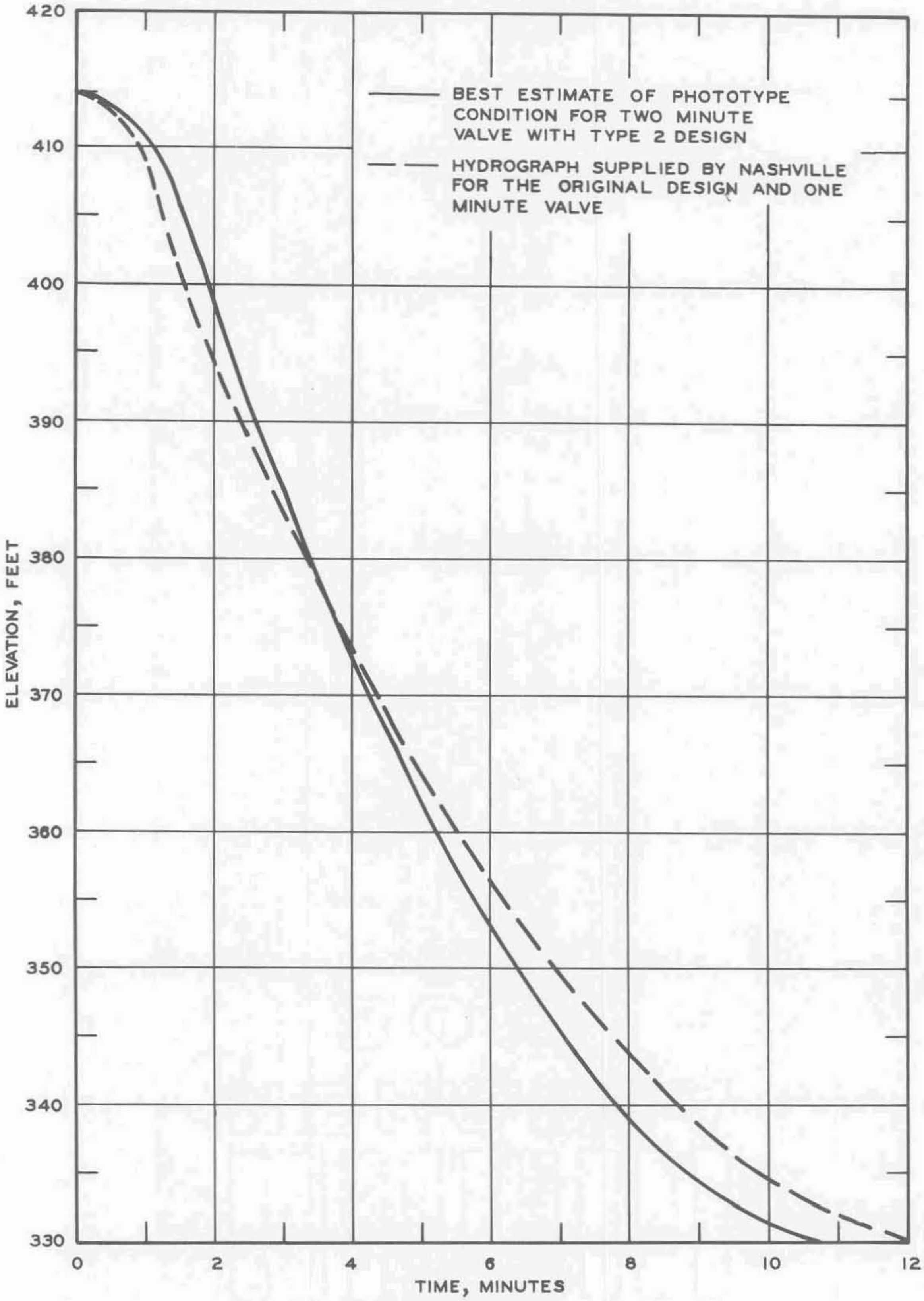


Figure 15. Lock stage versus time