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Memorandum
Chief, Hydraulic Structures Branch

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Hydraulic design guidelines for rafts to suppress vortex action - Grand Coulee Third Powerplant

This memorandum describes pertinent hydraulic model observations of vortex action in the forebay of the subject structure and provides guidelines for designing rafts to suppress the vortex action.

Introduction

Hydraulic studies conducted on a 1:120 scale model of the forebay and penstocks of Grand Coulee Third Powerplant indicated that objectionable, air-entraining vortices may occur in the forebay channel over the penstock intakes. Although it was recognized that the model was extremely small for detailed vortex studies, a more intensive vortex investigation was undertaken. Because construction of the forebay dam was already in progress at the time of the studies, corrective measures were limited to developing a raft system which might be used to control vortex formation.

This memorandum discusses the results of these qualitative studies and includes essential features to be considered in the raft design. A comprehensive report describing all the vortex studies in detail is presently being prepared.

General Observations and Considerations

Rafts tested in the hydraulic model prevented the formation of air-entraining vortices. Various areas, grid spacings, and depths of raft were tried (Figure 1). One 8-foot-deep raft was tested and did not appear to work any better than a 4-foot-deep raft. Thereafter, only 4-foot-deep rafts were tested.

The rafts worked equally as well when the top of the raft was just below the water surface (submerged). In fact, it appeared the rafts may be more effective when submerged. The most effective submergence depths were observed between 20 to 60 feet.

From the model tests it was concluded that the raft grid spacing should be between 10 to 20 feet, and the raft depth at least 4 feet. If a floating raft is used, the raft should extend 4 feet below the water surface (Figure 2). If a submerged raft is used, the grid spacing should be 10 feet. The thickness of the structural components is not believed crucial.

Figure 3 shows the area of the forebay where vortices formed in the model. For any given operating condition, the severe vortex action was confined to a local region bounded by a square varying between 40 by 40 to 100 by 100 feet. Depending upon which units were operating, these severe vortices could occur throughout the zone shown in Figure 3.

Raft protection over the semicircular area immediately above the trashrack is unnecessary (Figure 3). When a vortex moved into the water region above the trashrack, the vortex was dissipated. By not covering the semicircular area, a floating raft will have the freedom to move through water surface elevations of 1208 to 1290 feet.

A typical vortex is shown in Figure 4. Vortices which formed in the model were not steady or persistent. The strength of the vortex was a function of the distance from the face of the forebay dam (Figure 5). Generally, a 60-foot raft adequately suppressed all objectionable vortices.

When Units 19, 23, and 24 are operated, the vortex will form farther from the forebay dam (Figure 6). Although this vortex is located 120 feet from the headwall, it is not as severe as the vortex of Figure 4. If this vortex action should occur in the prototype, the raft coverage shown in Figure 3 will be inadequate.

Because the results of the model tests are inconclusive in defining what raft coverage is needed, the raft design should include a large degree of flexibility in raft placement. A raft system could be composed of individual components such that components could be added to make up the needed raft coverage. Also, it may be advantageous if the individual raft components could be readily joined together while floating in the forebay.

The 10- to 20-foot grid is believed to be an optimum range of raft grid spacing. This observation is based upon the large-scale turbulence which the model raft produced (Figure 7). If the raft grid size is larger than 20 feet, the raft will not provide enough disturbance to break up the vortices. However, with a grid spacing smaller than 10 feet a floating raft is less efficient. The areal extent of the water rotation which occurred in the model also confirms the 10- to 20-foot optimum grid spacing. The relative size of grid-to-water swirl areas is similar to the desirable area shown in Figure 8. A vortex has a larger circulation area at the water surface than below the water surface. This is why a submerged raft should have a smaller grid spacing than a floating raft.

Because the degree to which the model represents the prototype is unknown, the hydraulic model vortex tests must be considered qualitative. It will be necessary to observe prototype vortex conditions in the forebay channel to determine how well the model represented the prototype and whether a vortex problem exists.

Initial operation of the prototype probably will not exhibit the most severe vortex action. The hydraulic model tests indicated that the vortex severity increased as the number of operating units increased. The greatest change in vortex severity occurred with an increase from one to three operating units. A further increase in the number of operating units only slightly increased vortex severity. Rafts that work well for less severe conditions may be inadequate for the most severe conditions at some later date.

Recommended Guidelines for the Raft

Based on the preceding observations, the following guidelines are recommended for the raft design:

1. Grid spacing between structural components of the raft can vary from 10 to 20 feet, but should not be less than 10 feet (Figure 1).

2. The depth of the raft should be such that 4 feet of the floating raft extends below the water surface (Figure 2).

3. The area of vortex formation is 60 by 400 feet (Figure 3). This is for a three-unit installation. The preliminary raft design should provide raft protection to this area.

4. For aesthetic reasons, the raft could be completely submerged. In the model tests, rafts submerged 20 to 60 feet were slightly more effective than floating rafts. It is recommended that a 10-foot raft grid spacing be used for a submerged raft.

5. The raft should be designed to withstand normal water surface velocities which occur in the forebay channel and the rotational velocities of vortex action, which may reach

15 feet per second. The highest normal water surface velocities expected are from 6 to 9 feet per second. This condition is for 12 units operating at a water surface elevation of 1208 feet. 1/

Eugene R. Zeigler

1/ "Hydraulic Model Studies for Grand Coulee Third Powerplant," by D. L. King (to be published).

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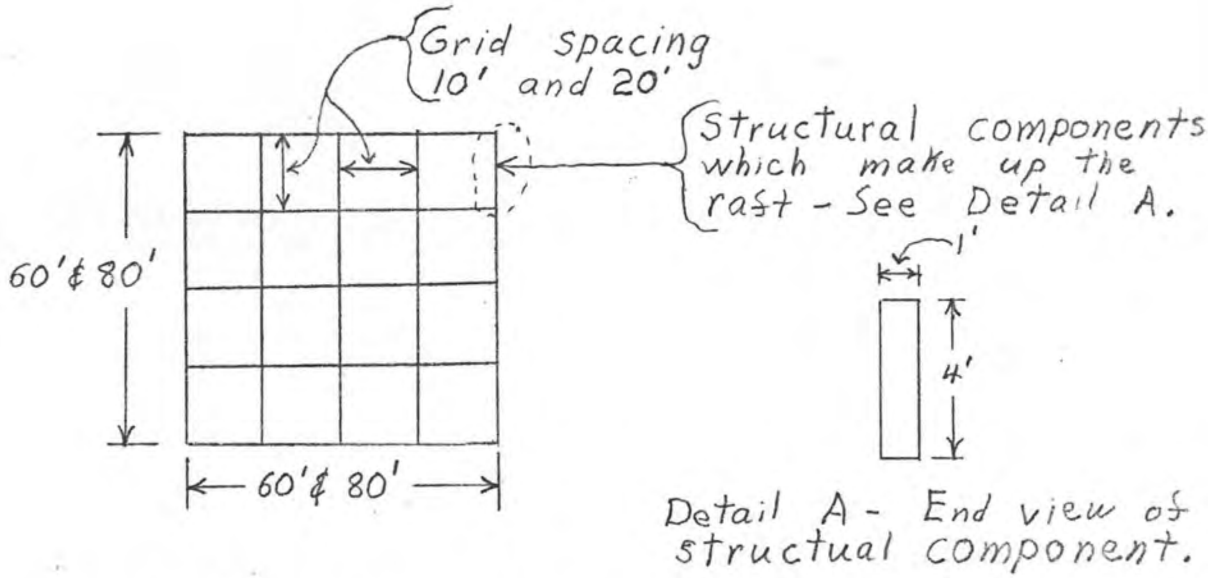

Figure 1. - Definition sketch for dimensions of model rafts tested.

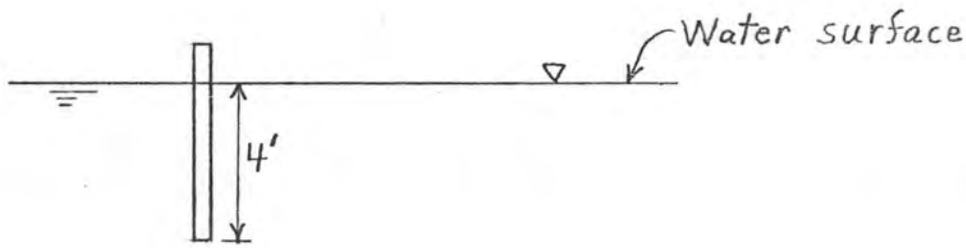

Figure 2. - Depth of raft extending into the water as illustrated by an end view of a structual component of a raft.

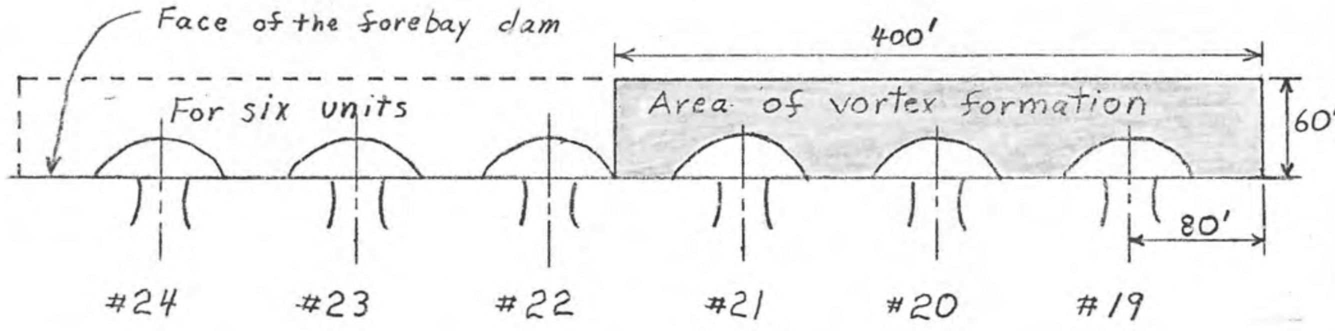

Figure 3. - Forebay area where vorticies may form.

Figure 4. - Water surface elevation 1290 feet and units number 19, 20, and 21 operating, each with 3-1/3 times the model Froude Number discharge.

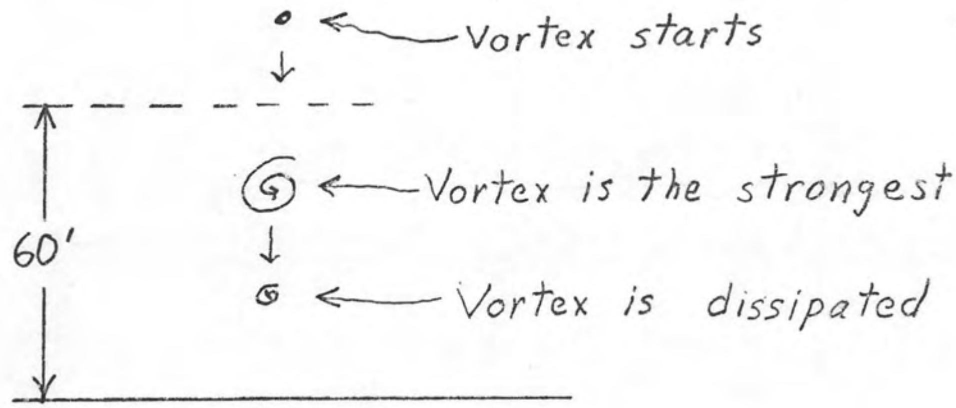

Figure 5. - Example of vortex travel.

Figure 6. - Water surface elevation 1290 feet and units number 19, 23, and 24 operating, each with 3-1/3 times the model Froude Number discharge.

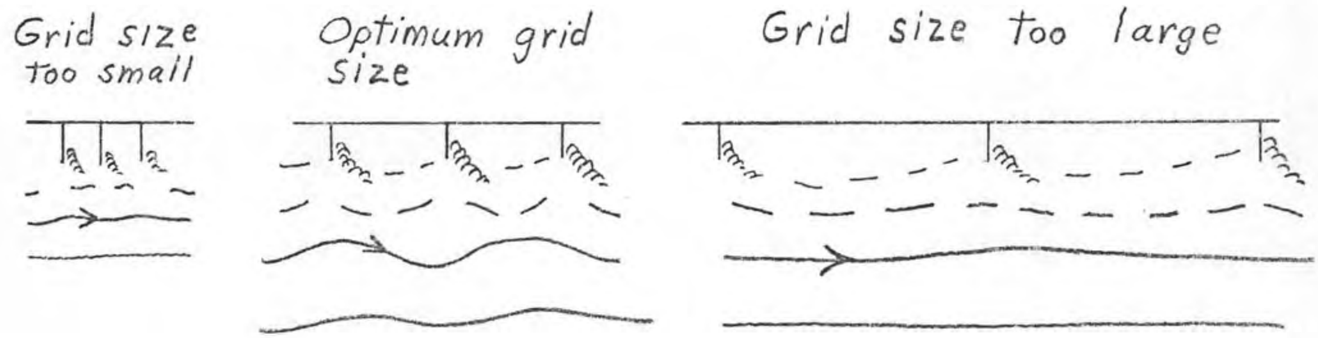

Figure 7. - Effect of raft grid spacing on turbulent fluctuations.

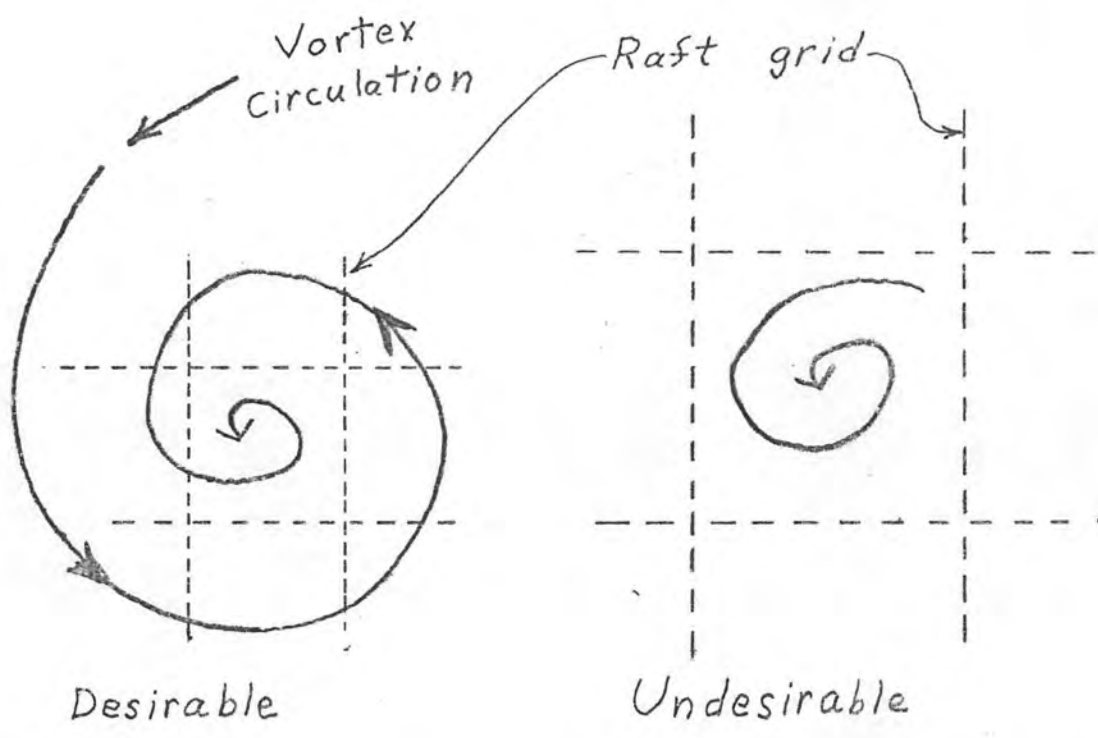

Figure 8. - Relation of the raft grid to the swirl area.