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HYDRAULIC MODEL STUDY OF OCHOCO DAM SPILLWAY MODIFICATIONS AND STILLING BASIN DESIGN

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The Bureau of Reclamation evaluated proposed modifications to the existing spillway for Ochoco Dam using a 1:36 scale model. The hydraulic model study was used to evaluate the performance of the spillway with modifications to the crest, inlet, and chute walls under a range of flows up to the new design flow of 15,000 ft³/s. The modified spillway must pass this flow without endangering the dam. In addition, the model was used to optimize the design of a new stilling basin and outlet channel to prevent erosion which could endanger the dam by exposing the aquifer that runs underneath and downstream from the dam.

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by

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U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

CONTENTS

FIGURES

Figure

CONTENTS—CONTINUED

FIGURES—CONTINUED

PURPOSE

The hydraulic model study was conducted to evaluate the performance of the existing spillway, with modifications to the crest, inlet, and chute walls, under a range of flows up to the new design discharge of 15,000 ft³/s. Additionally, a stilling basin and outlet channel were designed to prevent erosion of alluvial material downstream from the dam.

INTRODUCTION

Ochoco Dam was completed in 1921 by the Ochoco Irrigation District as part of the irrigation plan for the area north of Bend, Oregon (fig. 1). The newly raised, earth-filled dam is about 135 ft high and 1100 ft long. The existing spillway (fig. 2), located on the left abutment of the dam, has a 275-ft-long, curved, uncontrolled crest upstream from a 0.089 sloping and converging chute (fig. 3) that extends 410 ft downstream from the dam axis. The spillway was used early in its history, revealing poor flow conditions in the chute and erosion of the steep left hillside immediately downstream from the spillway. As a result, a deflector block (fig. 3, sec. B-B), a 75-ft-long chute extension, and deflector vanes were installed in 1949 (fig. 4) to prevent further erosion (Colgate, 1953). The deflector block provides a more uniform flow depth at the end of the chute to assist the vanes in redirecting the spillway flows away from the hillside. The spillway currently has no energy dissipating structure to protect the downstream channel from erosion.

CONCLUSIONS

The final layout for the modified spillway crest, stilling basin and outlet channel is shown on figures 5 and 6. Model investigations determined the following:

1. The modified spillway crest is shown on figure 7. The upstream 95-ft portion of the existing crest was removed and replaced with a broad crest section (fig. 7a) with 1:1 upstream and downstream slopes to an elevation 0.6 ft higher than the existing crest. Figure 8 demonstrates that the rating curve for the modified spillway crest and approach area will successfully pass the required discharge. A comparison of the new rating curve with the rating curve developed for the original crest shape shows that the modified spillway has a discharge capability similar to the existing spillway. In addition, the rating curve demonstrates that the modified spillway crest and approach area will pass the new PMF (probable maximum flood) of 42,200 ft³/s without causing overtopping of the dam.

2. The proposed geometry of the dam closure wall (fig. 7) between the dam and spillway chute adequately deflects flow into the chute up to the design flow rate of 15,000 ft³/s. Investigation of flows up to the PMF showed that above 41,000 ft³/s, overtopping of the lower section of the new dam closure wall occurs, and an additional modification would be required to contain flows of this magnitude.

3. Figure 9 shows water surface profiles with respect to the existing chute walls and invert, with and without the deflector block at the chute entrance, at the design flow. The profiles demonstrate that overtopping is substantially reduced with the deflector block removed, therefore minimizing the wall heights required to contain the flow.

4. The six downstream deflector vanes and the curved left wall at the downstream end of the spillway chute were designed to direct the flow to the right. The vanes and the wall had to be removed to obtain the desired impingement of spillway chute flows into the final stilling basin design. Fillets installed on the invert and both sides of the spillway chute (figs. 10 and 11) were designed to lift and center the uneven flow depth at the end of the spillway to obtain optimum performance of the stilling basin. Figure 12 shows the water surface profiles for the final chute configuration.

5. Figures 6 and 13 show the final design of the stilling basin. The basin design was based upon obtaining good hydraulic performance while working within the geological considerations that restricted the depth and extent of the stilling basin boundaries. Total sweepout of the hydraulic jump basin does not occur for flows up to the new PMF (42,200 ft³/s). As flow is increased to 60,000 ft³/s, the jump becomes more unstable and the toe of the jump moves farther downstream, but it never completely sweeps out of the basin.

6. Figures 6 and 14 show the final configuration for the outlet channel from the downstream end of the RCC (roller compacted concrete) stilling basin to the river channel. The model study provided incoming flow depths and velocities to the design team to evaluate alternatives for the final design. The outlet channel will be riprap-lined and was designed to transfer flow from the stilling basin area to the river channel without causing erosion below elevation 3000 ft.

DESIGN CRITERIA

Ochoco Dam was recently raised to an elevation of 3154 ft because of higher estimated values for the PMF. The new maximum water surface elevation associated with the PMF will produce a discharge that exceeds the capacity of the existing spillway. The decision was made to perform structural modifications that will allow safe passage of flows up to the new design flow of 15,000 ft³/s; an early warning system will be used for all spillway releases and dam failure modes above the 15,000-ft³/s level (Stanton, 1996; Fisher, 1996). In addition, an aquifer is located underneath the dam and extends across the downstream river channel. Previous studies indicate that allowing erosion of the confining material (El. 3000 ft) immediately above the artesian aquifer in the valley downstream from the dam could lead to dam failure by piping foundation material from under the dam through the lower alluvium. Therefore, exposure of the aquifer caused by erosion from spillway releases must be prevented to ensure the safety of the dam up to the design discharge of 15,000 ft³/s. These considerations require the following criteria:

- The modified spillway must safely pass the design flow without endangering the dam.

- The discharge capability must be comparable to the existing spillway so the modifications will not affect upstream residents.

- The new proposed stilling basin and outlet channel must perform adequately to prevent erosion of the dam toe and the downstream alluvium and river channel (located to the right side of the canyon) beyond a minimum elevation of 3000 ft.

In addition, the final design must be evaluated for a range of discharges up to the PMF of 42,200 ft³/s to assist in the evaluation of potential dam failure modes.

TEST PLAN

Model tests were conducted primarily to a design discharge of 15,000 ft³/s (unless otherwise stated) and were used to determine:

- Discharge rating curve for the proposed modified spillway crest and inlet area up to a reservoir elevation of 3154 ft and a discharge of about 60,000 ft³/s.

- Performance of the dam closure wall between the raised dam and existing spillway chute.

- Performance of the upstream chute deflector block, including modifications.

- Performance of the downstream deflector vanes, including modifications.

- Water surface profiles for the final modified spillway chute.

- Performance of the initial stilling basin design and necessary modifications.

- Stilling basin water surface profiles for the final basin design.

- Performance of the initial outlet channel design and modifications.

- Performance of the spillway chute and stilling basin final designs up to a discharge of 42,200 ft³/s.

A video tape documenting the final configuration is available upon request. This hydraulic model study report precedes the construction of the recommended design and therefore may not include final construction modifications.

THE MODEL

A geometric scale of 1:36 was used to model the reservoir area, the modified spillway crest and chute, the proposed stilling basin and outlet channel, and enough surrounding topography to accurately model flow conditions. The Froude law was used to scale the model because the hydraulic performance depends primarily on gravitational and inertial forces. Froude law similitude produces the following relationships between the model and the prototype:

Length ratio $L_r = 1:36$

Velocity ratio $V_r = L_r^{1/2} = 1:6$

Discharge ratio $Q_r = L_r^{5/2} = 1:7776$

Figure 15 shows the model extents with the dam, existing spillway location, and downstream river channel. Crest modifications included replacing the upstream 95 ft of the original crest with a broad crested weir at elevation 3131.3 ft (fig. 7). The remaining 180 ft of crest length will be repaired and the original crest shape will be retained. One-hundred-thirty feet of surrounding topography to the southeast of the dam and crest were modeled, including modifications to topography immediately upstream from the crest (fig. 16).

3

Riprap topography was modeled with moveable scaled rock. A dam closure wall between the newly raised dam and existing spillway chute was also modeled (fig. 7). The topography at the downstream end of the spillway chute was not constructed so that the new stilling basin and outlet channel could easily be installed. As the investigation progressed, about 350 ft of river channel topography was installed immediately downstream from the outlet channel. Figure 6 shows the final modeled spillway, stilling basin, and outlet channel designs.

Water was supplied to the model from the permanent laboratory venturi system. Reservoir elevations were calculated from point gage readings referenced to the original crest elevation (3130.7 ft).

INVESTIGATIONS

Model investigations were performed in sequential order from the spillway crest downstream to the river channel. This sequence assured that all upstream modifications that had a bearing on the remaining downstream investigations would be complete as the study progressed.

Spillway Approach, Crest, and Dam Closure Wall

The upstream 95 ft of spillway crest will be replaced with a broad-crested weir at elevation 3131.3 because of the poor condition of the existing concrete. The remaining crest length (180 ft) will be repaired to the original elevation of 3130.7. The upstream topography will be modified to install a seepage barrier. The proposed modifications for the spillway crest and approach channel were installed in the model (fig. 7). A discharge rating curve (fig. 8) was generated for the modified crest for the full discharge range up to 60,000 ft³/s, which corresponds to the maximum reservoir water surface elevation of 3154 ft without overtopping the dam. Comparison of the modified spillway crest discharge curve with the discharge rating curve from the 1949 Ochoco spillway model study indicates a comparable discharge capability (Colgate, 1953). This comparison verifies that upstream residents will not be inundated any sooner with the modified spillway design. The design flow of 15,000 ft³/s is passed with 6.55 ft of head over the original crest elevation at reservoir elevation 3137.25. The PMF is passed at reservoir elevation 3148 without overtopping the dam.

Figure 17 shows the head over the original crest (El. 3130.7) versus discharge coefficient for the modified spillway crest. The coefficient is a function of the head above the two crest elevations and their respective lengths. The discharge coefficient is also a function of the geometry of the downstream chute. As shown on figure 17, the discharge coefficient decreases with increasing head as submergence increases over the upstream section of the crest because of the constricted width of the spillway chute. The discharge coefficient was calculated as follows:

$$C = Q/(180H_o^{3/2} + 95H_n^{3/2})$$

where: C = discharge coefficient
          Q = discharge (ft³/s)
          H_o = head over the original crest (ft)
          H_n = head over the new crest section (ft) = H_o + 0.6 ft

Figure 18 shows flow over the crest at design flow. Flow over the crest is influenced by upstream topography, geometry and location of the dam closure wall, and downstream chute width. No movement of material in the approach channel was observed for flows up to the PMF.

4

The flow turning into the chute creates a contraction next to the lower bench of the dam closure (El. 3139.57 ft), producing draw down of the water surface next to the dam closure wall. The service road slope reduces the flow adjacent to the lower bench, thus preventing overtopping of the lower bench at higher discharges. The lower bench of the dam closure wall does not overtop until a discharge of about 41,000 ft³/s is reached. At a discharge of 42,200 ft³/s, the corner of the lower bench is overtopped, and would require the addition of a flow deflector to contain flows of this magnitude in the chute.

The Spillway Chute

The existing spillway chute wall heights were originally designed for a flow rate of 11,000 ft³/s. The alignment of the curved crest upstream from the chute led to poor flow conditions in the chute. Therefore, the deflector block, located at the chute entrance, was installed in 1949 to improve flow conditions at the end of the chute. Figure 19 shows the spillway chute water surface profiles for 15,000 ft³/s with respect to the spillway chute invert and existing walls with the deflector block and vanes intact. The left wall is overtopped where flow builds up behind the deflector block and also at sections downstream where cross waves cause overtopping on both sides of the chute. Cross waves occur because of the approach and curvature of the crest and are accentuated because of the location of the deflector block.

The following modifications were investigated to prevent or minimize the overtopping of the spillway chute walls at the design flow:

- The crest access road was diverted away from the dam closure wall so that upstream fill elevations in the area next to the closure wall were significantly reduced.

- The most upstream 52 ft of crest length was blocked off to reduce the amount of flow approaching from directly behind the deflector block.

- The deflector block was removed.

Diverting the access road created more flow next to the dam closure wall. However, although the location of the cross waves underwent a slight shift, the depth of overtopping was unchanged and therefore did not provide a solution to the problem.

Blocking the upstream portion of the crest increased flow depth in the middle of the spillway, but depth and position of overtopping along the spillway chute walls were relatively unchanged.

Removing the deflector block changed flow conditions significantly. Flow depths were more evenly distributed immediately downstream from the crest. Depth of flow overtopping the chute walls was reduced and the location shifted downstream (fig. 9). On the left wall, overtopping was reduced from about 6.5 ft to less than 2 ft between stations 4+00.0 and 5+00.0 and was reduced from about 4 ft at the upstream face of the deflector block to zero. The total extent of overtopping was reduced by about 50 ft along the left wall and was concentrated at the lower section of the chute. On the right wall, overtopping was reduced from 2.5 ft to about 0.5 ft in the lower portion of the chute and was reduced from about 2 ft to zero in the upstream section in the chute. Total overtopping with the block removed was reduced by about 80 ft along the right side and was located along one continuous section of the chute rather than two separate sections. Removal of the block caused uneven flow depths at the end of the chute with greater depth on the left side; however, overall flow conditions were improved.

5

Removing the deflector block significantly reduces the required wall heights. The wall raise will be confined to the lower portion of the chute, thereby reducing construction costs. As a result, the design team agreed that the deflector block be removed from the existing structure. All subsequent model investigations were performed without the deflector block.

Because the model does not simulate the effects of aeration in the flow depth of the spillway chute, additional elevation must be added to the new proposed wall heights. Engineering Monograph 41 (EM41) (Falvey, 1980) was used to determine the bulked or aerated depth in the spillway chute by relating it to the non-aerated depth that was measured in the model by:

$$d_b/d = 1/(1-C)$$

where: d_b =   bulked flow depth
         d =   flow depth (without aeration)
         C =   mean air concentration

Flow depths were measured in the model at several stations along the sloping chute. The mean air concentration was determined from EM41, which relates the air concentration to the distance down the slope of the chute. The bulked flow depth was calculated at the upstream end of the chute, where overtopping is more critical but aeration is less, and at the downstream end of the chute, where aeration is greatest. This analysis resulted in the addition of 3 ft to the final spillway chute wall heights.

Initial Stilling Basin and Chute Design

Considerations.—Optimization of the stilling basin design was a function of the hydraulic performance and the constraints in basin location, depth, and extent of geological considerations. Test pits and drill holes were evaluated to determine the location of the John Day foundation material. The foundation material is benched from left to right across the width of the basin area, and the elevation drops sharply on the right side. The extent of foundation material also drops sharply in elevation about 350 ft downstream from the spillway chute. The geological investigation also revealed extensive bedrock in the hillside to the left of the chute and high groundwater levels in the alluvium across the valley. The geological information dictated the following restrictions on the stilling basin:

● The positioning and extent of the basin were restricted on the right hand side so that adequate foundation would be available for the construction of the RCC basin.

● The depth of the basin and the location and height of the left wall were limited to minimize excavation of the hillside.

● Basin excavation depth was limited to avoid significant dewatering of the area during construction.

Initial Basin Design.—Figure 20 shows the initial stilling basin design to the excavation limits. The centerline of the initial basin design was located about 14 ft to the right of the spillway chute centerline. The basin invert at the upstream section of the stilling basin was 60 ft wide and sloped from elevation 3040.8 ft at station 6+64.0 to elevation 3020 ft at station 8+07.0. Downstream from station 8+07.0, the geology of the area allowed the basin to expand to give a greater area for dissipating energy. At about station 9+77.0, before the John Day foundation dropped sharply in elevation at the downstream boundary, the basin was used to turn flow to the right toward the river channel.

6

Deflector Vanes.—The performance of the downstream deflector vanes was investigated with respect to optimizing the hydraulic performance in the proposed stilling basin.

Investigations revealed that the downstream deflector vanes turned the flow sharply to the right for discharges from 1,000 to 11,000 ft³/s. Figure 21 shows modeled deflector vane performance at 5,000 ft³/s. Flow conditions in the basin changed as discharge was increased to 15,000 ft³/s because the vanes became partially submerged. This increase caused a portion of the flow to discharge straight out from the chute. Thus, two flow conditions were produced which would require the design of a very wide basin or a two-tiered basin to accommodate the different flow conditions. In addition, for all flows up to the design flow, the vanes directed the flow too far to the right to adequately design a basin within the boundary of geologic considerations. Individual vanes were selectively removed and flow conditions were evaluated. These tests produced little success and as a result, all six deflector vanes were removed.

Stilling Basin and Downstream Chute Design Approach .—The next step was to work with both the end of the spillway chute and the initial stilling basin design to optimize hydraulic performance for the design discharge of 15,000 ft³/s. This step included 1) determining to what extent the walls on both sides of the stilling basin could be moved toward the centerline of the basin to accommodate the foundation and minimize excavation and 2) modifying the end of the spillway chute to center the jet in the basin.

Designing the stilling basin and the downstream end of the chute to perform well throughout the range of discharges presented a unique problem because of the uneven flow depth at the end of the chute. The flow trajectory for high flows near 15,000 ft³/s impinged on the sloping floor of the stilling basin, creating a large boil on the right side near the end of the slope. Low flows produced a jet that followed the left hand side of the basin.

Two different approaches were taken to optimize the performance of the basin to give designers two options in evaluating construction costs.

The first approach (option 1) was to assume that no modifications would be made to the spillway chute other than those that had already been completed, including the removal of the deflector block and vanes. This approach meant dealing with an uneven flow depth and jet entering the stilling basin. In this case, modification of the basin geometry would provide energy dissipation. Modifications included wall angles and the placement of vanes, sills, blocks, or fillets in the stilling basin.

The second approach (option 2) was to work with the end of the spillway chute with fillets or vanes in an effort to center and converge the jet so the basin width could be minimized and good hydraulic performance could be achieved with minimal appurtenances in the basin.

Tailwater curves showed that for the design discharge of 15,000 ft³/s, the tailwater elevation was only about 3020 ft in the stilling basin area. This elevation provided no tailwater to assist with energy dissipation. So to begin the investigations, a main sill was installed downstream from the sloping section to force a hydraulic jump.

1. Option 1

   The first approach was to modify the basin geometry to create evenly distributed flow conditions downstream and maximize energy dissipation.

   A longitudinal vane was positioned in the basin along the length of the slope to try to split and dissipate the impinging jet. Several positions and orientations were tried; some success at splitting the jet was achieved at specific discharges. However, determining a vane position that performed adequately over the full range of discharges was difficult. The jet was very sensitive to small changes in vane positioning, and different flow conditions were produced whether the flow was increasing or decreasing. This approach was abandoned because basin performance could not be predicted with certainty.

   Next, three or four large blocks, 9 ft in height and width, were positioned on the slope at the upstream end of the basin so as to distribute the jet. However, determining a block arrangement that was effective at both low and high discharges was impossible.

   Finally, many smaller blocks, 5 ft in height, were positioned so as to affect jet impingement points and successfully distribute the jet at all discharges up to the design flow. As a result of these placements, a continuous sill (zigzag sill) was recommended that could be constructed using typical RCC construction techniques. In addition, the left and right basin walls along the sloped section were moved toward the centerline of the basin as much as possible while still maintaining good hydraulic performance. With this design complete, the main sill was then positioned to minimize wall heights. This design produces an evenly distributed hydraulic jump over the entire discharge range. Figure 22 shows this configuration with respect to the original basin invert outline.

2. Option 2

   This option dealt with attempts to modify the end of the chute to produce an acceptable trajectory into the basin over the full range of discharges. The zigzag sill recommended in option 1 was removed, and vanes or fillets were installed at the end of the chute to converge, lift, and center the jet in the basin. Several shapes and sizes of fillets and vanes were investigated. The left curved wall and some of the original deflector vanes could be used if a fillet was positioned on the right side of the chute to help evenly spread the flow into the basin. The final design consisted of a fillet on the right side with two of the original vanes and the left curved wall from the existing spillway. As with option 1, the left and right basin walls along the sloped section were moved toward the centerline of the basin, and the main sill was positioned to minimize wall heights. Figure 23 shows the final configuration with respect to the invert outline of the initial design.

   This configuration produces an even flow distribution in the basin at design discharge; at lower flows, the jet within the basin flows slightly left of center. Overall, this configuration was effective throughout the range of discharges.

Final Basin and Chute Design

Modified Basin Location.—The details of the two options were given to the design team. After reviewing the designs and reexamining the limits of foundation material, the decision was made to move the entire basin farther to the left. The centerline of the stilling basin was moved about 14 ft to the left of the original centerline, thereby aligning it with the centerline of the chute. Repositioning the basin centerline required further model investigations.

The third basin design option (option 3) was based on working with a simplified basin and modifications to the end of the chute, similar to the development of option 2.

Final Chute Design (Option 3).—Much had been learned from the previous investigations that refined the geometries for the end of the chute and basin. The realignment of the basin with the end of the chute required centering the jet with the new alignment. This centering did not allow use of the original vanes at the end of the chute. Additionally, the left curved wall at the end of the chute had to be removed and replaced with a separate fillet. This modification resulted in a final configuration consisting of fillets on both sides of the spillway chute (figs. 10 and 11) which feather back to the chute invert. The invert fillet is designed to lift the jet while the left and right wall fillets center the jet for optimum hydraulic performance in the basin. This configuration provided an even flow distribution in the basin at design discharge and acceptable conditions throughout the range of flows. Figure 12 shows the water surface profiles for the final chute configuration at the design flow. The increased water surface elevation at the end of the chute is caused by the higher invert elevation and constricted chute width where the fillets were installed. Figure 24 shows flow conditions in the modeled spillway chute for the final chute configuration at the design flow. Option 3 was accepted as the final chute design and was used in all subsequent investigations.

Final Basin Design.—Several simple configurations and orientations of sill placement in the stilling basin were investigated to further maximize energy dissipation. This investigation resulted in the final design of the stilling basin shown on figure 13. The addition of sills maximized energy dissipation in the basin by forcing a jump in the basin because no tailwater was available to create a jump naturally. However, the height of each sill created additional potential energy, so the amount of energy dissipated was limited, and the discharge per unit width remained quite high. The final design resulted in adding a lower bench (El. 3030 ft) to the upstream toe of the main sill (El. 3050 ft) to force the hydraulic jump sooner within the first pool. Then, because basin depth was limited, a second sill was necessary (El. 3031.25 ft) at station 9+23.53 to create a second pool to further calm the flow and to assist with turning the flow toward the outlet channel. Finally, a 5-ft sill (El. 3020 ft) was added at station 9+82 to further assist in energy dissipation at the entrance to the grouted riprap section of the outlet channel. Each of the sills was designed and positioned in the basin to maximize energy dissipation and minimize wall heights.

Figure 25 shows flow conditions for the final stilling basin design at the design flow. The second sill (station 9+23.53) and the invert elevation immediately downstream from the sill were not modified in the model to the final design. The vertical sill and higher invert elevation used in the model is considered to be a conservative representation, and the effect is considered to be minimal. Water surface profiles for the final basin design are shown on figure 26 and were used for designing wall heights.

9

Outlet Channel Design

The outlet channel was designed to transfer the design flow from the stilling basin across the alluvium to the river channel. Erosion in and downstream from the outlet channel must be limited to elevation 3000 ft to prevent endangering the dam by exposing the aquifer at the downstream dam toe or the river channel. Two of the design options considered were:

1. Confine all flows up to the design flow in the outlet channel, thus transferring the energy and the potential for erosion to the river channel.

2. Confine smaller flows in the outlet channel, such as those of historical record, and allow higher flows to spread out over the alluvium, distributing the energy.

Because of the high velocities exiting the stilling basin, the second option was determined to be more viable. The initial layout for the outlet channel was designed to contain flows up to 1100 ft^3/s. This flow corresponds to the safe river channel capacity through Prineville, Oregon, the city located immediately downstream from the dam. The channel was designed with a 30-ft width and a tapered berm on the left side of the outlet channel. The left berm was tapered in height from the wall height at the end of the basin to 3.75 ft at the river channel. Flows greater than 1100 ft^3/s would overtop the berm near the river channel and progressively erode upstream, gradually releasing the energy of the higher flows over a greater area. The right berm of the outlet channel was designed to contain flows up to the design flow (15,000 ft^3/s), because overtopping the right berm could cause erosion which could potentially approach the toe of the dam. The channel was modeled with grouted riprap sized for a maximum flow of 1100 ft^3/s. Velocities and flow depths were measured with this configuration to assist with the design of wall heights and the design of the final configuration for the channel. This information was also used as initial input to a numerical model for a degradation study of the outlet channel (Randle, 1996). The degradation study determined that the limits of erosion potential for this design would not go below elevation 3000 ft, which is the top of the critical confining layer of material above the aquifer.

The final configuration for the outlet channel was redesigned for the historical flood of record, 2000 ft^3/s (figs. 6 and 14). The tapered berm on the left side of the channel was replaced with a 6-ft berm of constant height. This berm would protect the adjacent farmland in the immediate area by containing flows less than 2000 ft^3/s and would be overtopped for higher flows, releasing flow over a greater area and thereby limiting the depth of erosion.

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VICINITY MAP

SCALE OF MILES
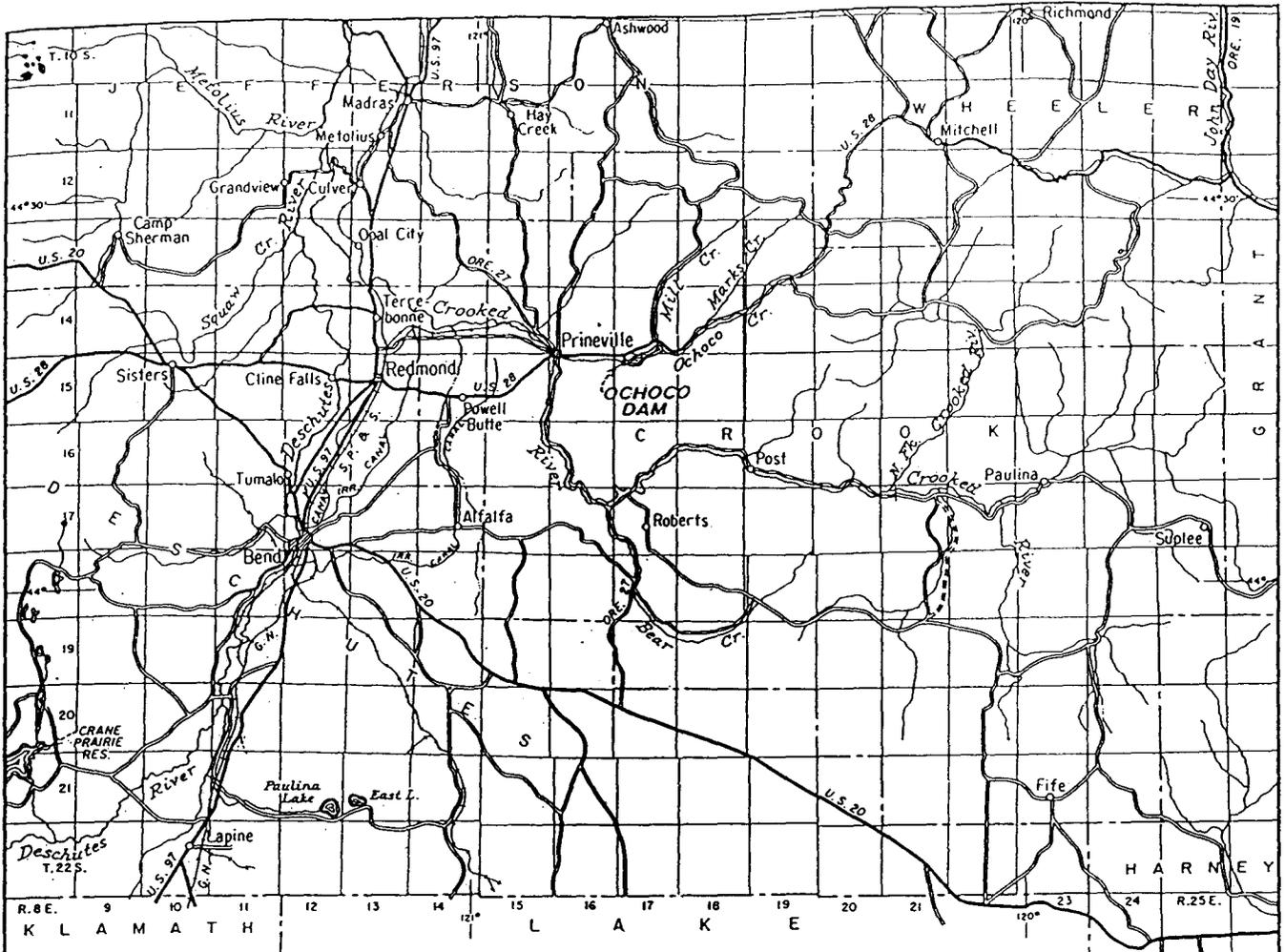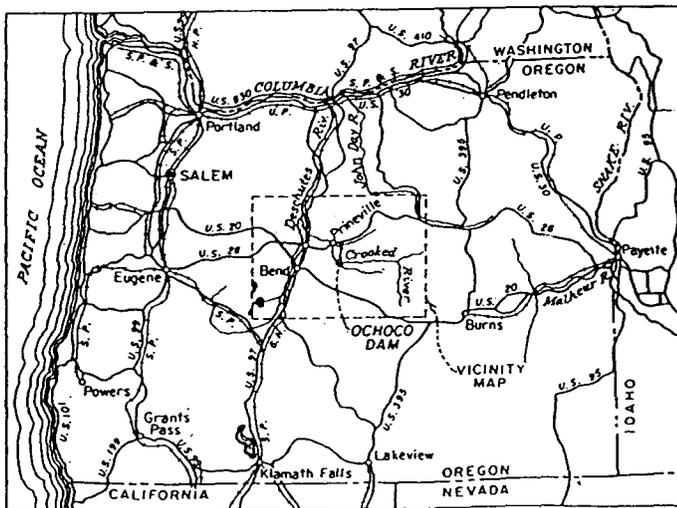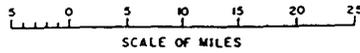
EXPLANATION
(Vicinity Map Only)

———————— OILED OR PAVED ROADS
———————— GRAVELLED ROADS
———————— IMPROVED ROADS

INDEX MAP

Figure 1. - Location of Ochoco Dam.   12
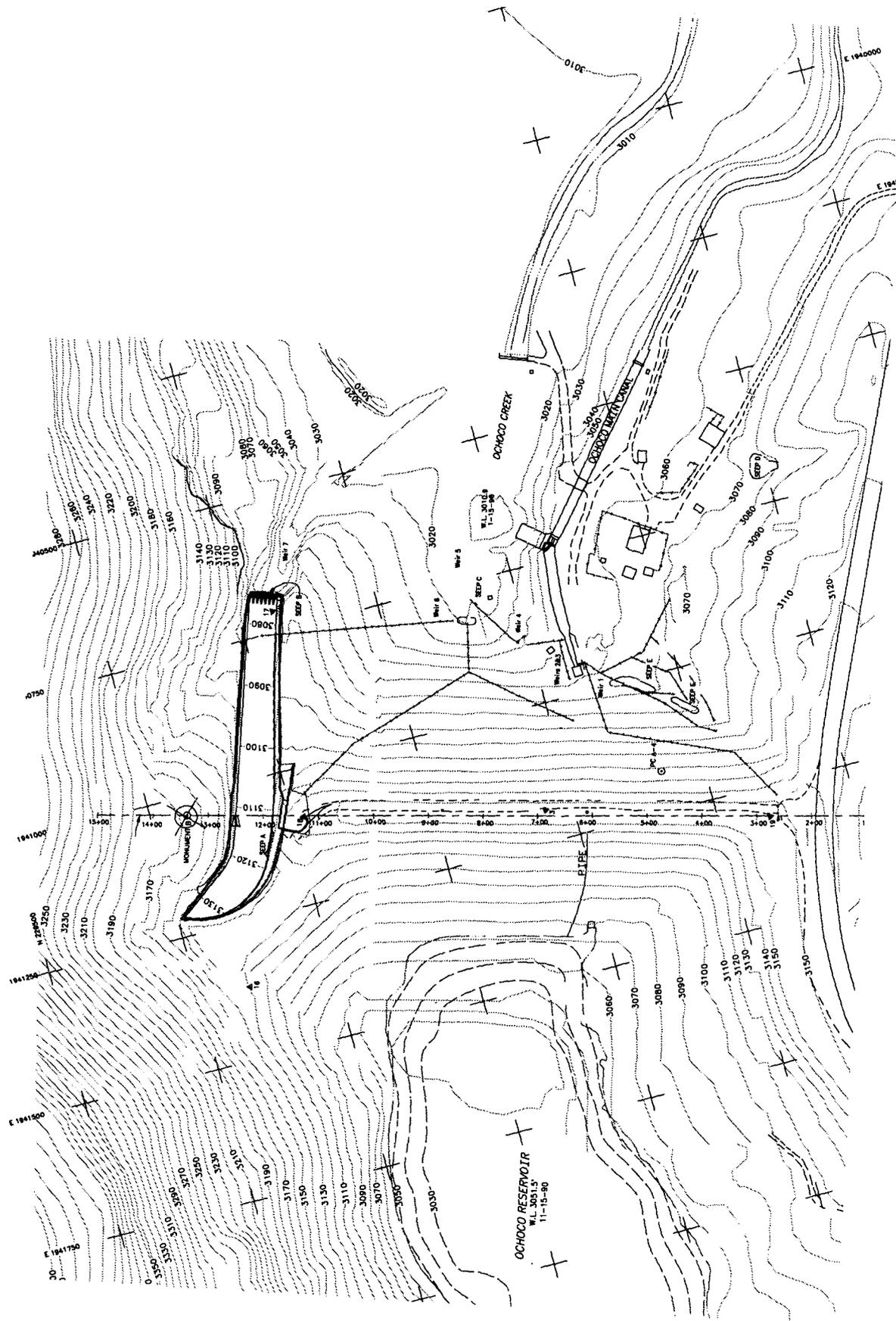
Figure 2. - General plan of Ochoco Dam and the existing spillway.

13
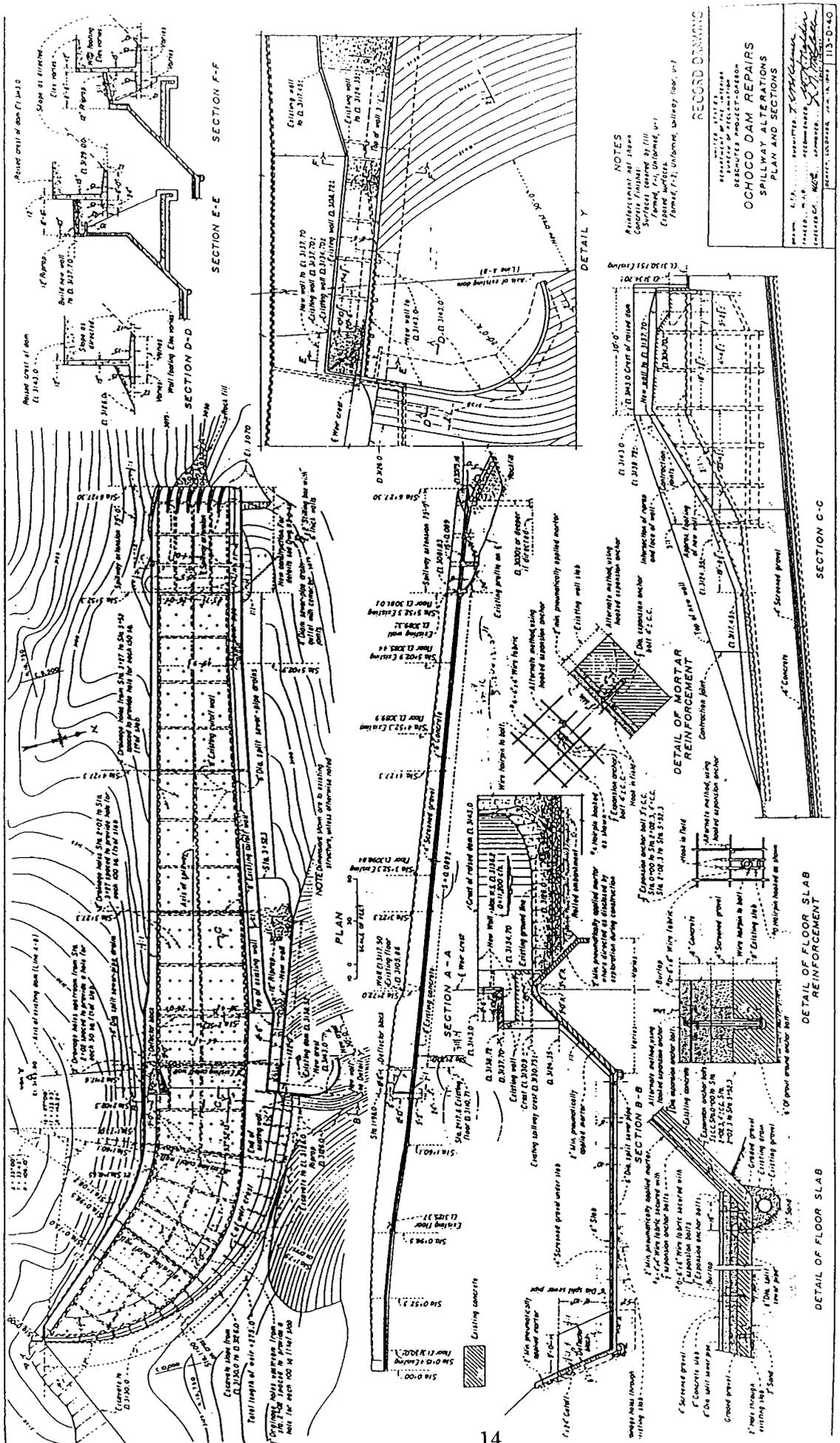
Figure 3. – Plan and section of the existing Ochoco Dam spillway.

14
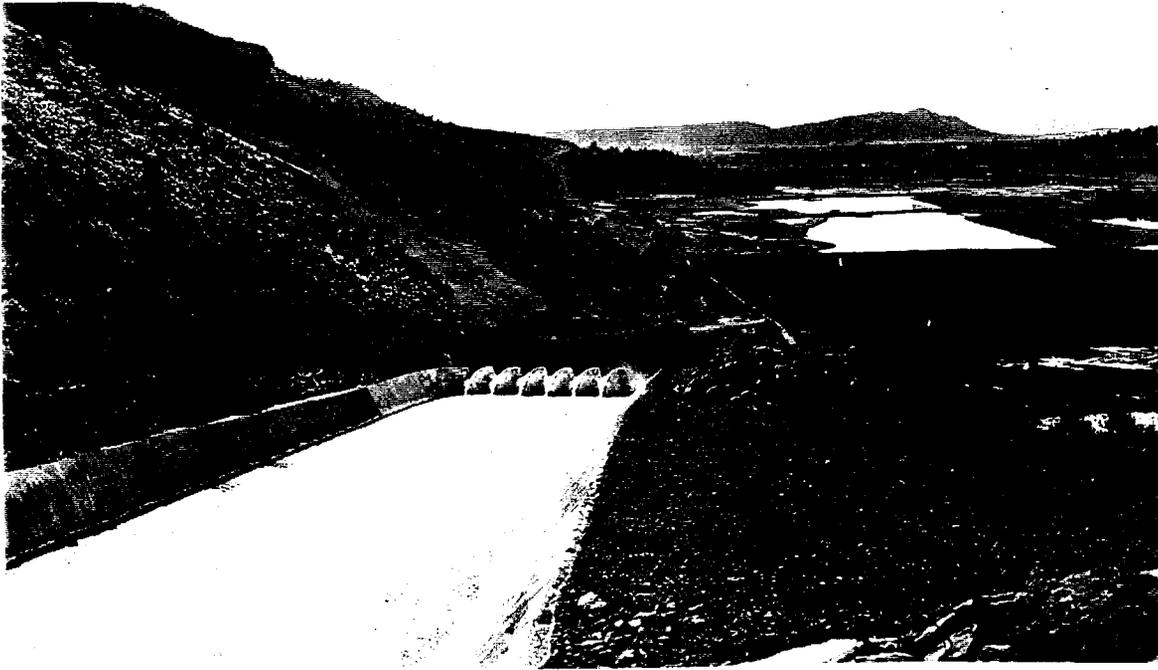
A. Looking down the spillway chute.
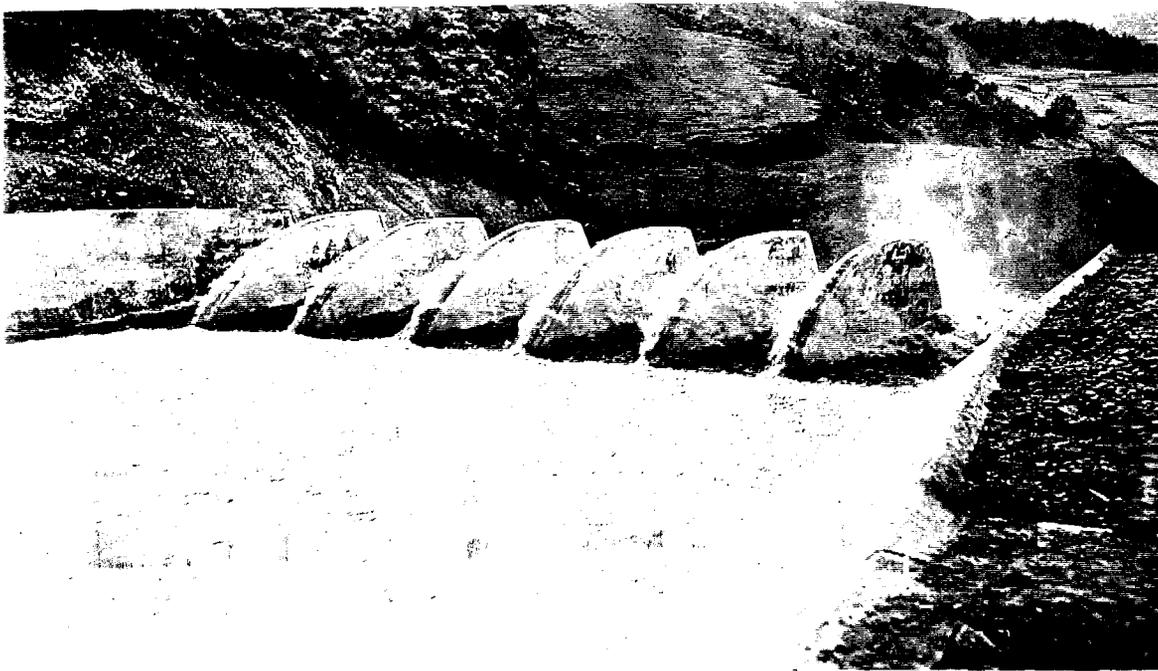
B. The flow deflectors from upstream.

Figure 4. - Prototype spillway chute extension and flow deflectors after repairs at a discharge of 750 ft³/s (Colgate, 1953).

15
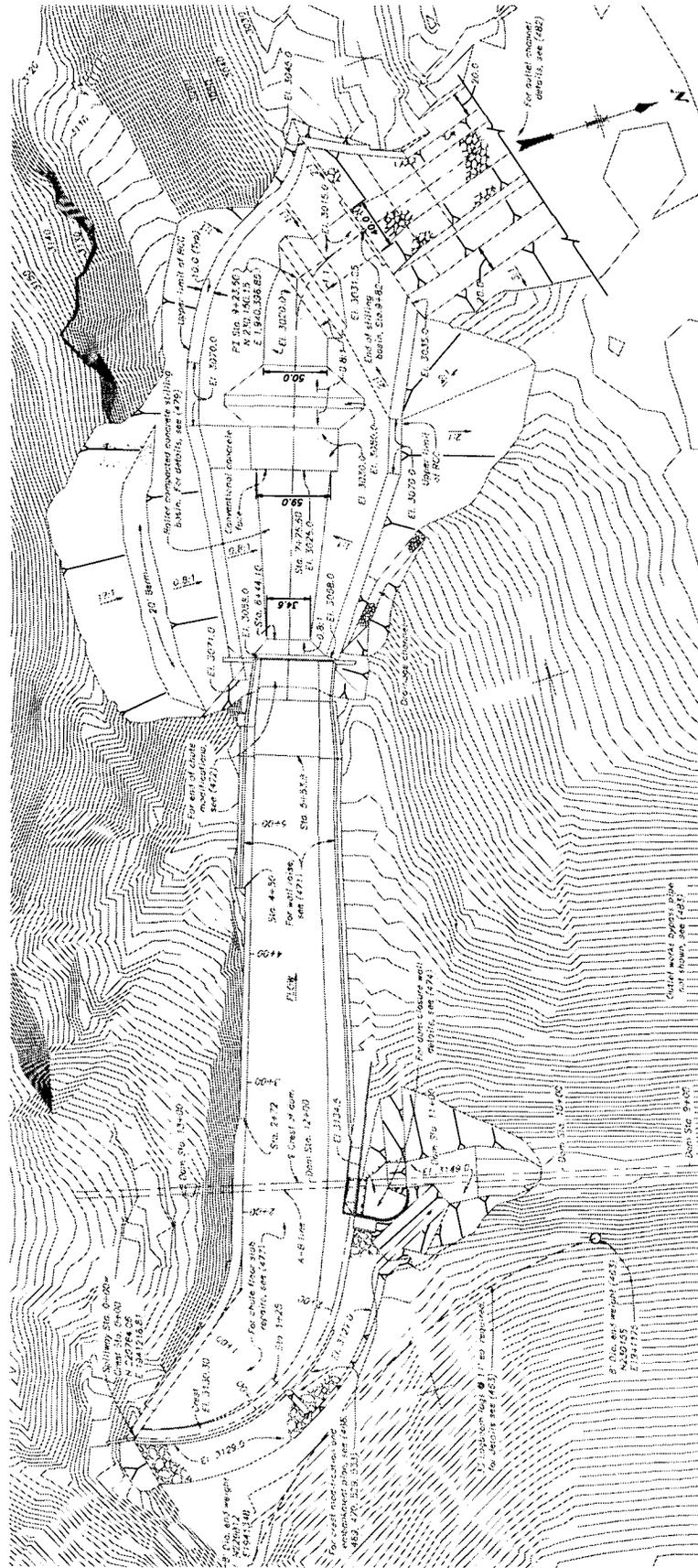
PLAN

Figure 5. - Final layout for Ochoco Dam spillway, stilling basin, and outlet channel.
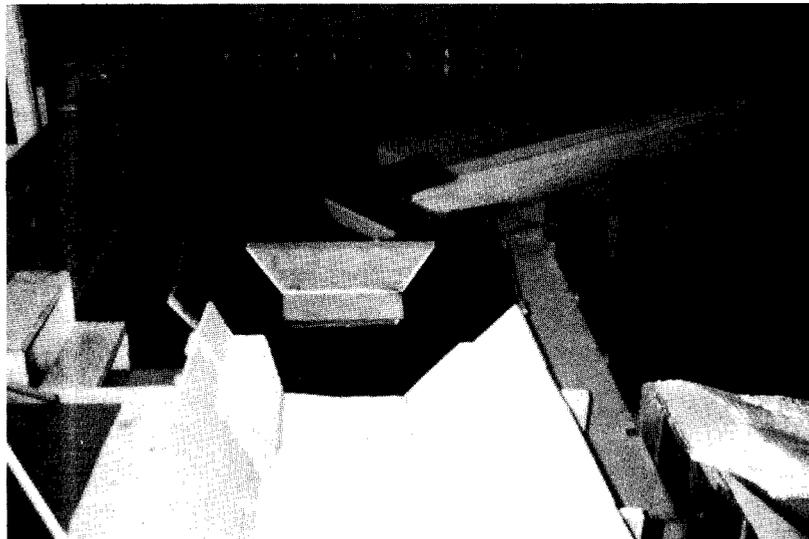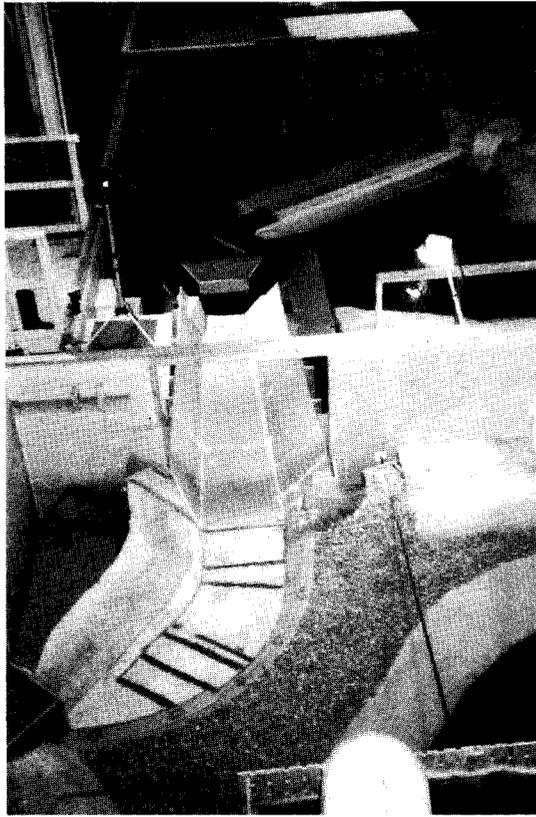
Figure 6. - Final modeled layout of the spillway, stilling basin, and outlet channel.

17
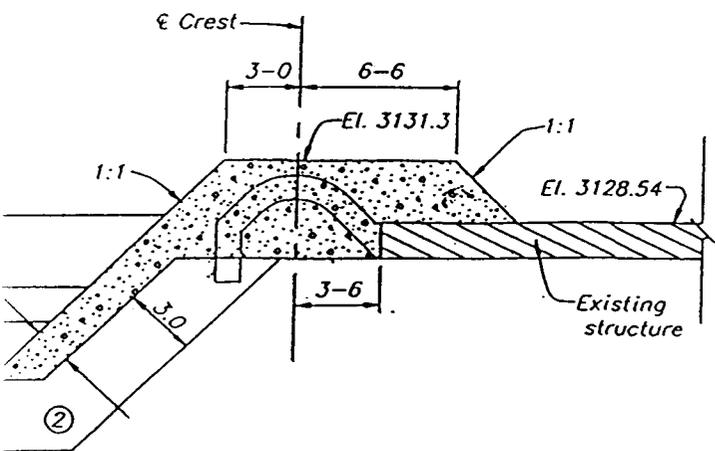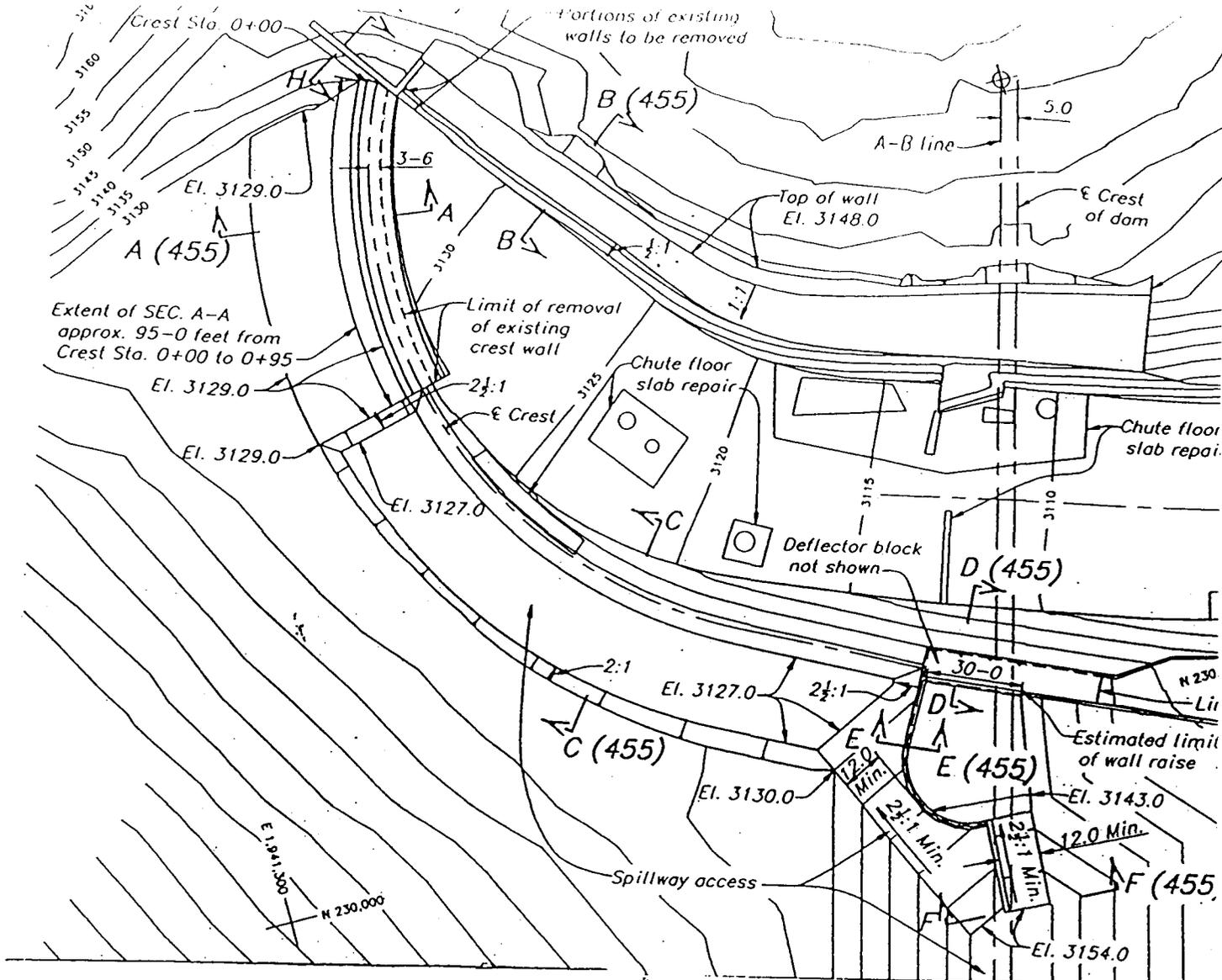
a) Section profile of modified crest
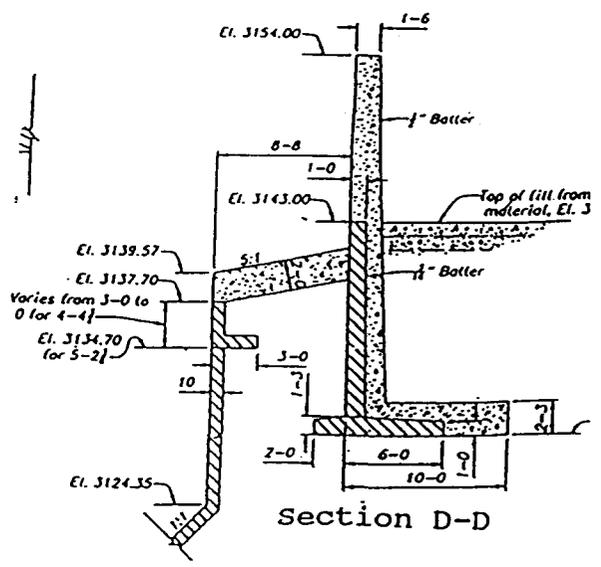
b) Modified geometry of dam closure wall

Section D-D

Figure 7. - Modified spillway crest and inlet area.

18
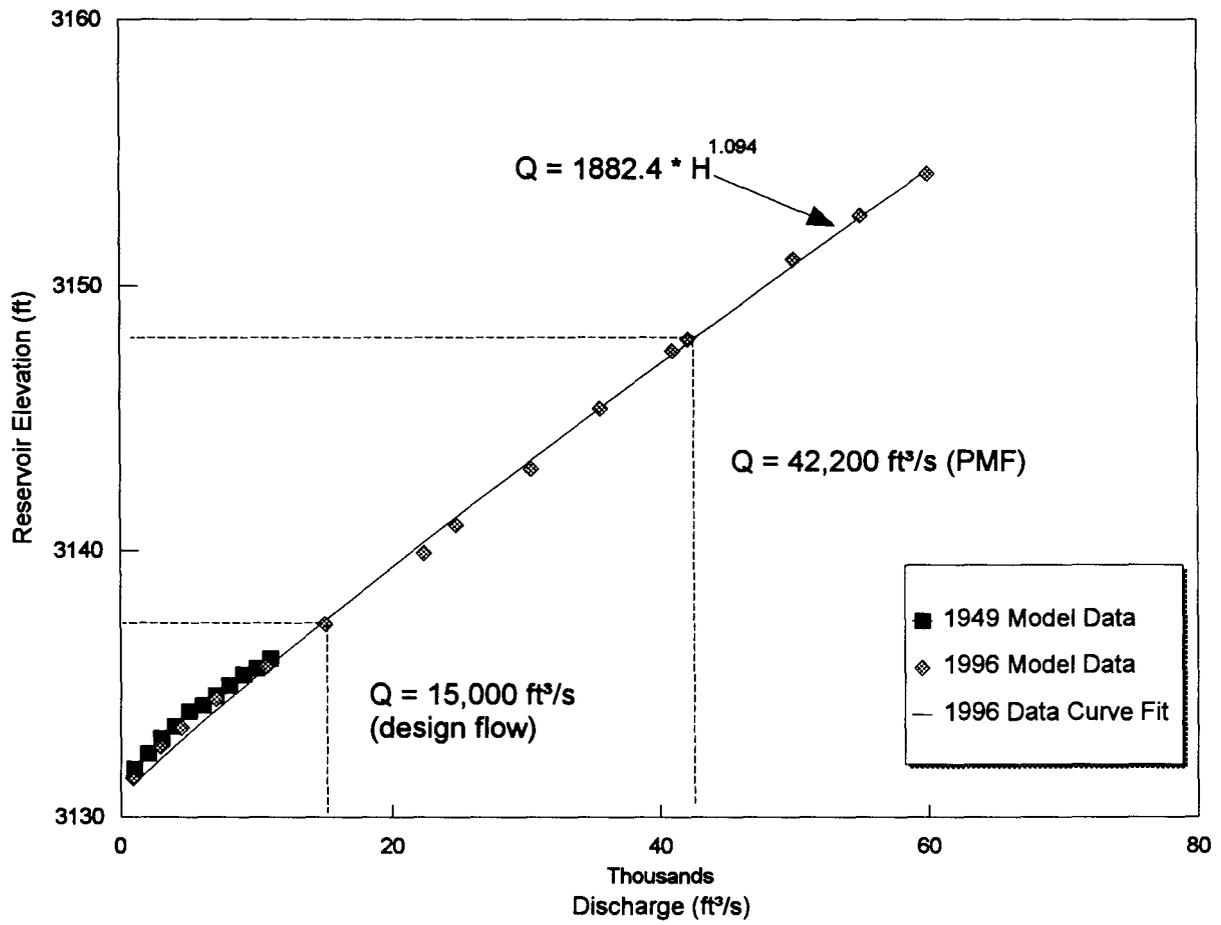
Figure 8. - Discharge rating curves for the 1949 and 1996 model studies.
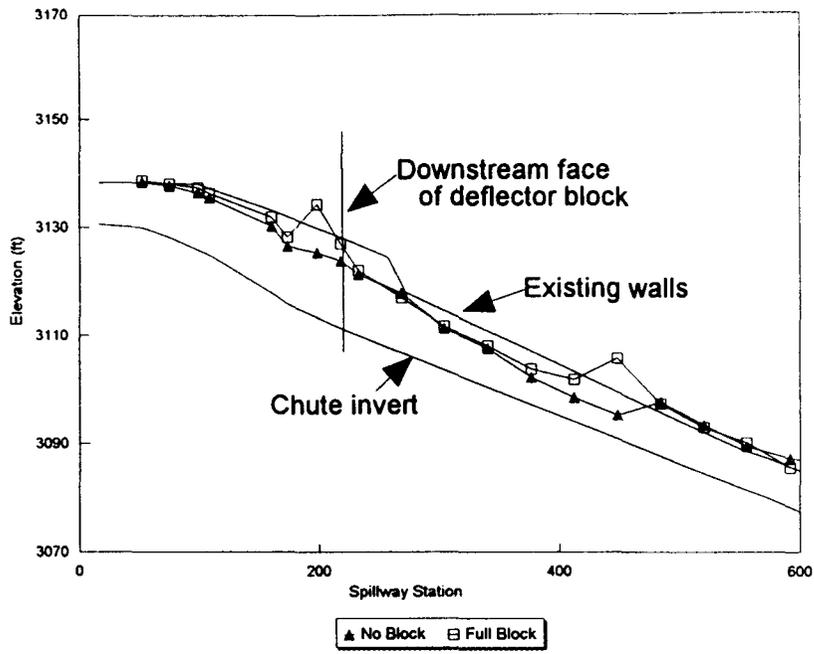
a) Left chute wall profiles
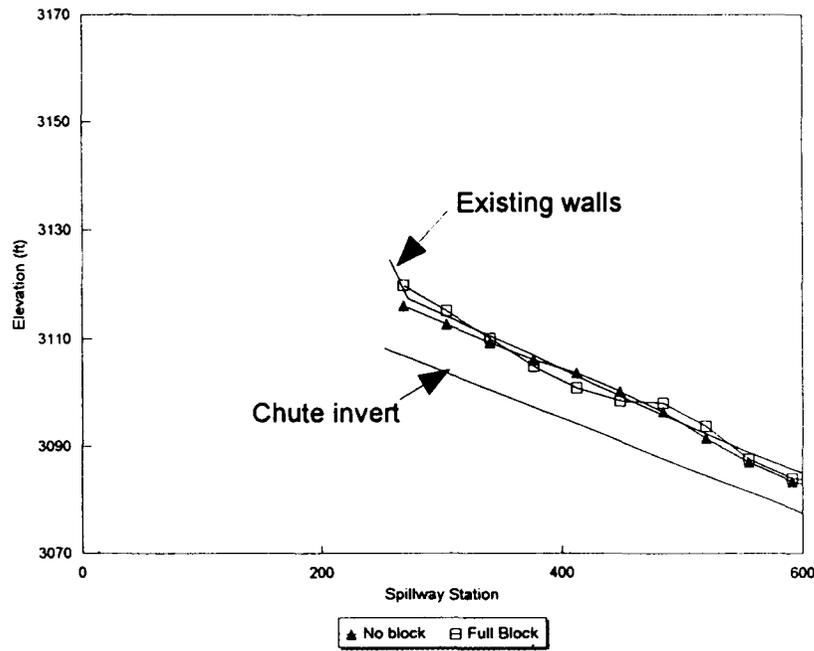
b) Right chute wall profiles

Figure 9. - Water surface profiles shown with and without the upstream deflector block at design discharge (15,000 ft³/s).

20

a) Section looking upstream at the end of the spillway chute

RIGHT FILLET

b) Isometric view of the right and left fillets

LEFT FILLET
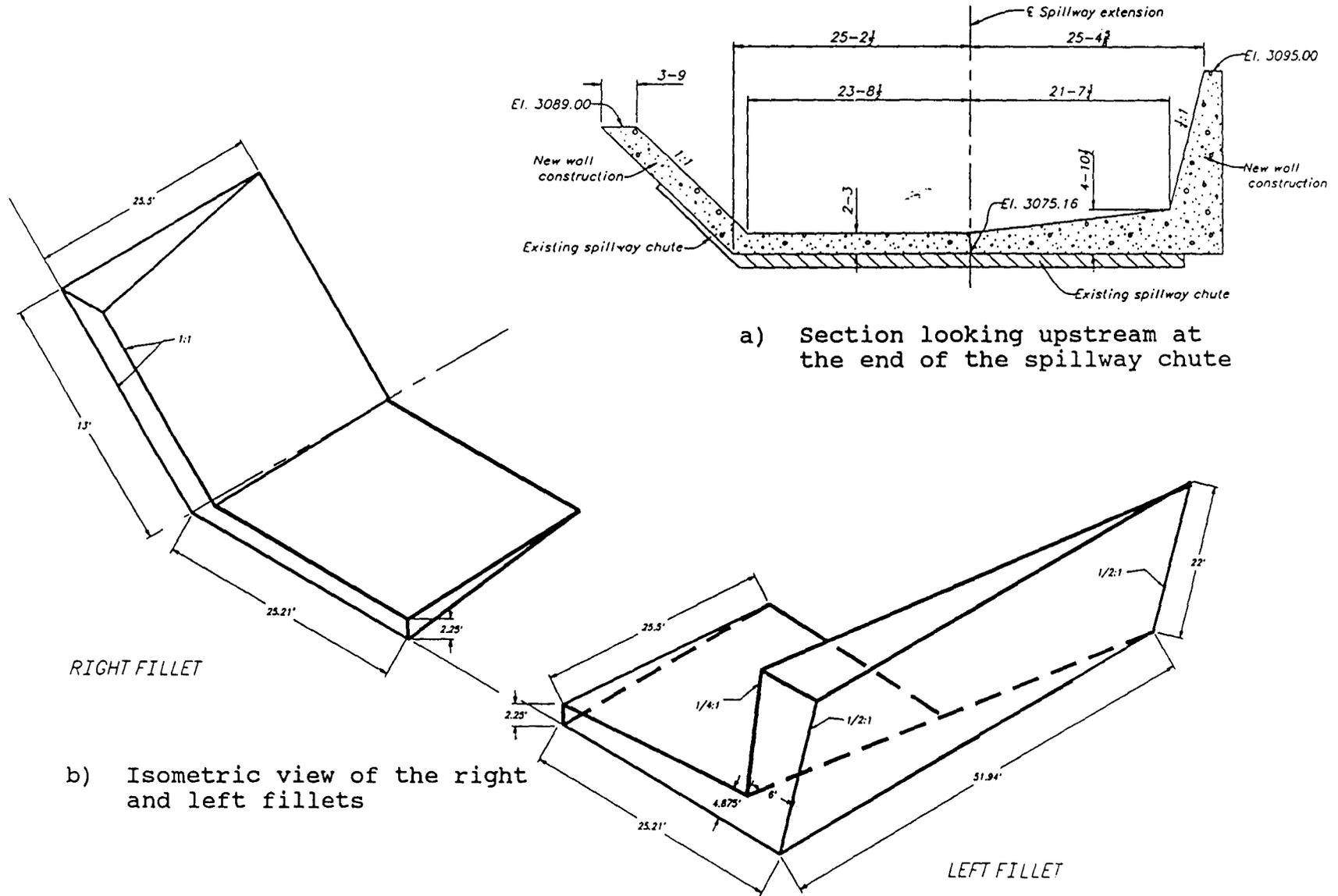
Figure 10. - Final fillet design for the end of the spillway chute.

21
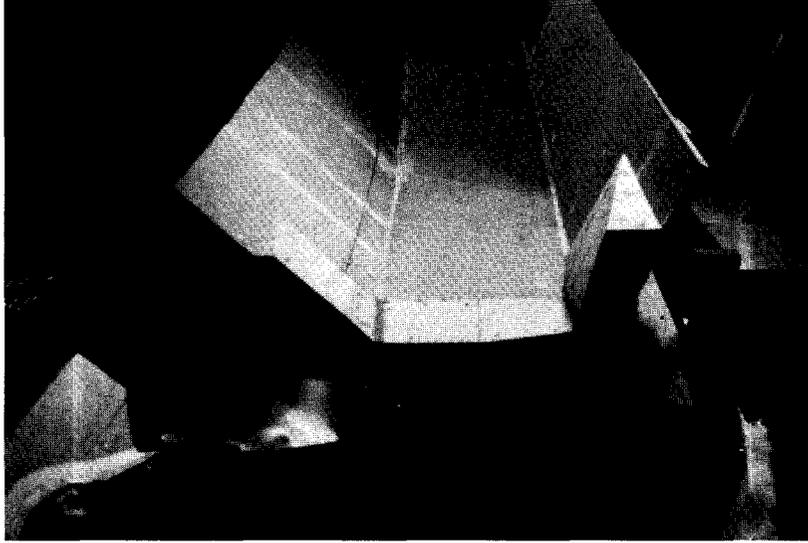
Figure 11. - Final chute fillet design.
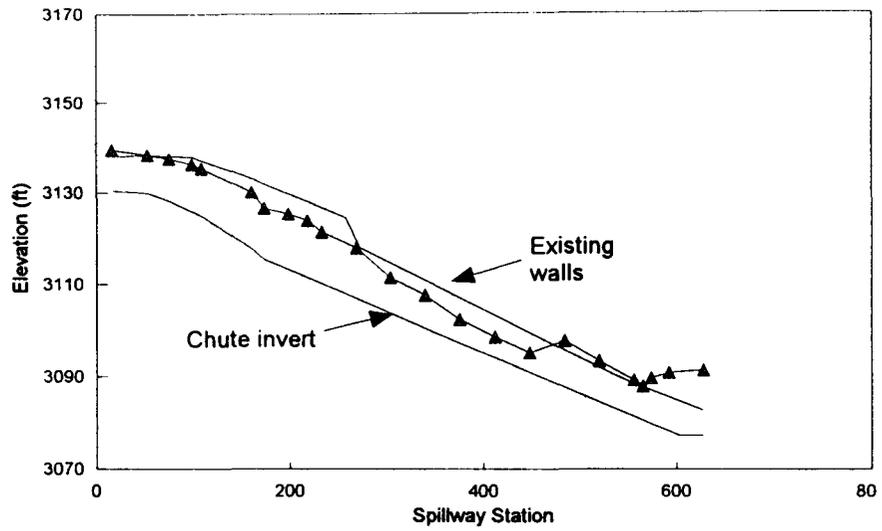
a) Left chute wall profile
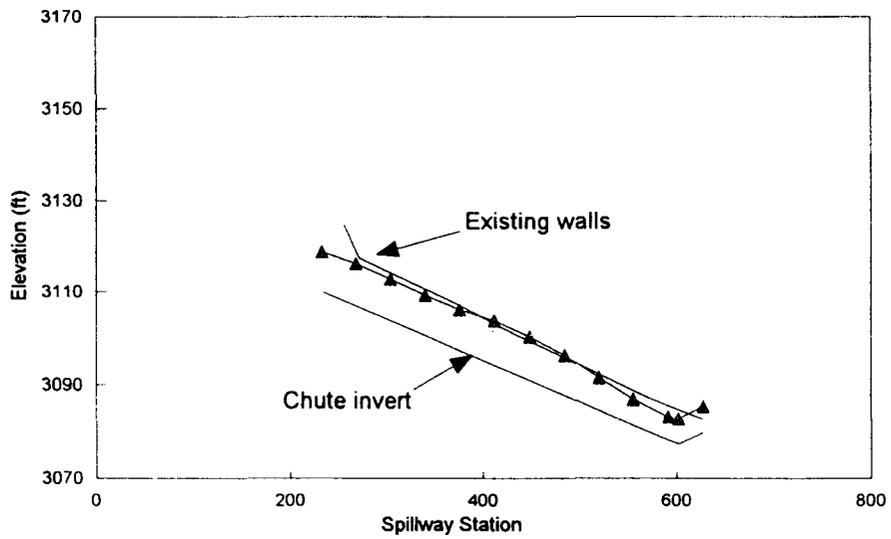
b) Right chute wall profile

Figure 12. - Spillway chute water surface profiles for the final chute design at 15,000 ft³/s.

23

Figure 13. - Final stilling basin design.

24

PLAN

PROFILE ALONG ₵ OUTLET CHANNEL

Figure 14. – Final design for the outlet channel.
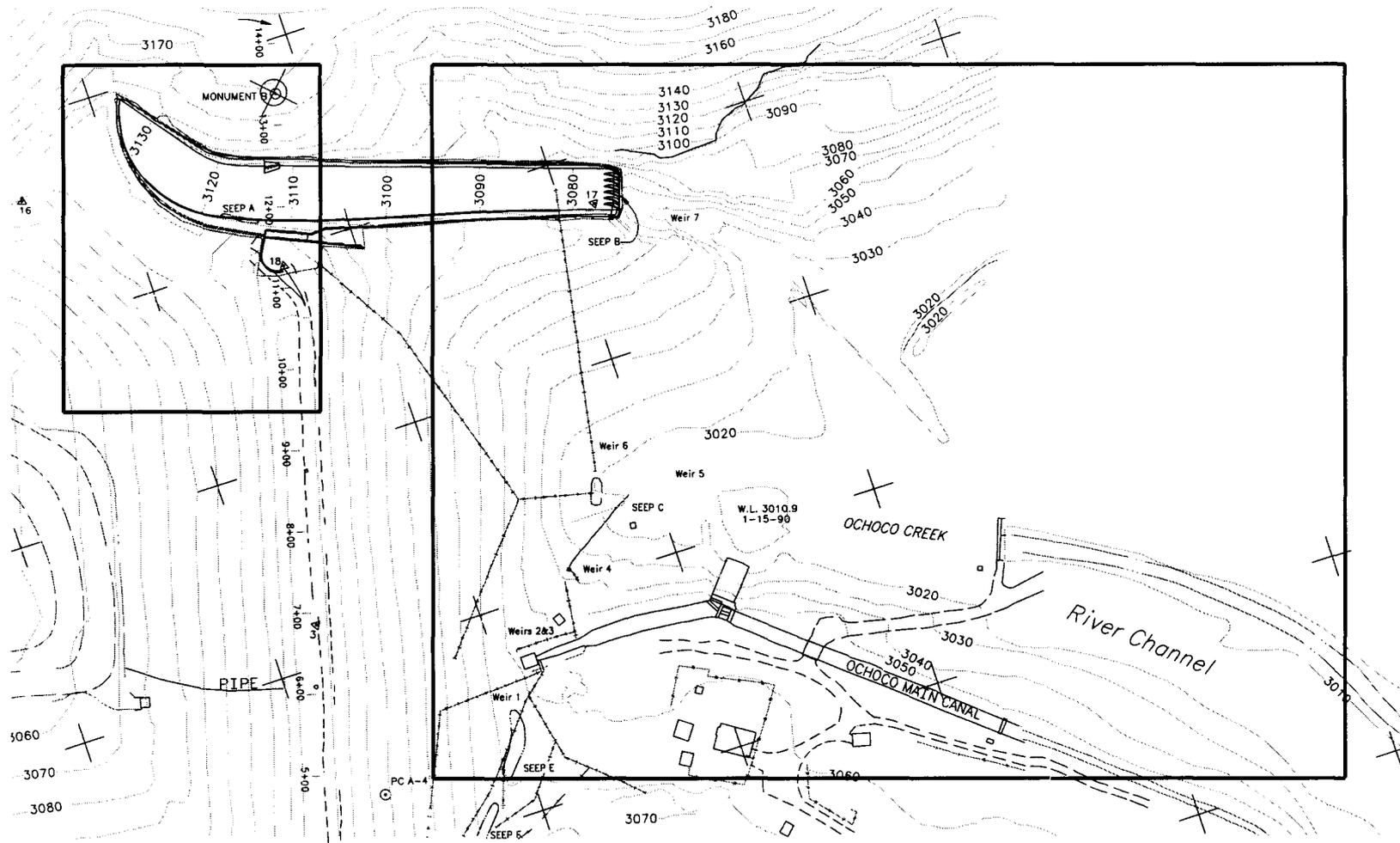
Figure 15. - Outline of model extents with the existing spillway and downstream river channel.
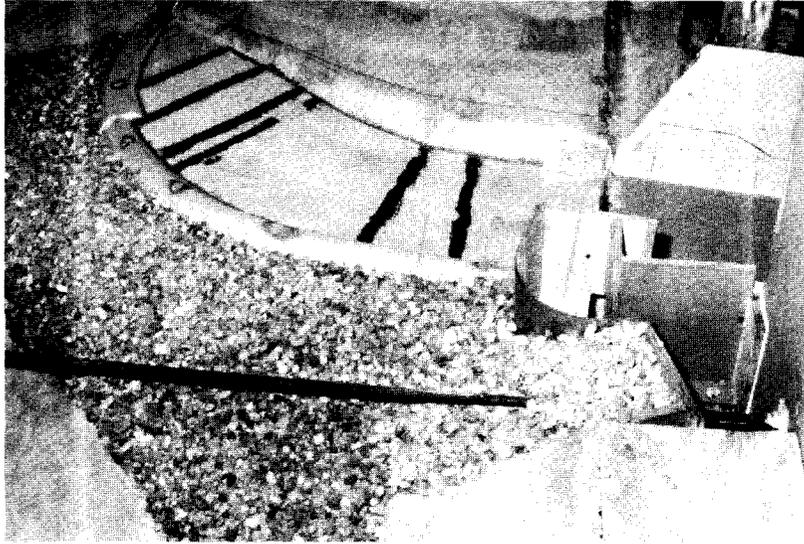
Figure 16. - Modified crest and approach area.
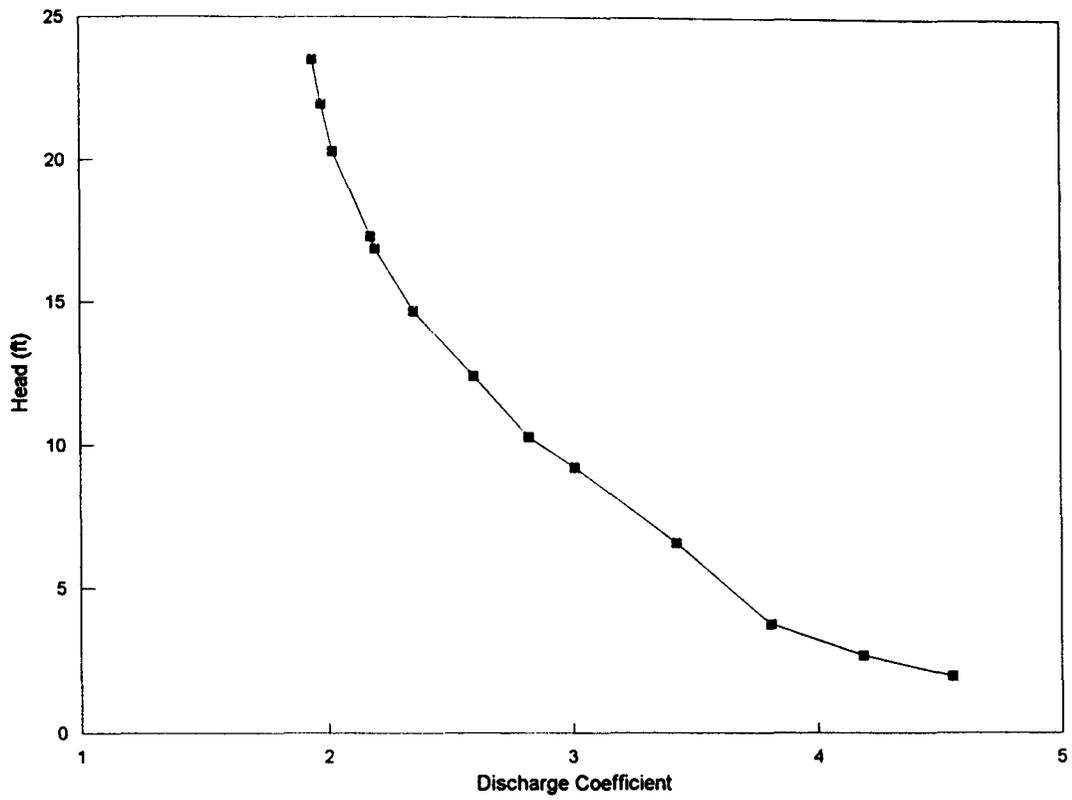
Figure 17. - Head versus discharge coefficient for the modified crest and inlet design.

27
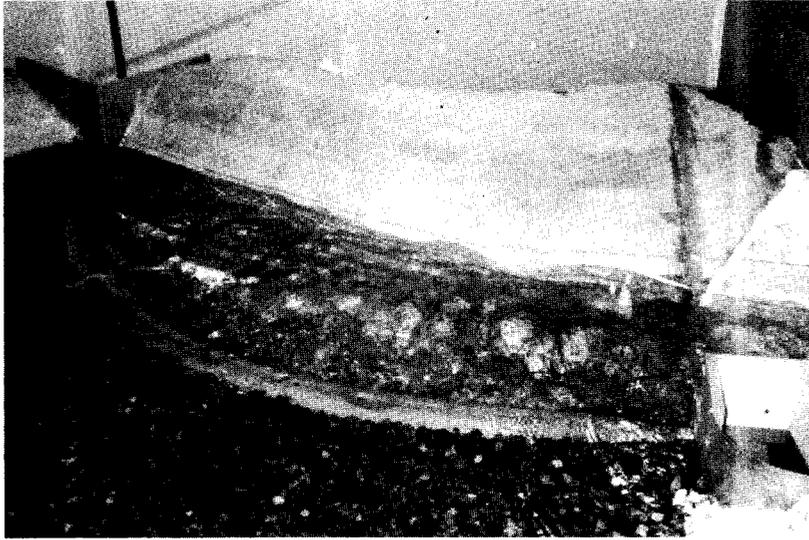
Figure 18. - Flow conditions over the modified crest and approach area at 15,000 ft^3/s.
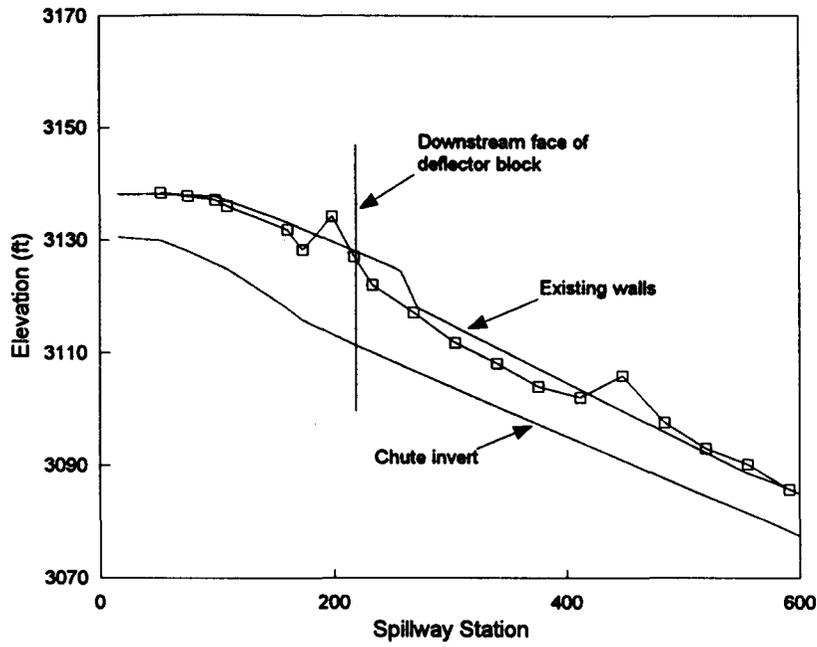
a) Left chute wall profile
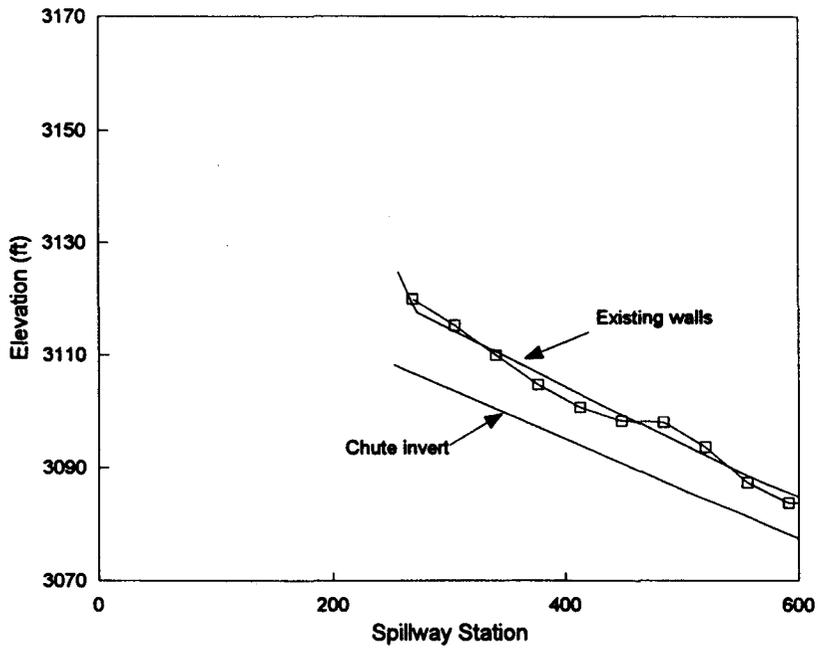
b) Right chute wall profile

Figure 19. - Spillway chute water surface profiles with the deflector block intact at 15,000 ft³/s

29
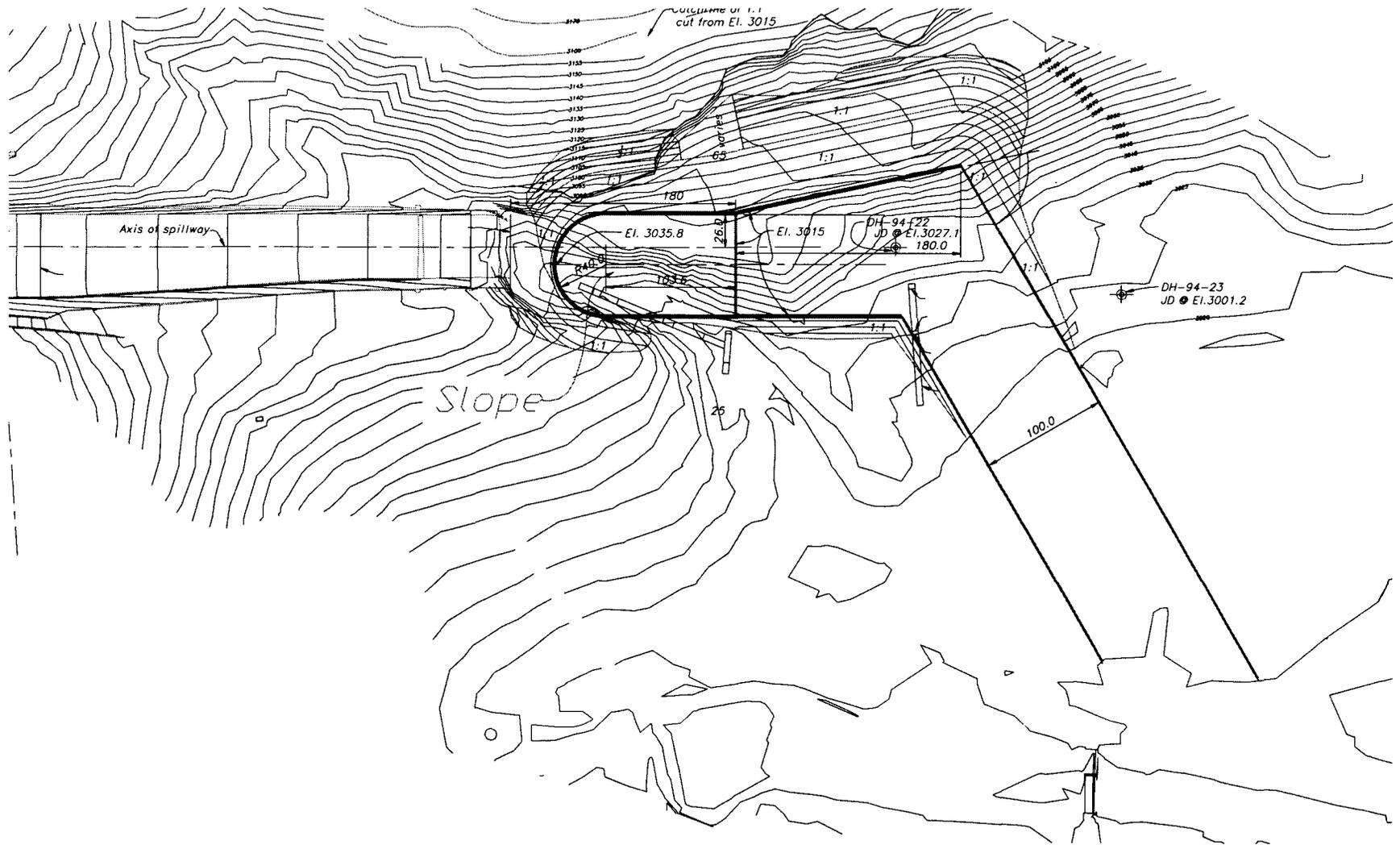
Figure 20. - Excavation boundaries for the initial stilling basin location and design.
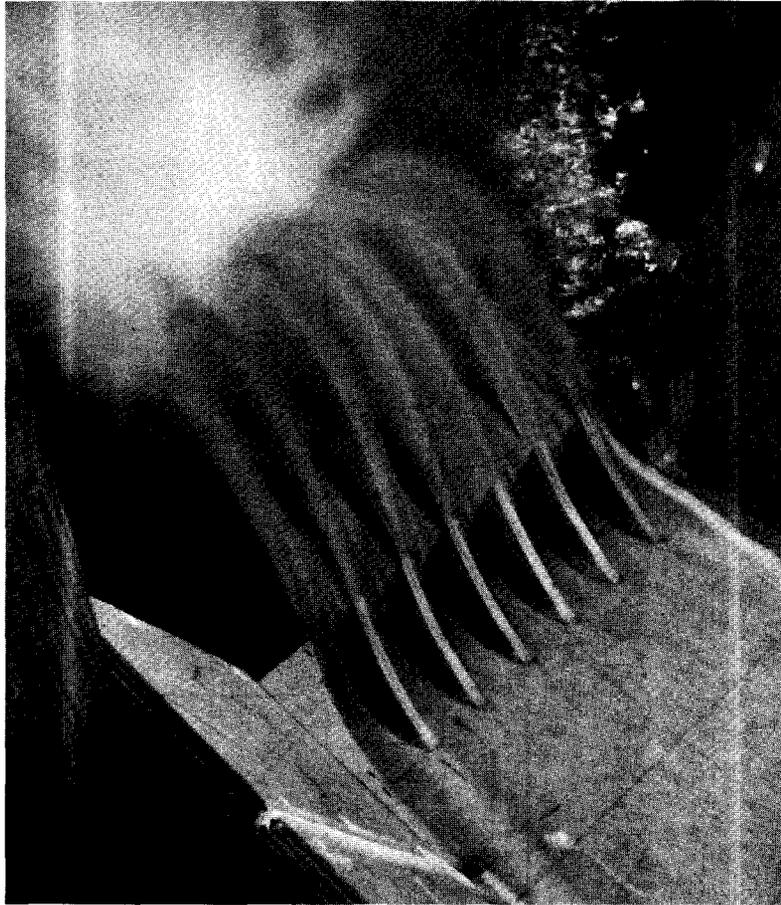
Figure 21. - Deflector vane performance at 5,000 ft³/s.

ORIGINAL BASIN
INVERT OUTLINE

OPTION 1 BASIN
INVERT OUTLINE

END OF SPILLWAY
CHUTE

EI. 3040.6

END OF
RAMP

69.8'

59.4'

12'

25'

R=23.25'

Sta. 6+27.3

24'

LOCATION OF UPSTREAM
TOE OF MAIN SILL

EI. 3025.0

36.75'

68.5'

107.6'

13.33'
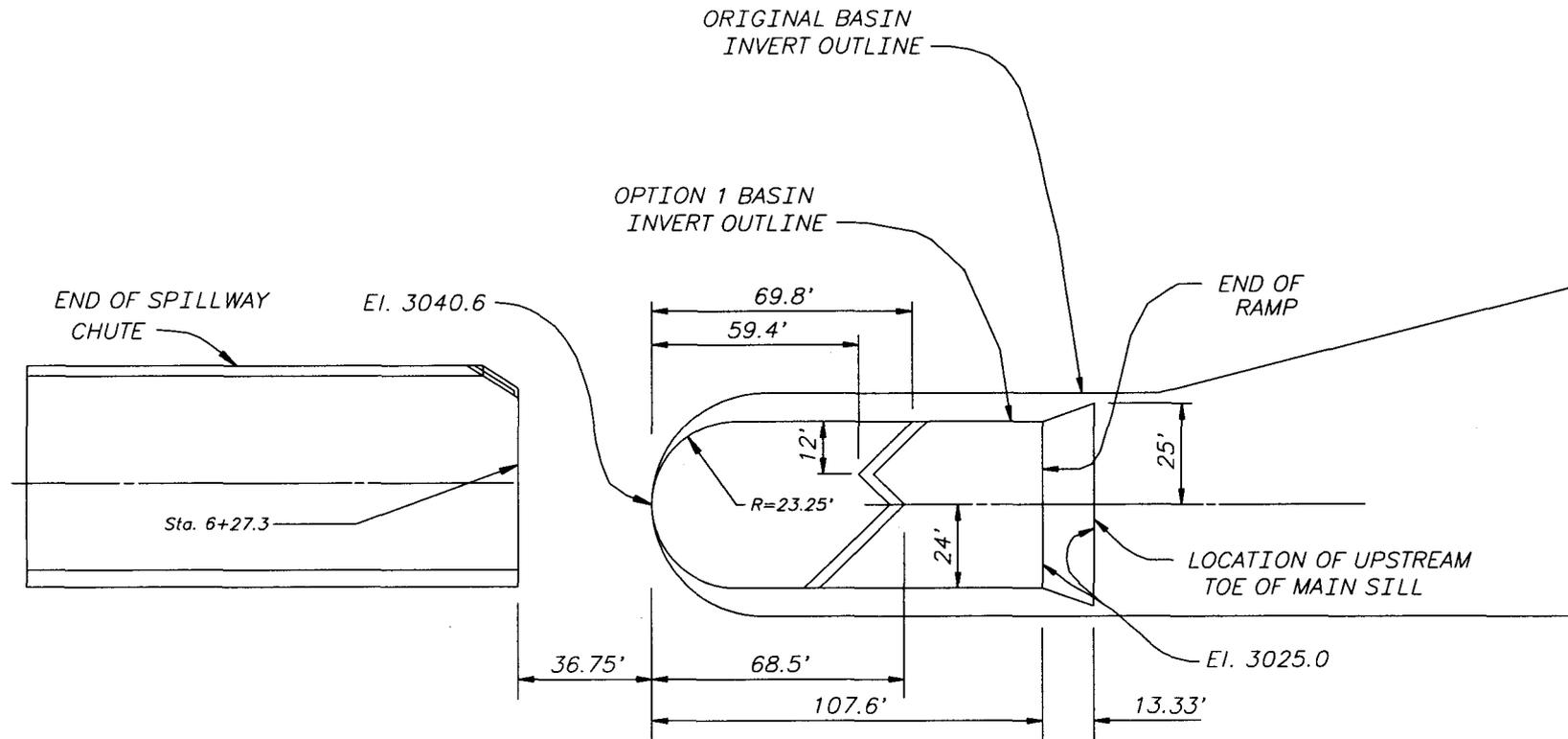
Figure 22. - Design for option 1 showing the zigzag sill located on the basin slope and the narrower basin width compared to the outline of the original invert design.

ORIGINAL BASIN
INVERT OUTLINE

OPTION 2 BASIN
INVERT OUTLINE

END OF
RAMP

END OF SPILLWAY
CHUTE

El. 3040.6

25'

Sta. 6+27.3

R=21'

24'

LOCATION OF UPSTREAM
TOE OF MAIN SILL

36.75'

SEE, DETAIL 1

El. 3025.0

107.6'

27.75'

Right Chute Wall
1:1

Sta. 627.3
El. 3031.5

MATCHES CHUTE
INVERT

Sta. 627.3
El. 3075

DETAIL 1
SPILLWAY CHUTE FILLET DESIGN FOR OPTION #2
ISOMETRIC VIEW
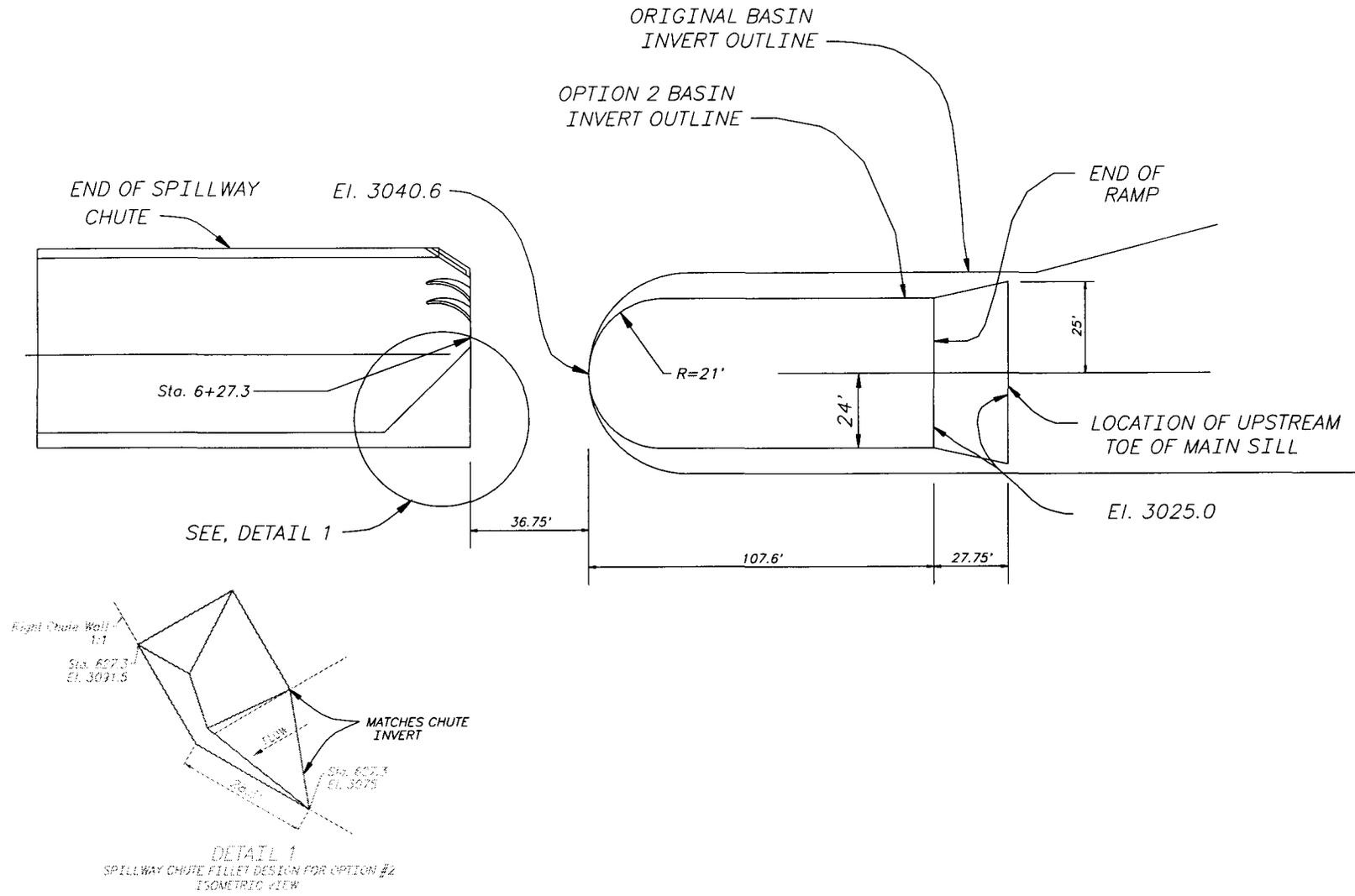
Figure 23. - Design for option 2 with respect to the outline of the original invert design.
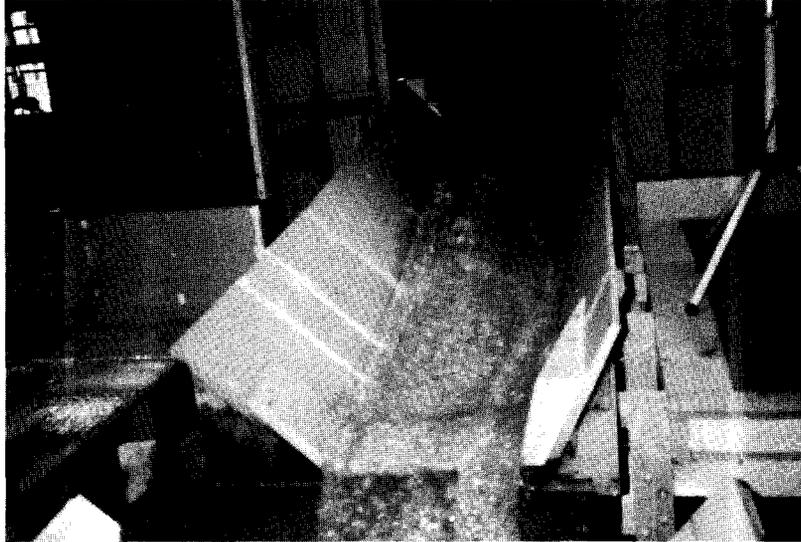
Figure 24. - Flow conditions for the final spillway chute design at 15,000 ft³/s.

Figure 25. - Flow conditions for the final stilling basin design at 15,000 ft³/s.

34
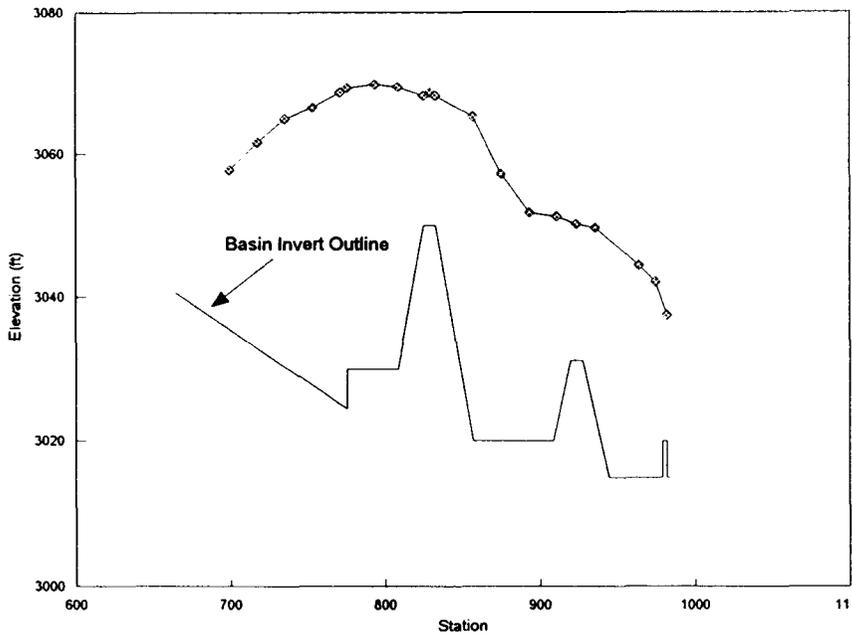
a) Left basin wall profile
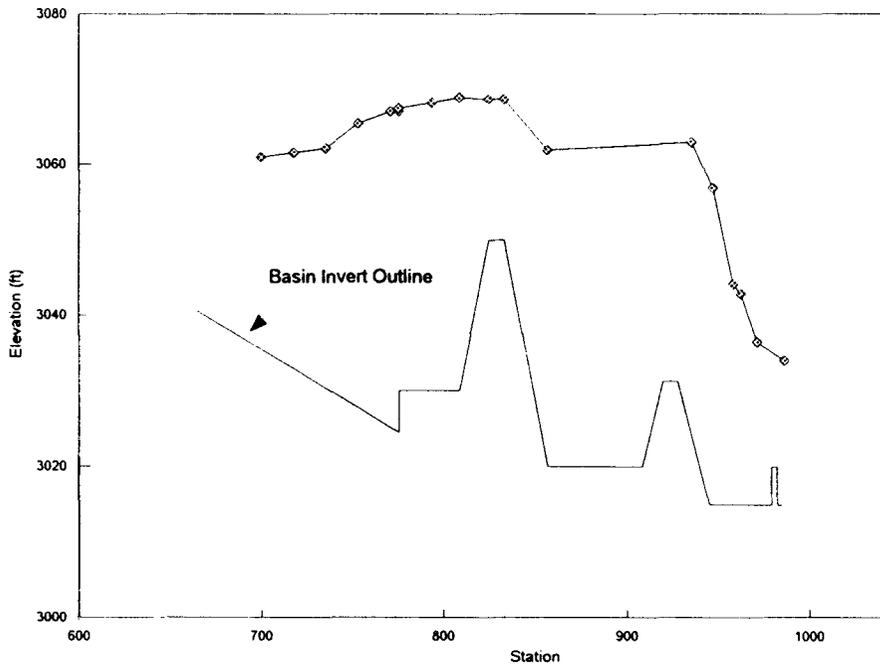

Figure 26. - Stilling basin water surface profiles for final basin design at 15,000 ft³/s for the a) left wall and b) right wall.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.