UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 167

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MODEL STUDIES FOR CALIBRATING SINGLE GATE ORIFICES

By

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Denver, Colorado
Feb. 12, 1945

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SUBJECT: MODEL STUDIES FOR CALIBRATING SINGLE GATE ORIFICES

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Under Direction of

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Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
February 12, 1945

Laboratory Report No. 167
Hydraulic Laboratory

Compiled by: C. V. Adkins
Reviewed by: J. E. Warnock

Subject: Model studies for calibrating single gate orifices.

1. There is a requirement for a small, cheap device to be installed at the ends of small laterals, capable of measuring accurately deliveries up to five second-feet. Figure 1 shows an arrangement for orifice measurement requiring but one open-type gate. It also shows an arrangement for measurement in a right-angle turnout from a lateral. These arrangements are not in accordance with conditions under which orifices have been rated so it was requested that a full-scale model be tested in the laboratory for the conditions outlined in paragraph 2.

2. From model studies it was desired that the discharge in second-feet be obtained for the combinations of opening and submergence of the gate, and difference in head across the gate as shown in table 1, where "U" equals the gate opening or distance from the bottom of the gate leaf to the floor level; "h" equals the corresponding difference in water surface one foot upstream and one foot downstream from the gate, or the difference in head across the gate; and "S" equals the corresponding distance from the bottom of the gate leaf to the water surface on the downstream side of the gate, or the gate submergence. A coefficient of discharge was to be obtained for each of

the combinations and an answer given to the question as to whether the amount of submergence affects the coefficient of discharge. Observations were to be made to see whether the turbulence was such as to prevent accurate reading of a staff gage.

Table 1

U in feet	h in feet	S in feet	U in feet	h in feet	S in feet
0.2	0.05	0.5 to 1.0	0.8	0.05	0.2 to 1.0
0.2	0.20	0.6 to 1.0	0.8	0.20	0.4 to 1.2
0.2	0.40	0.6 to 1.2	0.8	0.30	0.5 to 1.2
0.4	0.05	0.5 to 1.0	1.2	0.05	0.2 to 1.0
0.4	0.20	0.5 to 1.0	1.2	0.10	0.2 to 1.0
0.4	0.40	0.5 to 1.2	1.2	0.15	0.2 to 1.0

3. Due to difficulty in obtaining material for model construction the model was built to a 1:2.0 scale instead of full scale. Piezometers were placed in the channel walls one foot, prototype, each side of the gate and just above the floor level to measure the head across the gate. One pair of piezometers was connected to a differential water gage and the other pair to a water manometer.

4. Runs were made on the straight-ahead delivery arrangement for each of the specified gate openings. It was found that the gate would pass five second-feet for all except the 0.2-foot, prototype, opening. For this opening the maximum discharge was approximately three second-feet with the gate just submerged. The first discharge coefficients obtained were very unstable. When the velocity head of approach was considered, the coefficients were much more stable.

The coefficient could be varied for a constant flow by changing the submergence on the gate. For the smaller and larger gate openings the coefficient varied more than for the intermediate openings. It also increased for the larger openings. The head differences across the gate at large openings were so small that any error in reading would cause a large error in the discharge. Figure 2 shows values of $\frac{H}{U}$ plotted against values of C, where $C = \frac{Q}{A\sqrt{2gH}}$ and H equals the head difference across the gate plus the velocity head of approach. The discharge curves on figure 1 do not hold, since the velocity head of approach was not considered in their determination.

5. The condition of the water surface below the gate for measuring depends upon the control downstream. The water surface was too rough when operating the gate unsubmerged or at low submergence. An unsubmerged gate operating at the larger openings resulted in an intolerable water surface above the gate. It was possible to get an hydraulic jump which boiled against the upstream face of the gate. This condition could be eliminated by either raising the tailwater or closing the gate or by a combination of the two adjustments.

6. If the discharge coefficient could be raised it would become more stable since it would have a smaller range over which to vary. A lip having a 2.50-inch radius, model, was placed on the upstream face of the gate in an attempt to raise the coefficient, detail 1, figure 2. This arrangement raised and stabilized the coefficient as may be seen by comparing the two curves on figure 2. The coefficient became 1.0 for gate opening of 1.2 feet, prototype. The difference in head was so small that any error in reading would make a

large difference in discharge. Since a coefficient of 1.0 is impossible, it is evident that the method of measurement is not refined sufficiently for measuring small heads. The maximum gate opening would, therefore, be limited to 0.8 foot, prototype. This means of determining the discharge is not practical for field use since the velocity head of approach must be included to obtain a constant coefficient. The method was therefore abandoned. A staff gage would be of no value either since the velocity head of approach would not be determined by it. Furthermore, for submerged operation, an hydraulic jump formed below the gate, making the water surface too rough for staff gage reading.

7. Several designs of pitot tubes were used in an attempt to measure the velocity under the gate. For most cases the differential reading on the tube was so small that any error in reading caused considerable error in the discharge. This was evident in that even though extreme care was exercised in obtaining readings, a constant coefficient was not obtained for the pitot tubes. The velocities on this arrangement were too low to create a head differential large enough to reduce sufficiently the personal error. A pitot-tube arrangement could be used successfully for a design where the velocities are of the order of four feet per second or greater. The pitot-tube arrangement was abandoned for this design.

8. An observation run was sufficient to demonstrate that the right-angle turnout was unsatisfactory for accurate calibration. The approaching water piled up on one side above the gate and formed a whirl. The gate should be moved downstream far enough to allow the

approaching water to attain uniform velocity distribution. If moved downstream the arrangement would be similar to the plan for delivery ahead.

9. A constant coefficient could not be obtained for the gate without including the velocity head of approach. For large gate openings this velocity head was equivalent to the head difference across the gate. In such cases the available methods of measurement were not precise enough to obtain accurate results. Any small error in head reading would result in a serious error in discharge. The orifice-gate arrangement for water delivery was abandoned since no practical means could be devised for accurately measuring the discharge in the field.

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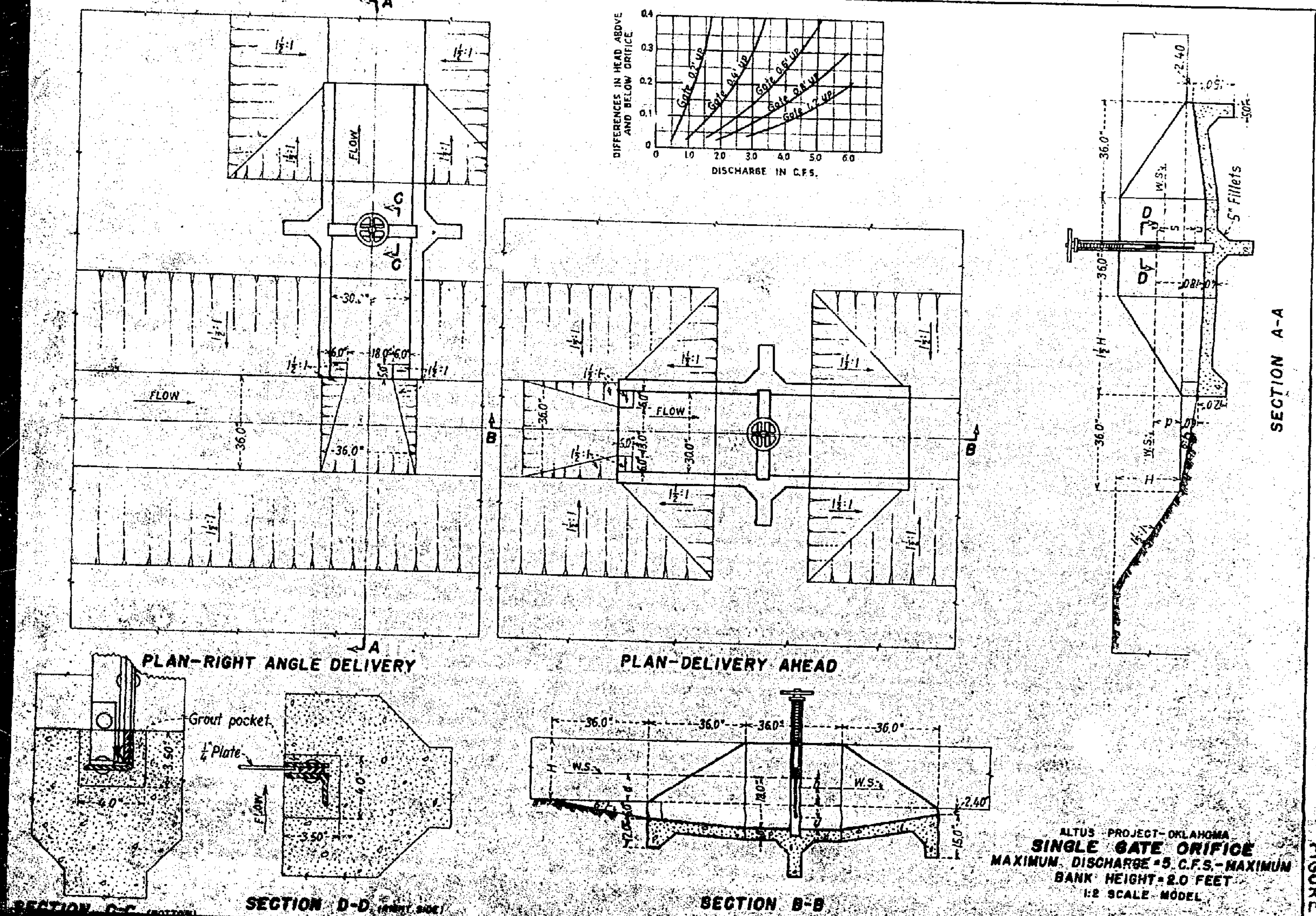
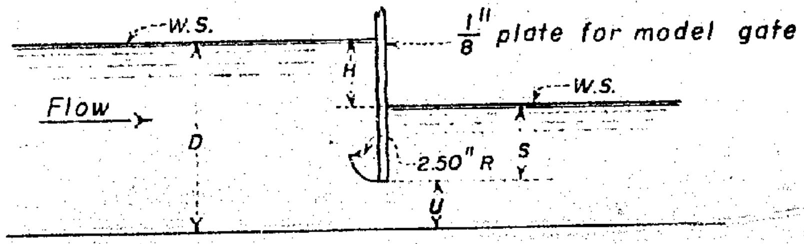


ALTUS PROJECT-OKLAHOMA
SINGLE GATE ORIFICE
MAXIMUM DISCHARGE = 5 C.F.S.-MAXIMUM BANK HEIGHT = 2.0 FEET
1:2 SCALE MODEL

FIGURE 1



DETAIL I

$$C = \frac{Q}{A\sqrt{2gH}}$$

Where H = the difference in head across the gate plus the velocity head of approach.

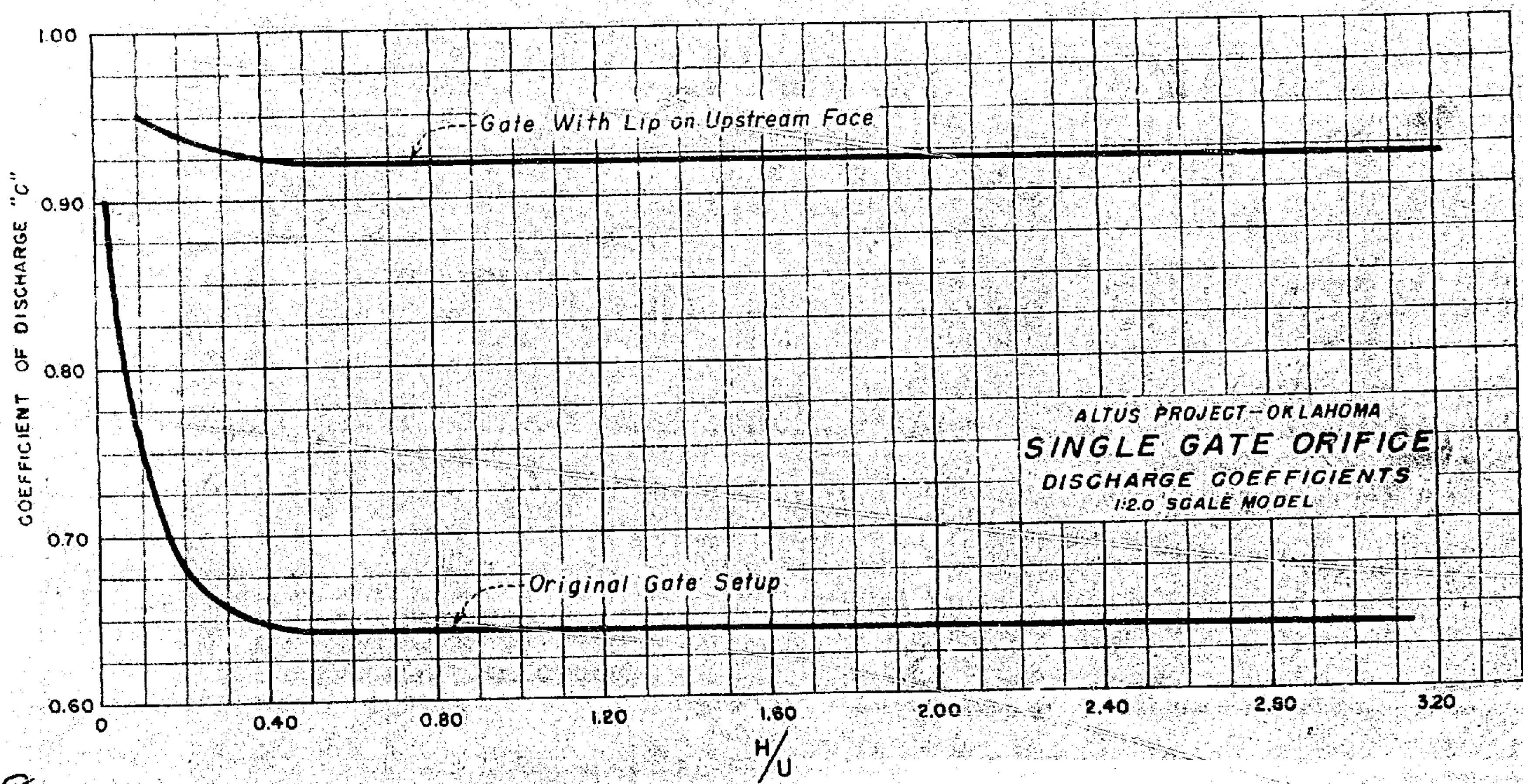


FIGURE 2