HYDRAULICS BRANCH

SUMMARY REPORT

FISCAL YEAR 1968

BUREAU OF RECLAMATION
OFFICE OF CHIEF ENGINEER
DIVISION OF RESEARH
DENVER, COLORADO

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HYDRAULICS BRANCH
DIVISION OF RESEARCH
OFFICE OF CHIEF ENGINEER
Denver, Colorado
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SECTION I - INTRODUCTION

This year witnessed a number of new highlights in the experience of the Hydraulics Branch. A few are mentioned in chronological order: participation in the XIIth Congress of the International Association for Hydraulic Research at Fort Collins and Denver; performance of water measurement tests with isotopes at Flatiron power and pumping plant; completion of hydraulic performance tests of the Yellowtail Dam outlet works hollow-jet valve stilling basin; initiation of studies on hydraulic stability of riprap material; initiation of studies of driven-well packing; completion of performance tests on the Canadian River Aqueduct.

Upon the optional retirement of A. J. Peterka, a change in the organization of the Branch was made to meet the ever-increasing technical challenges in a wide variety of hydraulics and all that it entails. (High degree of capability in fluid mechanics techniques, mathematics, computer technology, instrumentation, and ability to write and speak in the present-day technical language.)

The responsibilities of the Special Investigations Section were redefined as the Hydraulics Research Section and the Section contains personnel qualified to carry on the advanced research. Greater emphasis in the future will be required in the employment of advanced techniques in hydrodynamics, fluid mechanics, mathematical modeling, instrumentation, and analog and digital technology. Dr. Henry T. Falvey was promoted to the position of Head of the Hydraulics Research Section.

At the same time, the other section was defined as the Applied Hydraulics Section to continue the model studies applied to the design of structures and equipment as in the past and to include research of the more applied nature; W. E. Wagner is Section Head.

The Branch had the opportunity of a generation in being host to a large number of visitors who attended the XIIth Congress of IAHR held in Fort Collins, Colorado, September 11-14, 1967. Over 180 visited the laboratory on September 9 and several dozen in addition following the Congress, Figure 1. Messrs. Carlson, King, Falvey, Schuster, and Martin attended the Congress. Martin attended as the Bureau member of the National Advisory Committee for the Congress and the others presented papers. The XIIth Congress was characterized by the depth of many papers, the excellence of reporters, and the wealth of valuable research information available to those who attended the technical sessions and had discussions with eminent research engineers.

Figure 1

Tour of the Laboratory by International Association for Hydraulic Research and the International Hydrology Symposium - September 9, 1967

L. to r. - L. J. Tison, former member of Council and one of the founders of IAHR; H. M. Martin, W. E. Wagner; Mrs. H. J. Shoemaker; H. J. Shoemaker, Director, Waterloopkundig Laboratory, Delft, Holland and Secretary of IAHR.

Enos J. (Jim) Carlson won a $750 Special Act Award for his design of a "washing machine" rig which flushes the gravel bottoms of canals which provide spawning beds for salmon. The rig was used in the Tehama-Colusa Canal, Central Valley Project, which both conveys water and provides spawning facilities as an important fringe benefit to the California salmon industry. The canal was unsuitable for spawning due to sediment collecting along the gravel bottom, before Mr. Carlson came up with a solution, welcomed by a dozen Federal, state, and private agencies trying to combat the problem. Carlson's rig scours the canal bottom by use of a motorized baffle, which is lowered into the canal and forces the water beneath it and into the gravel bed, carrying away the accumulated sediment. A prototype of the canal baffle has been completed by the Washington Department of Fisheries and is used effectively in a canal near Olympia.

Engineering Monograph No. 25 "Hydraulic Design of Stilling Basins and Energy Dissipators" by A. J. Peterka, Research Division, went into its fourth printing since original publication in 1958, according to information recently received from the Superintendent of Documents.

Danny L. King served as President of the Denver Federal Center Professional Engineers Group this year.

On request of Utah State University, A. J. Peterka again lectured and lead discussions at the Utah Irrigators' Workshop at Logan, Utah, on the subject, "Water Measurement and Control." The workshop was held December 4-6, 1967.

In the interests of recruitment of graduating engineers, Harold M. Martin lectured to seniors and graduate students at the University of Iowa and Iowa State University in March 1968.

A mark of progress of research in flow of ground water was the publication of the Hydraulics Branch research study on Removal of Saline Water from Aquifers as a Department of Interior Water Resources Technical Publication, Research Report No. 13, authored by Enos J. Carlson.

Henry T. Falvey represented the Bureau at the MIT Third Biennial Meeting on Current Research in Hydraulics and Water Resources. The meeting provided an opportunity to observe the mathematical and experimental techniques successfully employed by one of the leading institutions in the country in the field of hydrodynamics and water resources.

Uldis J. Palde of the Hydraulics Branch participated in the Bureau Engineer Interchange Program from November 1, 1967 to May 1, 1968 at Sacramento. The purpose of the interchange program is to broaden the experience of selected engineers and increase their awareness of necessity for close cooperation between all departments of an agency. Clark P. Buyalski of Region 2 interchanged positions with Palde.

T. J. Rhone was appointed a member of Value Engineering Team No. 1, filling a vacancy created by the retirement of A. J. Peterka. The team will continue studies of penstock intakes and appurtenances.

Harold M. Martin continued his service as Chairman of the Water Resources Coordinating Committee of the American Society of Civil Engineers.

A. J. Peterka participated in the Western Water and Power Symposium at Los Angeles, California, April 8-9, 1968. He presented his paper, "A New Look at Penstock Entrance Designs," co-authored with E. A. Lindholm.

Mr. Peterka also lectured in March 1968 at the University of Wisconsin, Marquette University, and Wisconsin State University in connection with the college contact program.

As mentioned previously, A. J. Peterka retired with nearly 33 years of Federal service. After graduation from Case Institute of Technology, he began his Government career with the War Department in 1935. In 1936, he transferred to the Tennessee Valley Authority where he remained until July 1946, when he entered on duty in this office. He advanced to Head of the Special Investigations Section in July 1961.

He authored and co-authored innumerable papers and publications, many of which he presented to professional societies and to the general public. In 1949, he received the "James Laurie Prize" awarded by the ASCE for his paper, "Friction Coefficients in a Large Tunnel." He also wrote and narrated a 1-hour film which has been shown many times to trainees and visitors in the Hydraulic Laboratory.

Al is a Registered Professional Engineer in Colorado. He is a Fellow in the ASCE, and has served as a member and chairman of various committees in this organization. He was elected to the "U.S. Committee of the International Commission on Large Dams" and to the honorary fraternity, "Society of Sigma Xi." He was awarded a "Certificate of Appreciation" for his work in presenting technical material on educational television, KRMA-TV in Denver, Colorado. He has received two Special Act Awards, one each in 1962 and 1963, for co-authorship of technical papers which brought recognition to him and to the Bureau. In 1966, he received a Quality Increase.

He also has been active in civic affairs; served as a rating panel member on the Central Board of Examiners; served as a member of the Suggestions Sub-committee of the Incentive Awards Committee; is a past president of the Reclamation Technical Club; is a member of a Value Engineering team; and was a most enthusiastic college recruitment engineering representative.

SECTION II - STUDIES FOR BUREAU PROJECTS

This year the Branch experienced a wide variety of problems in the design and operation of structures, conveyances, and equipment. Several were studied with hydraulic models in the laboratory and others were studied in the prototype. Other studies were made using data available in laboratory reports, papers, and publications.

Hydraulics Branch reports, papers, and publications issued this year are listed in Section VII of this report. Nearly 400 pages of notes were dictated during the year on the activities of the Branch, including consultations, technical correspondence, technical conferences, and related responsibilities.

The major studies of the year were:

- Yellowtail Dam outlet works tests
- Yellowtail Dam spillway performance
- Grand Coulee Third Powerplant
- Tiber Dam Auxiliary outlet works
- Canadian River Aqueduct tests
- Conconnully Dam Spillway
- Bacon Siphon, Columbia Basin Project
- Grand Coulee Third Powerplant intake studies
- Tehama-Colusa Fish Concentrator
- Westlands District flow controller studies
- Morrow Point Dam spillway gate studies
- Grand Coulee Pump-turbine system studies
- Navajo Dam outlet works inspection
- Electronic instrumentation in field tests
- Wahluke Branch Canal turnout
- Grand Coulee Third Powerplant draft tube surge studies - Meeting with Board of Consultants

Yellowtail Dam Outlet Works Pressure Tests

In the interest of verifying analytical and laboratory studies of transient pressures in hydraulic stilling basins, pressure transducers and accelerometers were installed in the centerwall of the hollow-jet valve outlet stilling basin of Yellowtail Dam, illustrated in Figure 2.

From November 13-18, 1967, outlet works stilling basin was operated for five balanced flows between 3,000 and 5,000 cfs for a tailwater elevation of about 3185, five flows 500 to 2,500 cfs through only the right-hand side of the basin for a tailwater elevation of about 3186, and for seven balanced flows between 3,000 and 5,000 cfs for a tailwater elevation of about 3190. Pressure transducer and accelerometers measurements were recorded by direct-writing and magnetic tape recorders from instruments installed in the centerwall of the stilling basin, Figure 3.

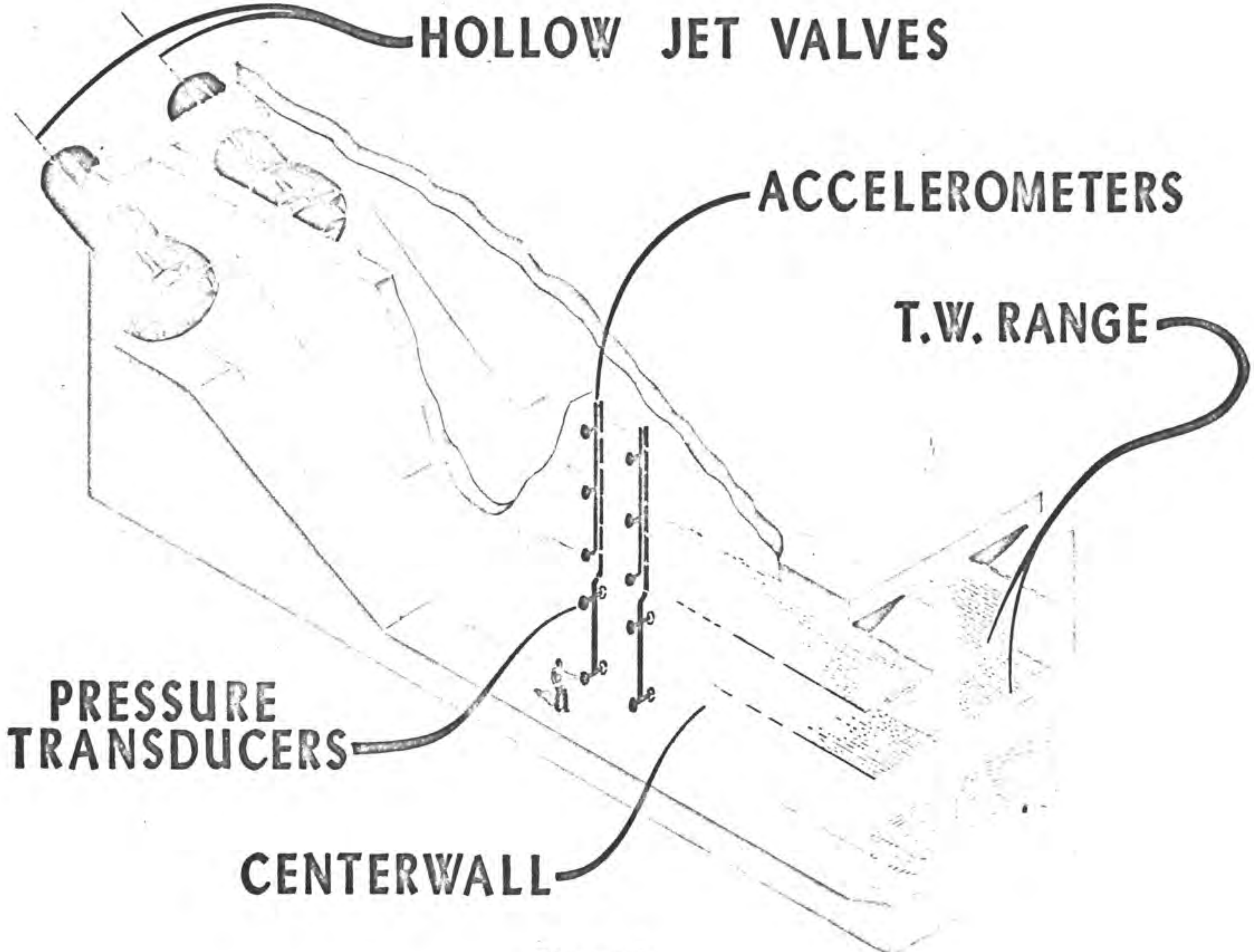


Figure 2

Location of pressure transducers in stilling basin

Discharge 5,000 cfs (design capacity). Valves open 49% at 445 feet of head. Tailwater elevation 3190; corresponds to Q from powerhouse of 7,500 and 5,000 cfs from stilling basin. Tailwater range for 12,000 cfs is from 3183 to 3190. H-1615-INA

Figure 3

Instrumentation arrangement: L to R

a. 7-channel, record/reproduce amplifiers; b. 14-channel frequency modulated magnetic tape transport (pressure recording); c. Honeywell, Electronick 19, high impedance recording voltmeter; d. Sanborn 2-channel carrier amplifier direct writing recorder (acceleration); e. 8-channel, carrier amplifier system for transducer signal condition to FM tape and; f. 8-channel, Sanborn direct-writing recorder for pressures; g. terminal box for transducer cables.

Yellowtail Dam Outlet Stilling Basin Tests

Reservoir elevations, tailwater elevations, operating heads, valve openings, and other related data were recorded during the tests. The maximum recorded differential pressure across the centerwall was 68 feet of water and the maximum pressure fluctuation on one side was 76 feet of water. Test recordings were of 3 minutes' duration; longer recordings might have showed higher pressures. If higher pressures than recorded did occur, there was no evidence of stilling basin movement or vibration, as shown by the accelerometer recordings.

Visual and photographic evidence and pressure and accelerometer measurements show that the stilling basin operation is satisfactory up to and including the design discharge of 5,000 cfs at a head of 442 feet, 24 feet less than maximum head, and for tailwater elevations between about 3185 and 3190, the maximum to be expected. No riprap movement was observed, but the stilling basin should be examined for debris before extensive future operation.

Yellowtail Dam Tunnel Spillway

The Yellowtail Dam tunnel spillway, designed for a maximum discharge of 92,000 cfs, operated over an extended period discharging about 15,000 cfs. Examination after flood releases revealed that the concrete tunnel lining had been damaged extensively by cavitation. A hydraulic scale model was used to design an aeration device for installation in the Yellowtail Dam spillway tunnel which would trap air in the flowing water to act as a cushion to prevent cavitation damage to the flow surfaces. The aerator, a slot perpendicular to the tunnel centerline, uses only the energy of the flowing water to draw air into the spillway stream, and is hydraulically sound at all spillway flows. The recommended aeration slot is now being installed in the sloping spillway tunnel just upstream from the vertical bend, Figure 4.

Aeration slots of various designs were installed in the vertical bend of the model spillway. A slot configuration which would operate satisfactorily at a given discharge could not be made to operate successfully for various discharges. Further model studies must be made to define the secondary flow conditions in the vertical bend before a successful aeration device can be designed for this location.

Grand Coulee Third Powerplant

The 1:120 scale model was used to develop the final configuration of the forebay channel for both 6-unit and 12-unit plants, Figure 5. Considerable modification was necessary to develop a more uniform velocity throughout the width and length of the channel. The model also indicated that the width of the channel could be reduced, resulting in lesser excavation costs. Data were obtained to determine the distribution of velocity in the tailrace channel with and without accompanying operation of the spillway and existing

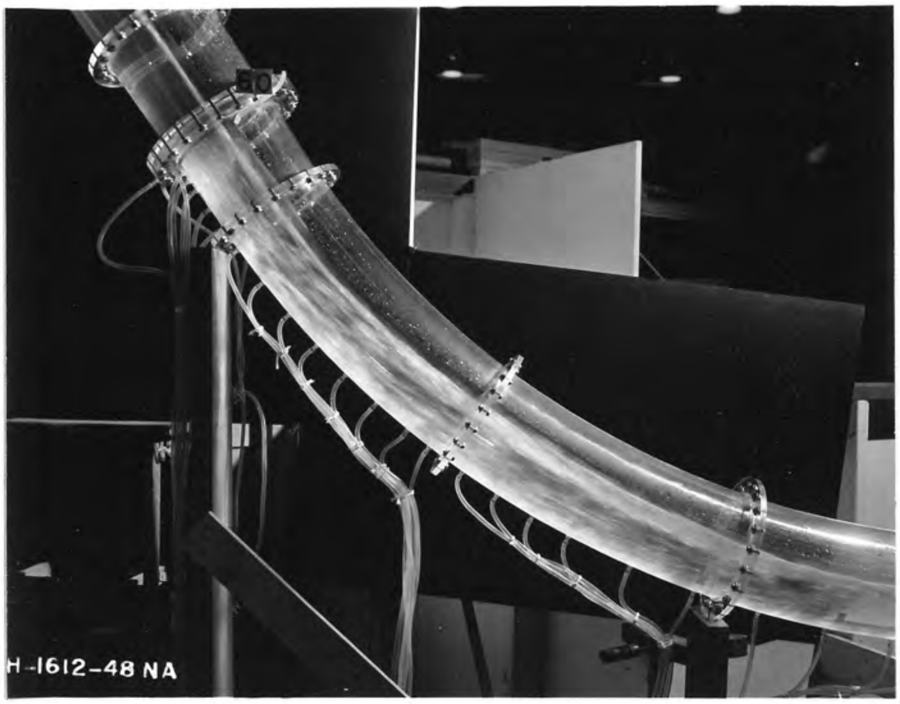


Figure 4

Yellowtail spillway repair study model. The air vent (upper left) draws air into stream.

Q = 60,000 cfs; design
Q = 92,000 cfs

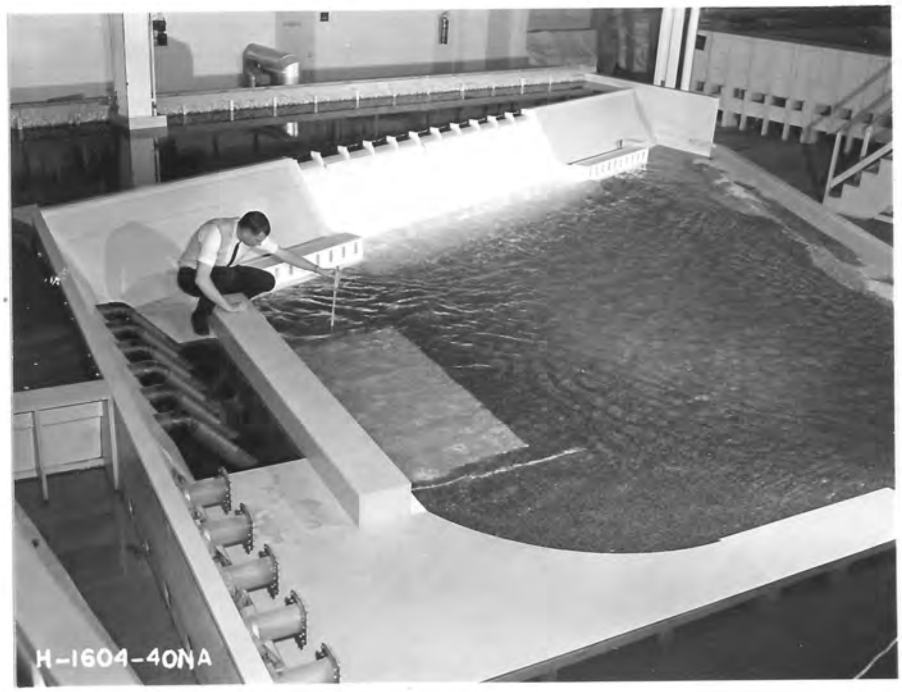


Figure 5

Grand Coulee Third Powerplant model

powerplants. Tailrace configurations and structure locations for both 6-unit and 12-unit plants are being evaluated.

Tiber Dam Auxiliary Outlet Works

The design of the auxiliary outlet works utilizing the existing canal outlet headworks structure containing two 7- by 12-foot slide gates was modeled and tested at a scale of 1:17.53 for flows up to 4,300 cfs at maximum reservoir elevation.

The design includes a drop inlet T-connection at the point of diversion from the modified existing tunnel, a vertical tunnel bend from the T-connection to a nearly horizontal circular tunnel, a 7-foot 3-inch by 9-foot 3-inch high-pressure gate with tunnel transitions upstream and downstream of the gate section, and a stilling basin.

Tests were conducted to determine the effectiveness of the drop inlet and the flow characteristics through the system. The stilling basin or gate was not tested.

Results showed that a curved deflector placed on the crown of the tunnel directly over the drop inlet eliminated the formation of a vortex. The study showed the need for maximum radius of curvature in the invert of the T-connection and along the crown of the vertical bend as well as an increased tunnel diameter to eliminate subatmospheric pressures in these areas. The transition downstream of the gate section was revised and the tunnel was enlarged to prevent choking of the flow.

Further tests were conducted to provide satisfactory operating instructions for outlet flows and for canal flows when both are operating simultaneously or individually.

Canadian River Aqueduct - Hydraulic Performance Tests

Tests were performed on the aqueduct from Amarillo reservoir to the Lubbock reservoir (Central System) to document water expulsion from certain features of the Central System; and to record transient pressures, obtain data for computation of pipeline friction coefficients and to check the accuracy of two flowmeters in the system.

Because the extensive hydraulic test along selected reaches of the Canadian River Aqueduct Central System required simultaneous data gathering at widely separated locations, a mobile test part of 18 persons was required. The mobile party did not include one man located at the Aqueduct Control Center near Sanford Dam who remotely controlled discharges in the Central System for test purposes and who recorded pertinent test data. Six men from the Region 5 Office, 5 men from the Project Construction Engineer's Office, and 2 hydraulic engineers from Denver made up the mobile test party.

Great distances involved, approximately 115 miles from the downstream end of the Central System to the control center, required communications facilities beyond the capability of two-way radio systems normally installed in vehicles. Therefore, the Project Construction Engineer had a commercial mobile telephone installed in a Government vehicle, and a commercial telephone installed at the Station 5080+10 flowmeter near the midpoint of the Central System. This permitted use of the mobile telephone from any location along the aqueduct to request a change in discharge by calling the control center and to determine when steady flow conditions existed in the aqueduct by calling a man stationed at the flowmeter.

Upstream and downstream pressures and water expulsion data were continuously recorded simultaneously at four structures during each of four pressure surge tests. Four pipeline hydraulic friction tests were completed in separate pipeline reaches of constant inside diameter. Sufficient hydraulic data were obtained to check the accuracy of the two flowmeters in the Central System Main Aqueduct. Preliminary recalculations of test results and pertinent observations were discussed with Regional and Construction Office personnel before return to Denver. Hydraulic pipeline friction and flowmeter data are being analyzed in the Hydraulics Branch. Analysis of analog records of pressure versus time is being performed in the Canals Branch with the aid of personnel and equipment of the Division of Data Processing. Results of these analyses will define pertinent hydraulic characteristics at a large portion of the Centeral System.

Conconully Dam Spillway, Okanogan Project, Montana

A 1:18 scale sectional model of the spillway was studied to verify the use of a baffled apron as an energy dissipator, Figure 6. The baffled apron was selected for the spillway rehabilitation because poor foundation conditions downstream from the dam precluded the use of a hydraulic jump basin or flip bucket.

The Conconully baffled apron was designed for a unit discharge of 28 cfs per foot of width, for a total spillway discharge of 11,600 cfs. (Previous aprons have been limited to a design unit discharge of 60 cfs.) The drop from maximum reservoir to riverbed is about 77 feet.

The model indicated satisfactory operation for a wide range of discharges up to and including the maximum. Flow velocities did not accelerate along the chute and there was only minor riverbed erosion at the base of the apron. In the initial tests the apron extended below the riverbed level and two rows of blocks at the end of the apron were covered with backfill. During operation at near maximum discharge there was some movement of the fill material on the apron. It was felt that this action might cause erosion damage to the concrete; therefore, the riverbed was

Figure 6

Conconully Dam Baffled Apron Model

excavated at the end of the apron and sloped upward on a 2:1 slope to the original level. The sloped surface was covered with 12- to 24-inch riprap. There was no riprap movement at any discharge with this configuration.

The model was also operated with unit discharges of 100 cfs and 150 cfs. Although the flow appearance was very rough with considerable splash and spray there was only minor riverbed erosion and the performance was considered satisfactory.

Discharge capacity tests showed that the maximum discharge over the spillway was attained at reservoir elevation 2295.5, 0.2 feet higher than the design value. When the upstream row of baffles was completely blocked, to simulate clogging with debris, the reservoir rose to elevation 2298.6, 1.1 feet below the dam crest.

Bacon Siphon

Bacon Siphon is an existing structure in the Columbia Basin Project. It is an inverted siphon, 23 feet 3 inches in diameter and approximately 1/5-mile long, designed to carry a canal flow of about 7,250 cfs. The capacity of the canal is to be increased to 19,300 cfs by widening and by branching off to a second siphon 28 feet in diameter.

A 1:48.9 scale model has been constructed, Figure 7, to determine the capacity of each of the two branches and to investigate the flow characteristics at the inlets and outlets to the siphons.

Grand Coulee Dam Third Powerplant Penstock Entrance Studies

The studies were started with an evaluation of the standard penstock entrance by modeling the Flaming Gorge entrance, using 8-inch-diameter pipe to represent 10-foot-diameter penstock. Evaluation was based on head loss from reservoir to one diameter downstream from end of entrance; pressure distribution on curved surfaces; and vortex tendencies; all tests were at Reynolds, numbers up to 1.2 by 10^6.

The original plan was to redesign the Flaming Gorge entrance using criteria developed by the VE team and thereby get a direct comparison of the two entrances. However, the VE team decided that due to the urgency for the Coulee Third Powerplant designs, the investigations should be directed toward developing a penstock entrance specifically for Coulee based on VE team criteria. The 30-foot-diameter penstocks were represented by 11-1/2-inch-diameter clear plastic conduit. All entrance curves and dimensions were related to the diameter. The first entrance tested had a 1:1 entrance area to penstock area ratio and a 2:1 height to width ratio. This entrance had a short radius quarter circle for entrance curves. The loss coefficient was very high, but

Figure 7

Bacon Siphon Model Scale, 1:48.9

diminished as the discharge increased. This tendency was reflected in the pressure distribution measurements as well. There was a very sharp pressure drop at entrance.

A very long compound radius curve for the entrance was tried next. A very good loss coefficient and pressure distribution was observed. The entrance curve was then gradually sharpened, with plasticene fillers until the loss coefficient showed a significant increase.

While these tests were being performed, an entrance with a 1.5:1 height to width ratio was built with a long compound radius entrance curve (the same as the second curve used on the 2:1 entrance).

There was very little change in the loss coefficient for this entrance and the pressure distribution seemed to be satisfactory. Two sharper entrance curves were also used on this entrance and head loss coefficients determined for each.

The shortest compound radius curve was selected for the Coulee Third Powerpland and a new entrance built. The new entrance had the curve on all four sides, but the curves did not extend to the p.c. The stoplog slots and seats made it necessary to cut off the curves. Complete loss measurements indicated that the "truncated" curves did not increase the loss coefficient; instead, at the higher Reynolds's numbers the loss coefficient was lower than it had been before. Pressure distribution was also satisfactory for this entrance.

The effect of the gate slots on the entrance loss was also determined to be almost negligible, whereas they had caused almost 50 percent of the loss in the Flaming Gorge entrance. The slots were 5 feet wide in the 29-foot-wide Coulee entrance while those in the 6.5-foot-wide Flaming Gorge entrance were 3 feet wide. The next tests concerned the bends in the penstocks.

The upstream bend was fixed by certain design criteria; however, the lower bend could be modified as desired. The upper bend was a constant diameter conduit accomplishing the 45° bend with a 160-foot-radius curvature. Three different configurations were tested for the lower elbow - 140-foot-radius reducing diameter in which the penstock diameter reduced from 40 to 35 feet, a 100-foot-radius reducing diameter, and a 100-foot-radius constant diameter elbow with a 20-foot-long reducing cone at the p.t. All four elbows were evaluated for head loss. The long radius upstream elbow had the lowest loss coefficient - the loss through the three lower elbows was essentially the same for all three and 50 percent higher than for the upper elbow.

Velocity traverses were obtained one diameter upstream from the p.c. of the lower elbow and one diameter downstream from the p.t. The lower traverse station is about at the entrance to the scroll case of the turbine. The velocity traverses were transformed to an isovel diagram. The diagram showed that upstream of the elbow the velocity was slightly higher near the crown, with a reduced velocity in the lower right quadrant. Downstream from the p.t. the velocity was slightly lower near the crown, and an almost-negligible higher velocity on the right side. This same general pattern was true for all three elbows.

Future studies will be to evaluate a trashrack, and to evaluate an alternate Coulee Third entrance with a 0.9 to 1 entrance area to penstock area ratio. Figure 8 shows two aspects of studies completed to date.

Tehama-Colusa Fish Concentration

A 1:2.5 scale model of the fish concentrator for the spawning channel of the Tehama-Colusa Canal has served in developing its final design.

The design includes an upward sloping section 11 feet three inches long followed by a downward sloping section 5 feet 0 inch long in a 10-foot 0-inch wide bypass from the spawning channel. Its function is to discharge 135 cfs through a perforated plate screen and adjustable orifice openings in the floor, while retaining 5 cfs above the screen to pass salmon fingerlings downstream to an electronic counting device. The design requirements were that the depth of flow over the crest of the structure be about 4 inches and the flow velocity be less than 10 feet per second in order not to frighten the fingerlings and cause them to turn upstream. After the fingerlings reached the downslope, the flow velocity was great enough to prevent them from returning upstream.

Testing on this structure was completed, and the report is now being prepared.

Westlands Irrigation District - Brooks Flowmeter Tests

The District installed a number of Brooks meters on a lateral to operate under heads of 40, 80, and about 175 feet. Some difficulty was experienced in their operation including weed seed puncturing of the pressure diaphragm, slippage of the O-ring seal, valve failing to close, and filling of the orifice control ports. The HydraulicsBranch was requested to perform a series of tests on a full size prototype flowmeter to determine the hydraulic characteristics of the valve as to repeatability of setting the discharge, vibration characteristics which had been noted in the field installation, registration accuracy, closure, and the ability of the valve to control flows for the minimum head loss required by the specifications. Extensive tests revealed a relatively large percentage of error in the meter flow indicator and totalizer compared to laboratory venturi meter discharge. Even after a number of adjustments of the meter by factory

Trashrack used in hydraulic model studies of conventional bellmouth.

Figure 8

Grand Coulee Third Powerplant Penstock Entrance Studies

Hydraulic model using 11.5-inch-diameter plastic pipe for the penstock, includes bellmouth entrance and trashrack structure. Electronic instrumentation was used to determine pressures and hydraulic losses throughout entrance system.

personnel and a more favorable setting of the meter with respect to the delivery pipe turnout, the margin of error was not reduced significantly. Since the meters are calibrated in the factory before shipment to the user and the factory calibration was not verified in the Hydraulics Branch, Brooks arranged for an independent calibration of the meter at the Alden Hydraulic Laboratory, Worcester Polytechnic Institute. The Worcester tests confirmed the Bureau tests. Brooks found that a rearrangement of the factory calibration facilities was desirable and will soon be able to perform a more accurate calibration of their meters before shipment.

Morrow Point Spillway Gate Study

The 1:24 scale model was used to assist in formulating head-discharge curves for spillway operation. Because of dissimilarities between the model and prototype gates it was necessary to adjust the data. Operation near full gate opening was investigated in detail because of complex pressure conditions in the spillway conduits.

Grand Coulee Pump Turbine Studies

The pumping plant at Grand Coulee Dam was constructed to house 12 pumps, and all the intakes, penstocks, and siphon elbows were completed in 1951; however, only 6 pumping units were installed initially. It was anticipated that irrigation demands would require additional pumps by 1973, and legislation was passed to permit the purchase and installation of the additional units. Recent studies revealed that the installation of pump-turbine units to meet peak power demands would realize a benefit-cost ratio of 10.5:1 over the installations of pumping units only.

Model studies were required to evaluate the hydraulic aspects of the exit ends of the pump conduits, including the siphon elbows and the canal near the headwall, and to determine the changes needed to allow the pumping conduits to be used as power penstocks for the units operating as turbines, Figure 9.

Loss measurements for reverse flow were made, and vortex formation at the headwall was observed. Each penstock entrance at the canal headwall was streamlined to prevent vortex formation. The recommended streamlined shape did not increase the hydraulic losses when the units were operating as pumps. Minimum pressures at the crown of the siphon elbows were about 8 feet of water above vapor pressure with two turbines operating at 2,500 cfs each and Banks Lake at minimum operating elevation 1568.

For the two pump-turbines now on order no changes to the siphon elbows will be necessary, but streamlining the penstock entrances at the headwall will be required to prevent vortex formation. Further model studies are needed to determine if changes to the siphon elbows are required for the satisfactory simultaneous operation of five turbines.

Shown in the model are the conduit and siphon for Units P-7 and P-8 discharging into canal leading to Banks Lake; pumping operation.

Figure 9

In this view, flow is toward Units P-7 and P-8, acting as turbines. Future Units P-9 to P-12 are stubbed off in present model study.

Navajo Dam Outlet Works Inspection

T. J. Rhone was a member of a team which inspected the outlet works which had experienced some structural distress during early releases. The outlet works stilling basin had been unwatered and the hollow-jet valves disassembled so that they could be inspected by prospective bidders on a repair and modification contract. The upstream section of the outer shells of the hollow-jet valves were heavily damaged from cavitation. Comparison of the curve of the shell with a template of the design curve showed wide variance throughout. The downstream portions of the shells and the needle showed only minor pitting and this was in isolated spots.

Abrasion caused by rocks and gravel had severely damaged the stilling basin floor. The main damage was on the sloping chutes downstream from the valves and on the horizontal floor just upstream from the baffle blocks. The reinforcing bars had been exposed and torn loose in both areas. Piles of sand and gravel covered most of the floor of the basin in the bays on each side of the centerwall and downstream near the baffle blocks. Most of the material was 2 inches or smaller in size. A few rocks 4 to 8 inches in diameter were noticed. A tangle of loose and partially loose reinforcing bars was located near the chute box. The side walls, centerwall, and wedges were braided a very small amount. The marks that had been left by the forms used in the 1965 repair of the large hole at the end of the wedge in the left bay were very plain as was the texture of the gunite that had been applied to the walls.

The travel report concluded that measures should be taken to prevent debris from entering the stilling basins. Specifications No. DC-6553 requires paving the area downstream from the stilling basin.

In the auxiliary outlet works the passage downstream from the 4- by 4-slide gate showed no evidence of increased cavitation damage. The steel-lined section immediately downstream from the gate had been coated with a liquid-applied neoprene. The gate had been operating with a discharge of 312 cfs at reservoir elevation 5980.72 for 2-1/2 days and the coating was beginning to fail.

The party also viewed the recently completed headworks and tunnel of the Navajo Indian Irrigation Project. The structures in concrete on this project showed exceptionally fine workmanship.

Electronic Instrumentation on Field Tests

R. H. Kuemmich assisted in the performance of a variety of tests on projects requiring trips to the field, as follows:

1. Fremont Canyon Powerplant. - Hydraulic performance tests of turbine Unit 2

2. Fremont Canyon Powerplant. - To perform tests and obtain oscillograph records and other data on Unit 1 after runner modifications and on Unit 2 after installation of vortex suppressor furnished by Newport News

3. Fryingpan-Arkansas Project. - To measure seismically the depth to bedrock at points designated by Region 7 geologists in Hunter Creek area of South Side Collection System

4. Yellowtail Dam. - Hydrodynamic pressure and accelerometer measurements in outlet works stilling basin centerwall

5. Southern Nevada Project. - To repair Bureau drill hole television equipment

Wahluke Branch Canal

A turnout from the subject canal was modeled at a scale of 1:6, Figure 10. The turnout is designed to discharge a maximum of 75 cfs when the branch canal flow ranges between 75 and 192 cfs. Tests were conducted on the model to determine the length and design characteristics of the grizzly in the canal floor, the configuration of the outlet below the grizzly, and the arrangement of the baffles required at the entrance to the constant head orifice turnout structure. The study was sufficiently general that the results were applied to other turnouts in the system.

Grand Coulee Dam Third Powerplant - Summary of Meeting with Board of Consultants on Draft Tube Surges

Participants

James W. Daily, Hunter Rouse, and Ray S. Quick, Consultants; W. H. Wolf, Associate Chief Engineer; T. M. Hollearin, Assistant Chief Designing Engineer; C. G. Bates and G. H. Johnson, Hydraulic Machinery Branch; C. C. Crawford and F. O. Ruud, Technical Engineering Analysis Branch; and H. M. Martin, W. E. Wagner, and H. T. Falvey, Hydraulics Branch.

Wednesday, February 28, 1968

The meeting was opened by Chairman Martin who, in the absence of Associate Chief Engineer Wolf, briefly explained the purpose of the meeting with the Board of Consultants and outlined the scope of the discussions as generally listed in the Agenda furnished each participant.

Later in the day, Mr. Wolf established the goals of the discussions. He explained that the Agenda was intended as a guide for informal exchange of information with USBR giving brief presentations of the surge problem to be followed with much discussion and expressions by the consultants.

Figure 10

1:6 scale hydraulic model of a turnout from the Wahluke Branch Canal. H-1621-14.

He asked that the Board submit an interim report before leaving Denver. This report should contain tentative recommendations and a general statement evaluating our proposed research program for solving the draft tube surging problem. The interim report will be treated as tentative and subject to revision after the consultants return to their respective offices and additional thought is given to the problem. The 4-day authorization for consultant work covers only the present meeting and does not preclude additional pay for later work. Mr. Wolf envisions the Board will continue to function until a solution to the problem is found.

Mr. Bates briefly explained Bureau experiences with draft tube surges, our present concern, and current program of investigation. USBR had very few powerplants prior to 1935 when Hoover units were installed. These units were set relatively high. Severe surges resulting in power swings up to one-half capacity have been experienced at Hoover at relatively low reservoir elevations and high tailwaters.

Since Hoover, we have installed some 300 units, of which about 20 percent have experienced surges, severe enough to require corrective action. Our units are expected to operate satisfactorily from 65 to 125 percent of design head and from 0 to 115 percent of rated capacity. If the units do not meet this criteria, the Bureau requires the manufacturer to provide corrective measures, including alteration of the air supply and installation of hardware. When the manufacturer fails, the Bureau assumes responsibility for providing corrective measures.

Recently, USBR has been concerned with surges at two specific plants:

Judge Francis Carr. - The Judge Francis Carr is a peaking plant having two units at end of a long tunnel with a 20-foot fluctuation in tailwater. This unit was designed for a head of 535 feet and a specific speed of 27 and operates at about 130 percent design head at startup and approximately at design head after full flow has been reached. The surges at this plant are most severe at 50 percent gate. At low tailwater, the surges were quieted by the admission of atmospheric air; however, no air is taken at high tailwater and the use of compressed air reduced the efficiency.

Fremont Canyon. - Fremont Canyon Powerplant has two units on a tunnel with surge tank. These units operate under no unusual heads or tailwater. Surges have been experienced at 80 percent to 100 percent gates. Vibration and measurable "bouncing" of the units were observed at high gates. Corrective measures included three 3-foot-high vanes placed across the draft tube 18 inches below the runner, the installation of a hollow cylinder in the draft tube throat, and air admission. With air admitted, the surges were eliminated, but the efficiency decreased 2 percent. The final solution was to open the vents in the runner which resulted in a 5 percent increase in peak efficiency at rated capacity and a 1 percent loss in maximum efficiency. These units were designed for a head of 300 feet and N_s of 33. These stainless-steel runners were modified by trimming the buckets to increase the discharge area about 10 percent ot conform with the manufacturer's intent. This modification narrowed the range of rough operation and reduced the surge amplitude and frequency.

Corrective measures which reduce the surges are not a complete solution because of the reduced efficiency and sometimes capacity. Changing the runner moves the range of rough operation into another area of the performance curve.

In regard to model studies, Mr. Bates explained that only in a few cases does the Bureau require the manufacturer to conduct model tests. Although we feel that model studies are the responsibility of the manufacturer, it has been our experience that he will model infrequently on his own.

The Bureau's immediate concern is the design of the units for Grand Coulee Third Powerplant. For Coulee Third, we have increased the specific speed as much as 150 percent, resulting in higher flow velocities and probably increased surging. These units are to be designed for a range of operating heads from 220 to 355 feet and a best efficiency head of 305 feet. The centerline of the units is elevation 946, and the tailwater will vary 53 feet from elevation 930 to 983. Full gate operation is required with tailwater elevations 958 to 983 feet. Because our experience has shown that varying heads and high tailwater aggravate surges, we believe Coulee Third requirements will be ideal for producing surges.

The research program of the Hydraulic Machinery Branch was limited to $4,000 in FY68. We expect to significantly accelerate this program with the following objectives:

1. Determine relationship between surges in model and prototype.

2. At first opportunity, obtain surge data on Hoover units. We have limited model data on existing and replacement runners for these units but current heads at Hoover Dam do not induce surging.

3. Good data have been obtained at Carr Powerplant. Manufacturer is being contacted to obtain his model data.

4. Learn more about our runners by measuring discharge angles, blade shape, and discharge area of existing runners. Manufacturer does not furnish detailed drawings of runners.

Dr. Rouse commented that the surge problem is universal and is not limited to any one or group of manufacturers.

Dr. Dailey suggested that we need to know more about the operation of the units and the physical dimensions of the runners.

Mr. Quick stated that the manufacturer's emphasis is on capacity and efficiency characteristics of the units rather than vibration and surge measurements. He has no knowledge of studies to determine smoothness of operation.

Dr. Falvey next discussed in detail the results of his analytic studies and library research. The library search is divided into three phases - basic swirling flow, mathematical theories, and model and prototype experiences. He described six basic flow regimes, ranging from laminar to extreme turbulent flow containing reverse flow cells. Charts were distributed which generally showed the range of stable and unstable swirls determined by several independent experimenters using a rotating perforated plate and several rotating tubes with different length-diameter ratios. Another chart plotted the effect of load on swirl angle for two specific speeds. He also explained his analysis of surge data obtained from Fremont Canyon Powerplant in which he attempted to segregate and compare the power swing with the primary and secondary periods of the surges measured on the spiral case and draft tube. He also discussed the various types of corrective devices, including vanes, free air, compressed air, hydraucone, extensions to the runner cone, fins, and tube or cylinders used to dampen the surges.

Dr. Falvey's discussion elicited the following general comments:

1. Maximum power swings occur when the surge pressures are in phase.

2. Most of the pounding and noise occurs when the pressures are not in phase.

3. Runner can be designed for only one operating condition.

4. Slight change in tailwater (1 foot in some cases) will initiate rough operation.

5. A better method of analyzing frequency and amplitude of surges is needed.

A 15-minute film of model studies of the draft tube for the existing Coulee units conducted in the late 1930's was shown to the group. The film clearly showed the swirling flow experienced in this model.

Mr. Ruud reiterated the need for a correlation between model and prototype data. He also asked why it is necessary to specify satisfactory operation over a wide range of heads as for Coulee Third when normal operation will occur in a relatively small head range. He briefly explained and distributed a proposed paper on a device to be placed in the zone of swirling flow (or reverse flow cell) to reduce surging.

Following lunch, Mr. Bates explained the method of contracting for Coulee Third units. The Coulee specifications call for technical proposals on March 15, 1968, and are restricted to domestic manufacturers. Technical proposals may include alternate details which will perform equally well or better than the specifications require. They must be approved by the Bureau. Then they will be considered competitive with bids conforming to the specifications.

Award will be to lowest bidder. The manufacturer will be required to build a model of the machine with three runners and one draft tube, the design of which is left to the manufacturer. Testing of the model will conform to the requirements of the International Test Code, which requires a runner at least 10 inches in diameter. Specifications require a minimum test head of 50 feet. The tests will be witnessed by the Bureau, who will participate in selection of the runners. The model will be turned over to the Bureau for storage or additional testing.

In answer to a question, Mr. Bates stated that a cylinder was tried by a foreign manufacturer and did some good at low gates. We tried the cylinder at Fremont Canyon but it was of no value at large gates.

Mr. Wolf stated that we would be interested in what tests should be specified in the specifications to find a solution to the surge problem.

Dr. Daily commented that the model should be tested at constant head but with variable tailwater to determine critical sigma with respect to surging.

Dr. Rouse believes that model surge data should scale up using the usual Froudian relationships and Reynolds effect need not be taken into account. The burden of proof should be that scaling laws are not valid rather than justifying their applicability.

Dr. Daily generally agreed except for possible penstock resonance and mechanical effects which will not be modeled.

In answer to Dr. Rouse's inquiry whether a maximum surge can be specified, Mr. Bates responded that the manufacturer's responsibility was limited to the draft tube. He cannot be responsible for power swings or penstock surges over which he has no control. Low frequencies of 1-2 cps and high amplitudes of 50 to 80 feet in the prototype are objectionable.

Dr. Daily inquired if our experience indicates any correlation of frequency with number of blades or RPM. Mr. Johnson replied no, and the frequency seems to decrease with discharge.

The consultants should consider what should be added to our specifications to obtain the desired information from the model.

Dr. Daily agrees that we should obtain runner measurements including area, profiles, and contours of the blades of existing units. These will give a picture of what manufacturers like and how they perform. He believes all turbines are extrapolated from a previous shape with no new design. Unless precautions are taken, the same turbine with its inherent problems will be supplied.

Following this discussion, the consultants were given a brief tour of the Hydraulics Laboratory.

Thursday, February 29, 1968

Mr. Johnson opened the discussions by describing our prototype test procedures. Pressure taps are placed at accessible locations which are limited to access doors in walls of the draft tube, head cover, and air vent pipes. We use commercial strain-type pressure transducers which are calibrated before installation and connected to tap with 1/4-inch Saran tubing. The transducers are mounted on foam rubber to prevent pickup of structural vibrations. Data are recorded on either two 2-channel or one 8-channel Sanborn recorders. Discharge is determined from spiral case flowmeter taps which are calibrated during acceptance tests. Head is measured with a deadweight tester and power output is read from rotating standards.

Mr. Johnson then described in detail the data from Fremont and Carr Powerplants shown on Exhibits 1 through 4 which were previously distributed to the participants. These graphs are generally self-explanatory and attached to each are tabulations of field data plotted in the graphs. The following additional information was given:

Exhibit No. 1. - Centerline of unit is elevation 5497. Diameter of runner - 7 feet, 3 inches; normal speed - 257 rpm; and N_s - 33. Although this test was made with a low tailwater, the plant sigma was still above critical. The peak in spiral case amplitude at 80 percent gate occurred when the second unit was started up, which resulted in a net difference in head of 5 feet; this peak was not repeated when the second unit was shut down.

Exhibit No. 2. - The total head for this test was about 6 feet higher than the head for the low tailwater test plotted in Exhibit 1. Best efficiency range for this unit is 60 to 70 percent gate.

Exhibit No. 3. - Runner modified by trimming 1 inch from trailing edge and grinding the lower side of each blade to feather the edge, which in effect increased the exit area 13 percent to what the manufacturer said it should be. Plotted data are for same unit and head within 1 foot of previous test (Exhibit 2).

Exhibit No. 4. - Plot of surge frequency and amplitude measured in draft tube with and without compressed air. Carr runner speed is 225 rpm and $N_s = 26$.

Considerable discussion ensued as to the need for issuing a supplemental notice to the Coulee Third specifications to assure that the manufacturer performs the necessary tests to provide data for selecting the best runner design. It was the consensus that although the specifications are adequate to protect the Bureau, amplification and clarification are needed to focus attention on the surging problem. Since the manufacturer historically is interested only in efficiency and capacity, he may not understand our concern and need for draft tube pressure fluctuations which occur during rough operation. This would require sufficient data to prepare a "hill" diagram including amplitude and frequency of surges for several values of sigma. It was agreed that the consultants would help phrase a supplemental notice which would give us the needed test data.

Mr. Quick described the procedure for competitive testing and awarding the contract for the Tehachapi pumps. Early in the program, shelf models were furnished and tested by Metropolitan Water District and efficiencies of about 86 percent were obtained while the state was looking for better than 91 percent. It became apparent that the best machine design would not be the cheapest, and with the Metropolitan Water District putting up $1M+, it was decided to award on the basis of competitive testing. Contracts were let with three combines of American and European companies (because of Buy-American policy) to fabricate and development test models of a single-, two-, and four-stage pumps at a cost of $130,000 each with 10-11 months' delivery time. The results of these model studies were furnished to the state who selected the four-stage pump for final award. Each of the three combines were then permitted to fabricate and development test a model of a four-stage pump to operate at prototype head of 1951 feet and 2750 rpm. Following the development phase, the three models were sent to the National Engineering Laboratory at East Kilbride, England, for independent testing. The confidential results were then sent to the state for evaluation at the bid opening. Model efficiencies obtained in the tests ranged from 88+ to 89.4, which were stepped up to comparative prototype efficiencies of 91.3 to 92.4. As a result of this procedure, the state obtained the most efficient units the art can offer, and the savings in power cost with the increased efficiency far exceeded the cost of the model program.

Dr. Falvey outlined the Hydraulics Branch test program and described proposed test facilities for investigating the surge problem. Our program has two objectives: (1) to develop corrective measures for existing problem units, and (2) to gain a knowledge of the surge phenomenon so that the problem can be avoided in future designs. He described our present idealized model with cone diffuser and spiral case of rectangular cross section, the limited test results, and changes in the model to investigate the Fontenelle diversion flows which were made through the unit without the runner. He then described our proposed test facility for continuing and accelerating our test program, and asked for comments on the workability of the test facility and the priorities of the two objectives.

Comments on the Above Program

The proposed test facility will be a system complicated by all the asymmetrical flow conditions in a turbine machine. Tests of this type should be conducted by the manufacturer, who has the best facilities for this type of testing in this country. We should use the fundamental approach by determining the flow characteristics of a symmetrical swirl in a simple tube of varying length. No provisions are made to remove entrained and dissolved air in the water which may affect the test results in the reduced pressure environment.

After considerable discussion of items that might be included in the supplemental notice to the Coulee Third specifications, Mr. Johnson was designated to prepare a draft of the technical aspects of the supplemental notice. This draft was reviewed and concurred in by the Board later in the day.

The meeting adjourned at 1:30 p.m., February 29, to permit the consultants to deliberate and prepare their recommendations.

Friday, March 1, 1968

The group reconvened at 1:00 p.m., March 1, when each consultant distributed a draft of his tentative recommendations and comments of our proposed research program for solving the surge problem. Later in the afternoon, the Board of Consultants, Hollearin, Martin, and Bates met with Chief Engineer Bellport to briefly discuss the meetings and the preliminary recommendation and conclusions of the Board.

SECTION III - COOPERATION WITH OUTSIDE AGENCIES

Cooperation and assistance were rendered other agencies on hydraulic problems. Most extensive were studies for the Division of Isotopes Development, U.S. Atomic Energy Commission; the Office of Saline Water, Department of the Interior; and the Forest Service, Department of Agriculture.

Studies for the Atomic Energy Commission

Phase III of a study was completed to establish feasibility and develop procedures for measuring water flow through high-head turbines and other hydraulic machines with radioactive tracers. The Hydraulics Branch and Chemical Engineering Branch are cooperating.

Three series of tests were conducted on a 6,000-foot-long, 6-foot-diameter penstock of the Flatiron Powerplant near Loveland, Colorado.

Thirty-five separate injections of radioactive Bromine-82 were made in the test series. Ninety-three discharge values were computed from these injections because multiple samples were obtained from the injections. Injections were made at 0.1, 0.4, and 1.0 radii from the pipe wall. These positions were selected to show the effect of the radial location of single-point injection upon mixing length. Measurements were made in pipeline lengths of about 48 and 300 pipe diameters to show the results for pipe lengths well above and well below the anticipated minimum mixing length. Sampling locations were installed at the draft tube, at the inlet of the turbine, and in the penstock at 300 and 48 diameters from the injection. The locations at the turbine were to explore any unique effects of the turbine upon mixing or other aspects of the measurement. The sampling locations on the penstock were made essentially at the pipe wall (0.03 of the radius) and at the centerline to determine the degree of mixing. Flow measurements with radioisotopes were compared with flow determinations by a carefully performed pitot tube traverse made completely across two diameters.

Also, results were compared with flow measurements as indicated by use of the calibrated flowmeter taps at the turbine. Specialized equipment developed for these tests include injection and sampling probes which could be located at various positions in the penstock diameter. Simplified pressure reducers based upon new hydraulic studies were developed for sampling the high-pressure penstocks. Samples were taken at pressures of 350 psi and 475 psi. Injections of tracer were made into the pipe through four configurations of holes in the injector tips at pressures ranging from about 295 psi to 950 psi. These studies were made to explore the possibility of using high-pressure injection to reduce the mixing length.

In general, the measurement had a greater variation than desirable. The results of the tests are not as precise as wanted, but were encouraging. The tests gave good information on lengths of pipe required to mix the pipe flow and tracer, radiation measurement procedures, and injection and sampling techniques. These studies showed that selective injection at a particular radius in the penstock did not give as much reduction in the mixing length as might have been suspected by the work of others.

Some of the discharges computed from the samples taken at the draft tube were obviously in error and the measurements had a greater variation than desirable. Investigation using a fluorometer showed that a significant amount of recirculation of water from the tailrace into the draft tube was occurring for the less than maximum discharge used in these tests. The recirculation caused excessive dilution of the sample being extracted from the draft tube and thus an error in the discharge measurements.

A series of measurements were made on the pump-turbine unit of Flatiron Powerplant to evaluate procedures and techniques applied to pump flow.

An economic study was made by the Division of Project Investigations to determine the potential benefits accruing from an increase in the operating efficiency of Bureau power and pumping plants possibly resulting from accurate discharge measurements by the radioisotope method. Preliminary findings for 3 million kilowatts from 11 million kilowatts installed or to be constructed by the Bureau, appraise the value for 1/2 percent gain in operating efficiency to be a quarter of a million dollars annually and have an accumulated present worth of over $2 million in 10 years.

For 1 million of 1.7 million horsepower installed capacity in pumping plants, a 1 percent increase in operating efficiency would have a possible value in pumping energy saved annually of a fifth of a million dollars and accumulate to about $1.7 million in 10 years.

Head Loss Studies - Office of Saline Water

A 1:2.33 scale model was used to determine the head loss for 118° F brine flowing through interstage piping between modules of the 2.5 MGD Universal Desalination Plant. Head loss coefficients for the system with and without a control valve were established for Reynolds numbers ranging from 170,000 to 1.2 by 10^6. Plenum entrance and exit losses were included in the system loss. The total head loss in the prototype system was determined from the model to be 0.53 foot without a control valve and 0.56 with a fully open butterfly valve installed at the downstream end of the connecting pipe.

Studies for the Forest Service, Department of Agriculture

A contract was negotiated with the Forest Service in which the Hydraulics Branch will carry on laboratory development studies for an energy dissipator to be used with 18-inch corrugated metal culverts or flumes installed on grades up to 66 percent with flow depths of 0.1 to 1.5 feet. The test procedure contemplates developing an energy dissipator to reduce flow velocity to 2 to 3-1/2 feet per second and provide good flow distribution at the end; determine debris problem (test with weeds, rocks, gravel, and sediment); insure that dissipator is as nearly self-cleaning as possible and will not become clogged with debris. The initial model will be of the baffle- or impact-type stilling basin having sufficient length and width to adequately dissipate the energy and provide uniform flow velocity over a relatively wide exit to meet the 3-1/2 feet per second maximum exit velocity criteria for specific energies of 5-10 feet.

SECTION IV - ASSISTANCE TO FOREIGN GOVERNMENTS

Assistance to foreign governments this year consisted largely of on-the-job training of engineers of other countries. Studies on the Patillas Dam (Puerto Rico) spillway were held in abeyance pending firming up of a new design. Estimates were made for hydraulic model studies for the design of the spillway for Toa Vaca Dam in Puerto Rico, and construction of a model was started.

An unusually large number of hydraulic engineers from other countries visited the Hydraulics Laboratory in connection with their travel to the XIIth Congress of the International Association for Hydraulic Research in Fort Collins, September 1967. This resulted in a large volume of technical correspondence with foreign laboratories.

Toa Vaca Dam Spillway

The dam and appurtenant features are being designed by the Bureau of Reclamation for the Puerto Rico Water Resources authority. The spillway will be a 106-foot-wide, radial-gate-controlled structure having a chute and flip bucket stilling basin that stills flows up to 26,000 cfs and flips a jet from the basin for flows in excess of this up to the maximum capacity of 78,000 cfs.

Construction of a model spillway was started. When completed, the 1:48 scale model will be used to determine approach conditions to the gate structure, distribution of flow between gates, water surface profiles, crest coefficients, pressure on crest, dynamic pressures in the stilling basin, flow characteristics in the stilling basin flip bucket, and erosion patterns in the impact area.

Foreign Trainees

Ram C. Chaudhary	Nepal	1- 8-68 to 4- 5-68
Talat Hameed Khawaja	Pakistan	2- 7-68 to 2- 8-68
Byeong Rib An	Korea	3-18-68 to 6-28-68

Foreign Observers

P. R. Bhave	Nagpur, India	11- 1-67 to 11-14-67
Dr. Harold Howe	Germany	4- 5-68
Nelson A. Ordonez	Lima, Peru	6-18-68
C. H. Sohan	Guyana	6-24-68

Foreign Visitors

Dr. H. R. Thorpe	New Zealand	7- 3-67
Fouad El-Kafrawy	United Arab Republic, Egypt	7- 3-67
Mr. and Mrs. Erik Heinrichson	Manitoba, Canada	7-25-67
Barry Rydz	England	9- 5-67
Bengt Abert	Stockholm, Sweden	9-15-67
Alfonso Alcedan	Peru	9-18-67
Karol Rohan	Czechoslovakia	9-18-67
L. J. Jaffrey	England	9-20-67
E. Miller	Kilmarnock, Scotland	9-27-67 to 9-29-67
Dr. Seiichi Saito	Japan	9-29-67
Dr. Masaaki Shirakura	Japan	9-29-67
M. I. Chowdhury	Dacca, Pakistan	11-24-67
Richard Waller	Australia	12- 1-67
M. Hiramatsu	Osaka, Japan	1-24-68
Tomio Takahashi	Tokyo, Japan	1-24-68
Jalil Ahmad Mian	Lahore, West Pakistan	1-29-68
Prof. K.L.V. Ramu	India	1-29-68 to 1-30-68
Mr. Lindquist	Sweden	3- 1-68
Mr. Melend	Sweden	3- 1-68
Dr. E. Muhlemann	Zurich	4-26-68
J. L. Webster	Vancouver, B.C.	6-10-68
S. O. Russel	Vancouver, B.C.	6-10-68
Javier Varela	Madrid, Spain	6-13-68
Ramon E. Cadenas	Venezuela	6-17-68
Dr. Constantine S. Iamandi	Bucharest, Romania	6-20-68

SECTION V - HYDRAULIC INVESTIGATIONS

This section contains descriptive material on the research program being carried on in the Hydraulics Branch. Much of it was prepared upon request of higher headquarters.

A. Water Resources Engineering Research - Hydraulics Branch - Accomplishments in FY68 and Program for FY69

B. Narrative Justification for General Investigations, General Engineering and Research, Water Resources Engineering Research (Hydraulic Research) - FY70

C. Control Schedule - General Investigations - Water Resources Engineering Research - FY69 to FY75

A. WATER RESOURCES ENGINEERING RESEARCH
HYDRAULICS BRANCH

June 30, 1968

	Research Project Title	DR number	FY 1968	FY 1969
1.	Pipeline and tunnel hydraulics	186	15,000	5,000
2.	Energy dissipators	188	10,000	2,500
3.	Instrumentation, data acquisition, and computer techniques	189	5,000	17,500
4.	Gates, valves, and orifices	191	10,000	5,000
5.	Open channel hydraulics	195	15,000	15,000
6.	Flow surface protection	203	--	5,000
7.	Intakes, entrances, and transitions	204	40,000	40,000
8.	Quality of water as affected by stratified flow	220	15,000	15,000
9.	Water measurement	221	50,000	50,000
10.	Stability of artificial and natural channels	132	--	--
11.	Aquifers and drainage	133	25,000	35,000
12.	Seepage	206	5,000	--
	Total		190,000	190,000

WATER RESOURCES ENGINEERING RESEARCH
HYDRAULICS BRANCH
June 30, 1968

Accomplishments in FY68 and Program for FY69

1. Pipeline and Tunnel Hydraulics $5,000 DR-186

Pressure surges can develop in long pipelines and create damaging overpressures and other operating difficulties during filling, draining, or operating at less than design discharge. Check towers, pipe stands, and air relief structures are often installed in pipelines to prevent high operating heads and permit use of relatively lightweight, inexpensive pipe. The optimum size and configuration of towers, stands, and air vents can be determined by scale model studies; however, the determination of the proper location of these structures to prevent surging is a complex problem requiring both analytical and model studies.

Theoretical analysis of head loss caused by surface resistance is required to design a water conveyance. The predominant factor in the analysis is the shear of the fluid at the solid boundary interface. The boundary shear is influenced by the roughness of the boundary surface which will vary depending on the method used to construct the structure. The cost and size of the conveyance thus depends on the accuracy with which the surface roughness and its attendant head loss can be predicted. Hydraulic loss evaluation techniques must be developed to establish the relative merits of various surfaces. Prototype measurements are being made as part of an extensive study to provide the necessary correlations between theoretical and experimental values of surface resistance head loss.

Accomplished FY 68

A hydraulic model was used to determine the adequacy of the computer program regarding the general problem of pipeline surging. The computer program was developed and refined until good correlation was obtained between computer program and model results.

A simplified computer program was developed to predict surging in a pipeline with steady inflow. Report No. Hyd-582, "Surging in a Laboratory Pipeline with Steady Inflow" was issued.

A field study was made concerning the hydraulic performance of various features of the 115-mile-long central system of the Canadian River Aqueduct.

Scheduled FY69

Surge data derived from the Canadian River Aqueduct will be analyzed and compared with model and computer program results. Hydraulic friction loss data from 54-, 66-, and 72-inch precast concrete conduits will be analyzed. Hydraulic friction data from two large concrete-lined tunnels will be analyzed and reported.

2. Energy Dissipators $2,500 DR-188

Extremely high energy forces in flowing water have always been an important consideration in designing hydraulic structures. To effectively contain or dissipate these forces before the water is discharged into the downstream channel is one of the greatest areas of uncertainty in designing water conveyance systems. The objective of this research is to develop, for general use, the many possible types of energy dissipators, including hydraulic jump, stilling wells, impact-type stilling basins, flip buckets, sudden enlargements, plunge basins, and baffled aprons. By developing and generalizing these structures, future laboratory developmental work on individual structures will be minimized.

Hydraulic jump stilling basins are a primary need for overfall spillways and canal drops. Five types of hydraulic jump basins have been developed and generalized for most combinations of head, height of fall, and unit discharge. Four other types of energy dissipators have been developed for use where hydraulic jump basins are not feasible. These dissipators are roller buckets, impact-type basins, flip buckets, and baffled aprons. Special purpose energy dissipators such as vertical stilling wells, turbine-type, and sudden enlargements as used with outlet works controlled by gates and valves are being developed. A series of progress reports has been issued on phases of the overall program.

The use of sudden enlargements downstream from gates or valves offers an economical solution to specific installations if damage by cavitation can be eliminated or reduced. Tests are needed to evaluate schemes whereby cavitation effects are minimized by using sudden enlargements and by admission of air. Design parameters for determining the cavitation index and general performance of specific types of control devices should be developed for general use.

This continuing program will be directed toward completing the following:

a. Hollow-jet valve basins
b. Vertical stilling wells
c. Sudden enlargements
d. Prototype studies

Accomplished FY68

Dynamic pressure and vibration measurements were made on the centerwall of the Yellowtail Dam outlet works stilling basin. Visual and photographic evidence and the pressure and accelerometer measurements showed that the stilling basin operation is satisfactory up to and including the design discharge of 5,000 cfs at a head of 442 feet, or 24 feet less than maximum head. Plans were made for the purchase of accelerometers and pressure transducers for installation in the Sugar Loaf and Crystal Dam outlet works stilling basins. The report on the modified design procedures for the Type VI stilling basin was completed. Studies were made to extend the allowable design discharge for a baffled apron type of energy dissipator.

Scheduled FY69

Reports on a sudden enlargement energy dissipator downstream from a butterfly valve, on the modified design procedures for the Type VI stilling basin, and on a large capacity baffled apron energy dissipator will be published. A report on narrow, deep, slide gate stilling basins will be prepared. Investigations on vertical stilling wells will continue. Studies will be started to develop a compact, portable energy dissipator suitable for use with corrugated metal highway culverts. The program for installing instrumentation and obtaining pressure, vibration, and surge measurement in prototype energy dissipators will continue.

3. Instrumentation, Data Acquisition, and Computer Techniques
$17,500 DR-189

Research of steady and unsteady flow requires instrumentation for recording and processing data in short periods of time. Instrumentation for this purpose is being developed, manufactured, and improved continuously and can be adapted to provide precise measurements. Selection of recording instruments is partly controlled by the method of data analysis. Both digital and analog methods are used. Thus, the purpose of this program is to study modern instruments and data analysis methods to improve research investigations.

Accomplished FY68

A general updating of equipment was possible during the year. Modules and accessories to complete assembly of systems were purchased for use by laboratory engineers. Included were: module cabinets for enclosing rack mounted instrument systems, amplifiers for low-level d-c transducer signals, and a recorder for studies requiring accurate recording of slowly varying signals from transducers of pressure, displacement, and temperature.

A root mean square voltmeter for calibration and signal analyses was bought to complement a frequency analyzer purchased in fiscal year 1967.

A second digital printed tape unit was bought after study to increase the speed of acquisition of temperature data from stratified flow studies.

The printed tape output from voltage to frequency converters and integrated digital voltmeters is used continually for acquiring average values of varying analog signals.

A differential micrometer stilling well manometer and 12- and 48-inch Pitot tubes were acquired after comparing Bureau construction costs and the manufacturer's price. These Pitot tubes and manometers are used for velocity distribution measurements and for calibration of pressure transducers.

A tape loop adapter for frequency analysis of fluctuating signals was purchased for the frequency modulated magnetic tape system. Signals recorded from model and prototype structures on tape can be analyzed for amplitude and frequency to provide better design information, Figure 11.

A fluorometer for the accurate measurement of the concentration of fluorescent dyes was bought for use in diffusion studies of tracers. The fluorometer is also used for measuring discharge by the color-velocity and dilution methods. Flow distribution may also be traced using this instrument. This equipment has been used for prototype tracing of water circulation in a draft tube at Flatiron Power and Pumping Plant and discharge measurements in the Canadian River Aqueduct. This multiple-use instrument should have general application to laboratory investigations including stratified flow and ground water models.

Other components of equipment were studied and purchased to increase the versatility of our data acquisition systems.

A General Electric time-sharing terminal was obtained for use by Division of Research personnel. Studies were completed showing that a second time-sharing terminal with an X-Y plotter attached would be economically feasible. A recommendation to obtain this additional equipment has been made. Ten engineers in the Branch were trained to use the time-sharing terminal. Arrangements were made to obtain about 2 hours per day of quick turnaround time for engineering applications on the Honeywell H-800/200 equipment. Studies of a possible real-time data collection, data evaluation, data reduction, and control computer system are continuing.

Scheduled FY69

Instruments supplied by various manufacturers and those developed in fields of fluid and applied mechanics will be studied for possible use in the Hydraulics Branch. Studies will be made to find more extensive uses for the modular systems already acquired for laboratory and field studies. Data measured by these systems will be supplied to the design divisions to increase the knowledge of structure behavior.

Figure 11

Instrument assembly used in analyzing transient pressure data recorded on magnetic tape. H-1625-INA

Computer techniques, programs, and applications will be evaluated to provide efficient means of analyzing the data acquired from research investigations. Study will be continued to use computers to control model operations and the instruments used to acquire data from these models.

4. Gates, Valves, and Orifices $5,000 DR-191

Frequently cavitation and vibration in gates and valves can be prevented by admitting air. The required vent size can be determined for cases in which a hydraulic jump forms in the downstream conduit and for a falling water surface. However, empirical relationships are required for other conditions such as high-velocity flow in a conduit flowing partially full, spray downstream from a slide gate operating at small openings, and flow from a Howell-Bunger valve. In addition, model and prototype comparison is required to verify the empirical relationships.

Flared or divergent sidewalls frequently are used downstream from slide gates. Although these walls may be beneficial in spreading the jet, severe subatmospheric pressures and cavitation can occur where divergence starts. Tests are needed to determine the severity of negative pressures for various rates of divergence, the maximum operating heads that are permissible, and design changes that might be used to avoid or minimize low pressure tendencies.

High-velocity flows passing through slide gates have necessitated complicated transitions to change the shape of the flow to that of the tunnel. The sides and bottom transition surfaces must redirect the flow very gradually to prevent low pressure areas from developing. Studies are needed to investigate the possibility of using aerated, away-from-the-flow offsets in conjunction with simple transitions to the downstream conduit shape. This configuration has the capability of eliminating low pressure regions at greatly reduced cost.

Regulation of reservoir elevation is frequently accomplished with spillway gates automatically controlled by floats in stilling wells. Maintaining the correct gate openings for various reservoir levels requires that the flow through the intake from the reservoir to the stilling well be accurately controlled. In recent years, fixed orifices have been used for this control. As a result, discharge coefficients for orifice plates located in unusual settings, and for circular openings in pipe walls, are needed to improve the design of these automatic controls.

Improved gate seal design has been made possible through recent developments in synthetic materials and bonding procedures. Studies of seals, seal-clamping arrangements, seal gaps, and seat designs are needed to meet the demand for better sealing under difficult situations.

Radial gates are often used to control reservoir elevations by releasing flow of water over spillways. Efficient use of these gates requires that the rate of flow passing the structures be accurately known. The wide variety of structural shapes and the numerous physical dimensions, shapes, and settings of the gates create an infinite number of combinations affecting flow rate. Empirical data to evaluate these variables for specific installations are being generalized.

Anticipated future research needs include investigation of torque required to operate butterfly valves, effects of gate slot and slide gate shapes on production of spray at small gate openings, and consideration of the mechanics by which droplets of water create air movement.

Accomplished FY68

A report containing design criteria for determining discharge coefficients for a wide variety of radial gate configurations and spillway crest shapes was completed and will be issued during FY69.

High-head gate seals incorporating improvements made through earlier investigations were tested. Report No. Hyd-582, "High-head Gate Seal Studies" was issued, and a movie describing the tests was made.

Analytical studies of air vent size and air demand were completed for Morrow Point Dam Powerplant intake structure. A computer program was written to compute quantity of air flowing into a gate chamber and gate chamber pressures for the case of a falling water surface in the chamber. The report describing these studies is being reviewed and will be issued in FY69.

A report describing the orifice studies is being written.

Scheduled FY69

Analytical, model, and prototype studies on air demand will continue. Determination of air flow quantities over a rapidly moving water surface in a partially filled conduit will be emphasized. The effect on the pressure distribution of a vertical curve in the conduit upstream from a slide gate will be investigated. Studies will be made to complete the data for orifices with irregular upstream and downstream piping. The use of away-from-the-flow offsets immediately downstream from slide gates in free surface tunnels will be investigated.

5. Open Channel Hydraulics $15,000 DR-195

Minimum head losses in canals and canal structures are essential to an economical and efficient open channel flow system for transporting irrigation water. Irrigation canal structures include drops, turnouts, wasteways, overchutes, culverts, transitions, bifurcations, side channel weirs, and other structures less frequently encountered. Verification of model studies with field tests on a number of individual designs is required. Whenever possible, the design should also be studied analytically to develop general methods for design computations.

Field measurements show that present design procedures are not adequate to account for effects of size, alinement, and aquatic growths on the flow capacity of large canals. The measurements substantiate field reports of operational difficulties and emphasize the need for research and testing to develop improved methods of evaluating flow resistance.

Extensive use of upstream water supplied has resulted in salt water intrusion and a reduction in the quantity of fresh water available in estuaries. Laboratory studies on river hydraulics and tidal transients in estuaries are needed to determine methods of preventing contamination of fresh river water by sea water intrusion.

The use of large pumping plants creates the problem of designing approach channels that will contain the bore wave or surge created if the pumps suddenly stop. A knowledge of the celerity and growth of these surges, and of methods of carrying off a part of the surge, is necessary to obtain an effective and economical method of reducing their magnitudes.

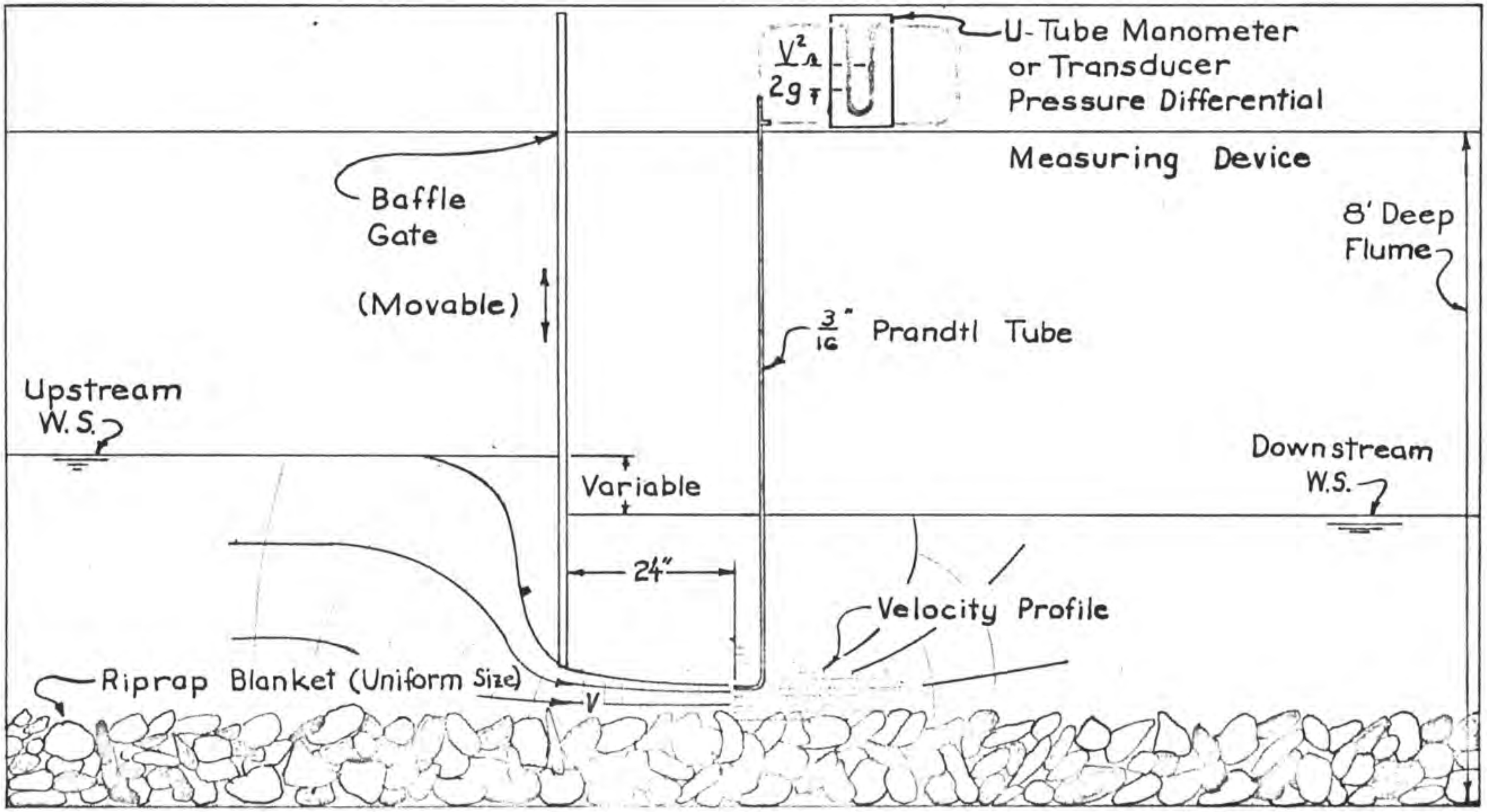
The design of riprap size and thickness for bed and bank protection from scour is a difficult problem. At present, a rule of thumb or an experience factor must be resorted to in attempting to solve the problem. Laboratory studies and field investigations are needed to develop a rational criteria upon which the design of riprap protection can be based.

Future research needs include further verification of model test results with measured prototype results on culverts, transitions, drops, and bifurcations.

Accomplished FY68

Studies were accelerated on the stability of riprap under a variety of controlled hydraulic conditions, Figure 12.

Twenty-four tests were conducted in the 8-foot-deep flume using various sizes of uniform rounded and angular riprap. Riprap in sizes from 3/4 inch to 9 inches were used in the tests. The velocity distribution under the baffle gate was measured when the riprap just began to move and when the riprap had scoured to a depth of approximately 6 inches. Velocities and velocity fluctuations were measured using a Prandtl tube and recorder.



STABILITY OF RIPRAP

HYDRAULIC FLUME STUDY, 1:1 SCALE

FIGURE 12.

Scheduled FY69

Tests will be continued on a range of sizes of uniform riprap. Studies will be conducted to relate the stability of various sizes of riprap with critical velocities. The stability of graded riprap will then be determined and compared with the stability of uniform riprap. Point velocities will be measured with a Prandtl tube and the velocity distribution recorded with an electronic recorder. Velocity fluctuations will be analyzed and related with beginning scour.

6. Flow Surface Protection $5,000 DR-203

Surfaces in spillways and outlet works subjected to high-velocity flows must be protected against damage by cavitation erosion. This protection may take the form of proper surface configuration to prevent cavitation, reduction of cavitation effects by admitting air, or use of materials resistant to cavitation damage. A thorough knowledge of cavitation tendencies of various surface irregularities is needed to determine the most effective and least expensive method of protection. Much of this knowledge can be gained in the laboratory in high-velocity water tunnel tests. Representative joints, humps, offsets, and depressions can be placed in the apparatus and subjected to high-velocity flows and low pressures. The pressure velocity combinations that produce cavitation can be determined for each shape tested, and cavitation index values obtained. Studies to date have established such parameters for several offset shapes protruding into the flow.

The boundary layer thickness of flow affects velocities near the flow surfaces and affects the cavitation potential of the irregularity. Knowledge of the rate at which the turbulent boundary layer develops downstream from gates and valves is necessary to properly evaluate cavitation potentials of downstream flow surface irregularities.

Air entrained in flowing water acts as a cushion against the damaging action of cavitation. More information is needed about the amount of air required to prevent damage, the method of introducing air into the stream, and the optimum location for air admission.

Accomplished FY68

Laboratory studies to determine the size, shape, and location of an aeration groove to admit air into a high-velocity stream in a steep concrete tunnel were made. Field investigations of the extent and location of cavitation damage in a tunnel spillway were made.

Scheduled FY69

An on-site study of the effect of an aeration groove in a steep concrete tunnel will be made. A report will be prepared regarding the model and field study of the aeration groove. An examination will be made of the flow surfaces in an outlet works discharging onto a spillway face where simultaneous spillway and outlet operation has caused damage. Protective measures will be determined for these surfaces.

7. Intakes, Entrances, and Transitions $40,000 DR-204

Entrances to penstocks or outlet pipes are normally streamlined and made as large as practicable to minimize entrance losses, maintain positive pressures throughout the entrance, and prevent formation of vortices which may reduce capacity and entrain air. These entrances are often equipped with bulkhead gates which can be closed to unwater the conduit or stop the flow in cases of emergency. The high costs of these gates and trashracks, and the attendant high costs of the large openings, make it desirable to keep the openings and equipment as small as possible. Operation of several existing structures shows that the head loss at penstock entrances is very small, and that presently used entrance sizes could be considerably reduced with little loss in performance. A test program will be conducted to determine the actual losses caused by entrances of different sizes and configuration. These tests will be extended to determine minimum submergences required to maintain adequate pressures and prevent vortices.

Surging in draft tubes has caused troublesome operation characteristics for many powerplants and in some cases has restricted power output. Studies will be made of basic flow properties in draft tubes to eliminate or reduce the tendency for surging and to permit a more compact arrangement in underground powerplants.

Studies are also needed to determine the performance of the newly designed 135° pump intake elbows when used as draft tubes. Draft tube type service will be encountered on some new pumping units that operate both as pumps and as turbines.

Accomplished FY68

Studies were made on two entrance designs for the Grand Coulee Third Powerplant. An entrance with the same area as the penstock and a 1-1/2:1 height-to-width ratio proved superior to an entrance with an area equal to 9/10ths of the penstock area. The studies were expanded to determine whether an asymmetrical approach flow caused excessive turbulence in the penstocks. A study of flow concentrations in draft tubes having swirl was completed and published in Report Hyd-571, "Hydraulic Model Studies of the Fontenelle Powerplant Draft Tube," Seedskadee Project, Wyoming. A model turbine runner and an air test facility to investigate the basic flow phenomena were completed.

Scheduled FY69

The penstock entrance studies will be continued to further refine the entrance design for the Grand Coulee Third Powerplant. To define the effect of an asymmetrical approach flow, an entrance with one side flared in the direction of the approach flow will be tested. A report on the penstock entrance studies will be prepared. Research will continue by exploring the effects of draft tube length and inlet swirl on amplitude and frequency of surging. Power spectral density measurements of the surges in the draft tube will be obtained.

8. Quality of Water as Affected by Stratified Flow 1/ $15,000 DR-220

Problems in water quality control are sediment movement in reservoirs, salinity of river flows allocated to irrigation, and salinity intrusion in estuaries. Increasing attention is being given to selective withdrawal of reservoir storage for control of downstream temperature and dissolved oxygen content. For example, at certain times of the year downstream water users require warm water for irrigating certain crops; at other times, cooler water is needed during the fish-spawning season, etc.

A library research program showed that some areas of water-quality control have received little or no attention. To obtain data in some of these areas, studies will be made of reservoir geometry and intake geometry on selective withdrawals, optimum intake design, model studies of particular reservoirs and their correlation with prototype data, correlation of temperature distribution with dissolved oxygen in reservoirs, artificial alteration of density currents in reservoirs and estuaries, effects of hydraulic structures such as stilling basins on reoxygenation of rivers, and effects of earthquakes on movement and possible destratification of water in reservoirs.

Accomplished FY68

Studies were made of flow patterns and temperature distribution in the vicinity of the outlet for several conditions of temperature stratification. Temperatures were measured with 30 thermistor probes attached to the inner walls of the test flume. Movement of dye was recorded by still photographs and time-lapse motion pictures. Three-dimensional circulation in the flume was observed. A proposed mathematical model was reviewed for possible application to this study.

1/Formerly Stratified Flow (Reservoir).

Scheduled FY69

Temperature control equipment will be installed in the test flume and attempts will be made to simulate stratification in a specific prototype reservoir with selective withdrawal facilities. Model and prototype operation will be compared. A mathematical model will be considered for use in conjunction with the hydraulic model studies. Library research will continue. A progress report will be issued.

9. Water Measurement

Commitment of more and more of our water resources compels us to improve water measuring methods, to increase measuring accuracy, and to make the information available and understandable to people measuring the water. Distribution of water from older systems of canals and laterals needed only an understanding of relatively simple measuring devices. Some of the newer distribution systems demand a much greater knowledge of numerous complicated measuring devices and water controls. The expected increased automation of water control and its measurement will raise the level of knowledge needed to account for water into and out of the distribution system. Studies are planned to increase our knowledge of both the old and new devices and to inform others of the results.

Accomplished FY68

A Brooks Irrigation Flowmeter/Controller was investigated in the laboratory at the request of the Mechanical Branch. The 10-inch controller, designed to control a preset flow rate over a head range of about 10 to 175 feet, was a production model like those installed in the Westlands Irrigation District, California. The controller includes a tapered tube in which a float is positioned by the flow. The meter indicates, totalizes, and controls the flow rate and is used to shut off the flow. The discharge capacity, flow totalizing and indicating accuracy, head loss, control, and shutoff characteristics were studied in the investigation. A memorandum report is being prepared on the results of the study.

A draft report completed on the trapezoidal flume is being reviewed. The report presents the results of laboratory studies of a flat-bottomed trapezoidal flume with smooth and sand-roughened sides.

Limited studies of a shunt-flow meter manufactured by the BIF Company were made. The meter is designed to totalize and indicate the flow rate of a larger meter. A part of the flow in the main meter is bypassed through the shunt-flow meter. The discharge of the main meter is thus inferred from the head-capacity characteristics of the two meters. The device properly used might reduce the cost of installing a register for a large main meter.

A study was completed on an enlarged weir box turnout. The normal design capacity of these turnouts is about 5 cfs, and capacities of 12 to 20 cfs are now being considered. A full-sized structure for a 4-foot suppressed weir was constructed in the laboratory. The weir box, with a 12-cfs capacity, was studied for accuracy of discharge measurement and included the development of a baffle to provide a quiet flow in the weir pool. A report will be written on the results of the study.

Three series of discharge measurements using radioisotopes were made in the 6,000-foot-long, 6-foot-diameter penstock of the Flatiron Powerplant near Loveland, Colorado. Thirty-five separate injections of radioactive Bromine resulted in ninety-three separate discharge computations. The measurements explored the effects of injection position in the pipe cross section, the mixing length, position of sample withdrawal, and the general techniques of applying the radioisotope method to discharge measurement, Figure 13. Another series of discharge measurements were made at the Flatiron plant on the pump-turbine unit operating as a pump. In general, the measurements at the turbine and the pump had greater variations than desirable.

The results of the tests were not as precise as desired, but were encouraging. The tests gave good information on lengths of pipe required to mix the pipe flow and tracer, radiation measurement procedures, and injection and sampling techniques. A report is being prepared on the results of these measurements.

Studies were completed on an 8-inch Dall Flow tube. The discharge capacity, head loss, and accuracy were measured for this device and report of the results will be written.

Evaluation of information presented by manufacturers was continued on the acoustic, magnetic, and turbine flow measuring devices. No laboratory investigations were performed but a trial of the acoustic meter was made at O'Neil Pumping Plant, Central Valley Project, California.

A continuing review was made of publications from universities, Government, and private industry to keep abreast of changes being made in flow measurement devices. Contacts were maintained with industrial representatives to obtain information on newer models and modifications of devices previously noted. The information was used to answer questions and advise designers and operators of irrigation systems.

The volume <u>Water Measurement Procedures</u> was revised for the November 1967 Irrigation Operators' Workshop. Two members of the Hydraulics Branch staff lectured to a total of 120 in attendance, in groups of 30. Figure 14 shows a laboratory demonstration following a lecture.

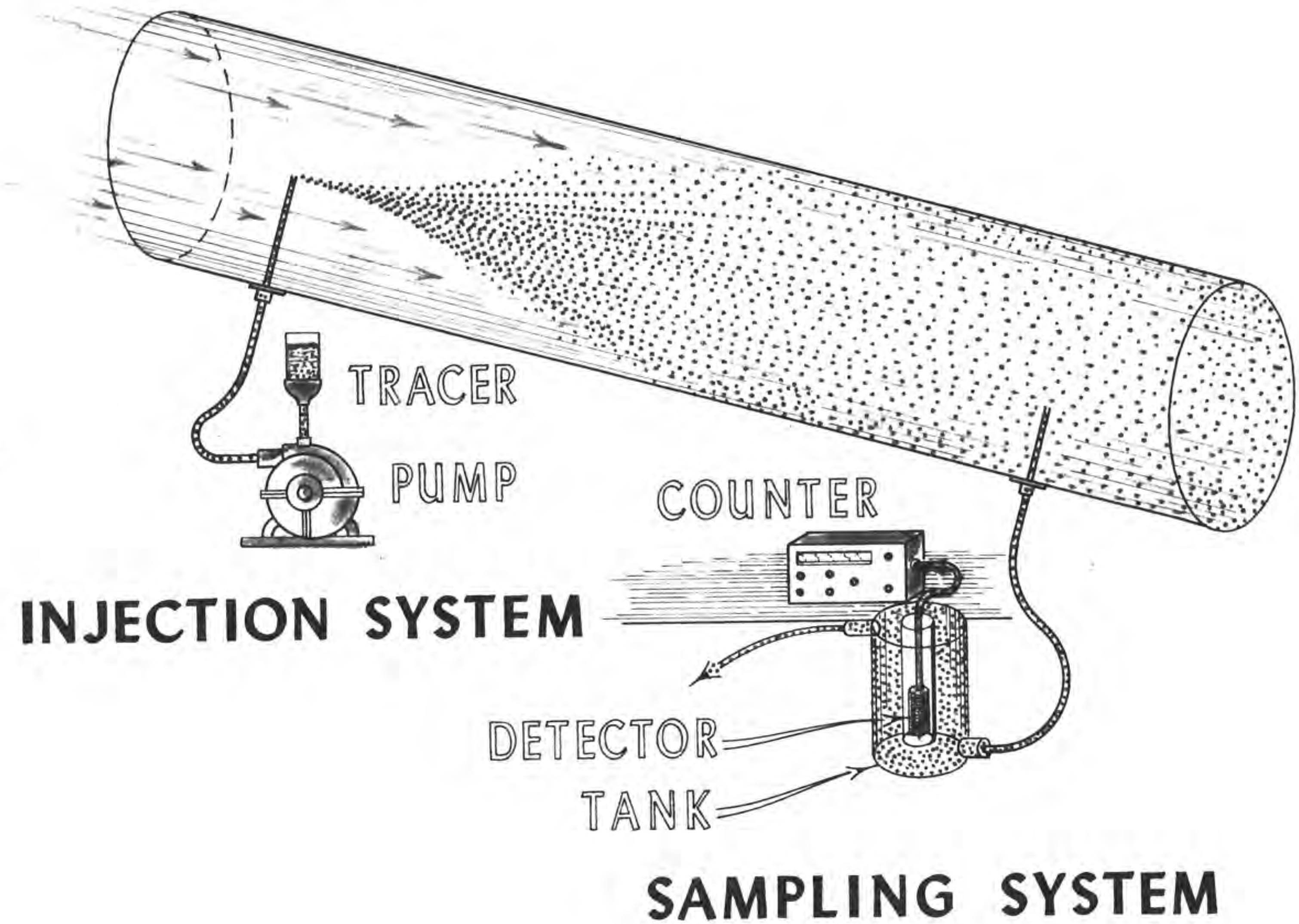


Figure 13

Tracer Flow Measurement

Figure 14

Demonstration of a Parshall flume under various head conditions - The 1967 Irrigation Operators' Workshop, Denver, Colorado. H-1616-INA.

Scheduled FY69

Evaluation of open and closed conduit measuring devices will be continued in preparation for increased automating of controls and other facilities of distribution systems. Phase IV of five phases of the radioisotope discharge measurement program had been started and will continue with emphasis placed largely on field measurements at the Flatiron Powerplant and Pumping Plant. The collection of information will continue on acoustic, momentum, thermal, tracer, and newer forms of measurement devices.

10. Stability of Artificial and Natural Channels DR-132

Scour on the outside and deposition on the inside of curves of unlined trapezoidal canals has increased canal maintenance costs. A number of research studies have been made, including collection of data from field sites and tests on a hydraulic model in the laboratory, to determine the various forces involved as water flows around curves in canals. A trapezoidal canal 50 feet long containing a curved section was used in laboratory testing. Recommendations have been made to reshape the canals to reduce scour and deposition.

Recent studies have concentrated on canals built in cohesive earth materials. Field tests have been made on three tractive force test reaches on Farwell Main Canal, previously set up and controlled for test purposes.

Accomplished FY68

A fifth set of cross-section surveys were made on the three test reaches on Farwell Main Canal and compared with cross sections previously surveyed. Continuous recordings were made of water surface gage readings at each of the three trapezoidal check and measuring devices. Scour and deposition were determined by computations using ADP equipment. A report of model studies of the three trapezoidal measuring devices is being prepared.

Scheduled FY69

Continuous water surface recordings to determine fluctuations in discharge will be made by field personnel at each of the three trapezoidal measuring devices downstream from the three test reaches. A sixth set of cross-section surveys will be made at the end of the irrigation season. A set of field measurements including velocity distribution, boundary shear, water surface slope, and vane shear tests on the soil will be made at the maximum canal capacity discharge which is expected to occur during 1968.

11. Aquifers and Drainage $35,000 DR-133

On many irrigation projects, ground water is becoming increasingly salty and a better understanding is needed of the movement of saline ground water in aquifers when fresh water is applied to the land surface. Previous studies of the behavior of fresh water and sea water interfaces in coastal areas, and construction of flow nets, indicate that selective drainage from two-part and one-part aquifers may not be practical. The water table in some irrigated areas is maintained below the root zone by pumping from wells. Hydraulic model studies in a 4-1/2-foot-deep tank are being made to study removal of saline water and/or fresh aquifer water by pump wells.

Design of drainage systems on sloping land presents problems that are not readily solved by methods used for drainage systems for level land. Hydraulic model and analytical studies are required to make adequate solutions of the problems of removal of saline water from single- and two-part aquifers and for drainage of sloping lands.

Drilling and developing wells become increasingly important as the demand for more irrigation, municipal, and industrial water rises. Although wells have been used to furnish water throughout recorded history, many procedures used in the drilling and developing of wells are not fully understood. Because of these uncertainties, many finished wells do not produce the expected capacity. Studies are needed to determine the effects of drilling procedures on the aquifer, and on how to best develop the wells under specific aquifer conditions.

Accomplished FY68

Research Report No. 13, "Removal of Saline Water from Aquifers," was published and distributed.

Sixty-two tests were completed on the 60-foot-long by 2-foot-wide by 2-1/2-foot-deep flume to study drainage from sloping land. Drain spacings of 6 and 12 feet in the flume were studied on slopes from 0 to 10 percent.

A series of tests were conducted using plastic pipe up to 23 feet long to determine to what degree gravel pack material would segregate when placed in a water-filled well. A computer program was prepared to predict the mean gravel size, permeability, effective gravel size, and rate of deposit at all levels in the gravel pack around the well. The computer program was checked by laboratory tests conducted in the simulated well.

Scheduled FY69

Tests will be continued using the 60-foot-long flume and the data obtained will be analyzed to study the effect of drainage of sloping agricultural land upon the spacing of tile drains, Figure 15.

Tests will be continued to study gravel packs in wells and the action of gravel pack and surrounding aquifer material during well development, Figure 16.

12. Seepage DR-206

Water losses from canals and pipelines have been reduced by various types of linings and sealants. These means of seepage reduction are used in areas where high losses are expected in new canals or where evident in older canals. As water uses multiply and available water becomes scarce, the tracing and measurement of seepage becomes increasingly important. The problem of locating the parts of conveyances that seep enough to justify the cost of lining is difficult and needs research to develop convenient and accurate methods.

Accomplished FY68

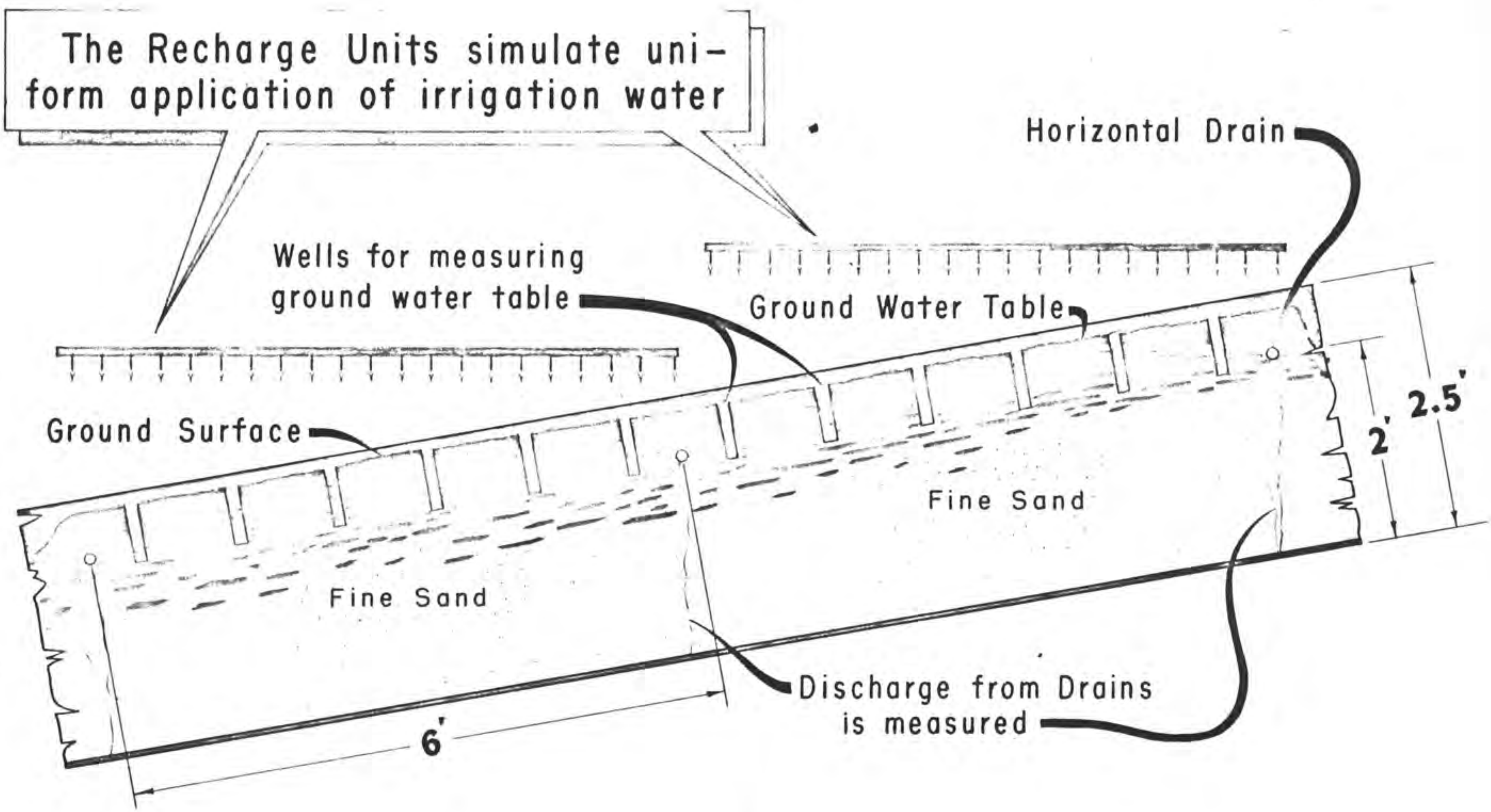
Electrical logging tests in the 32- by 4- by 4-foot laboratory seepage tank were completed. A report, "Laboratory Tank Studies and Electrical Canal Logging to Detect Seepage - LCCL Program," Hyd 570, was published to give the results of these studies. No definite correlation could be found between the voltages present in the flume and the amount of seepage.

Information on the techniques of measuring seepage were used to help plan a series of seepage tanks in the Denver Office contract work for the Office of Saline Water. Brine evaporation ponds considered for use at demineralizer sites require tight linings. Various sealing materials are being considered and will be tested in seepage tanks to be located at the Dalpra Farm north of Denver, Colorado.

Assistance was given to Denver Office and field personnel in planning and performing seepage measurements.

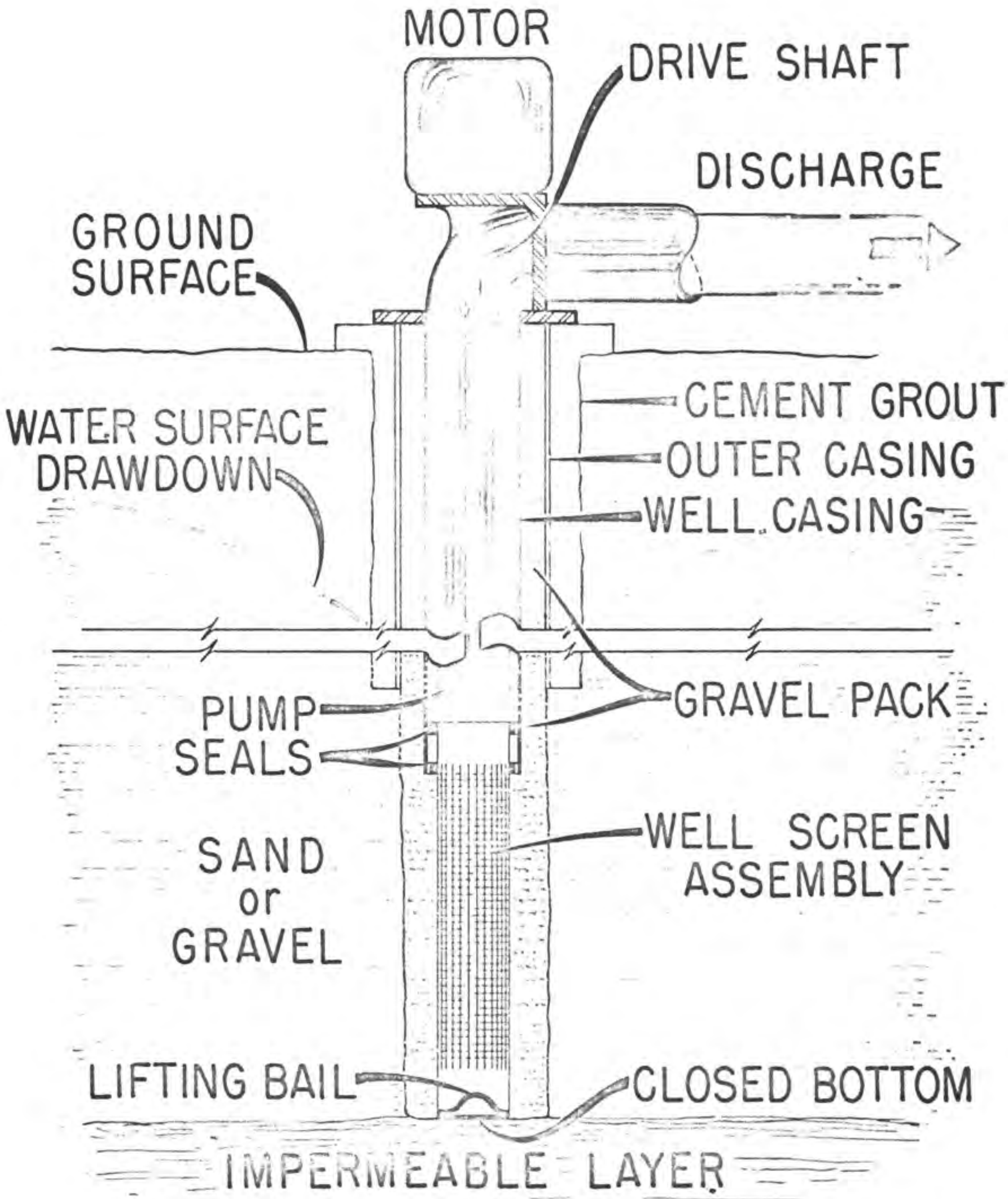
Scheduled FY69

A current awareness program will be followed to assist O&M and the Denver Office in evaluating seepage losses and in assisting as required in seepage measurements.



ADJUSTABLE SLOPING FLUME TO STUDY DRAINAGE FROM SLOPING IRRIGATED LAND

Figure 15



WELL with SCREEN & GRAVEL PACK

Figure 16

B. NARRATIVE JUSTIFICATION
FOR
GENERAL INVESTIGATIONS
GENERAL ENGINEERING AND RESEARCH
WATER RESOURCES ENGINEERING RESEARCH

Project: Hydraulic Research - FY70 OFFICE OF CHIEF ENGINEER

Description: Hydraulic research is required to supply new and advanced information on the hydraulic behavior and performance of structures, conveyances, equipment, reservoirs, and aquifers, including flow measurements, drainage, seepage, and well mechanics. These studies are performed in the laboratory and at completed Bureau hydraulic works to obtain information that will improve planning, design, construction, and operation of hydraulic works and systems; develop techniques for improved analysis and synthesis of hydraulic systems; correlate hydraulic performance of hydraulic works with design criteria; and achieve economies in construction and maintenance.

New flow measurement techniques, new and improved methods of observing and recording hydraulic transients, and more rapid and precise techniques of data interpretation must be developed. Studies leading to a greater penetration of understanding of flow in porous media must also be pursued on a broader scale.

Extensive studies are made on energy dissipators that convert flows from high to low velocity to prevent flow channel erosion and structural damage to dams, canals, and rivers; to evaluate hydraulic phenomena such as cavitation, vibration, pressure distribution, velocity distribution, air demand, and friction losses introduced by physical characteristics of flow surfaces and configurations of conduits and hydraulic equipment; to study hydraulic transient phenomena; to develop design criteria for open channels, including channel stability and estuarine behavior; to establish seepage-loss measurement methods and equations; to investigate draft-tube surges in turbines and governor systems; to advance the knowledge of stratified flow in reservoirs and conveyances; and to develop and improve laboratory techniques, instrumentation, and test equipment.

Studies are pursued to extend knowledge of flow of ground water in a variety of aquifers, to determine factors affecting the design of various types of drains, and factors affecting measurement of seepage from canals.

Accelerated research is pursued to evaluate waterflow measurement techniques and devices, develop new methods and devices, and improve methods of water accountability. Investigations include use of tracer methods to measure discharges in high-head turbines, pumps, and conduits.

Status: The status of each program activity is as follows:

1. Energy dissipators. - Dynamic pressure and vibration measurements were made on the center wall of a hollow-jet valve stilling basin. Plans were made for purchase and installation of accelerometers and pressure transducers in a slide gate stilling basin. The report on modified design procedures for the Types VI stilling basin was completed. Studies were made to extend the allowable design discharge for a baffled apron type of energy dissipator.

2. Gates, valves, and orifices. - A report containing design criteria for a wide variety of radial gate configurations and spillway crest shapes was written. A high-head seal test facility is being used to test a variety of seal-clamp bar designs and clearances under moving conditions at heads up to 600 feet. A computer program was written for computing the quantity of air flowing into a gate chamber and the gate chamber pressures for the care of emergency closure with a falling water surface in the chamber. A report was completed and is being reviewed. A report describing gate-control orifice studies is in preparation.

3. Pipeline and tunnel hydraulics. - A computer program was developed to be applied to the general problems of pipeline surging. A hydraulic model was used to debug and refine the computer program. Good correlation was obtained between computer program and model results. A report was issued regarding surging in a laboratory pipeline with steady inflow. A field study was made to determine the hydraulic performance of various features of the 115-mile-long central system of the Canadian River Aqueduct. Data obtained from a field test of inverted siphons and free-flow tunnels along a 32-mile-long reach of the Salt Lake Aqueduct have been analyzed.

4. Instrumentation. - Instruments were critically studied and selections were purchased to increase engineering capability for monitoring and acquiring hydraulic data for analysis. Ten engineers in the Branch were trained to use the time-sharing computer terminal for rapid analysis of the data from applied and research studies.

5. Flow Surface Protection. - Laboratory studies were made to determine the size, shape, and location of an aeration groove to reduce cavitation damage in a steep concrete tunnel by admitting air into the high velocity stream. Field investigations were made to determine the extent, location, and cause of cavitation damage in a tunnel spillway.

6. Open-channel hydraulics. - The timed and number of experiments were increased in the study of the stability of riprap. Various sizes of rounded and angular riprap were studied to find the critical velocity causing movement of the rock.

7. Intakes, entrances, and transitions. - Studies were continued on two simplified penstock entrances. A still smaller entrance was tested and compared with the other two entrances. The studies were expanded to determine the effect of unsymmetrical approach flow on turbulence in the penstock. A board of consultants was convened to evaluate the research program in turbine surging and vibration. Based on the consultants recommendations, an air model was constructed to study the basic flow phenomena of swirling flow. An extensive bibliography of swirling flow and turbine draft tube surging was compiled. An analytic study of surging in an existing powerplant was initiated. A plan was initiated to field test a siphon elbow in a discharge line, and a test access fitting was installed in the elbow.

8. Stratified flow. - Tests were made to verify theories of selective withdrawal. A progress report was started, which will include the results of these tests and the applicability of previous research by others to USBR problems.

9. Aquifers and drainage. - Research Report No. 13, "Removal of Saline Water from Aquifers," was published. Tests were continued in a laboratory flume to study drainage from sloping land. Tests were conducted in a simulated well to determine to what degree gravel park material would segregate when placed in a water-filled well. A computer program was prepared to predict mean gravel size, permeability, effective gravel size, and rate of deposit at all levels in the gravel park around the well.

10. Seepage. - A report of the completed laboratory electric logging tests was published. Available information and techniques of measuring seepage were used to plan seepage tanks for work of the Office of Saline Water. Assistance was given to the field offices in planning and performing seepage measurements.

11. Stability of artificial channels. - A fifth set of cross-section surveys were made on the three test reaches on Farwell Main Canal and compared with cross sections surveyed during the past 4 years. Continuous recordings were made of water surface gage readings at each of the three trapezoidal check and measuring devices. A report of the model studies to calibrate the three trapezoidal measuring devices was completed. The data from the test reaches built in cohesive earth materials will be analyzed and the knowledge gained will be used in improving methods of design of canals in cohesive earth materials.

12. Water measurement. - A series of field discharge measurements using the "total count" method and BR-82 as a tracer were completed at Flatiron Power and Pumping Plant, Colorado Big Thompson Project. The measurements gave good information on lengths of pipe required to mix the tracer in the pipe flow, radiation measurement procedures, and injection and sampling techniques. A report of the results was

in progress. Studies were made of standard devices, i.e., a trapezoidal flume, weir box turnout, a shunt flowmeter and an 8-inch Dall flow tube. A study of the characteristics of a flow controller/indicator were continued on a production model designed for irrigation turnouts. An evaluation of an acoustic meter was made by the salt-velocity method at the O'Neill Pumping Plant, Central Valley Project, California. Literature studies were continued on proposed large magnetic flowmeters (12 to 18 feet) and on the acoustic method of water measurement. Continual reviews of publications from universities, government, and private industry were made to keep abreast of changes and new offerings in flow measurement devices.

Justification: The Bureau's extensive responsibilities for water supply result in a wide range of problems to be solved by hydraulic research. The research provides knowledge for specific design problems and for general application in developing efficient and economical hydraulic systems. Field and laboratory studies are necessary to supply basic technical information on free and pressure flow phenomena. Continued study of pressure and vibration forces is needed for hydraulic energy dissipators. Studies as yet have not produced a flexible gate seal for satisfactory performance at a head of 600 feet. An analytical and experimental investigation is needed on the amplitude and frequency of hydraulic surges caused by the interaction of turbines and draft tub s. Studies on the entrances to penstocks are to continue to optimize the relationship of the size and shape of opening, the gate, and the head loss. Investigations are necessary to explain the fluid dynamics of the movement of air and the quantity of the movement above fast flowing water in partially filled conduits. Field and laboratory studies have shown the need for continued study of surges in pipeline distribution systems. Cost reduction in stabilizing channel banks downstream from energy dissipators requires continued study of the forces on riprap in turbulent flow. Data from measurements of surface resistance to flow in tunnels should be analyzed to provide design information. Gates and valves should be studied to find means of reducing the torque and the tendency for cavitation at small openings at high heads. Studies should continue on the development of energy dissipators for small calvert size flows and ranging to those for slide gate structures under high heads. The studies should be supported by prototype measurements of pressure, vibration and surging in the dissipators. The supply of good quality water requires a better knowledge of the causes and effects of reservoir stratification. Studies should continue to provide this knowledge.

The relation of seepage and waterflow should be studied to increase the understanding of the design of agricultural drains and the behavior of gravel packs and aquifer material around well screens and casings.

Studies of instruments and computer techniques should continue for the purpose of improving data acquisition and analysis. To meet Bureau responsibilities as a technical expert and advisor in water measurement, research should stress new and convenient methods of measuring both large and small quantities of water. The methods should include tracers, acoustic, magnetic, thermometric, and pressure differential methods of measurements. Older structures should be evaluated to provide a reliable accounting for the available water. Greater emphasis should be placed on measurements in closed conduit systems for increased efficiency and ease of water control.

LEGEND: Types of Activity

Preconstruction and Other Work — Construction

LINE NO.	CLASS AND ACCOUNT	PROGRAM ITEM	QUANTITY	UNIT	ESTIMATED TOTAL	TOTAL TO JUNE 30,68	FISCAL YEARS 1969	1970	1971	1972	1973	1974	1975	BALANCE TO COMPLETE	ESTIMATED COMPLETION DATE	LINE NO.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1		GENERAL ENGINEERING AND RESEARCH														1
2	18-00-0801	Water Resources Engineering Research														2
3		Chemistry and Physics Technology in Materials and Methods			2,581,000	684,317	113,300	152,000	270,000	290,000	300,000	260,000	250,000	251,383		3
4		Concrete			2,500,000	562,827	89,400	110,000	245,000	250,000	265,000	270,000	280,000	437,773		4
5		Earthquake Engineering			2,042,000		87,100	175,000	[illegible]	200,000	202,000	213,000	220,000	767,900		5
6		Electric Power			13,610,000	787,120	228,900	405,000	[illegible]	1,921,000	1,971,000	2,021,000	2,200,000	2,256,980		6
7		Evaporation Reduction			5,950,000	1,941,807	280,900	313,000	500,000	500,000	500,000	500,000	500,000	914,293		7
8		Hydraulics			5,200,000	1,478,764	241,500	313,000	440,000	480,000	490,000	500,000	510,000	746,736		8
9		Hydrogeology of Reservoir and Canal Leakage			1,087,000		28,000	60,000	166,000	167,000	168,000	169,000	170,000	160,000		9
10		Laboratory Instrumentation Systems			1,947,000			250,000	235,000	245,000	257,000	170,000	190,000	640,000		10
11		Open and Closed Conduit Systems			4,113,000	720,230	135,200	220,000	469,000	467,000	342,000	293,000	290,000	1,156,570		11
12		Rock Mechanics			3,080,000	267,749	101,300	140,000	361,000	363,000	411,000	411,000	420,000	604,951		12
13		Scientific Communication and Documentation			450,000	51,899	15,000	25,000	40,000	50,000	50,000	50,000	50,000	118,101		13
14		Soils Engineering			4,092,000	893,031	187,900	250,000	431,000	477,000	488,000	508,000	515,000	342,069		14
15		Structures			5,310,000	1,018,720	193,900	262,000	489,000	551,000	551,000	591,000	600,000	1,073,380		15
16		Water Quality and Pollution Control			8,048,000	149,209	192,500	343,000	708,000	808,000	859,000	1,010,000	1,100,000	2,878,291		16
17		Weed Control and Herbicide Residues			2,061,000	455,350	86,100	164,000	240,000	250,000	270,000	280,000	290,000	25,550		17
18		TOTAL COST			62,071,000	9,011,023	1,981,000	3,182,000	6,585,000	7,019,000	7,119,000	7,245,000	7,555,000	12,373,977		18
19		Adjustments			-7,476	-7,476										19
20		Transfers, Credits, and Other Expenditures				20,489	-20,489									20
21																21
22		TOTAL EXPENDITURES			62,063,524	9,024,036	1,960,511	3,182,000	6,585,000	7,019,000	7,119,000	7,245,000	7,555,000	12,373,977		22
23		Undelivered Orders				176,402	-176,402									23
24																24
25		TOTAL OBLIGATIONS			62,063,524	9,200,438	1,784,109	3,182,000	6,585,000	7,019,000	7,119,000	7,245,000	7,555,000	12,373,977		25
26																26
27																27
28		Allotment					1,706,000									28
29		Prior Year Funds Available					17,109									29
30		Allotment Required						3,117,000	6,585,000	7,019,000	7,119,000	7,245,000	7,555,000			30
31		Proposed Increase for Pay Raise					61,000	65,000								31
32																32
33																33

Notes: Reflects proposed supplemental appropriation request for pay increase.

Recommended: G. E. Burnett (Operating Office Head) 8-9-68 (Date)

Recommended: Barlow H. Johnson Acting (Chief Engineer) 8-9-68 (Date)

Recommended: ________ (Chief, Div. of PC & P) ________ (Date)

Approved: ________ (Commissioner) ________ (Date)

Revised: 8-9-68 (Date)

SHEET 1 OF 1 SHEETS

Form PF-3 — MARCH 1964

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

CONTROL SCHEDULE

GENERAL INVESTIGATIONS
Water Resources Engineering Research

Denver, Colorado (Office) — July 23, 1968 (Date) — CE (Region)

☒ GENERAL INVESTIGATIONS ☐ LOAN PROGRAM ☐ CONSTRUCTION ☐ OTHER

C. Control Schedule

SECTION VI - GENERAL DISTRIBUTIVE ACTIVITIES

A. General Description and Identification

B. Special Activities

1. Membership in Technical Organizations
2. Professional Papers
3. Continuing Education of Staff
4. Exhibits

A. General Description and Identification

Costs of this office consist of three principal elements: direct charges, general administrative expense, and general distributive expense. Direct-charge projects are administered through the program process while general administrative and general distributive expense costs are administered by means of the office budget. A detailed listing of the cost categories is found in Section X.

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY68)

Name	Membership in founder societies	Membership in other technical organizations	Registered professional engineer	Other
Martin	Fellow, ASCE	International Association for Hydraulic Research Colorado Chapter, Society of the Sigma Xi	Colorado No. 1086	Chairman, Water Resources Coordinating Committee, American Society of Civil Engineers, 1966-68; Chairman, National Advisory Committee for the International Hydraulics Congress and Hydrology Symposium, Fort Collins, Colo., Sept. 1967 Member, Colorado Section, ASCE
Peterka	Fellow, ASCE	Hydraulics Division, Colorado Section, ASCE Colorado Chapter, Society of the Sigma Xi Reclamation Technical Club	Colorado Engineer and Land Surveyor No. 3650	ASCE Representative on Work Group 4 - Liquid Measurement in Open Channels by Dilution Methods, Committee TC/113 of the International Standards Organization Member, Value Engineering Team No. 1 Chairman, Value Engineering Team No. 6 Reviewed two papers for Hydraulics Division, ASCE, Publications Committee Participated in lecture and discussion course for Irrigation Operators Workshop - Nov 1967 in Denver and Dec 1967 in Logan, Utah

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY68)

Name	Membership in founder societies	Membership in other technical organizations	Registered professional engineer	Other
Wagner	Fellow, ASCE	International Association for Hydraulic Research U.S. Commission on Large Dams Colorado Chapter, Society of the Sigma Xi DFC Professional Engineers Group Reclamation Technical Club	Colorado No. 2128	Member, Hydraulic Structures Committee, Hydraulics Division, ASCE Member, Colorado Section, ASCE Member, Value Engineering Team No. 8
Enger	Member, ASCE	Association for Computing Machinery (ACM) International Association for Hydraulic Research American Radio Relay League AGU	Colorado No. 3195	Member, ASCE Task Committee on Erosion of Cohesive Materials Member, Colorado Section, ASCE DFC Professional Engineers Group Reclamation Technical Club
Carlson	Fellow, ASCE	International Association for Hydraulic Research U.S. Committee, International Commission on Irrigation and Drainage	Colorado Engineer and Land Surveyor	Member, Hydraulics and Irrigation and Drainage Divisions, Colorado Section, ASCE DFC Professional Engineers Group

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY68)

Name	Membership in founder societies	Membership in other technical organizations	Registered professional engineer	Other
Carlson		Colorado Chapter, Society of the Sigma Xi Reclamation Technical Club Col., USAR, Corps of Engineers, Asst. Instructor, Command and General Staff College, 5046 USAR School		Received USBR Special Acts Award $750 for Meritorious Service in Developing Baffle-Gate Cleaning Device which will benefit Federal, State, and Private Agencies faced with the problem of cleaning sediment from artificial fish spawning gravels Reviewed 2 papers for Publications Committee of Hydraulics Division, ASCE
Schuster	ASME	International Association for Hydraulic Research Colorado Chapter, Society of the Sigma Xi	Colorado	Reclamation Technical Club
Rhone	ASCE	Colorado Section, ASCE Member, ASCE Task Committee on Branching Conduits	Colorado	
Dexter			Colorado	Reclamation Technical Club
Falvey	ASCE	IAHR	EIT	

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY68)

Name	Membership in founder societies	Membership in other technical organizations	Registered professional engineer	Other
Beichley	Member, ASCE	Bureau of Reclamation Technical Club	Colorado	
		U.S. Naval Reserve Research Co. 9-21		
King	Associate Member, ASCE	Colorado Section, ASCE	Colorado No. 5633	
		Professional Engineers of Colorado, Functional Section for Engineers in Government		
		President, DFC Professional Engineers Group		
		Reclamation Technical Club		
Colgate	ASCE	Colorado Section, ASCE	Colorado	5002 Research and Development (U.S. Army Reserve)
		Reclamation Technical Club		
Isbester	None	Reclamation Technical Club		
Dodge		Reclamation Technical Club	EIT	
		DFC Professional Engineer		
		MICH Professional Engineers		

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY68)

Name	Membership in founder societies	Membership in other technical organizations	Registered professional engineer	Other
Zeigler			Colorado	Reclamation Technical Club DFC Professional Engineers Group
Palde	Associate Member, ASCE	Colorado Section, ASCE DFC Professional Engineers Group Reclamation Technical Club	EIT (Georgia)	
Kuemmich	Instrument Society of America	Reclamation Technical Club Colorado Mineral Society American Numismatic Association		Colorado-Wyoming Numismatic Assn. Federal Coin Club

B. SPECIAL ACTIVITIES

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY68, or in Preparation

Author	Title of paper	Meeting (place and date)	Paper published
Martin	Hydraulic Laboratory Practice in Water Resources Engineering	Pacific Southwest Inter-Agency Committee - Water Management Subcommittee; at Las Vegas, Nevada - December 4-6, 1967	Illustrated lecture
	New Challenges in Water Resources Engineering	University of Iowa - Engineering Faculty Luncheon, March 13, 1968	Informal talk at luncheon from prepared notes
	The Civil Engineer and Water for the Future	University of Iowa - Civil Engineering Department Seminar - March 13, 1968	Illustrated lecture
		State University of Iowa - Meeting of Civil Engineering faculty and students - March 14, 1968	Illustrated lecture
	Present Day Research for Water Resources Engineering	University of Iowa - Graduate School Seminar in Mechanics and Hydraulics - March 13, 1968	Illustrated lecture
Peterka	Water Measurement Lectures (4)	Irrigation Operators' Workshop, Nov 1967, Denver, Colorado	Delivered series of four slide-illustrated lectures to conferees
	Water Measurement Lectures (5)		Delivered series of five slide-illustrated lectures to conferees
			Publication - Water Measurement Procedures - Irrigation Operators' Workshop 1967 - Report No. HYD-577 used as a handout for Workshop meetings. This is a 155-page publication for use in lectures and as an aid in Bureau and District Offices.

B. SPECIAL ACTIVITIES

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY68, or in Preparation

Author	Title of paper	Meeting (place and date)	Paper published
Peterka	Why and How We Use Value Engineering	University of Wisconsin - February 13, 1968	
	Hydraulics and Hydrology	University of Wisconsin - February 13, 1968	
	Water Resources Development	University of Wisconsin - February 14, 1968	
	Revolutionary Hydraulic Concepts Improve Design and Performance of Giant Dams	University of Wisconsin - February 14, 1968	
	Revolutionary Hydraulic Concepts Improve Design and Performance of Giant Dams	Marquette University - February 15, 1968	
	Revolutionary Hydraulic Concepts Improve Design and Performance of Giant Dams	Wisconsin State University - February 19, 1968	
	Why and How We Use Value Engineering	Wisconsin State University - February 20, 1968	
Wagner	Reviewed the paper "Energy Dissipation for Flow from Vertical Conduits" for ASCE Committee on Publications	August 1967	

B. SPECIAL ACTIVITIES

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY68, or in Preparation

Author	Title of paper	Meeting (place and date)	Paper published
Enger	Erosion of Cohesive Sediments (Coauthored with Smerdon and Masch)	Water Resources Meeting - New York - Fall 1967	Has been approved for publication in Journal of Hydraulics Division ASCE
	Evolution of Computer Concepts in a Hydraulic Laboratory	Being prepared for Hydraulic Division Conference being held at MIT on August 21-23, 1968	Course presented for Denver Univ. one evening, May 9, 1968 - Teaching for Professional Engineer Examination - Hydraulics
Carlson	Baffle Gate Method for Cleaning Salmon Beds in Canals	International Association for Hydraulic Research - XIIth Congress - Colorado State University, Fort Collins - September 11-14, 1967	Proceedings of XIIth Congress of IAHR, Volume 3
Schuster	Five lectures - Water Measurement Procedures	Irrigation Operators' Workshop - November 27 to December 1, 1967 Denver Federal Center	
Holley Schuster	Radial Diffusion in Turbulent Pipe Flow	XIIth Congress, IAHR, Fort Collins, Colorado - September 1967	Proceedings of XIIth Congress, Volume 4
Rhone	Review paper for ASCE Hydraulics Division - "Hydraulic Properties and their Influencing Factors in Small Unlined Rock Tunnels" by Seppo Phiha		
Falvey	Hydrodynamic Pressures in Conduits Downstream from Regulating Gates	XIIth IAHR Congress - Fort Collins, Colorado - September 11-14, 1967	Proceedings XIIth Congress, IAHR

B. SPECIAL ACTIVITIES

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY68, or in Preparation

Author	Title of Paper	Meeting (place and date)	Paper published
King	Analysis of Random Pressure Fluctuations in Stilling Basins	XIIth Congress, IAHR, Fort Collins, Colorado - September 11-14, 1967	Paper B 25, Volume 2, Proceedings
	Hydraulic Model Studies for Morrow Point Dam		Engineering Monograph No. 37 - A Department of the Interior Water Resources Technical Publication
Colgate	(Reviewed two papers for ASCE)		

B. SPECIAL ACTIVITIES

3. Continuing Education of Hydraulics Branch Staff (FY68)

Name	Course Title and Number	Type In-service - Gov, non-Gov facility or military	Place (DU, etc)	Credit Yes or No	Remarks (including other studies)
Peterka	Irrigation Operators' Workshop	Utah State Univ.	Logan, Utah	Cert. awarded	Attended lectures on Water Use, Water Delivery Problems, and Sprinkler Irrigation
	Supervision and Group Performance	Government facil.	Bldg. 67 - DFC	Yes Completion Cert. awarded	40-hour course in Supervision Problems and Techniques
Wagner	Application of Value Analysis Engineering Skills	In-Service - Gov.	DFC	No	
Carlson	Middle Management Institute Conducted by Civil Service Comm.	In-Service - Gov.	Boulder, Colorado	Cert. awarded	November 13-16, 1967
	Russian Translation Seminar	In-Service - Gov.	Chief Engineer's Office	No	Meet 2 hours per week and translate articles from Russian Literature
Schuster	Organization and Management Principles	In-Service	Bureau	No	50 hours (10-week course)
	Basic Course in Solid-State Electronics	Non-Gov facility	Residence	No	
	IBM Art of Dictation	In-Service - Gov.	DFC	No	

B. SPECIAL ACTIVITIES

3. Continuing Education of Hydraulics Branch Staff(FY68)

Name	Course Title and Number	Type In-service - Gov, non-Gov facility or military	Place (DU, etc)	Credit Yes or No	Remarks (including other studies)
Enger	FØRTRAN Time-Sharing Course	Non-Government	GE Center	No	6-hour course
	Analog and Hybrid Computers in Industry	Non-Government	EAI	No	6 hours
	Mathematical Bases for Management Decision Making	In-Service - Gov.	Residence	No	Programmed Inst. Course
	Effective Executive Practices	In-Service - Gov.	Residence	No	Programmed Inst. Course
	An Introduction to Basic Supervision of People	In-Service - Gov.	Residence	No	Programmed Inst. Course
	Application of Value Analysis/ Engineering Skills	In-Service - Gov.	Residence	No	Programmed Inst. Course
	Creating Agreement	In-Service - Gov.	Residence	No	Programmed Inst. Course
	Theory and Applications of Digital and Analog Models	Government	USGS	No	3-hour course
	Seminar on Integrated Civil Engineering Systems and Mathematical Programing Systems	Non-Government	Albany Hotel	No	3-hour course by McDonnell Automation Company
Rhone	Organization and Management Principles	In-Service - Gov.	DFC	No	
	How to Conduct the Appraisal Interview	In-Service - Gov.	DFC	No	

B. SPECIAL ACTIVITIES

3. Continuing Education of Hydraulics Branch Staff (FY68)

Name	Course Title and Number	Type In-service - Gov, non-Gov facility or military	Place (DU, etc)	Credit Yes or No	Remarks (including other studies)
Dexter	Organization and Management Principles	In-service	DFC	No	3 hours per week class plus outside assignments
	Bureau-wide Driver Improvement Program	In-service - Gov.	DFC	No	10-hour course
Falvey	Intergovernmental Career Development Program	Non-Gov. facility	DU	No	
	Practical Solutions of Machinery and Maintenance Vibration Problems	In-service - Gov.	DFC	No	
Beichley	Improving your Written Communications	In-service - Gov.	DFC	No	Self-improvement course
	Research Reserve Upper Midwest Seminar	Military	Minneapolis, Minnesota	No	2 weeks
King	Introductory Descriptive Statistics	In-service - Gov.			Programed instruction course
	Brackish Water Desalting	In-service - Gov.	DFC	No	5-13-68 to 5-22-68 (15-hour course)
Colgate	Bureau-wide Driver Improvement Program	In-service	DFC	Yes	
Zeigler	Improving your Written Communications	Government		No	6-hour programed course

B. SPECIAL ACTIVITIES

3. Continuing Education of Hydraulics Branch Staff (FY68)

Name	Course Title and Number	Type In-service - Gov, non-Gov facility or military	Place (DU, etc)	Credit Yes or No	Remarks (including other studies)
Palde	Bureau Engineer Interchange Program	In-service - Gov.	Sacramento, California	No	11-9-67 to 5-3-68
Kuemmich	Sanborn Recorder Systems	Non-Gov. facility	Englewood	No	H. P. Neely
	Solid State Circuitry	Non-Gov. facility	Englewood	No	H. P. Neely
	Bureau-wide Driver Improvement Program	In-service - Gov.	DFC	No	10-hour course

4. Exhibits

Lake Powell Terrain Model. - This model was completed in March 1968 and is on permanent display in the rotunda of the Visitor Center at Glen Canyon Dam, Figure 17. Though built by contract, the design and the supervision of construction were done by this Branch. The model is considered an outstanding portrayal of the terrain surrounding Lake Powell, and the contractor did a commendable job with a difficult task.

Lake Hefner Film on Evaporation Reduction. - Drawings for the animated portion of this film, started last fiscal year, were completed and successfully filmed. The animation illustrates the objectives and operation of the study.

Grand Coulee Third Powerplant. - Completed in April 1968 this model was built to study the phases of excavation required for construction of the initial six units of the Third Powerplant, Figure 18. Built of rigid foam plastic and plaster at 1:1200 scale the model shows, by removable segments, the principal stages of excavation, the cofferdams, and the forebay dam and powerplant installations.

Assistance was also given the S&A Branch in the construction of basic models for the study of the excavation around the exposed penstocks for the Third Powerplant.

Lost Creek Outlet Works. - A segmented model was built for an exhibit in a court case to settle a dispute over actual and required excavation around one of the tunnel portals. The 1:120 scale, 4-square-foot model was made of rigid foam plastic. Vertical cuts, radial about the portal show cross sections of the original surface, required excavation and actual excavation.

Morrow Point Dam. - Assistance was given the shops in the repair of the animated model of the dam and appurtenances. The model was extensively damaged on its return from Europe.

Alliance Substation. - A portion of the substation was modeled for Region 7 for use as an exhibit in a court case involving an accident that occurred during a modification of the substation. The 38- by 53-inch model at 3/4" = 1'0" consisted of the structures and facilities in the three east bays and immediate vicinity, as they existed at the time of the accident.

Models Refurbished. - The rest of the models from the Building 53 display area were moved to Building 56. Three more models were refurbished this year, namely Kortes Dam, Bartlett Dam, and Grand Coulee Dam Powerplant sectional model. A total of seven models have now been refurbished and are on display south of the main lobby in Building 56. Renovation of the Glen Canyon Dam model is now under way.

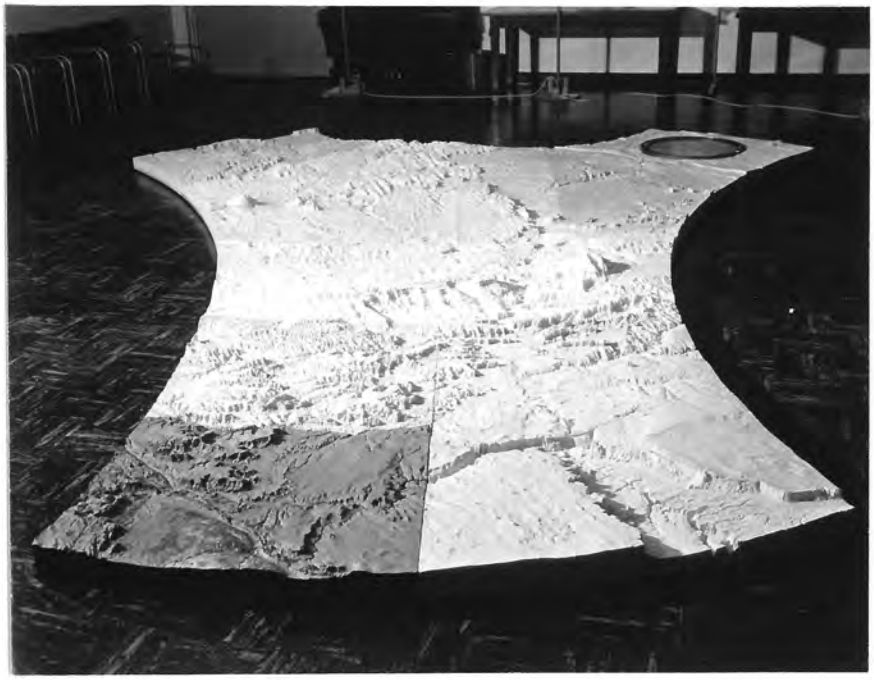


Figure 17

Lake Powell Terrain Model - View from downstream and looking ENE. Scale - Horizontal 1:42240 (1-1/2" per mile; Vertical exaggeration 2-3/4:1. Outside diameter 20 feet. Navajo Mountain on right in mid-distance (Px-D-58939).

Closeup of Navajo Mountain area. Shows 1/16" contours representing 80' prototype before modeling. Px-D-58543.

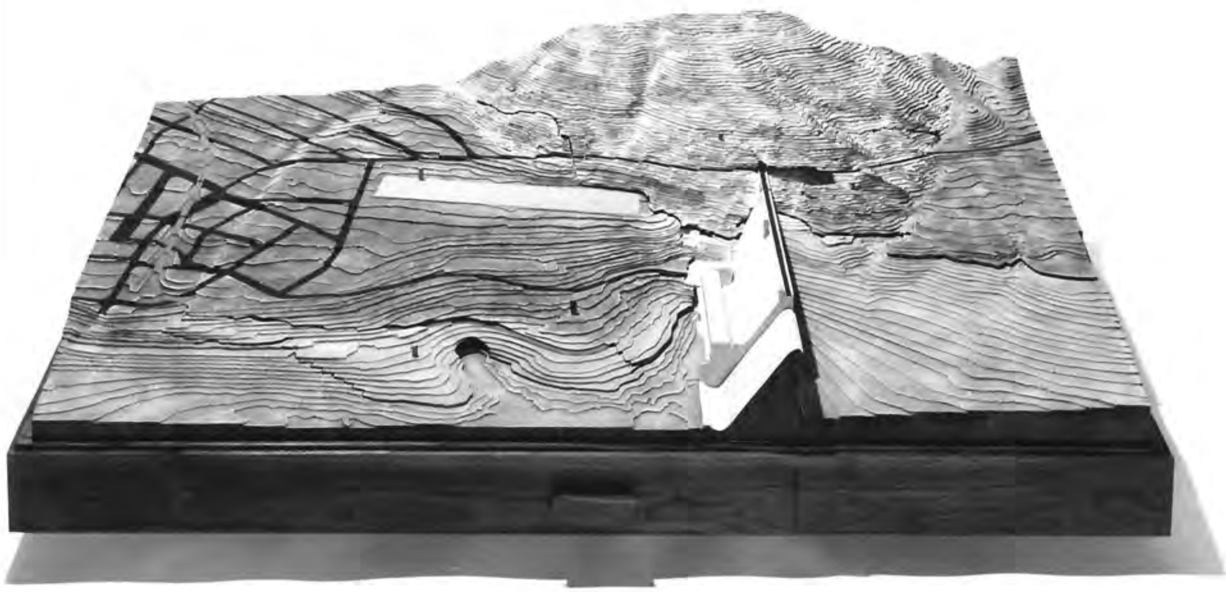


Figure 18

Grand Coulee Dam Third Powerplant Excavation Model
Scale 1:1200 1" = 100'

East Bank with inserts to show conditions prior to Third Powerplant excavation - H-1610-14 (60647)

It has been suggested that the Third Powerplant be added to the old Grand Coulee Dam model if and when the latter is refurbished. Technical and Foreign Services Branch has been informed that (1) the existing model is in poor condition, (2) one entire section would have to be discarded, (3) display space sufficiently large is not available, and (4) a new, smaller scale model would cost no more than repair, modification and expansion of the old model.

Auburn Dam Geology Model. - A 4- by 8-foot, 1:600 scale model in the vicinity of the damsite is now under construction. Built of clear plastic with removable horizontal sheets at 50-foot intervals (or less in critical areas) the model will permit three-dimensional viewing of data applied to the various levels.

SECTION VII - LABORATORY REPORTS, ENGINEERING MONOGRAPHS, PAPERS, PUBLICATIONS, AND TRAVEL REPORTS ISSUED DURING FY68 (LABORATORY MOTION PICTURE FILMS INCLUDED)

Laboratory Report No.		Author
Hyd-485	Canal Capacity Studies - Wave Formation by Bridge Piers - August 15, 1967	J. C. Schuster
Hyd-567	Hydraulic Model Studies of the El Vado Outlet Works Flip Bucket February 1968	T. J. Isbester
Hyd-570	Laboratory Tank Studies of Electrical Canal Logging to Detect Seepage - May 1968	R. A. Dodge
Hyd-571	Hydraulic Model Studies of the Fontenelle Powerplant Draft Tube and Tailrace - August 1967	H. T. Falvey
Hyd-573	Hydraulic Model Studies of the Modified Outlet Works Stilling Basin, Navajo Dam, Colorado River Storage Project, New Mexico - June 15, 1967	D. L. King
Hyd-574	Investigation of a 4-inch Magnetic Flowmeter May 19, 1967	C. E. Brockway J. C. Schuster
Hyd-575	Attenuation of Surge Waves by a Side Weir in a Trapezoidal Channel - April 25, 1967	S. Rungrongtoanin
Hyd-576	Hydraulic Model Studies of the Bartlett Dam Spillway, Salt River Project, Arizona	G. L. Beichley
Hyd-577	Water Measurement Procedures - Irrigation Operators' Workshop - 1967 - Oct. 15, 1967	A. J. Peterka
Hyd-578	Pipeline Discharge Measurements with Radioisotopes - September 1967	J. C. Schuster
Hyd-579	An Artificially Produced Velocity Barrier for Controlling Fish Movement - Tehama-Colusa Canal - November 1967	E. R. Zeigler
Hyd-580	Surging in a Laboratory Pipeline with Steady Flow - September 1967	E. R. Holley

Hyd-582	High Head Gate Seal Studies - March 1968	R. D. Mohrbacher

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Research Report No. 13 U.S. Department of Interior Bureau of Reclamation	<u>Removal of Saline Water from Aquifers</u> A Water Resources Technical Publication - 1968	E. J. Carlson

* * * * *

<u>Papers and Publications</u>

PAP-229	Erosion of Cohesive Sediments - June 1967 (A report prepared by Task Committee on Erosion of Cohesive Materials, Committee on Sedimentation, ASCE)	F. D. Masch E. T. Smerdon P. F. Enger
PAP-230	Preliminary report on hydraulic model studies, Bartlett Dam Spillway - June 20, 1967 (Memo to Chief Research Scientist) (Hyd-576)	H. M. Martin
PAP-231	Training Evaluation Report - Two-week summer session at Massachusetts Institute of Technology, Cambridge, Mass., "Ground Water Hydrology and Flow through Porous Media - July 27, 1967 (Memo to Chief, Personnel Branch)	E. J. Carlson
PAP-232	Section of Full Spread of a Turbulent Flow with a Sudden Enlargement in the Channel, by G. A. Lilitskii (Translation No. 722) August 1967	D. L. King (Translator)
PAP-233	Forces required to operate a gate valve - September 12, 1967	Wen Hsiung Huang
PAP-234	Training Evaluation Report - Participation in Middle Management Institute, Boulder Colorado, November 13-16, 1967 (Memo to Chief, Personnel Branch - December 5, 1967)	E. J. Carlson

Papers and publications	Title	Author
PAP-235	Hydraulics Branch Summary Report, Fiscal Year 1967	H. M. Martin
PAP-236	Determination of Soil Permeability by the Method of Large Rings, by V. E. Rainin and E. A. Makarycheva (Russian) USBR Translation 686	P. F. Enger (Translator)
PAP-237	The Position of the Lower Section of the Jet on Drops and Ski-Jump Spillways, by S. E. Eliasberg (Russian) USBR Translation 735	
PAP-238	Designing the Approach Channel for Shaft Spillways, by A. R. Skue (Russian) USBR Translation 734	D. L. King (Translator)
PAP-239	A New Look at Penstock Entrance Designs (Paper presented at Western Water and Power Symposium, Los Angeles, California, April 8-9, 1968)	A. J. Peterka E. A. Lindholm
PAP-240	Methods of Controlling and Sealing Contraction Cracks in Concrete Canal Lining - Value Engineering Study (V.E. Team No. 11), Phase 1, Final Report - September 1967 (For U.S. Government Use Only)	A. J. Peterka G. W. Birch H. O. Broughton J. C.Backstrom C. A. Swanson
PAP-241	"Organization and Activities of the Denver Federal Center Professional Engineers Group." A discussion presented at the Southwestern Regional Meeting of N.S.P.E., November 2-4, 1967, in Colorado Springs, Colorado	D. L. King
PAP-242	Amarillo Regulating Reservoir to Lubbock Regulating Reservoir - Hydraulic Performance Tests - Test Plan - Canadian River Project, Main Aqueduct, Central System (November 1967)	R. B. Dexter
Travel reports		
TR-3335	Flood releases from reservoir - Yellowtail Dam - MRBP (August 3, 1967)	L. M. Christiansen W. E. Wagner

Travel reports	Title	Author
TR-3336	Flood release - Yellowtail Dam - MRBP (August 8, 1967)	L. M. Christiansen W. E. Wagner
TR-3338	Ponding test of Reach 1 - San Luis Canal - San Luis Unit - Central Valley Project (July 28, 1967)	R. B. Dexter
TR-3341	Travel to Navajo Dam - Colorado River Storage Project (August 14, 1967)	J. C. Doman R.R. Nicholas T. J. Rhone
TR-3346	Inspection of spillway tunnel - Yellowtail Dam - Missouri River Basin Project (August 28, 1967)	A. T. Lewis W. E. Wagner James Legas
TR-3351	Report on trip to Fremont Canyon Powerplant - Travel Authorizations No. 81077 and 71079 (September 11, 1967)	G. H. Johnson R. H. Kuemmich
TR-3362	Ad Hoc Committee to study spillway repair - Yellowtail Dam - Missouri River Basin Project (September 22, 1967)	M. A. Jabara D. L. King R. J. Elfert R. C. Borden
TR-3362A	Supplement to Travel Report dated September 22, 1967, concerning Ad Hoc Committee study of Yellowtail Dam spillway repairs - Missouri River Basin Project (October 9, 1967)	M. A. Jabara D. L. King R. J. Elfert R. C. Borden
TR-3366	Lake Powell Terrain Model Inspection, Page, Arizona (October 6, 1967)	H. R. Schroeder
TR-3369	Participation in the XIIth Congress of the International Association for Hydraulic Research, Colorado State University, Fort Collins, Colorado (October 12, 1967)	E. J. Carlson D. L. King H. T. Falvey J. C. Schuster H. M. Martin
TR-3375	Report on trip to Fremont Canyon Powerplant - Travel Authorizations No. 81216 and 81215 (October 23, 1967)	G. H. Johnson R. H. Kuemmich
TR-3388	Seismic field measurements in Hunter Creek area of South Side Collection System, Fryingpan-Arkansas Project, as requested by Regional Director, Region 7, Denver, Colo. (November 30, 1967)	R. H. Kuemmich

Travel reports	Title	Author
TR-3393	Attendance at meeting of Water Management Subcommittee of the Pacific Southwest Inter-Agency Committee (December 13, 1967)	H. M. Martin
TR-3396	Rehabilitation of pressure transducers in the centerwall of the Yellowtail Dam Outlet Works Stilling Basin - Yellowtail Unit - Missouri River Basin Project (December 20, 1967)	R. B. Dexter
TR-3400	Attendance at meeting of Committee on Hydraulic Structures, ASCE (December 28, 1967)	W. E. Wagner
TR-3402	Lectures at Utah Irrigators' Workshop, Logan, Utah (December 29, 1967)	A. J. Peterka
TR-3406	Hydrodynamic pressure and acceleration measurements - Yellowtail outlet works stilling basin - Yellowtail Unit - Missouri River Basin Project (December 22, 1967)	J. C. Schuster R. H. Kuemmich
TR-3413	Attendance at ASCE Specialty Conference, "Current Research into the Effects of Reservoirs on Water Quality" (Feb. 9, 1968)	D. L. King
TR-3418	College recruitment (March 4, 1968)	A. J. Peterka
TR-3421	College recruitment (March 21, 1968)	H. M. Martin
TR-3431	Alliance Substation, model for court exhibit - Nels Larive v United States Civil No. 67-40S, U.S.D.C., D. of South Dakota; Kay Larive v United States, Civil No. 1328L, U.S.D.C., D. of Nebraska (Justice File CLW:EMH:mh 157-69-67) - (April 24, 1968)	H. R. Schroeder L. L. Frey
TR-3433	Participation in Western Water and Power Symposium, Los Angeles (April 29, 1968)	A. J. Peterka
TR-3440	Attendance at Third Biennial Meeting on Current Research in Hydraulics and Water Resources (May 8, 1968)	H. T. Falvey

Travel reports	Title	Author
TR-3452	Hydraulic performance test - Canadian River Aqueduct from Amarillo Reservoir to Lubbock Reservoir (Central System) - Canadian River Project, Texas (June 7, 1968)	R. B. Dexter R. A. Dodge
TR-3458	Report on trip to Los Banos, California - Travel Authorizations No. 81951, 81952, and 81978 (June 19, 1968)	G. H. Johnson A. E. Rickett R. H. Kuemmich

Laboratory Films Made During FY68

San Diego Saline Water Test Facility. - Edited and captioned 500 feet of silent color film showing operation of 1:8.93 models of preliminary and recommended designs and flow-improving appurtenances. At 24 and 64 fps. Original on file. Office of Saline Water has copy for reference.

Stratified Flow Research. - About 200 feet of silent color film. Time-lapse at 1-second and 2-second intervals showing flow patterns. Not edited or captioned.

Grand Coulee Third Powerplant. - About 80 feet of silent color film showing flow conditions in forebay and tailrace for 6 units spaced at 119 feet. Operation with and without existing powerplants and spillway. At 16 fps. Not edited or captioned.

High Head Gate Seals. - About 1,200 feet of 16-mm color film has been edited and titled showing the performance of several different seal designs at head up to 600 feet in a laboratory. Two copies of this film have been duplicated. One duplicate was sent to Huntington Rubber Mills who furnished the test seals. The original and one copy are available in the Denver Office. An additional 600 feet of unedited film were recently taken of later seal designs. Film speed is 24 fps.

Yellowtail Dam Spillway. - About 650 feet of color, silent, 24-32 fps edited 16-mm film with captions showing operation of the spillway with hydraulic jump in the basin, with the jump sweeping from the basin, and with the basin functioning as a flip bucket. Two duplicates were made. One was sent to Region 6 for their use and the other is for Denver Office use.

Canadian River Aqueduct. - Central System (Canadian River Project). - One hundred feet of 16-mm color at 24 fps of water expulsion from Sta. 5446 air vent and water overflow from Sta. 5445 pipe check structure during prototype hydraulic test, April 1968. Not edited or captioned.

Riprap Study. - Three hundred feet of 16-mm color film showing tests in 8-foot deep by 4-foot wide flume. Riprap in sizes 3/4 inch to 9 inches were tested at full scale. Film taken at 24 fps.

Draft Tube Surge Studies. - One hundred feet of color film of rope vortex in Fontenelle Draft Tube with swirl imparted by wicket gates. The installation does not contain a runner. Film is without captions and is not edited.

Yellowtail Dam Spillway Model. - Design of aeration slot for Yellowtail Dam Spillway to admit air into the flowing water to prevent cavitation damage.

200 feet, color 24 frames per second. Flow from 3,000-92,000 cfs. Unedited.

100 feet, color 32 and 64 frames per second. Study of air bubbles. Unedited.

100 feet each, 150, 500, and 1,000 frames per second. Colo. Study of bubble mixing and direction of flow. Unedited.

SECTION VIII - COMPUTER TECHNIQUES AND DATA ACQUISITION

Time-sharing Computer Use

A time-sharing teletype terminal was installed in the Division of Research and has been extensively used by personnel in the Hydraulics Branch. The terminal provides turnaround time within a few seconds and is easily programmed in a time-sharing FORTRAN or an extended basic language. All interested engineers within the Branch have been trained use the terminal and they rapidly write their own programs. The terminal has provided such a powerful tool for the Division that another time-sharing terminal with an X-Y plotter attached will soon be installed. The X-Y plotter will permit engineers to plot functions from the computer terminal and the terminal may be used without the X-Y plotter if desired.

To further extend use of the time-sharing terminals, a contract is being written for services for third-generation computers which will allow programs to be compiled in FORTRAN IV. This will provide more compatibility between the time-sharing terminals and the larger computers.

Quick Turnaround on Large Computer

During the year, arrangements were made for direct access to a large (32 K core memory) computer for 2 or 3 hours per day. This service permits engineers to deliver their FORTRAN IV programs to the computer room and be provided with the output within minutes. The service will provide 2 to 5 runs per day and is a measurable improvement over the 24-hour turnaround time of the past.

Documentation

A documentation and index system has been implemented within the Branch. The system developed is open ended and permits subroutines to be entered or deleted as the system expands. Routines related to problems encountered may readily be located and used for programming.

Advanced Planning for ADP Equipment

Studies of equipment needed for future ADP requirements continue. At some future date a real-time, data collection, data reduction, and control computer system may be obtained. During the past year, studies of several configurations have been conducted. Although to date no configuration has been found acceptable, the improvement in these systems indicates that a system that meets the necessary requirements may soon be developed.

Statistical Sample Showing Use of ADP in Hydraulics Branch

The following tables drawn from a report to the Chief Research Scientist indicate the relative use of the computer center by the Branch:

Table 1

SUMMARY OF DIVISION RELATIVE ADP WORK - 1968

Branch and Section	Percent of ADP Branch work accomplished by selection	Percent of ADP Division work performed
Concrete and Structural		20
Concrete Materials	36	
Concrete Properties	2	
Structural	62	
Reports and Field	0	
Chemical Engineering		10
Applied Physics	27	
Bituminous and Petro	14	
Coatings	8	
Chemistry	1	
Other	50	
Hydraulics		25
Applied Hyd	26	
Hyd Research	23	
Other	51	
Soils Engineering		24
Special Invest	31	
Control	62	
Equipment	7	
Water Conservation		18
Biological	0	
Saline Water	99	
Evaporation Reduct	1	
Electric Power		2
Field Tests	0	
Special Projects	24	
Other	76	

Table 2

SUMMARY TABLE

DIVISION OF RESEARCH COMPUTER USE FOR 1968
from July 1, 1967 to May 1, 1968

Branch	Approx Percent Development	CDC 6400 Costs $	Time-sharing Terminal Costs $	H800/200 and Other Costs $	Total Cost $
Concrete and Structural	3	976	113	5,464	6,553
Chemical Engineering	97	160	757	2,751	3,668
Hydraulics	28	1,035	1,558	6,820	9,413
Soils Engineering	1	825	784	7,044	8,653
Water Conservation	33	0	1,863	4,645	6,508
Electric Power	52	222	61	434	717

Table 3

GE Terminal Usage
June 1968

HYDRAULICS BRANCH

June	No. of Addresses	CPU Time Sec	Terminal Time Min	Costs $
3	6	120	96	20.8
4	1	1	2	.37
5	1	1	1	.21
6	2	1	3	.54
7	2	1	3	.54
10	2	1	3	.54
11	4	4	11	1.99
12	2	1	6	1.04
13	1	1	3	.54
14	1	1	3	.54
17	3	4	7	1.33
18	2	1	6	1.04
19	1	2	2	.41
20	6	19	36	6.76
21	4	47	35	7.71
24	3	3	13	2.29
25	5	61	55	11.61
26	2	5	7	1.37
27	2	32	29	6.11
28	2	1	15	2.54
TOTALS	52	307	336	68.28
Avg/Day	3	15	17	3.41

SECTION IX - PERSONNEL

On June 30, 1968, the Hydraulics Branch staff consisted of the following persons:

Regular Staff - Hydraulics Branch

Harold M. Martin, BSCE, MSCE, PE, Chief of Hydraulics Branch
William E. Wagner, BSCE, MSCE, PE, Head of Section
Henry T. Falvey, BSCE, MSCE, Dr.-Eng., Head of Section
Enos J. Carlson, BSCE, MSCE, PE, Hydraulic Research Engineer
Jack C. Schuster, BSME, MSME, PE, Hydraulic Research Engineer
Thomas J. Rhone, BSCE, PE, Hydraulic Research Engineer
Robert B. Dexter, BSME, PE, Research Hydraulic Engineer
Phillip F. Enger, BSCE, MSCE, PE, Research Hydraulic Engineer
Glenn L. Beichley, BSCE, MSCE, PE, Hydraulic Research Engineer
Russel A. Dodge, Jr., BSCE, Hydraulic Research Engineer
Danny L. King, BSCE, MSCE, PE, Hydraulic Research Engineer
Donald Colgate, BSCE, PE, Hydraulic Research Engineer
Uldis J. Palde, BSCE, Hydraulic Research Engineer
Eugene R. Zeigler, BSCE, PE, Hydraulic Research Engineer
Thomas J. Isbester, BSME, Hydraulic Research Engineer
Robert H. Kuemmich, Electronic Development Technician
Howard R. Schroeder, Visual Information Specialist
Lysle L. Frey, Exhibits Specialist
Laura S. Hawthorn, Secretary

During FY68, Alvin J. Peterka, Head of Special Investigation Section, retired from Bureau service.

Dr. Henry T. Falvey was appointed head of a newly constituted section, The Hydraulics Research Section.

Dr. E. R. Holley, Jr., completed his Ford Foundation residency in the Hydraulics Branch and returned to the University of Illinois after 15 months of research.

Professor Roy Bremer, University of Detroit, completed a 3-month tour of research in August 1967.

The following engineers on rotation training worked in the Hydraulics Branch during the year:

Rotation Engineers

Joseph G. Turner, Jr. - Wagner - January 15 to April 12, 1968

The following tabulation shows the statistical history of the Branch since 1961:

Recapitulation of Staff Statistics

Date	Permanent employees	Total annual salaries	Temporary employees	Military furlough	Trainees	On detail	Educational leave
1-1-51	47	$211,885	1	1	6	-	-
1-1-52	41	219,035	-	2	1	1	1
1-1-53	39	219,445	-	1	1	-	-
1-1-54	30	178,145	-	1	3	-	-
7-1-54	25	162,170	-	1	-	2	-
7-1-55	21	127,000	-	2	-	-	-
7-1-56	20	134,595	1*	2	3**	-	-
7-1-57	22	153,735	1*	-	1**	1	-
7-1-58	21	173,505	2*	-	1**	1	-
7-1-59	20	167,410	-	-	-	-	-
7-1-60	23	188,977	-	-	1*	-	-
7-1-61	24	205,660	-	-	-	-	-
7-1-62	22	185,405	-	-	-	-	1
7-1-63	23	219,605	1*	-	-	-	1
7-1-64	24	236,995	-	-	-	-	1
7-1-65	23	243,130	-	-	2	-	0
7-1-66	22	245,748	2	-	2	-	0
7-1-67	20	244,382	1	-	-	-	0
7-1-68	19	259,117	1	-	-	-	0

*University faculty members employed during summer months.
**Engineering students working during summer months.

SECTION X - TIME AND COST DISTRIBUTION BY CLASSIFICATION OF WORK

Summary for FY68

This section consists of three parts as follows:

A. Percentage of Labor Distribution for FY68
B. Labor and Additive Expenditures - FY68
C. Water Resources Engineering Research - Monthly Cost Report - June 30, 1968.

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A DIVISION OF RESEARCH
Percentage of labor distribution July 1, 1967 through 6-30-68

	Conc-Stru.	Chem	Hyd.	Soils	Lab. Shop	Water Cons.	Elec. Pwr.	Division Actual	Division Budget	Rate of Expend.
DIRECT CHARGE - TOTAL	85.0	81.4	76.7	88.5	62.2	93.8	83.3	82.8	83.1	98.4
Bureau Projects	61.6	37.0	23.6	56.9	36.5	6.3	12.7	41.4	42.2	96.8
Outside Agencies	11.3	21.2	17.4	4.5	8.8	53.2	-	16.7	16.7	98.6
Foreign Activities	0.5	0.3	0.8	1.2	-	0.1	-	0.5	0.4	116.9
Fabrication Orders	-	-	-	0.1	5.8	-	-	0.5	0.5	100.2
WREResearch	11.6	22.9	34.6	24.4	10.9	34.1	70.6	23.4	22.7	101.9
Automatic Data Processing	-	-	0.3	1.5	0.1	-	-	0.3	0.6	50.2
GENERAL DISTRIBUTIVE EXPENSE - TOTAL	15.0	18.6	23.3	11.5	37.8	6.2	16.7	17.2	16.9	100.6
General Operating Expense	10.3	10.2	10.7	6.6	37.3	3.8	8.3	11.3	10.2	110.3
Bur.-wide Pers. Services	-	-	0.8	0.2	-	-	-	0.2	0.2	94.2
Employee Incent. Awards	-	-	0.4	0.2	0.1	-	0.4	0.1	0.1	157.3
Equipment Maintenance	3.4	3.5	4.7	4.3	23.7	2.0	7.1	5.5	4.9	111.4
Bldg. Maint. & Alter.	-	1.1	0.2	0.1	1.9	-	-	0.4	0.2	214.9
Equipment Acquisitions	-	-	-	-	0.1	-	-	-	-	25.4
Supplies & Misc. Services	6.9	5.6	4.6	1.8	11.4	1.8	0.8	5.1	4.8	105.7
Indirect Engineering Expense	4.6	8.3	12.6	4.9	0.5	2.5	8.4	5.9	6.7	86.1
Technical Studies	0.2	0.3	1.1	1.0	-	-	0.1	0.4	0.6	67.7
Staff Development	1.9	2.9	5.0	2.5	0.4	2.3	3.8	2.6	3.0	85.3
Tech. Stds. & Procedures	1.1	1.0	0.3	0.3	-	-	-	0.6	0.7	81.2
ADP Advisory Group	-	0.7	3.3	0.9	-	-	0.1	0.7	0.7	89.3
Bur-wide Direction & Suprv.	1.5	3.4	2.8	0.2	0.1	0.1	4.5	1.6	1.7	94.8

DIVISION OF RESEARCH

B. LABOR/ADDITIVE EXPENDITURES - FISCAL YEAR 1969

Hydraulics Branch Cost Center 830 Date of this report 6-30-68

Feature	Production Order or Job Number	Labor+additive Annual Budget	Labor+additive Expended to date	% spent in 100% of time Branch	% spent in 100% of time Division	Rate of Expenditure
Bureau Project Work		95,350	75,678	79.4	96.8	
Outside Agencies		40,800	55,680	136.5	98.6	
Foreign Activities		2,500	2,575	103.0	116.9	
Fabrication Orders	01-0-7001-66-					
Water Resources Engr. Research						
Aquatic Weed Control	18-0-801-76-01		358			
Chem. & Phys. Technology	-02		329			
Concrete	-03					
Electric Power	-04					
Evaporation Reduction	-05	415	412			
Hydraulics	-06	99,500	108,526	109.1	106.4	
Open & Closed Conduit System	-08	1,000	1,520			
Soils Engineering	-10					
Struct. & Rock Mechanics	-11					
Water Chemistry	-12					
		100,915	111,145	110.1	101.9	
Automatic Data Processing	-70-13		885			
Gen. Program Assistance	01-0-6100-00-72-02					
Automation of Soils Lab.	-72-32					
		1,000	885	88.5	50.2	
Total Direct Charges		240,565	245,963	102.2	98.4	
Bur.-wide Personnel Services	01-0-3000-00-01-09	2,200	2,632	119.6	94.2	
Employee Incent. Awards Prog.	01-0-3000-00-02-01	500	1,126	375.3	157.3	
Equipment Maintenance						
Office equipment	01-0-3000-00-03-01		1,124			
Laboratory equipment	-03-03		8,202			
Technical equipment	-03-04		5,853			
Electric load analyzer	-03-05					
		15,000	15,179	101.2	111.4	
Building Alterations & Maintenance						
Research Eng. Occupancy	01-0-3000-00-04-02		695			
Office Building No. 67	-04-05					
ADP Occupancy	-04-15					
		1,000	695	69.5	214.9	
Equipment Acquisitions	01-0-3000-00-05-01					

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Cost Center 830 Date of this report 6-30-68

	Production Order or Job Number	Labor/additive Annual Budget	Expended to date	& spent in 100% of time Branch	Division	Rate of Expend- iture
Supplies and Misc. Services	-08-04		507			
Office moves	01-0-3000-00-08-07					
Details to Washington Off.	-08-09					
Safety meetings	-08-10		1,068			
Misc. shop supplies & service	-08-11					
Technical info. service	-08-16		13,135			
Records management (retired)	-08-18		112			
		18,200	14,822	81.4	105.7	
Total General Expense		36,700	34,454	93.9	110.3	
Technical Studies						
Data analysis - structures	01-0-3100-00-01-01					
Photoelastic studies	-01-02					
Value engineering projects	-01-25		1,968			
Preparation of project data	-01-31		1,691			
		4,000	3,659	91.5	67.7	
Staff Development						
Rotation Engineer training	01-0-3100-00-02-01		103			
In-service train.-gov't	-02-04		3,236			
Train.-in non-govt facil.	-02-05		615			
Train.-applications of ADP	-02-06					
Participation in prof., gov't	-02-08		133			
& civic activities	-02-09		10,607			
Irrig. Operators workshop	-02-10		1,492			
		23,400	16,186	69.2	85.3	
Technical Standards & Procedures						
Standard Designs & dwgs.	01-0-3100-00-03-01					
Standard specifications	-03-02					
Reclamation instructions	-03-03					
Manuals, stds., and guides	-03-05		1,026			
		7,000	1,026	14.7	81.2	
ADP Advisory Group	01-0-3100-00-04-01	10,000	10,495	105.0	89.3	
Bureau-wide Direction & Superv.						
General Staff supervision	01-0-3100-00-05-01	7,900	9,054	114.6	94.8	
Total Indirect Engineering Expense		52,300	40,420	77.3	86.1	
Total Indirect Charges		89,000	74,874	84.1	100.6	
TOTAL ALL COSTS		329,565	320,837	97.4	98.7	

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Division of Research
C. WATER RESOURCES . INEERING RESEARCH
Monthly Cost Report--June 30, 1968

Job No. or Production Order	Title	Labor	Other direct costs	Distri-butive costs	Total costs	Obliga-tions	Total costs and obligations	Cost program
18-0-801-76-01	Aquatic Weed Control	30,773	38,321	9,232	78,326	575	78,901	78,800
18-0-801-76-02	Chem.&Physics Technology	75,453	18,600	22,635	116,688	3,333	120,021	107,400
18-0-801-76-03	Concrete	51,253	8,245	15,376	74,874	9,406	84,280	84,800
18-0-801-76-04	Electric Power	90,714	19,509	27,124	137,347	20,010	157,357	166,600
18-0-801-76-05	Evaporation Reduction	78,271	146,034	23,429	247,734	13,494	261,228	261,700
18-0-801-76-06	Hydraulics	121,220	34,253	36,367	191,840	8,426	200,266	197,400
18-0-801-76-07	Rock Mechanics	14,053	17,073	4,216	35,342	9,057	44,399	35,850
18-0-801-76-08	Open & Closed Conduit Sys.	28,978	52,241	8,694	89,913	4,106	94,019	96,400
18-0-801-76-09	Sci. Comm. & Documentation	8,846	3,220	2,934	15,000	-	15,000	15,000
18-0-801-76-10	Soils Engineering	110,932	25,756	33,280	169,968	7,853	177,821	176,300
18-0-801-76-11	Structures	35,891	27,882	10,768	74,541	30,376	104,917	106,760
18-0-801-76-12	Water Chemistry	29,952	34,246	8,991	73,189	40,919	114,108	139,500
18-0-801-76-13	OER Support	20,577	8,476	6,912	35,965	-	35,965	39,500
18-0-801-76-99	Audit of Contracts	-	1,630	-	1,630	4,408	6,038	-
	Division of Research	696,913	435,486	209,958	1,342,357	151,963	1,494,320	1,506,03[illegible]
	Design Division	106,498	44,054	31,950	182,502	11,783	194,285	201,19[illegible]
	Geology Division	12,721	5,180	3,495	21,396	12,658	34,054	32,80[illegible]
	ADP Development Costs	-	287	-	287	-	287	-
	GRAND TOTAL	816,132	485,007	245,403	1,546,542	176,404	1,722,946	1,740,0[illegible]

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SALINE WATER PROGRAM
Monthly Cost Rep :--June 30, 1968

Job No. or Production Order	Title	Labor	Other direct costs	Distri-butive costs	Total costs	Obliga-tions	Total costs and obligations	Cost program
86-0-800-03-01-01	Evaluation of concretes	33,993	8,232	10,198	52,423	--	52,423	40,454
86-0-800-03-01-02	Wall section model	3,716	248	1,115	5,079	--	5,079	72,510
86-0-800-03-01-03	Accessory coatings, etc.	21,426	3,522	6,427	31,375	--	31,375	64,179
86-0-800-03-01-04	Conc.reinf. materials	251	--	75	326	--	326	2,191
86-0-800-03-01-05	Conc. Microstru. invest.	4,056	--	1,217	5,273	--	5,273	17,208
86-0-800-03-04-01	Contract Administration	9,084	3,688	2,671	15,443	--	15,443	2,436
86-0-800-03-05-01	Pump Inlet Sys. W.O. 5	7,300	235	2,190	9,725	--	9,725	10,538
86-0-800-03-06-01	Stable Binder for Conc.	26,834	618	8,050	35,502	--	35,502	40,131
86-0-800-03-07-01	Pump Contract	--	288,662	--	288,662	--	288,662	435,682
86-0-800-03-09	Reverse Osmosis Plants	73,625	94,028	22,085	189,738	1,301	191,039	209,000
86-0-800-03-10	Sites for Field Testing	11,026	12,001	3,308	26,335	--	26,335	46,000
86-0-800-03-11-01	Concrete Test Vessel	26,898	16,290	8,075	51,263	33,638	84,901	165,000
86-0-800-03-12-01	Disposal of Effluents	36,912	13,088	11,076	61,076	6,049	67,125	123,500
86-0-800-03-13	Reverse osmosis No. 7	100,740	52,513	30,218	183,471	13,303	196,774	242,700
03-08-01	Desalted Water for Irrig.	10,610	71,989	3,183	85,782	--	85,782	82,723
03-14	Electrodialysis W.O. No. 8	33,995	4,842	10,188	49,025	1,692	50,717	84,000
03-15-01	Inspection Services	--	9,150	--	9,150	--	9,150	20,000
03-16-01	Concrete-polymer materials	3,177	328	953	4,458	--	4,458	45,000
10-01-01	Film Distribution	--	969	--	969	--	969	--
		403,643	580,403	121,029	1,105,075	55,983	1,161,058	1,703,[illegible]

SECTION XI - BUDGET REVIEW
Hydraulics Branch
FY69

	FY 67	FY 68 Estimated 4-1-68	FY 69
Bureau Project Work	64,674	94,050	(108,500)
Region 1 - $47,000; Region 2 - $30,600; Region 3 - $4,000; Region 4 - $10,800; Region 5 - $ 5,500; Region 6 - $5,600; Region 7 - $ 5,000			
Outside Agencies	10,844	40,800	(26,600)
Atomic Energy Commission - Radioisotope Phase IV			15,000
OSW - Intermodule head loss study			2,000
Pump intake manifold study			2,000
Brine seepage ponds			2,000
Work Order No. 7 (292)			1,600
Forest Service - Energy dissipator			4,000
Foreign Activities	2,798	2,500	(22,500)
Patillas Dam Spillway, Puerto Rico			8,000
Toa Vaca Dam Spillway, Puerto Rico			12,000
Training Foreign Engineers			2,500
Water Resources Engineering Research	130,734	97,000	(97,000)
Automatic Data Processing	3,800	1,000	1,000
Total Direct Charges	214,808	235,350	247,600
Total General Expense	43,388	36,700	40,000
Total Indirect Engineering Expense	42,600	52,300	52,400
Total Indirect Charges	85,988	89,000	92,400
Grand Total Charges	300,796	324,350	348,000