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John R Freeman

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NATIONAL HYDRAULIC LABORATORY

PROGRESS REPORT

DESIGNS, ESTIMATES OF COST AND COMPARISONS OF DESIGNS

RELATING TO

THE NATIONAL HYDRAULIC LABORATORY AT THE UNITED STATES BUREAU OF STANDARDS, WASHINGTON, D. C., PREPARED BY JOHN R. FREEMAN, CONSULTING ENGINEER PROVIDENCE, R. I.

[Supplemental to Senate Document No. 208]

PRESENTED BY MR. HEBERT

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PROGRESS REPORT ON
NATIONAL HYDRAULIC LABORATORY

PROVIDENCE, R. I., *February 24, 1931.*

Hon. JOSEPH E. RANSDELL,
Hon. FELIX HEBERT,
United States Senators,
Senate Office Building, Washington, D. C.

GENTLEMEN: I appreciate your interest and desire to learn of progress of the national hydraulic laboratory, for which a few months ago Congress appropriated $350,000.

Much progress has been made by the staff of the Bureau of Standards in preparing plans, which it was hoped would be ready to submit to contractors for bids early in March, but I regret to report that these plans, so far as developed up to a few days ago, *will not give a laboratory that can fulfill the promises* which I made in the various hearings before Congress from 1922 to 1929, about useful *large-scale* fundamental research for improving the economy and accuracy of measurements of water by weirs, orifices, etc., nor has adequate provision yet been made for fundamental research concerning the hydraulic laws governing the flow of water in channels of various shapes at various velocities and slopes.

The Bureau's plans now nearing completion will nevertheless provide a laboratory in which a vast amount of useful work can be done, covering perhaps nine-tenths of the problems likely to be presented, and will give a laboratory generally comparable in scope with the best existing laboratories in Europe and America, excepting one or two of the recent European laboratories, notably the new laboratory at Obernach, near Munich, *to which it probably will be decidedly inferior* in precision of measurement for large-scale work.

This Obernach laboratory was promoted by some of the foremost European engineers, largely for testing out scale effect and for testing the accuracy with which the so-called doctrine of similitude, as used in experiments with extremely small models will be confirmed by experiments on much larger models, or with the behavior of the actual hydraulic structure.

These European hydraulic laboratories have each cost very much less than the sum provided for building this American national laboratory, but each has had the great advantage of being designed by an engineer of large practical experience. They have been graduallv developed step by step during the past 20 years. The vast majority of researches on flow of water by means of models and the doctrine of hydraulic similitudes are best tried out in their preliminary stages with discharge of water seldom exceeding 5 cubic feet of water per second. The laboratory proposed by the Bureau staff can handle up to 250 cubic feet per second or double that in any of the European laboratories, but apparently will fail *in precision of measurement of large quantities,* and in opportunity for fundamental research in general fiields of great importance to the designers of large hydraulic works

By a skillful use of the congressional appropriation of $350,000, it was entirely possible to have had here in Washington a national hydraulic laboratory not equaled by any now in existence anywhere in the world, in its scope both for ordinary small-scale researches and *for large-scale researches* in which flows of water up to 500 cubic feet per second could be measured with a degree of accuracy heretofore unequaled (viz, with errors of measurement not exceeding about one-tenth of 1 per cent), and many determinations made of hydraulic coefficients in formulas for measuring the flow of water so accurately that once made they would serve all practical needs for a hundred years to come.

Such large-scale experiments are highly important to American public service engineering, as a means of developing and testing improved forms of water-measurement weirs, for promoting better forms of baffle piers and other means of dissipating destructive energy of current at the foot of high over-fall dams and spillways, and as a means for devising better forms of sluiceways, more effective syphon spillways, and for developing standard economic methods of riprap for preventing the erosion of earthen river banks by swift currents.

Also, it was highly important, and was possible within this appropriation, to design this laboratory of such scale and scope as to permit much needed determinations of the *effect of turbulence* and of twisting currents upon measurements of the flow of water by weirs, current meters, Venturi meters, Pitot tubes, and other instruments, by means of experiments on such a large scale as to command the confidence of practical engineers to much greater degree than the small-scale determinations heretofore made.

But, as I have said above, this great opportunity has been sacrificed, apparently through lack of experience of the members of the Bureau staff to whom this problem of design was assigned, and who had no background of practical experience either in large engineering design, or in the special problems of design for controlling or measuring large volumes of water. *The problem of designing this laboratory was intrusted to skillful physicists rather than to experienced and skillful engineers.*

Substantially every one of the great hydraulic laboratories of Europe, which for 10 years past have been contributing so greatly to the advance of engineering knowledge, has been designed chiefly by an eminent engineer of mature age, *who had a background of 5 or 10 years or more of engineering experience on large and important work,* and so brought to his designing of the laboratory a highly valuable experience. Also it is worthy of note that the great contributions to the science and practice of hydraulics in America have been by engineers of large practical experience, like the late James B. Francis, Clemens Herschel, of Venturi Meter fame, and various other engineers, including those of the United States Reclamation Service, the hydrographic branch of the United States Geological Survey, and certain enterprising engineers of the United States Department of Agriculture, and other branches, and *not by mathematical physicists.*

Senator Ransdell will so well remember my many earnest conferences with him on these matters during the past eight years that he may wonder why I have been unable to successfully advise our friends of the Bureau toward making a better use of the appropriation. I must beg him to remember that the Director of the Bureau of Standards and his staff *have the sole authority over the design*, and that they naturally have pride of opinion in their own capacity and skill for meeting any conceivable requirement for scientific research. The laboratory will be more of a physicists' design than that of a design by engineers experienced in hydraulic construction.

In my more than a half century of engineering, largely on hydraulic problems of great magnitude, I have also happened to have an uncommonly large experience with problems of hydraulic experiment in various laboratories. For more than 20 years I have been deeply interested in hydraulic research, and have made three extended tours for study of the hydraulic laboratories of Europe and have personally visited most of the notable laboratories in America. The results of a part of these studies are set forth in the large volume which you possess, copies of which were given to a large number of your associates in Congress, entitled "Hydraulic Laboratory Practice." Also I have helped 10 or more American engineers to study in these laboratories abroad through the endowment of traveling scholarships each giving sufficient stipend for a year of study and travel abroad. Last summer, at my own expense, I made another tour of the European hydraulic laboratories, mainly for the purpose of learning of the very latest developments, and for aiding in the design of this national hydraulic laboratory at the Bureau of Standards.

I have tried in every reasonable way, as was stated in my letter to Senator Ransdell of June 24, 1930, to make my information available to the Bureau staff, but, although I have been treated with great politeness, I have been unable to bring them to understand the practical needs of various highly important features of the design.

In my letter of June 24, 1930, to Senator Ransdell, Secretary Lamont, and Director Burgess (which was published as Senate Document No. 208) I tried to make plain some of these matters. I am pleased to state that the later drawings for the laboratory by the Bureau staff, by whom four successive studies have been made by them, show vast improvement compared with their first sketches, which I mentioned in the communication just cited, and over which I was so greatly disturbed. But these Bureau designs still fall *far short of what might be possible in scope and precision* under this appropriation of $350,000, and after repeated conferences I am now on the point of making no further effort toward improving the design of this laboratory.

To show how hard I have tried to aid in making this national laboratory the very best in the world, I may state that in the preparation of various sets of drawings that I have presented to the Bureau staff, I have personally expended in pay rolls to assistant engineers and draftsmen, nearly $6,000, exclusive of office overhead and exclusive of my own time and traveling expenses, which time would have been of much value to me if otherwise applied.

I attach hereto a set of drawings and estimates of cost showing my latest and final effort, in a design which I am confident could be built within the appropriation and fit this laboratory both for the ordinary small-scale work, and for the large-scale fundamental research that is highly important to engineers in the Government services of reclamation, flood control, and river and harbor engineering, and also to engineers engaged in large problems of water supply and water power development. The attached estimates of cost were made up with extreme care in conference with the chief estimator of The Turner Construction Co., which built two of the most recent large buildings at the Bureau of Standards, and *include allowance in the unit cost for contractor's profit.* The total, which is slightly less than the appropriation of $350,000 made by Congress, thus covers the price at which *one of the foremost building contractors in the United States is ready to bid for the completed building.* Mr. Turner states that probably the contracts *could be now placed at a smaller total cost than this estimate,* because of the present business depression and the desire of various large contractors to maintain their organizations together at sacrifice of ordinary rates of profit.

I attach also a copy of my letter dated February 20, 1931, transmitting these designs to Doctor Burgess, which may interest you and some of your associates in the Senate and House, who made this appropriation of $350,000 available.

Following the letter to Doctor Burgess is a comparison of my plans with the most recent Bureau plans, which comparison I presented to him along with these final designs.

If the laboratory fails in some important respects to produce the results promised in the various congressional hearings, I hope that the documents which I now present will nevertheless permit you to still think kindly of my own efforts and good intentions. It may be well to explain that some of the features which are of highest importance, like the large measuring basin, the large forebay, the pump seats, and the main flumes, *have to be built into the very foundations of the original structure* and can not be properly added later. The pumps for producing the largest rates of discharge can advantageously be added a year or more later after previous research upon small model pumps for the purpose of perfecting the final design and so making of these large pumps instruments of research, useful for future designs in large drainage works.

Very truly yours,

John R. Freeman.

[Copy]

February 21, 1931.

Dr. George K. Burgess,
Director Bureau of Standards,
Washington, D. C.

Dear Doctor Burgess: I am extremely sorry to have been prevented by illness from attending the conference with you which I had intended to have on January 27. I had my Pullman space and transportation all engaged Monday, but ventured a visit to my doctor, who sent me to bed for two weeks of intensive rest cure. The reason I missed my conference with you in New York, at the American Society of Civil Engineers, on January 21, was that after listening to your paper and two or three others, I found myself "all in," and went back to my hotel and to bed, in order to recuperate for the evening ordeal, in which I was on the schedule for a conspicuous part.

This detention by illness, the longest that I have suffered in 50 years, upset my plans seriously, and, although I have been at the office for several days past, am not yet back to 100 per cent efficiency.

I now intend coming to Washington some time next week, for I still have hopes of making plain to you that the laboratory as proposed by Mr. Eaton *can not possibly fulfill the promises made to Congress about fundamental research.* The chief defect of the Bureau's design is the small size of its measuring basin, which will prevent making important research with fairly large discharges *on a cubic-foot basis* of direct measurement and with a precision close to one-tenth of 1 per cent.

Mr. Eaton has been relying largely on the Venturi meters, for basic measurements, but this will not command the confidence of those who know the possibility of error in Venturi measurements due to air bubbles, twisting of the current, and lack of precision in piezometer readings, particularly with relatively small quantities flowing.

An important defect in nearly all the European laboratories, except that at Obernach, including the costly new laboratory at Zurich, is this inability to *positively* measure large quantities *with precision.* Moreover, I hoped that our American laboratory might excel all now in existence in Europe and in America by its ability to make much needed fundamental research on weirs, dams, orifices, and channel flow, *with large quantities and a precision of measurement never yet equalled.*

My designs are worked out with this feature in view and with the idea of *fully meeting the promises made in the hearings before Congress.*

I regret that somehow in examining my designs your attention became chiefly focused on the large discharge proposed of 500 cubic feet per second instead of on the far more important feature of precise measurement of large quantities *in a measuring basin* with the aid of a quick moving diverting gate, which I am sure is entirely feasible from having used one in smaller-scale research. The quickly moving chronograph gate and the big measuring basin are fundamental requirements which have to be built into the original structure and its foundations. The pump for very large quantities can preferably be added later, after we have had some researches with model pumps, similar to the two set-ups that I saw in Europe last summer, one at Munich and another at Toulouse.

You may wonder at my earnestness in all of this, but I have been working on these ideas for more than 25 years and believe that now or never is the chance for a national hydraulic laboratory which can do things beyond the research of the many college laboratories and most of those in Europe, but which also can do the ordinary run of researches, which occupy most of the time of existing laboratories, with facilities not now excelled anywhere on earth.

The most eminent laboratory directors, like De Thierry, Rehbock, and Thoma have repeatedly urged on my attention that for the best routine work the laboratory should have abundant open floor space on which *temporary* set-ups of apparatus designed to meet the special problem can be conveniently erected and removed after the research is completed. In addition to the big flume, the big measuring basin, for facilities for precise measurement of large discharge, I have provided for both the small scale and the large scale research.

While at home ill I gave much thought to these matters and immediately upon returning to my office started Mr. Chick, at revising the drawings, so as to incorporate several improvements which both increased the capacity and lessened the cost, and I am now sending to you blue prints of this my final design marked "Study No. 4."

Many of the component parts, skimmer weir, diverting gate, forebay and forebay gate, also the special reinforcement of concrete will have the same details as shown in my previous set of about 27 sheets of blue prints.

Costs: On the basis of the unit costs in the Turner estimate, and while providing the same quality of construction shown in my latest previous design, including superabundant steel reinforcement of the concrete against temperature stresses and other stresses, and for preserving alignment and preventing distortion and settlement cracks, Mr. Chick, after carefully and precisely computing quantities, estimates a cost of buildings and fixed equipment, including contractor's profit at $289,480. Substantially the same items were previously estimated at $306,303, showing a saving of about $16,823 by simplification of design as per photostat of detailed estimate inclosed.

We find also that everything needed in portable apparatus to put the laboratory into immediate operative condition for four or five researches of the ordinary type going on simultaneously can be provided for the further sum of $59,812. *This brings the total cost slightly within the congressional appropriation of $350,000.*

Limestone finish: The preceding figures coming very closely to $350,000 for my design do not include limestone finish. We judge after allowing for the extent of the basement walls which are covered by a banking up of earth to avoid temperature stresses and also to give support, that a suitable amount of limestone trim, including parapet, window sills, and water-table course at the bottom, should not add more than $5,000, after deducting $4,150, which we have allowed for special concrete coloring and including window sills, window caps, etc. This extra $5,000 will be covered by the contingencies provided for in the following paragraphs.

For contingencies: As a safeguard for contingencies there can be held in reserve the cost of the propeller pump of 250 or 300 cubic feet per second discharge capacity, amounting to $12,000, which pump can be advantageously deferred for a year, pending research on a small model of same.

Moreover, parts of portable equipment, self-contained apparatus. etc., can be added gradually as cause for research develops, amounting to a total of about $15,000, which can, as you once suggested to me, be paid for from the first six months' appropriation for maintenance and operation. This gives a margin for contingencies of about $27,000, although I believe these contingencies will probably not arise.

Foundations.—I still maintain (and I am no novice in difficult foundations—for example, the Panama locks at Gatun, the dam site of rock broken by intersecting fault zones at Holter, Mont.; the dam site on possibly yielding foundations at San Pablo, Calif., etc., and from all that I have yet been able to learn about the underground conditions at the laboratory site, and from conferences with Doctor Stratton about foundations for your existing buildings) I believe the laboratory can be made safer against settlement cracks and distortion by practically floating the whole mass of the heavily reinforced foundation walls upon the decomposed rock on the levels which I have shown, than can be done by carrying detached foundation piers down to the so-called solid rock, which is not at all solid.

I am so confident that the whole laboratory could be completed *according to my designs herewith submitted*, with pumps upward of 250 cubic feet per second capacity, with attachments planned for future large pumps giving a total discharge capacity of 500 or perhaps 600 cubic feet per second, that I would be entirely willing to personally deposit the sum of $50,000 with the National Research Council, or other appropriate place, from which could be taken any sum found necessary to cover the over run or any sum necessary for repairs due to settlement cracks which occur within the next two years. I should make this deposit with the utmost confidence that it would not be called on for a single dollar, either for overrun or for repairs. Should loss occur I would take it cheerfully. It would simply be deducted from further contribution which I have been long intending to make for the advancement of hydraulic science.

I regret that in my personal conferences I have failed to make clear the purposes of design, and regret exceedingly that so much attention was given to the figure of 500 cubic feet per second of pump capacity, because this matter of *pump capacity is of no significance whatever in comparison with the necessity for a large measuring basin of substantially the size that I have indicated, fitted with a quick swinging gate, so that the error of measurement may rarely, if ever, greatly exceed one-tenth of 1 per cent.*

American services of water supply, flood control, and power development greatly need some precise, *large-scale* researches relative to flood discharge over dams, also discharges through orifices, and the determination of coefficients for new forms of water-measuring weirs and for determining coefficients of discharge of existing dams used for gaging flood discharge. Researches are needed for gate designs giving the least loss of head, also in baffle piers attached to the downstream face of dams for dissipating energy and preventing erosion, as well as for the effect of disturbance and turbulence in causing errors in measurement of discharge. I have provided for all of these in my designs.

The precision of measurement of large quantities (up to even 500 cubic feet per second) is the very essence of my design, and of its purpose to permit new determinations of weir coefficients and new forms of weir that should have world-wide acceptance for a century to come, and immediately be *of great practical value to hydraulic engineers engaged on large projects.*

The opportunity for fundamental research of this scope and quality of research would immediately stamp this laboratory as without a superior or equal in the world, and in my judgment, such fundamental research is of far greater importance to the greater Federal services than the mere ability to duplicate the *small-scale researches such as are within the capacity of many existing laboratories.*

Attached hereto are photostats of detailed estimates of cost, referred to above.

Since the inclosed sheets of blue prints include no elevations, it may be well to make plain that the estimates attached hereto comprise pediment, bridge, grading, and ornamental architectural accessories included in my previous estimates.

I inclose several sheets of comparisons of capacity, etc., which clearly demonstrate the superiority of the Freeman design, particularly considering that its cost will be no greater than that the Bureau design of February 4, 1931. Probably it will be much less.

Very truly yours,

John R. Freeman.

Appendix No. 1

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.

[Estimate by A. C. Chick, based upon revised plans by John R. Freeman, as of February 14, 1931, and unit prices mostly submitted by Turner Construction Co., of Philadelphia, as of December 31, 1930. This estimate of quantities has been determined independently of that of December 31, 1930]

Item	Quantity	Unit	Unit cost	Estimated total cost
General contractor				
1. Concrete (liberal estimate; walls made exceptionally thick to prevent serious deflection and to aid in securing water-tightness).	176, 803	Cubic foot	$0. 251	$44, 378. 00
2. Reinforcement steel (reinforcement computed to take load stresses on basis of 16,000 pounds per square inch; ratio of steel to concrete, for resisting shrinkage and temperature stresses, has in all cases been taken at or greater than 0.005 volumetric basis, in walls, in excess of that required to take load stresses, with provision for contraction joints not over 50 feet apart).	629, 137	Pounds	. 330	20, 762. 00
3. Floor finish (dusted on)	55, 387	Square foot	. 050	2, 769. 00
4. Forms:				
Wood—				
(a) Footings	610	do	. 120	73. 00
(b) Floor slabs	6, 434	do	. 283	1, 820. 00
(c) Floors on steel	56, 866	do	. 145	8, 246. 00
(d) Walls (double)	31, 564	do	. 365	11, 520. 00
(e) Walls (curved)	1, 659	do	. 600	995. 00
(f) Stairs	365	Linear foot	1. 000	365. 00
(g) Sills and coping	1, 763	do	. 600	1, 057. 00
(h) Water table and belt	1, 784	do	1. 000	1, 784. 00
Metal—(a) Interior walls of main and return flumes	12, 370	Square foot	. 500	6, 185. 00
5. Integral waterproofing: None provided. Allowance has been made for using a higher grade of concrete with extra quantity of cement, which is deemed a better guarantee of water-tighness than the use of integral waterproofing compounds.				
6. Special coloring of concrete trim to match Indiana limestone used on some of the other buildings at the Bureau of Standards. This includes special selection of aggregate.				1, 000. 00
7. Exterior finish of concrete wall surfaces (including rustication).	5, 130	Square foot	. 060	309. 00
8. Interior concrete finish (pointing walls and ceilings)	126, 210	do	. 020	2, 524. 00
9. Interior finish of main and return flumes (pointed, carborundum rubbed, and smoothly surfaced).	12, 370	do	. 060	742. 00
10. Brickwork:				
Facebrick	132	Thousand	70. 000	9, 240. 00
Common brick	188	do	42. 000	7, 896. 00
Basement floor	21	do	40. 000	840. 00
11. Scaffold lumber	50	Thousand feet	30. 000	1, 500. 00
12. Wood doors	918	Square foot	1. 750	1, 606. 00
13. Roof plank (2-inch)	2, 200	do	. 160	352. 00
14. Bridge and walkway (main entrance, 2d floor)	380	do	1. 500	570. 00
15. Leveling	25, 000	do	. 020	500. 00
16. Hardware				450. 00
17. Contraction joints in concrete walls (copper)	628	Linear foot	1. 000	628. 00
Subtotal (general contractor)				128, 111. 00

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.—Continued

Item	Quantity	Unit	Unit cost	Estimated total cost
Subcontractor				
18. Clearing site				$500.00
19. Excavation	27,700	Cubic yards	$0.850	23,545.00
20. Backfill and rough grading				1,000.00
21. Metal column forms (rented)	39		15.000	585.00
22. Structural steel, including paint	322	Ton	70.000	22,540.00
23. Structural steel (beams and plate) for propeller pump chamber.	50	do	100.000	5,000.00
24. Structural steel—forebay	85	do	100.000	8,500.00
25. Structural steel in tie across outlet of forebay, including vertical girders, anchor rods, steel plate lining for water passages, etc.	46	do	100.000	4,600.00
26. Steel stairs	1,035	Square foot	2.250	2,328.00
27. Iron-pipe rail, 1¼-inch	577	Linear foot	1.800	1,038.00
28. Iron ladders	50	Pound	.100	5.00
29. Steel commercial projected sash	10,260	Square foot	.450	4,617.00
30. Metal toilet partitions	8		50.000	400.00
31. Wood and glass partitions	2,200	Square foot	.800	1,760.00
32. Toilet walls (8-inch brick)	18.5	Thousand	42.000	777.00
33. Plastering (Defer).				
34. Roofing (tar and gravel, 20-year)	23,550	Square foot	.110	2,590.00
35. Flashing	900	Linear foot	.350	315.00
36. Painting (wood and iron only)	39,700	Square foot	.050	1,985
37. Glazing	10,260	do	.200	2,052.00
38. Plumbing (fixtures in place only)	29	Fixtures	100.000	2,900.00
39. Hot and cold water (piping and hot water supply)				720.00
40. Ground-water tile drains	1,200	Linear foot	.400	480.00
41. Cast-iron drains:				
(*a*) Inside building—				
8-inch	70	do	1.000	70.00
6-inch	350	do	.900	315.00
4-inch	70	do	.700	49.00
(*b*) Outside building—				
8-inch	35	do	1.000	35.00
6-inch	135	do	.900	121.00
42. Tile drain pipe:				
12-inch to sewer in Tilden Street	50	do	2.000	100.00
8-inch	100	do	.400	40.00
6-inch	400	do	.300	120.00
43. Manhole catch basin				75.00
44. Valves on cast-iron drains:				
8-inch gate	1			45.00
6-inch gate	1			35.00
45. Floor drains with traps and strainer covers:				
8-inch	2			125.00
6-inch	1			50.00
4-inch	1			20.00
46. Heating (radiation surface and piping only: Supply from central heating plant).	10,420	Square foot	1,250	13,025.00
47. Electric wiring (lighting and convenience outlets only):				
Lighting	310	Outlet	12.000	3,720.00
Convenience outlet	50	do	5.000	250.00
48. Steam and electric lines from power house				10,000.00
49. Water and gas connections:				
Water				1,250.00
6-inch water meter				350.00
Two 8-inch valves				90.00
Gas connection				200.00
50. Crane and rails (two only at present)				2,800.00
51. Elevator (shaft only provided).				
52. Projected pediments for outside trim				1,000.00
53. Borings (already made)				500.00
54. Propeller pump discharge pipe (riveted steel)	4.5	Ton	90.000	405.00
Subtotal (subcontractor)				123,017.00

Estimate of quantities and cost for constructing national hydraulic laboratory at Bureau of Standards, Washington, D. C.—Continued

SUMMARY

Item	Quantity	Unit	Unit cost	Estimated total cost
General contractor				$128, 111. 00
1½ per cent tools and supplies				1, 920. 00
Cleaning	63, 300	Square foot	$0. 0300	1, 899. 00
2 per cent liability insurance				2, 560. 00
5 per cent general expense				6, 400. 00
Special protection	63, 300	do	. 0025	158. 00
				141, 048. 00
Subcontractor				123, 017. 00
Engineering department				2, 500. 00
Construction department	4	Month		2, 800. 00
Accounting department	4	do		2, 800. 00
Installation				3, 000. 00
Plant rental—				
Concrete	6, 550	Cubic yards	. 4000	2, 620. 00
Brick	340	Thousand	. 5000	170. 00
				136, 907. 00

General contractor	$141, 048
Subcontractor	136, 907
Contractor's bond (1⅛ per cent of $277,955)	3, 125
Architect's fee	8, 400
Grand total for building and fixed apparatus	289, 480

The above estimate of $289,480 covers everything in the line of building and foundations and fixed equipment needed for greatly expanding the scale of experimentation as to discharges of from 500 to 600 cubic feet per second as proposed in the hearings before Congress; also, for researches on scale effect, etc., and fundamental research to meet practical requirements for many years to come.

It includes *a large supply basin,* a large forebay, *a large experiment flume,* and *a large measuring basin* sufficient for all future needs of this laboratory, which for economy and efficiency *must be incorporated in the foundations of the original structure*

In addition, it provides abundant clear floor space for research work by means of a wide variety of temporary set-ups, using volumes of water seldom exceeding 5 to 10 cubic feet per second, but permitting the use of quantities up to or greater than 100 cubic feet per second, for this purpose, if desired.

Provision is made for installation now, or at any future time, of a large propeller-type pump, so arranged as to permit fundamental research on cavitation and turbulence, in the pump itself, as well as supplying the need of a large quantity (250 to 300 cubic feet per second) of water for miscellaneous research work in the large flume, or in the return flume, or in apparatus temporarily set up in either of said flumes, the floors of which provide a substantial support for very heavy floor loads.

Estimate of cost of semifixed equipment and apparatus necessary to make the national hydraulic laboratory operative upon completion of the building.

None of the following items have been included in the above estimate, which purports to cover only the building, foundations, and fixed equipment.

1. Skimmer weir for 40-foot diameter steel forebay. The final design should preferably be based on experiments made on a small scale model of one-eighth to one-fourth full-size linear dimensions. Present designs (Dec. 30, 1930) show that this skimmer weir and down spout, with necessary counterbalancing water tanks for compensating excesssive buoyancy, will weigh approximately 20.5 tons. A small, local structural steel company has submitted a bid of $5,500 for supplying this skimmer weir, complete; to this should be added, say, $500 for installation, making its total cost, in place — $6, 000
2. Hoisting tackle for skimmer weir; 30-ton capacity, endless, screw-drum winch, with 6-part wire-rope hoist — 1, 000

3. Glass panels in main flume and return flume		$2,000
4. Stilling plates (included in cost of steel forebay).		
5. Pivot-knife gate at discharge end of main flume—hand operated at first for small quantities of water; equipment for compressed-air operation for large quantities can be installed at any desired future time at a cost probably not exceeding $1,500		1,500
6. Venturi meter 6 by 3 feet throat *Defer installation*. The intake and outlet sections should be installed now. These consist of steel plate sections embedded in concrete and flanged to permit future attachment of the Venturi meter—3 tons, at $120		360
7. Tilting river flume. Make flanged connection to steel forebay at this time and defer piping. One 4-foot diameter saddle and flange with cover plate is included in cost of piping.		
8. Miscellaneous small flumes:		
One glass-walled flume about 3 feet deep and 1.5 feet wide by about 50 feet long (demountable)		2,000
Constant-head tank and weir box for above flume (portable)		1,000
9. Miscellaneous small apparatus, gages, etc., over and above that already possessed by the Bureau of Standards		2,000
10. Electrical equipment, transformers, etc., sufficient to provide lighting and furnish power to all small pumps		5,000
11. Piping, valves, etc., necessary to make laboratory operative for fully 90 per cent of all contemplated work for the next two years		10,000
12. Centrifugal pumps (motors and complete equipment):		
One 25 cubic foot per second, capacity	$3,000	
One 20 cubic foot per second (for measuring basin)	2,500	
One 10 cubic foot per second	1,600	
Two 5 cubic foot per second	2,600	
One 3 cubic foot per second	900	
One 2 cubic foot per second	700	
Plus installation and connection (25 per cent)	2,800	
		14,100
13. One 250 cubic foot per second adjustable-blade propeller pump (could be deferred a year or more) complete with motor thrust bearing, etc		12,000
14. Additional hoisting equipment:		
For return flume, 2-ton block and trolley		150
For forebay gates, 2½-ton block and trolley		200
15. Wooden forebay gates and stop logs		500
16. Two portable constant-head tanks and weir boxes for miscellaneous research set-ups handling not more than 5 cubic foot-seconds		2,000
Total		59,810

SUMMARY OF TOTAL ESTIMATE OF COST OF BUILDING AND EQUIPMENT

Building and fixed equipment	$289,480
Semifixed equipment and apparatus	59,810
Total	349,290

If necessary some savings could be made by deferring a part of the above equipment for a year as follows:

Propeller pump	$12,000
Portable constant head tank	1,000
25 cubic foot per second centrifugal pump	3,000
Total savings thus possible	16,000

Bringing total necessary cost of entire laboratory buildings and equipment ready for service to $233,290; thus leaving $16,710 to take care of any possible contingencies.

Appendix No. 2 to letter to Dr. George K. Burgess, Director

Comparison of essential features of J. R. Freeman's study No. 4, as of February 14, 1931, with the Bureau of Standards' design No. II, as modified up to February 4, 1931. (By John R. Freeman and A. C. Chick)

Item	J. R. Freeman's study No. 4, Feb. 14, 1931	Bureau of Standards' design No. II, Feb. 4, 1931
Size of building:		
Dimensions—		
Head (east) portion	103 feet 8 inches by 115 feet 8 inches	81 feet by 92 feet 6 inches, plus supply basin extension, 40 feet by 85 feet 6 inches.
Narrow (west) portion	62 feet by 201 feet 8 inches	61 feet by 203 feet 6 inches, plus measuring basin extension, 45 feet 6 inches by 62 feet.
Contents—		
Exclusive of measuring basin and supply basin	1,075,600 cubic feet	1,026,950 cubic feet.
Including measuring basin and supply basin	1,434,500 cubic feet	1,302,550 cubic feet.
Foundation area	24,500 square feet	26,150 square feet.
Superstructure area	24,500 square feet	19,920 square feet.
Foundation area that serves no useful purpose for superstructure	None	6,230 square feet.
Measuring basin: [1]		
Surface area	4,080 square feet	2,540 square feet.
Usable depth	20 feet	12 feet.
Capacity	81,600 cubic feet (Inside of building.)	30,480 cubic feet. (Outside of building.)
Forebay [2]	40-foot diameter; steel; 44 feet high above flume floor.	26 by 27 feet square; concrete; 25 feet high above flume floor.
Pump supply basin:		
Area	8,840 square feet	High level 4,935 square feet. Low level 5,000 square feet Total 9,935 square feet.
Usable water depth	14 to 16 feet	High level 9 feet. Low level 7 feet.±
Usable volume	124,000 to 140,000 cubic feet (Inside building.)	High level 44,400 cubic feet. Low level 35,000 cubic feet.± Total 79,400 cubic feet. (Partly outside building.)
Main flume;		
Cross-section [3]—		
Width	15 feet	12 feet.
Maximum depth	21 feet	Do.
Normal depth	16 feet	Do.
Usable length	222 feet	213 feet.

Return flume: [4]		
Cross-section—		
Width	8 feet	6 feet.
Depth	11 feet	13 feet.
Usable length	190 feet	168 feet.
High level return flume [5]	None; 36-inch pipe used instead as more economical of space and more convenient.	6 feet wide by 13 feet deep. (Not needed.)
Permanent Venturi meters [6]	None; or can be one 6 by 3 feet with capacity of 175 cubic feet per second; or one 8 by 4 feet, with capacity of 300 cubic feet per second.	Two; One 8 by 4 feet, with capacity of 300 cubic feet per second. One 3 by 1m feet, with capacity of 45 cubic feet per second.
Auxiliary second floor [7]	Feasible and inexpensive	None.[8]
Third floor	None	Useful area: Single area 45 by 78 feet unobstructed.
Roof	Concrete [9]	Poured gypsum on sheet rock.[10]
Gates	3 timber gates [12]	7 metal gates.[13]
Skimmer weir	Single unit [14]	4 units.[15]
Length of overflow crest	2,200 linear feet	1,600 linear feet.
Water-supply line for miscellaneous set ups	30-inch diameter [16]	30 and 20-inch.[17] (Single pipe line.)
Weigh tanks	None in beginning [18]	2 tanks, each of 20 tons, or about 640 cubic feet, capacity.
Basement story	18 feet clear height [19]	14 feet clear height.
Total floor area	3,940 square feet	6,125 square feet.
Useful clear area	2,800 square feet	3,330 square feet.

[1] Measuring basin of Bureau design is entirely outside the building proper. It must therefore be covered with a roof (or floor) which will serve no other useful purpose. No portion of the north, south, or west walls of the Bureau design for measuring basin is so located as to serve as foundation walls of the proposed future extension of the laboratory in that direction. The proposed future enlarging of the Bureau measuring basin is not a feasible thing to do, because of extreme difficulty of making new concrete joints water-tight where new walls and floor join the old structure.

[2] Bureau's concrete forebay is subject to serious cracking and consequent leakage. It is more expensive to construct than the steel cylinder. It also is not as adaptable as the circular steel forebay to the many demands for attaching pipes for supplying water to experimental set-ups or for attaching pump discharge pipes.

[3] The purpose of the large cross-section of the Freeman flume is to give convenient space and "elbow room" for fundamental research on large depths on many forms of weirs, dams, baffle piers, and Venturi meters, under both normal and disturbed or turbulent flow.

[4] The greater depth of the Bureau return flume makes the use of this flume for experimental purposes more difficult and inaccessible.

[5] The Bureau's high-level return flume is a needless expense. It's primary purpose is to return water to the supply basin from small experiments using not over 40 or 50 cubic feet per second. A pipe line 36 inches in diameter would serve equally well. The inclusion of this high-level return flume in the Bureau design requires that this portion of the laboratory building be about 8 feet wider than would otherwise be necessary. The space thus involved above the first floor (8 feet wide by 31 feet high by 203 feet long) (50,400 cubic feet and costing probably upward of $5,000) is of little, if any, practical use.

[6] For water measurement purposes this is less accurate and precise over a wider range than the measuring basin or special forms of weir.

[7] The second floor in J. R. Freeman's study No. 4 for the entire length of the narrow portion of the building and north of the central building columns, can be inexpensively extended to the south edge of the main flume wherever desired, for increased width (as for a crooked river flume) supported on steel columns 20 feet apart, so arranged as not to interfere materially with the operation of the main flume. Bracket supports can be provided on the columns along the north side of the building so that, to any extent desired, second floor area over the main flume can be extended by removable flooring.

[8] Extension of second floor to south edge of main flume has been considered.

[9] Useful for floor load of 50 pounds per square foot over entire area and is available for experiments on roof.

[10] Not durable and not strong; can not be used for out-of-door experiments on roof.

[12] Timber gates are much more practical, durable, and cheap; more convenient for attachments. Similar timber gates are in almost universal use for 50 years past in the large water-power developments in New England. Mr. Freeman has designed many, such timber gates which have been long in successful use.

[13] Expensive and cumbrous.

[14] Less costly; more readily and easily adjusted with precision.

[15] Cumbrous; difficult of precise adjustment.

[16] Serves 2 floors.

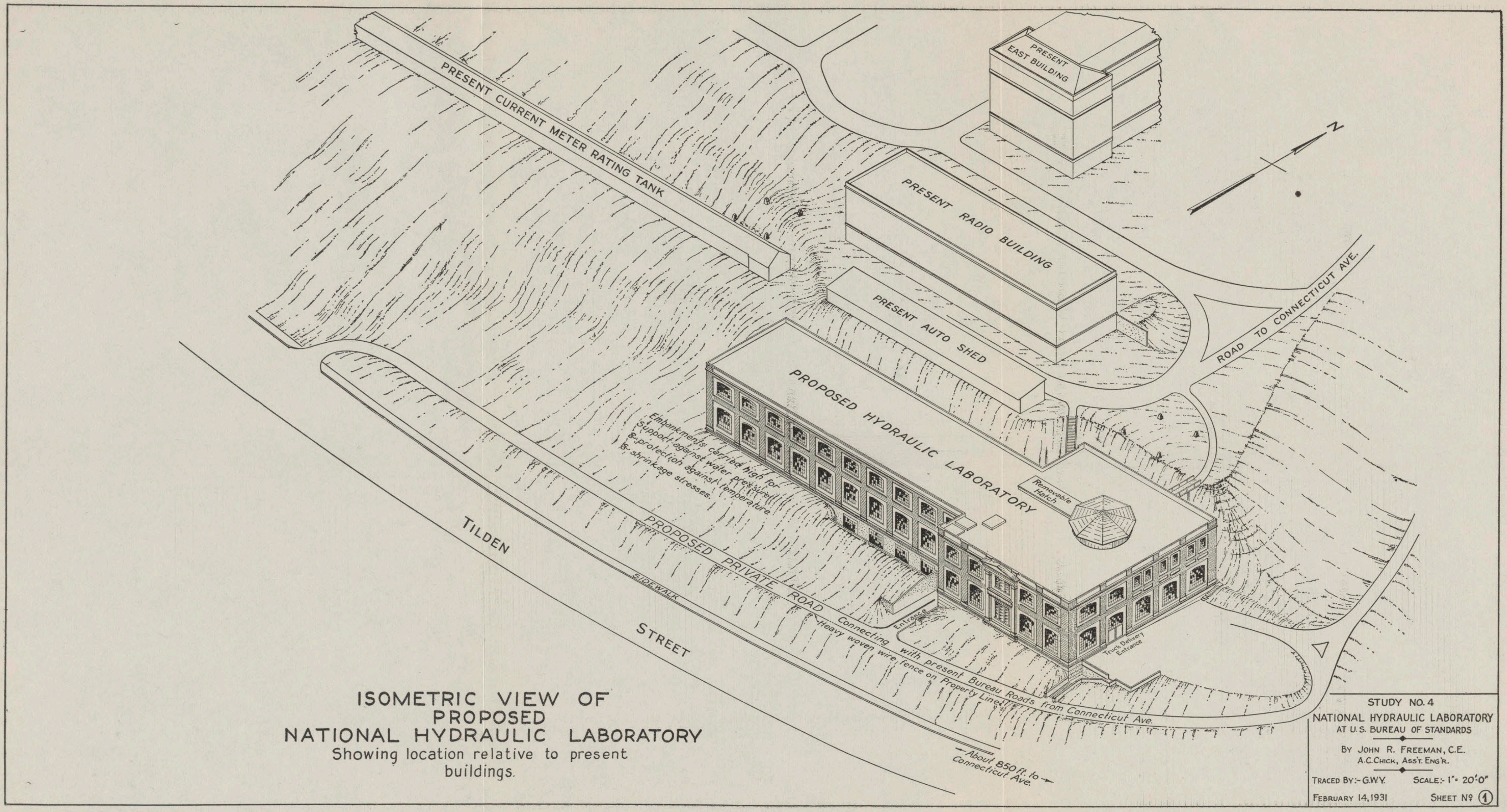
[17] Serves 1 floor.

[18] Space is provided for adding these tanks in future if desired.

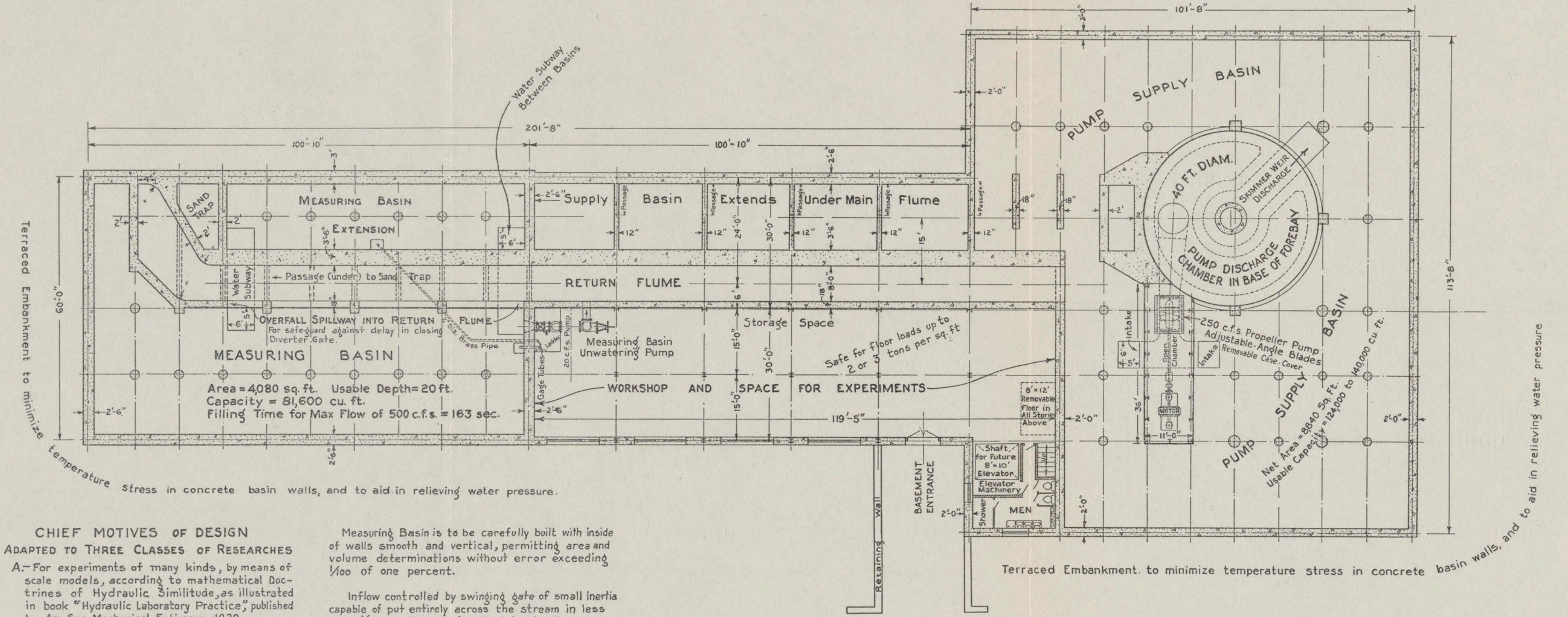
[19] Great height desirable for photographic records.

Comparison of essential features of J. R. Freeman's study No. 4, as of February 14, 1931, with the Bureau of Standards' design No. II, as modified up to February 4, 1931—Continued

Item	J. R. Freeman's study No. 4, Feb. 14, 1931	Bureau of Standards' design No. II, Feb. 4, 1931
First story (clear height)	18 feet [19]	16 feet.
Total area (within walls)	23,700 square feet	18,870 square feet.
Floor area, exclusive of forebay, main flume, and open-top return flume	15,900 square feet	13,000 square feet.
Space used for offices, elevator, and stairs	240 square feet	1,250 square feet.
Useful clear floor space for experiment purposes	12,100 square feet	9,250 square feet.
Second story (clear height)	14.5 feet	14.5 feet.
Total area (within building walls)	23,700 square feet	18,870 square feet.
Total floor area exclusive of forebay and high walls of main flume	16,550 square feet	11,720 square feet.
Total office space plus toilets, elevator, and stairways	2,410 square feet	1,240 square feet.
Useful clear floor space, for experiment purposes	13,300 square feet	8,360 square feet.
Third story (clear height)	None	11 feet.±
Total area (within building walls)		7,000 square feet.
Total area in office space, elevator, and stairway		1,240 square feet.
Useful clear floor space for experiment purposes		5,100 square feet.
Summary of useful clear floor space for experiment set-ups:		
Basement	2,800 square feet	3,330 square feet.
First story	12,100 square feet	9,250 square feet.
Second story	13,300 square feet	8,360 square feet.
Third story		5,100 square feet.
Total	28,200 square feet	26,040 square feet.
Foundations [20]	To sound undisturbed decomposed rock, like that for all present buildings at Bureau of Standards, except new power house.[21]	Carried much deeper to so-called "firm" rock.
Propeller pump	250 cubic feet per second; no suction lift [22]	None.
Centrifugal pumps:		
Large size [23]	200 cubic foot-seconds (future)	125 cubic foot-seconds (future?). 75 cubic foot-seconds (future?). 75 cubic foot-seconds. (Submerged.)
Small pumps—		
For unwatering measuring basin	20 cubic foot-seconds	20 cubic foot-seconds.
For supplying small experiments	25 cubic foot-seconds 10 cubic foot-seconds 5 cubic foot-seconds	20 cubic foot-seconds. 10 cubic foot-seconds. 5 cubic foot-seconds.
For supplying self-contained constant-head units	5 cubic foot-seconds 3 cubic foot-seconds 2 cubic foot-seconds	



ISOMETRIC VIEW OF
PROPOSED
NATIONAL HYDRAULIC LABORATORY
Showing location relative to present buildings.



CHIEF MOTIVES OF DESIGN

ADAPTED TO THREE CLASSES OF RESEARCHES

A.– For experiments of many kinds, by means of scale models, according to mathematical Doctrines of Hydraulic Similitude, as illustrated in book "Hydraulic Laboratory Practice," published by Am. Soc. Mechanical Engineers, 1929.

B.– For Large Scale Fundamental Research for determining with great precision and accuracy Coefficients of Discharge of Dams, Weirs, "Venturis", Orifices, and Channels – of great variety of form, roughness of surface, and various disturbance of approaching currents, for practical use.

C.– "Scale Effect", or extent of difference in coefficients between large structures and small models, due surface tension, boundary layer effects, turbulence, etc.

Measuring Basin is to be carefully built with inside of walls smooth and vertical, permitting area and volume determinations without error exceeding 1/100 of one percent.

Inflow controlled by swinging gate of small inertia capable of put entirely across the stream in less than 1/2 second, and of mid-point being timed by chronograph within about 1/10 second, so that for all except largest quantities the precision of measurements of rate of discharge need contain no errors greater than 1/10 of one percent, and give coefficients with far greater accuracy than heretofore possible.

For Class "A" Researches, constituting probably 90 percent of all laboratory work, no such great precision of discharge measurement is necessary.

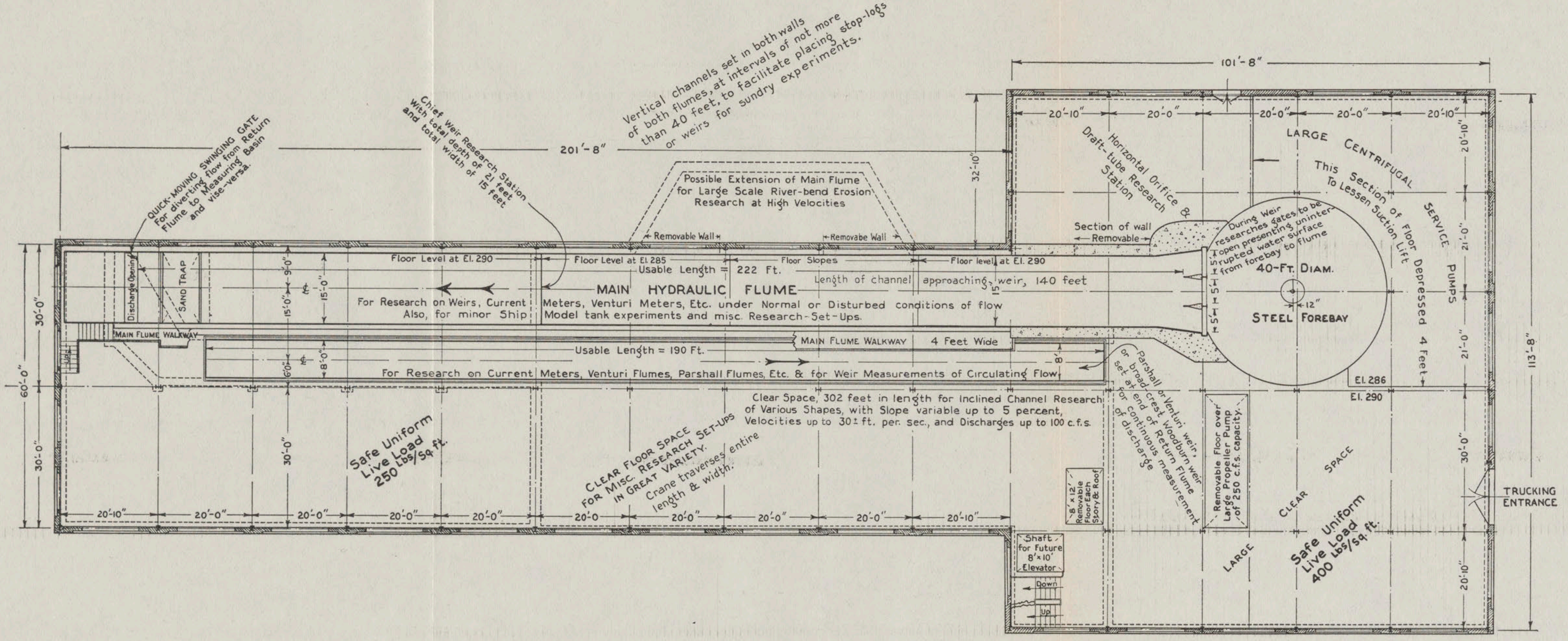
PLAN OF BASEMENT

Scale: 1/8" = 1'-0"

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T. ENG'R.

TRACED BY:– E.C.A. SCALE:– 1/8" = 1'-0"
FEBRUARY 14, 1931 SHEET No 2



PLAN OF 1ST. STORY
Scale:- 1/8" = 1'-0"

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T ENG'R

TRACED BY:- E.C.A. SCALE:- 1/8" = 1'-0"
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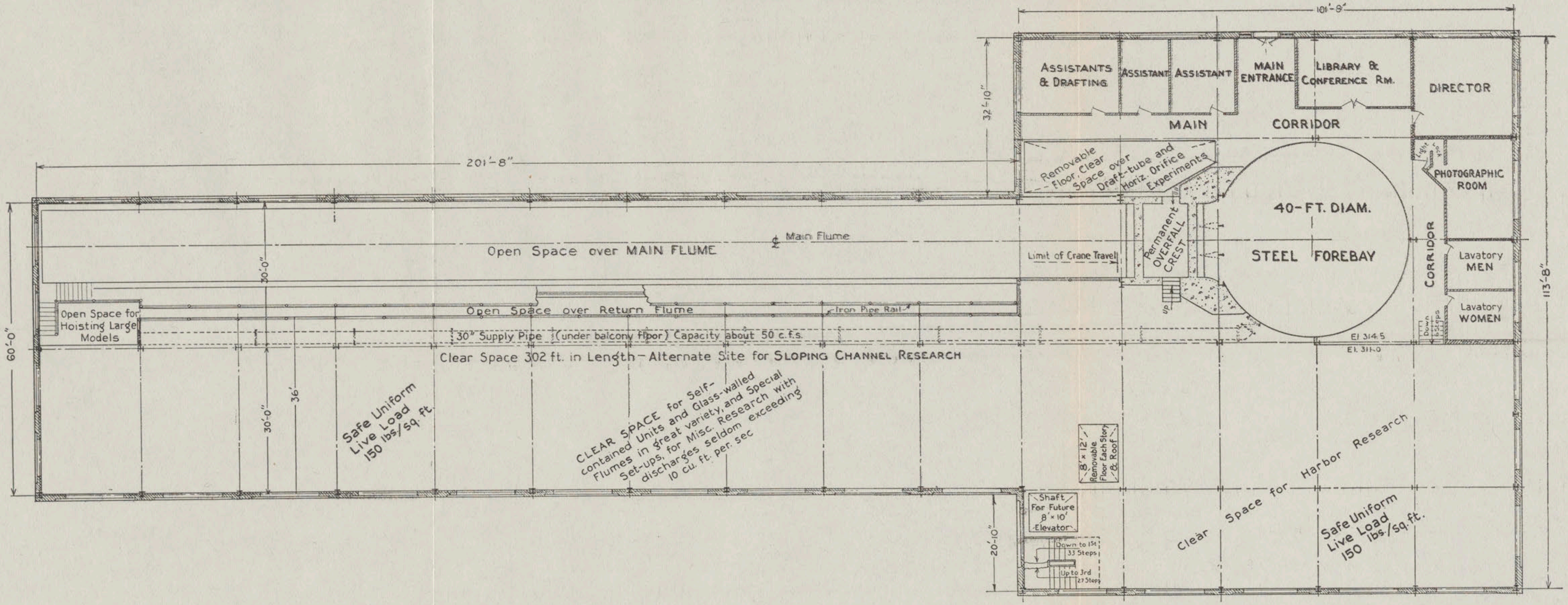

PLAN OF 2ND STORY

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NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R

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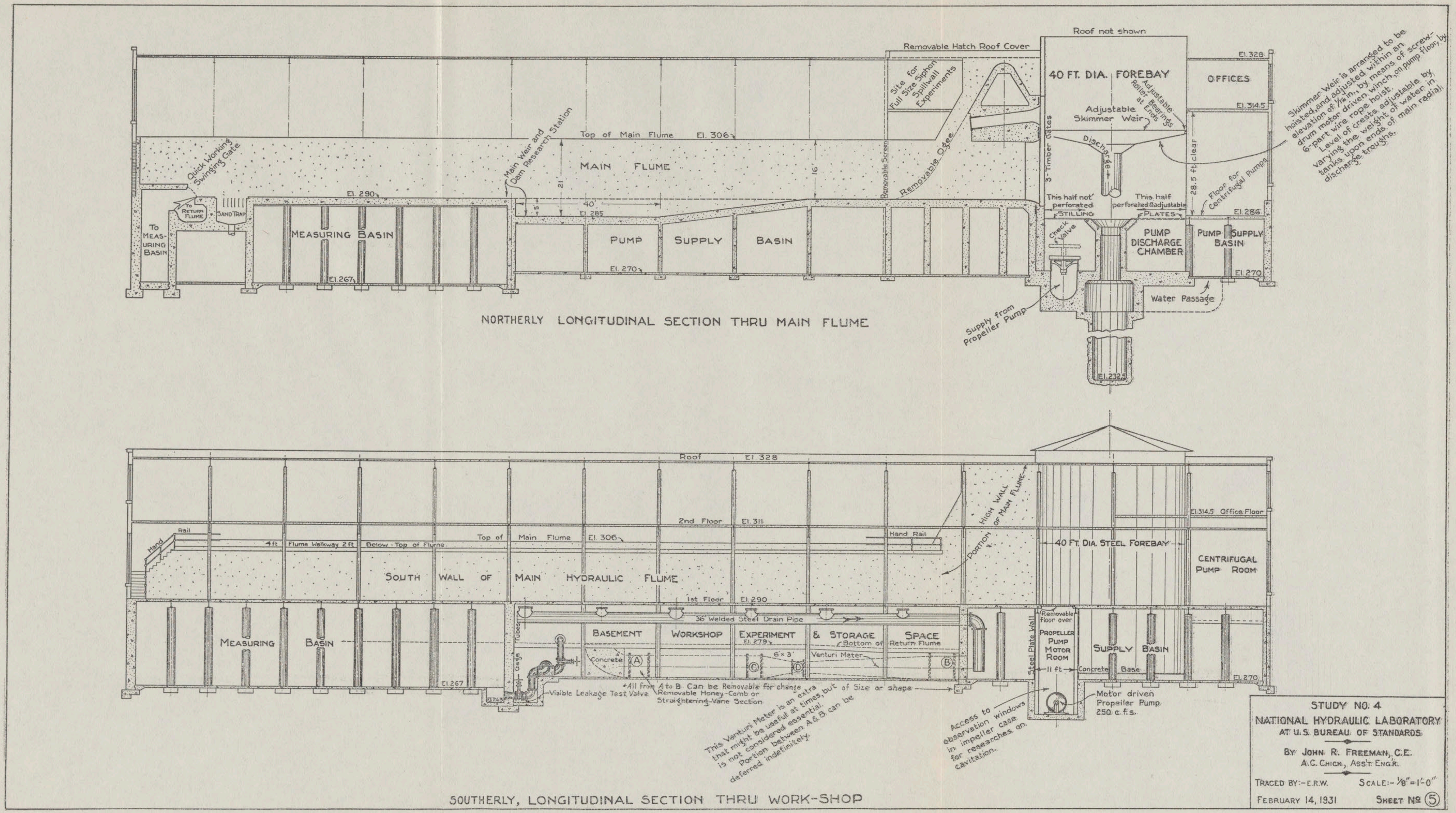

Roof not shown
Removable Hatch Roof Cover
El. 328
40 FT. DIA. FOREBAY
OFFICES
Site for Full Size Siphon Spillwall Experiments
Adjustable Roller Bearings at Ends
Adjustable Skimmer Weir
El. 314.5
Skimmer Weir is arranged to be hoisted, and adjusted within an elevation of 1/16 in., by means of screw-drum motor driven winch, on pump floor, by 6-part wire rope hoist. Level of crests adjustable by varying the weight of water in tanks upon ends of main radial discharge troughs.
Top of Main Flume El. 306
Quick Working Swinging Gate
Main Weir and Dam Research Station
MAIN FLUME
Removable Ogee
Removable Screen
3-Timber Gates
28.5 ft. clear
Floor for Centrifugal Pumps
El. 290
To Return Flume
Sand Trap
40'
21
16'
El. 285
This half not perforated
STILLING
This half perforated & adjustable
PLATES
El. 286
To Measuring Basin
MEASURING BASIN
PUMP SUPPLY BASIN
Check Valve
PUMP DISCHARGE CHAMBER
PUMP SUPPLY BASIN
El. 267
El. 270
El. 270
Water Passage
Supply from Propeller Pump
El. 232.5
NORTHERLY LONGITUDINAL SECTION THRU MAIN FLUME
Roof El. 328
El. 314.5 Office Floor
2nd Floor El. 311
Hand Rail
Hand Rail
4 ft. Flume Walkway 2 ft. Below Top of Flume
Top of Main Flume El. 306
Portion High Wall of Main Flume
40 Ft. Dia. Steel Forebay
SOUTH WALL OF MAIN HYDRAULIC FLUME
CENTRIFUGAL PUMP ROOM
1st Floor El. 290
36" Welded Steel Drain Pipe
Removable floor over
MEASURING BASIN
Tubes
Gage
BASEMENT WORKSHOP EXPERIMENT & STORAGE SPACE
El. 279
Bottom of Return Flume
Concrete
A
6'×3'
C
D
Venturi Meter
B
Steel Plate Wall
PROPELLER PUMP MOTOR ROOM
11 ft.
Concrete Base
SUPPLY BASIN
El. 267
El. 270
Visible Leakage Test Valve
*All from A to B Can be Removable for change of Size or shape
Removable Honey-Comb or Straightening-Vane Section
This Venturi Meter is an extra that might be useful at times, but is not considered essential. Portion between A & B can be deferred indefinitely.
Access to observation windows in impeller case for researches on cavitation.
Motor driven Propeller Pump 250 c.f.s.
SOUTHERLY, LONGITUDINAL SECTION THRU WORK-SHOP
STUDY No. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T. ENG'R.
TRACED BY:- E.R.W.
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FEBRUARY 14, 1931
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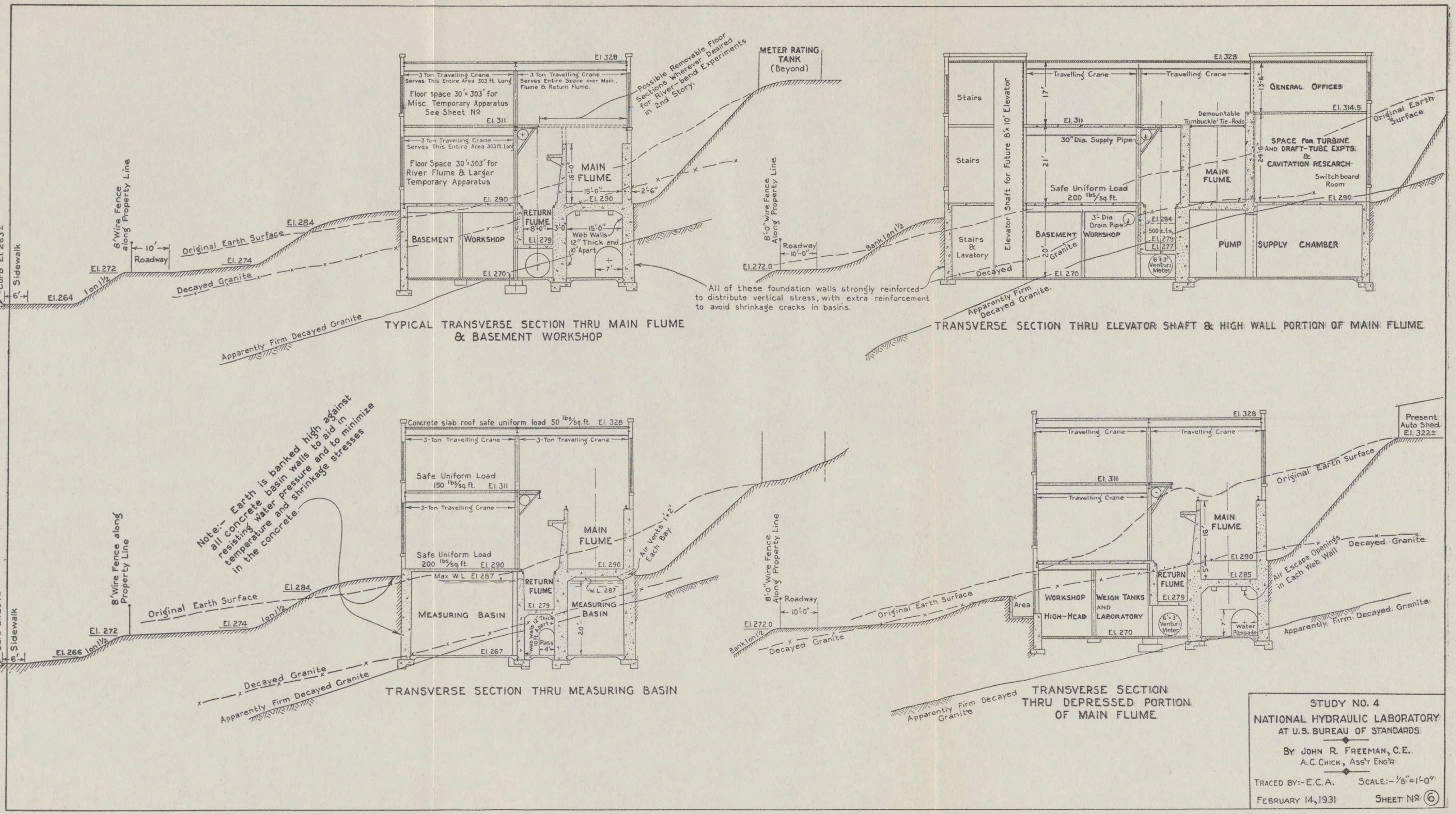
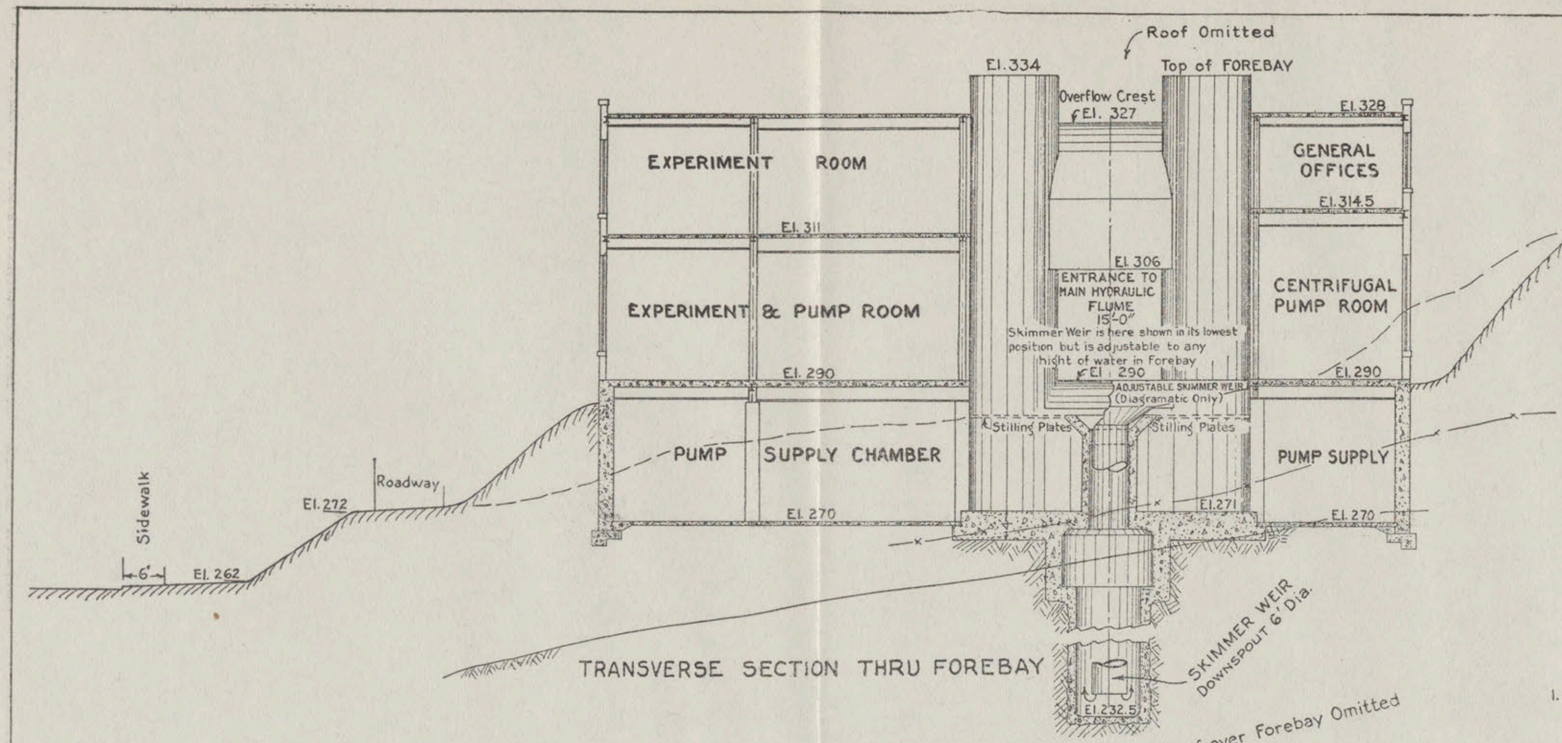
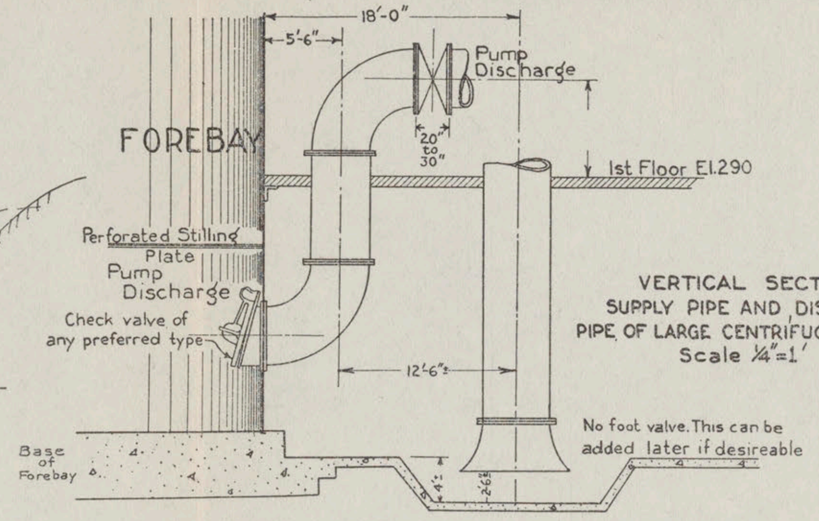


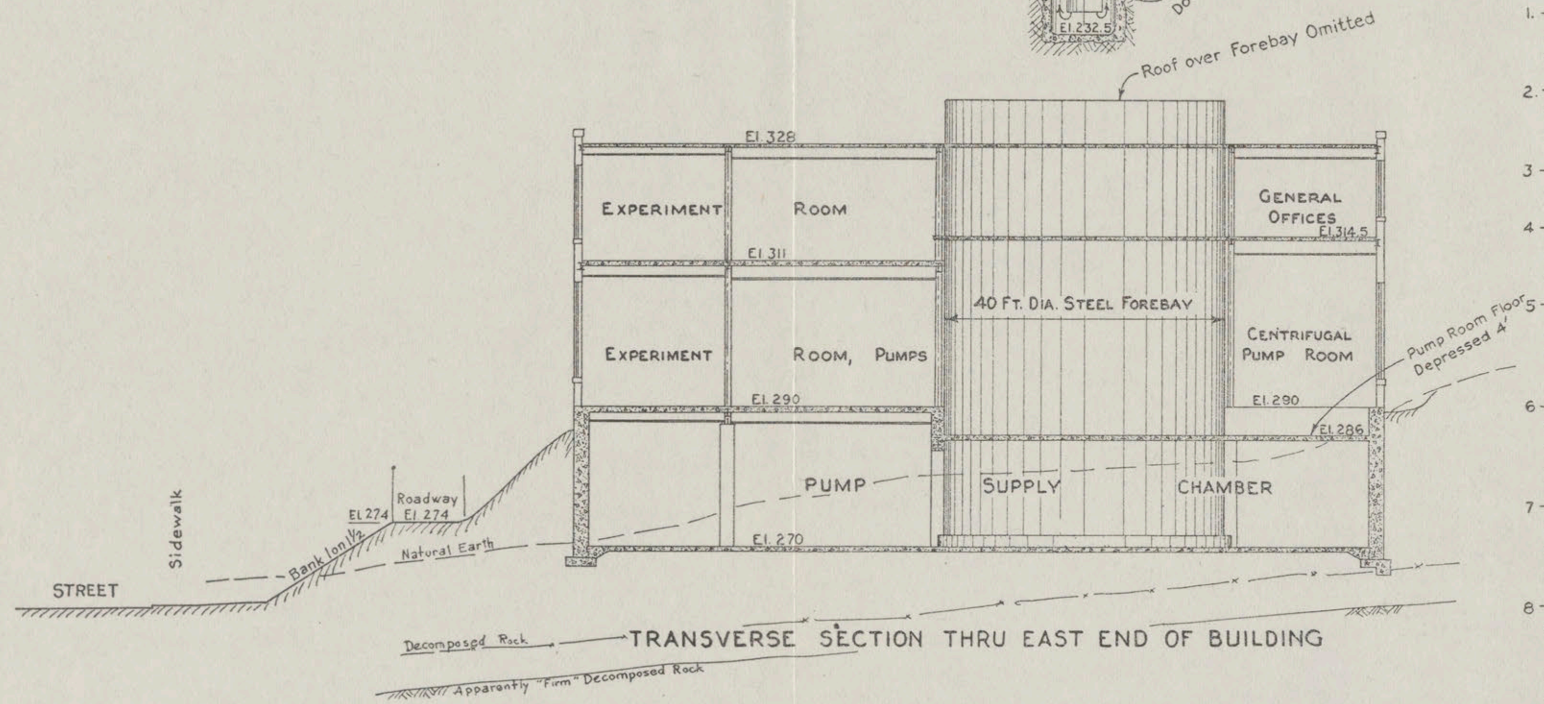
42509—S. Doc. 308, 71-3. (Face p. 15.) No. 6



TRANSVERSE SECTION THRU FOREBAY



VERTICAL SECTION
SUPPLY PIPE AND DISCHARGE
PIPE OF LARGE CENTRIFUGAL PUMPS.
Scale 1/4"=1'



TRANSVERSE SECTION THRU EAST END OF BUILDING

GENERAL SPECIFICATIONS COVERING DESIGN OF STRUCTURAL STEEL AND REINFORCED CONCRETE AS ALLOWED FOR IN ACCOMPANYING ESTIMATE OF COST.

1. — All structural steel beams are designed on basis of 16,000 lbs/sq.in. maximum extreme fiber stress under total dead plus assumed live loads.

2. — All steel columns are designed to withstand eccentric loads from floor beams, cranes, etc., with maximum fibre stress not exceeding 16,000 lbs/sq.in.

3 — All concrete structurers are designed on basis of 700 lbs/sq.in) maximum compressive stress.

4 — All concrete reinforcement steel is designed for a maximum tensile stress of 16,000 lbs/sq in. for resisting dead plus assumed live loads.

5 — For resisting shrinkage and temperature stresses, not less than 0.5 of one percent (ratio of steel to concrete, by cross-sectional area) of reinforcing steel has been provided in all cases where walls must retain water.

6 — For all important concrete work, such as basin walls and floors, flume walls and floors, etc. a mixture in proportion 1:1½:3 (cement: sand: aggregate) or equivalent, shall be used.

7 — All concrete materials to be carefully graded and thoroughly mixed, not less than 1½ minutes per. batch, and well tamped and vibrated into place to give a dense, impervious concrete as nearly water-proof as practicable.

8 — Form work to be of extra quality, securely braced to give smooth even surfaces of concrete.

Forms for interior walls of Measuring Basin to be of planed lumber and rigidly held in place to prevent distortion so that finished concrete wall surface shall not be more than 3/4 in. out of alignment in a length of 100 ft. and not more than 1/8 in. out of alignment in a length of 10 feet.

Forms for interior walls of Main and Return Flumes shall be steel, rigidly supported and braced to give finished concrete surface not more than 1/2 in. out of alignment in length of flume, and not more than 1/8 in. out of alignment in any length of 10 feet.

9 — Base of all wall footings are horizontally reinforced for spreading the load over the decomposed rock.

10 — All concrete foundation walls are diagonally reinforced in vertical plane to give added girder strength for distributing load over decomposed rock.

The accompanying Estimate of Cost, based on detailed design, is made up from present scale of contract prices, in conference with the Turner Construction Co. of Philadelphia and Charles T. Main Inc., of Boston with the understanding that the Turner Construction Co. would be ready to submit a lump sum bid for the entire structure at price corresponding.

NOTE: That due to present industrial depression exceptionally low current bids are being made by large contracting concerns desirous of retaining their organization against better times.

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T. ENG'R

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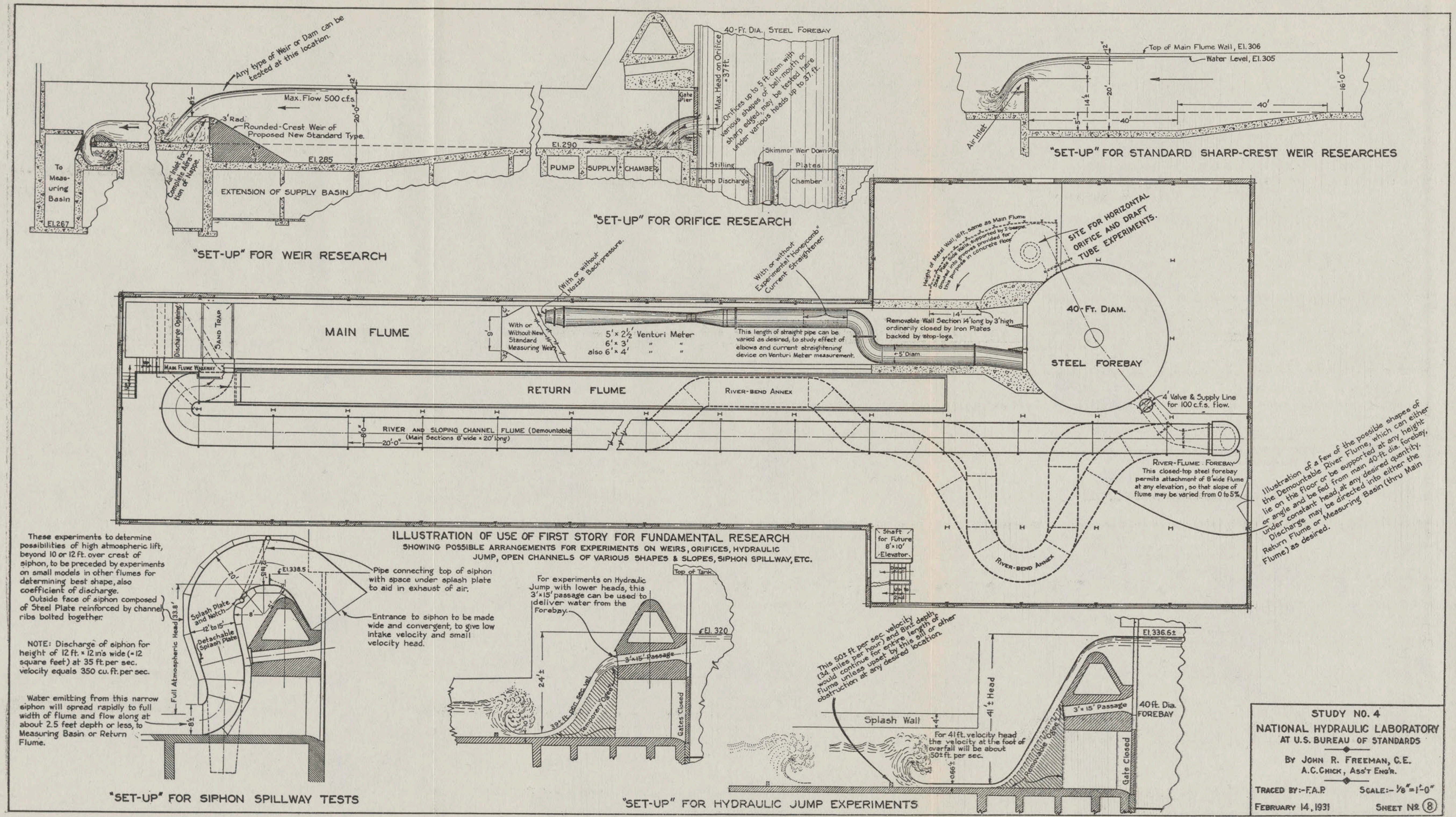
FEBRUARY 14, 1931 SHEET No 7



"SET-UP" FOR WEIR RESEARCH
Any type of Weir or Dam can be tested at this location.
Max. Flow 500 c.f.s.
3' Rad.
Rounded-Crest Weir of Proposed New Standard Type.
Air Inlet for Complete Aeration of Nappe
To Measuring Basin
El. 267
El. 285
EXTENSION OF SUPPLY BASIN
"SET-UP" FOR ORIFICE RESEARCH
40-Ft. Dia. Steel Forebay
Max. Head on Orifice ±37 Ft.
Orifices up to 5 ft. diam. with various shapes of bell-mouth or sharp edged may be tested here under various heads up to 37 ft.
Gate Pier
El. 290
PUMP SUPPLY CHAMBER
Stilling
Plates
Skimmer Weir Down-Pipe
Pump Discharge
Chamber
"SET-UP" FOR STANDARD SHARP-CREST WEIR RESEARCHES
Top of Main Flume Wall, El. 306
Water Level, El. 305
Air Inlet
ILLUSTRATION OF USE OF FIRST STORY FOR FUNDAMENTAL RESEARCH
SHOWING POSSIBLE ARRANGEMENTS FOR EXPERIMENTS ON WEIRS, ORIFICES, HYDRAULIC JUMP, OPEN CHANNELS OF VARIOUS SHAPES & SLOPES, SIPHON SPILLWAY, ETC.
MAIN FLUME
Discharge Opening
SAND TRAP
With or Without New Standard Measuring Weir
(With or without Nozzle Back-pressure.
5' × 2½' Venturi Meter
6' × 3' " "
also 6' × 4' " "
With or without Experimental "Honeycomb" Current Straightener.
This length of straight pipe can be varied as desired, to study effect of elbows and current straightening device on Venturi Meter measurement.
5' Diam.
Removable Wall Section 14' long by 3' high ordinarily closed by Iron Plates backed by stop-logs.
40-Ft. Diam.
STEEL FOREBAY
SITE FOR HORIZONTAL ORIFICE AND DRAFT TUBE EXPERIMENTS.
Height of Metal Wall, 16 ft., same as Main Flume
4' Valve & Supply Line for 100 c.f.s. flow.
MAIN FLUME WALKWAY
RETURN FLUME
River-bend Annex
RIVER AND SLOPING CHANNEL FLUME (Demountable) (Main Sections 8' wide × 20' long)
20'-0"
River-Flume Forebay
This closed-top steel forebay permits attachment of 8' wide flume at any elevation, so that slope of flume may be varied from 0 to 5%
Illustration of a few of the possible shapes of the Demountable River Flume, which can either lie on the floor or be supported at any height or angle and be fed from main 40-ft. dia. forebay, under constant head, at any desired quantity. Discharge may be directed into either the Return Flume or Measuring Basin (thru Main Flume) as desired.
Shaft for Future 8' × 10' Elevator
River-bend Annex
These experiments to determine possibilities of high atmospheric lift, beyond 10 or 12 ft. over crest of siphon, to be preceded by experiments on small models in other flumes for determining best shape, also coefficient of discharge.
Outside face of siphon composed of Steel Plate reinforced by channel ribs bolted together.
NOTE: Discharge of siphon for height of 12 ft. × 12 in's wide (=12 square feet) at 35 ft. per sec. velocity equals 350 cu. ft. per sec.
Water emitting from this narrow siphon will spread rapidly to full width of flume and flow along at about 2.5 feet depth or less, to Measuring Basin or Return Flume.
Pipe connecting top of siphon with space under splash plate to aid in exhaust of air.
Entrance to siphon to be made wide and convergent, to give low intake velocity and small velocity head.
El. 338.5
Splash Plate and Notch
12' to 15'
Detachable Splash Plate
Full Atmospheric Head 33.8'
"SET-UP" FOR SIPHON SPILLWAY TESTS
For experiments on Hydraulic Jump with lower heads, this 3' × 15' passage can be used to deliver water from the Forebay.
Top of Tank
El. 320
3' × 15' Passage
24'±
Temporary Ogee
Gates Closed
This 50± ft. per sec. velocity (34 miles per hour) and 8± ft. depth would continue for entire length of flume unless upset by this sill or other obstruction at any desired location.
El. 336.6±
41'± Head
Splash Wall
For 41 ft. velocity head the velocity at the foot of overfall will be about 50± ft. per sec.
3' × 15' Passage
40 ft. Dia. FOREBAY
Removable Ogee
Gate Closed
"SET-UP" FOR HYDRAULIC JUMP EXPERIMENTS
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A. C. CHICK, ASS'T ENG'R.
TRACED BY:- F.A.P.
SCALE:- 1/8" = 1'-0"
FEBRUARY 14, 1931
SHEET No. 8

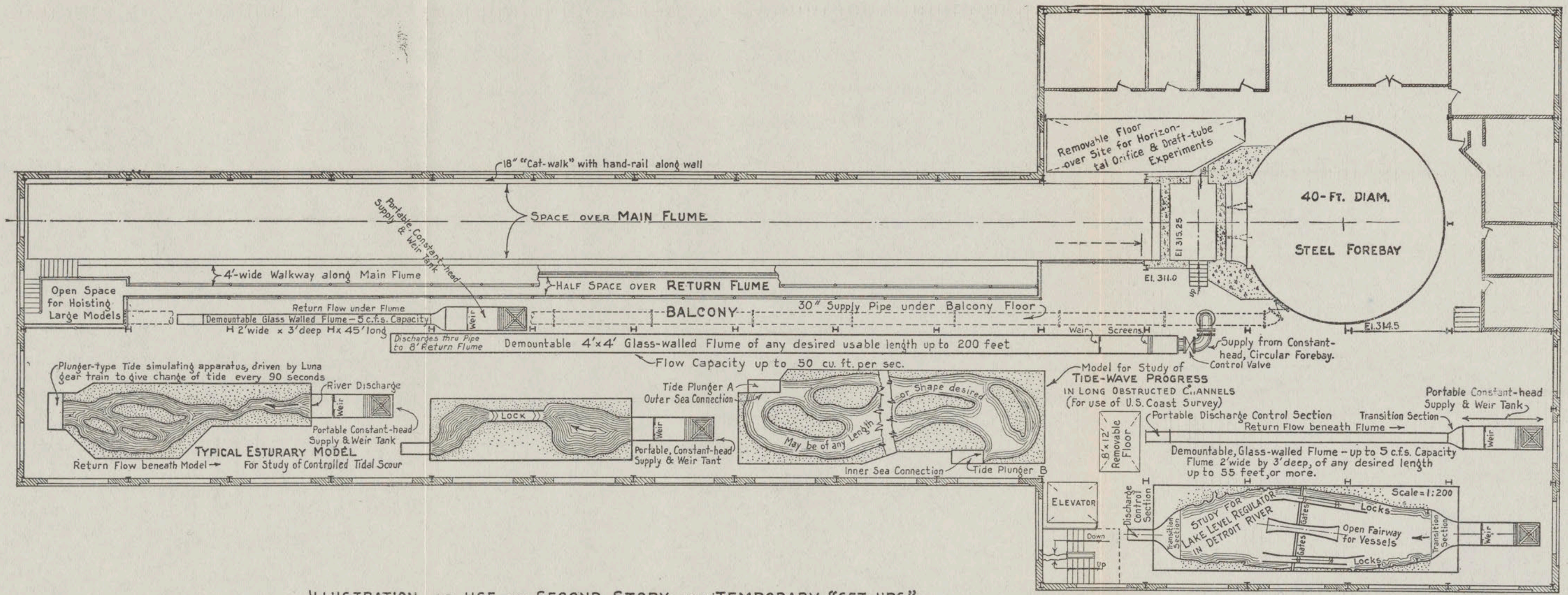
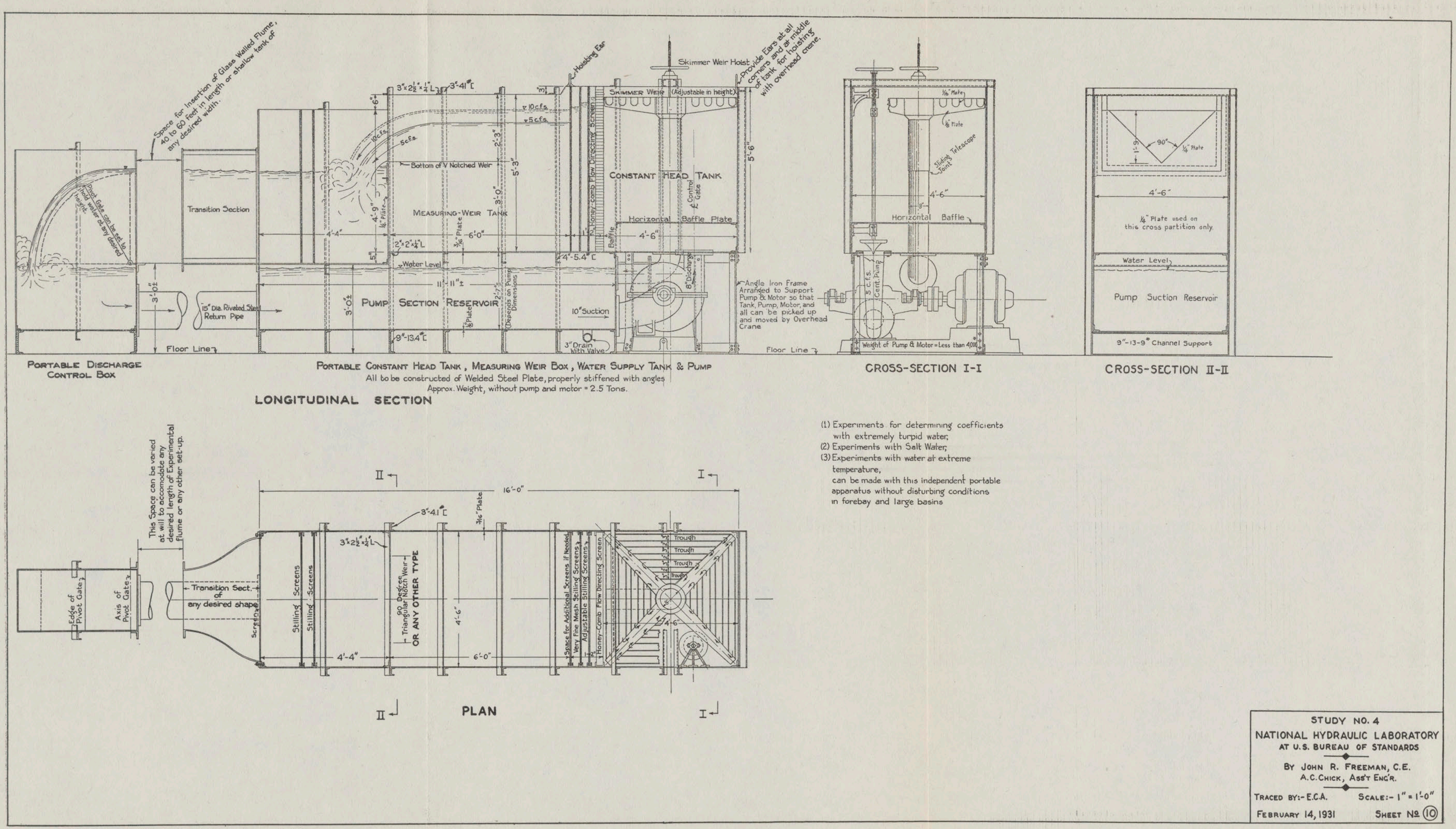
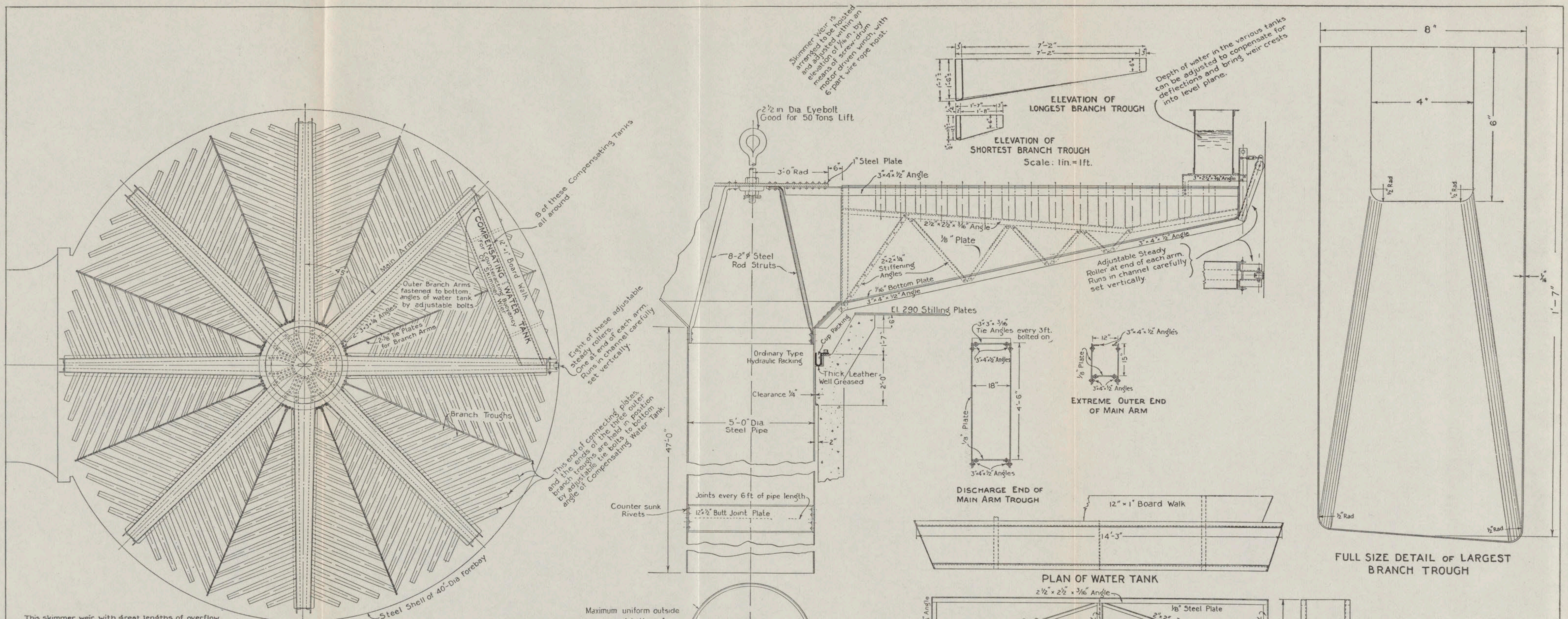


ILLUSTRATION OF USE OF SECOND STORY FOR TEMPORARY "SET-UPS"
SHOWING A HALF-DOZEN RESEARCHES OF ORDINARY TYPE IN PROGRESS SIMULTANEOUSLY
WITH OPEN FLOOR SPACE AVAILABLE FOR SEVERAL MORE RESEARCHES

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R.
TRACED BY:-
SCALE:- 1/8" = 1'-0"
FEBRUARY 14, 1931
SHEET No 9



42509—S. Doc. 308, 71-3. (Face p. 15.) No. 10



This skimmer weir, with great lengths of overflow crest, is of great importance as a means of maintaining constant head with great precision. A slight excess of water will be pumped and wasted over skimmer weir.
An increase in pumpage over flume discharge, of 25 cu. ft. per sec., would increase height only about 0.01 foot.
100 c.f.s. can be discharged with depth of 0.6 feet, and a maximum of 500 c.f.s. could flow over skimmer weir with a depth of only about 0.15 ft.

2096 Ft. Crest Length in Branch Troughs
128 Ft. Crest Length in Main Arms
2224 Ft. Total Usable Crest Length

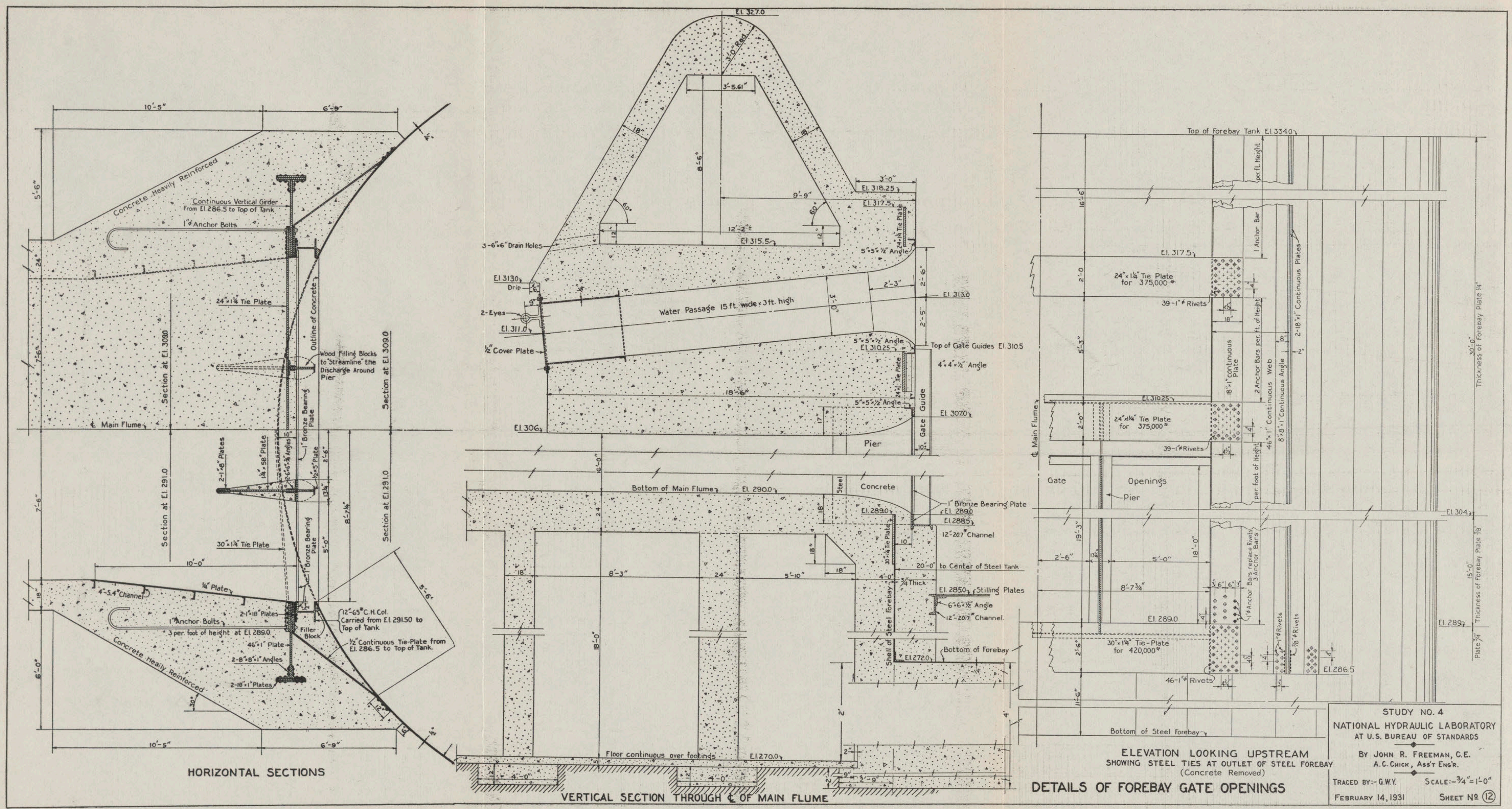
Aproximate Weight of Skimmer Weir Complete	11.0 Tons
Aproximate Weight of 5 ft. Down Pipe	5.0 "
Aproximate Weight of Compensating Water Tanks	3.5 "
Aproximate Total Weight Complete	20.5 Tons
Aproximate Flotation of Skimmer Weir when to point of admitting over weir crests.	31.2 Tons
Excess Flotation over weight of Skimmer Weir which must be compensated for by partially filling water tanks for this purpose supported on outer ends of main arms of Skimmer Weir.	10.7 Tons

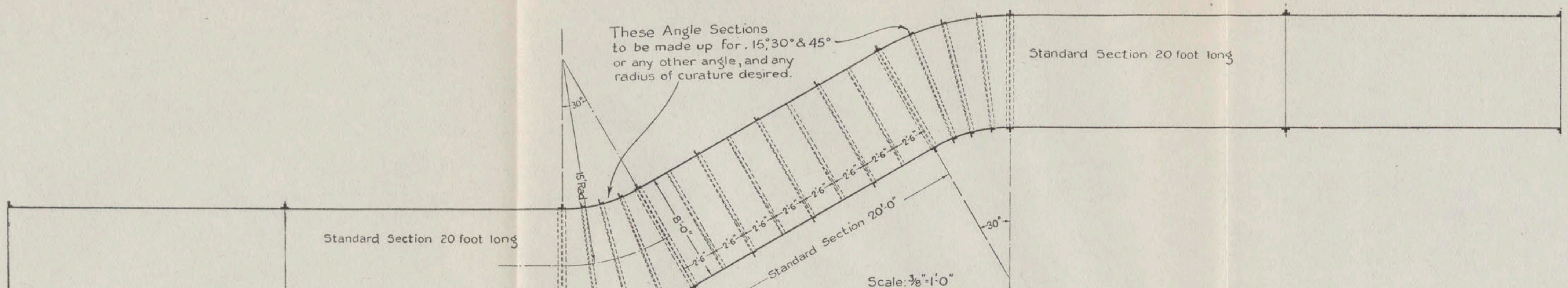
STUDY FOR DESIGN OF SKIMMER WEIR
FOR 40-FT. DIA. FOREBAY

STUDY No. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS

By John R. Freeman, C.E.
A.C. Chick, Ass't Eng'r

Traced by:- E.C.A. Scale:- 1/8"=1'-0"
February 14, 1931 Sheet No. 11


HORIZONTAL SECTIONS
Concrete Heavily Reinforced
Continuous Vertical Girder From El. 286.5 to Top of Tank
1" Anchor Bolts
24"x1¼" Tie Plate
Outline of Concrete
Wood Filling Blocks to "Streamline" the Discharge Around Pier
Section at El. 309.0
Main Flume
1" Bronze Bearing Plate
Section at El. 291.0
2-1"x8" Plates
14"x5/8" Plate
30"x1¼" Tie Plate
¼" Plate
4"-5.4# Channel
1" Anchor Bolts 3 per foot of height at El. 289.0
2-1"x18" Plates
46"x1" Plate
2-8"x8"x1" Angles
2-18"x1" Plates
Filler Block
12"-65# C.H. Col. Carried from El. 291.50 to Top of Tank
½" Continuous Tie-Plate from El. 286.5 to Top of Tank.
Concrete Heavily Reinforced
10'-5"
6'-9"
5'-6"
7'-6"
6'-0"
10'-0"
5'-6"
VERTICAL SECTION THROUGH ℄ OF MAIN FLUME
El. 327.0
3'-0" Rad.
3'-5.61"
8'-6"
9'-9"
12'-2"
El. 318.25
El. 317.5
El. 315.5
3-6"x6" Drain Holes
5"x5"x½" Angle
El. 313.0
Drip
2-Eyes
El. 311.0
½" Cover Plate
Water Passage 15 ft. wide x 3 ft. high
El. 310.25
Top of Gate Guides El. 310.5
4"x4"x½" Angle
18'-6"
Gate Guide
El. 307.0
El. 306
Pier
Concrete
Steel
Bottom of Main Flume
El. 290.0
1" Bronze Bearing Plate
El. 289.0
El. 288.5
12"-20.7# Channel
20'-0" to Center of Steel Tank
¾" Thick
El. 285.0
Stilling Plates
6"x6"x½" Angle
12"-20.7# Channel
Shell of Steel Forebay
El. 272.0
Bottom of Forebay
Floor continuous over footings
El. 270.0
8'-3"
5'-10"
18'-0"
16'-0"
4'-0"
2'-9"
ELEVATION LOOKING UPSTREAM
SHOWING STEEL TIES AT OUTLET OF STEEL FOREBAY
(Concrete Removed)
Top of Forebay Tank El. 334.0
El. 317.5
24"x1¼" Tie Plate for 375,000#
39-1"# Rivets
1 Anchor Bar per ft. Height
2-18"x1" Continuous Plates
18"x1" continuous Plate
2 Anchor Bars per ft. of Height
46"x1" Continuous Web
8"x8"x1" Continuous Angle
Thickness of Forebay Plate 1⁄4"
El. 310.25
24"x1¼" Tie Plate for 375,000#
Main Flume
Gate
Openings
Pier
El. 304
3 Anchor Bars per foot of Height
Anchor Bars replace Rivets
El. 289.0
30"x1¼" Tie-Plate for 420,000#
46-1"# Rivets
El. 286.5
Thickness of Forebay Plate 7/8"
Plate 3/4"
Bottom of Steel Forebay
El. 289
DETAILS OF FOREBAY GATE OPENINGS
STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R.
TRACED BY:- G.W.Y.
SCALE:- 3/4" = 1'-0"
FEBRUARY 14, 1931
SHEET Nº 12



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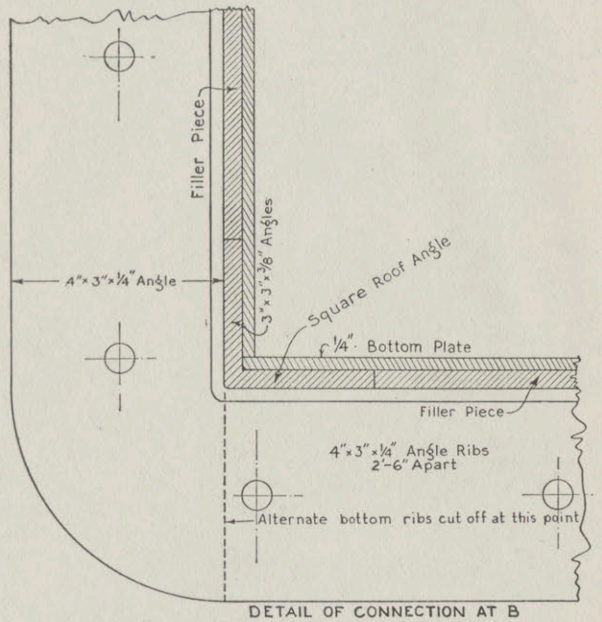
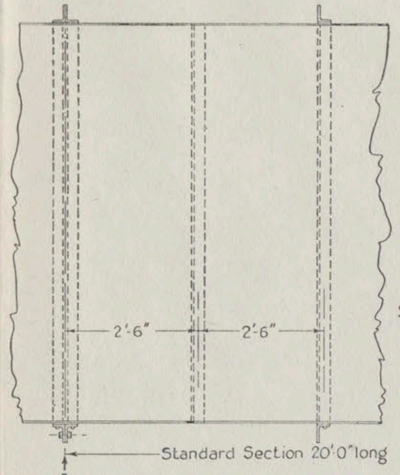
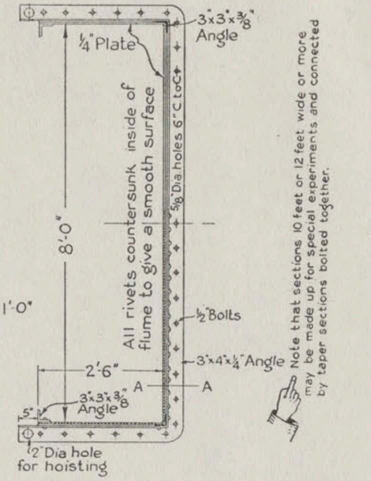
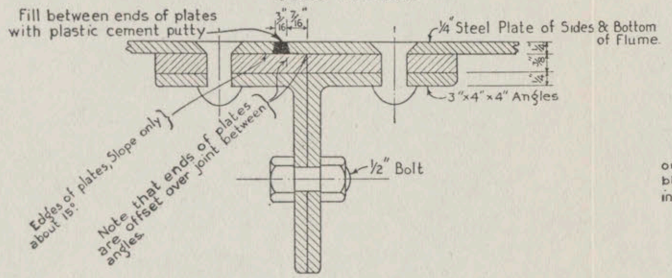


DETAIL OF CONNECTION AT B
Scale Full Size

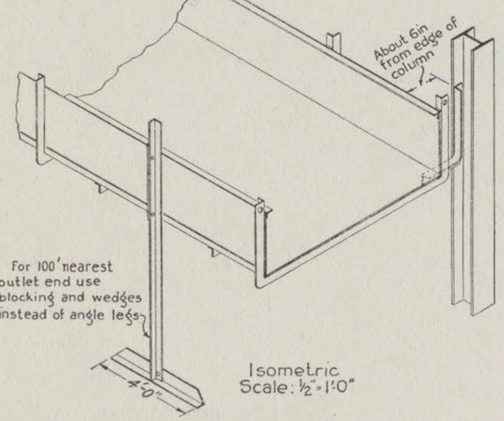


Scale: 1"=1'-0"



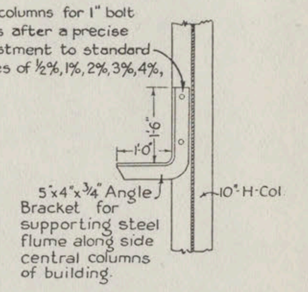


DETAIL OF CONNECTIONS AT A-A
Scale Full Size

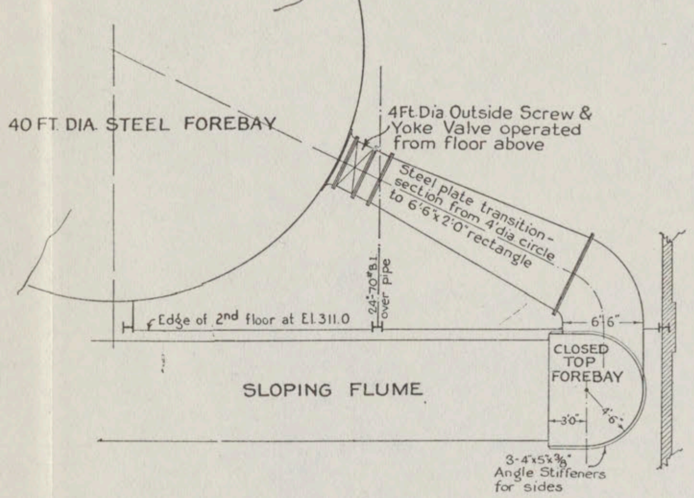


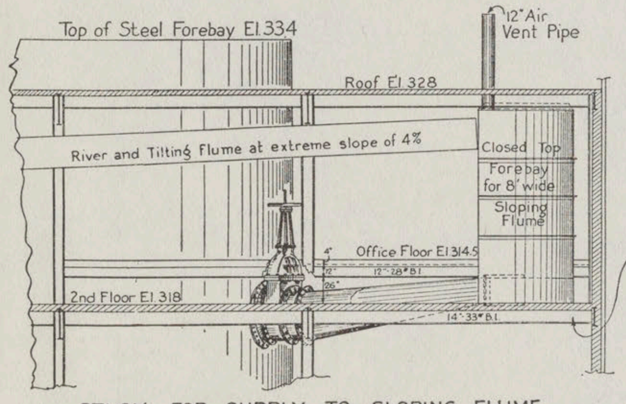
Isometric
Scale: 1/2"=1'-0"

STUDY FOR DESIGN OF 8FT. WIDE SLOPING FLUME
For Many Experiments This Flume Will Lay on Floor.

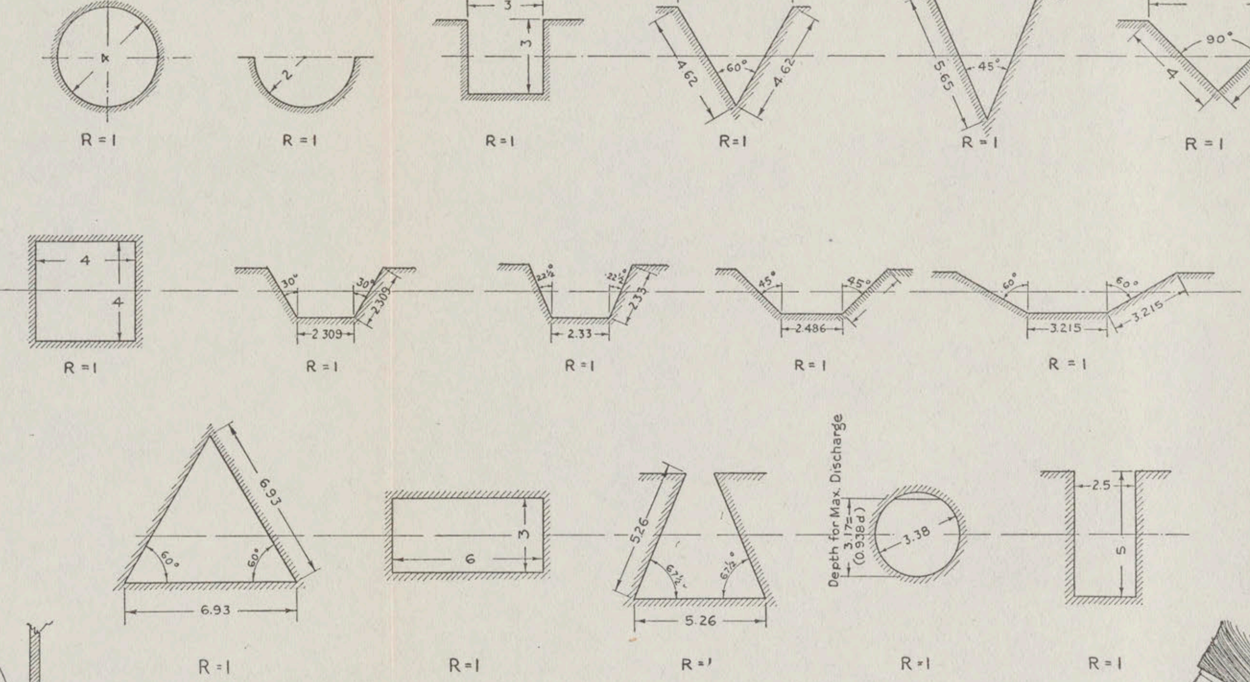


DETAIL OF BRACKET SUPPORT ON CENTRAL BLDG. COLUMNS
Scale: 1"=1'0"

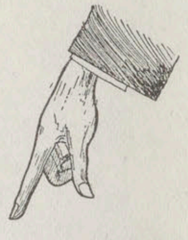




STUDY FOR SUPPLY TO SLOPING FLUME
(IF LOCATED IN 2nd STORY) May be located in 1st story
Scale: 1"=4'0"



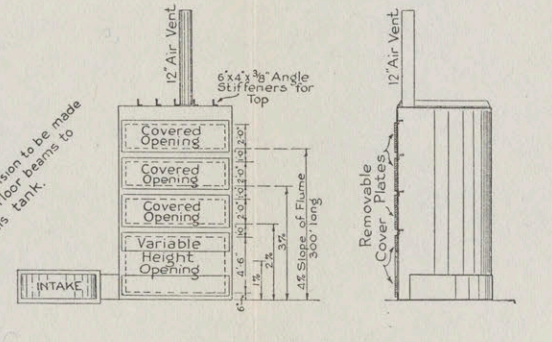
In the above figures, the dimensions are in any units of lineal measure desired, i.e. inches, or feet etc.
In all of the above figures the MEAN HYDRAULIC RADIUS (R) is the same and R=1
This means that channels of the above shapes and sizes would all give the same mean velocity of flow providing the slope was the same and constant and that the material of which the conduit was made was the same in each case, according to formulas now in common use – which is highly improbable.
The quantity discharged would, of course, vary according to the cross-sectional area of the stream.



STUDY OF THE NEED OF "SHAPE FACTOR" FOR FLOW IN CONDUITS
ESTIMATING

Study No 3 comprised 27 large sheets of outlines and construction details, drawn up for purpose of accurately estimating cost, many of which were not changed for this final Study No 4.

Those drawings comprising details of structural steel, reinforced concrete and various minor details of construction, are not reproduced in this set of 13 sheets comprising J.R.F. Study No. 4



FRONT ELEVATION OF FOREBAY

VERTICAL SECTION THROUGH FOREBAY

Scale: 1"=4'0"

STUDY NO. 4
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
BY JOHN R. FREEMAN, C.E.
A.C. CHICK, ASS'T ENG'R
TRACED BY:– R.B. SCALE:– AS SHOWN
FEBRUARY 14, 1931 SHEET No 13

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PPORT
UMNS

Facilities for small-scale experimental work: Constant-head supply tanks......	First floor: Supply from 40-foot diameter steel forebay, through 30-inch supply line running length of building and available for supplying the second as well as the first story experiments.[24]	First floor: Supply from concrete forebay through 30 and 20 inch pipe line under the first floor. Second floor: One large constant-head tank of 3 compartments for supplying 20, 10, and 10 cubic feet per second, respectively. Third floor: One small constant-head tank of 2 compartments for supplying up to 10 cubic feet per second each.[25]

[20] Test pits very few, borings inconclusive. The term "firm" rock, as used by the Bureau staff in designating the character of the rock upon which they propose to rest the foundations of the building, is misleading. This rock, classified as "firm," is a decomposed granite similar to the overlying decomposed material, but slightly harder, as indicated by greater resistance to penetration by the drill. The two deep test pits were refilled before I had opportunity to personally examine the material *in situ*. I desired opportunity to examine it in conference with Doctor White or other experts from the United States Geological Survey. I have conferred repeatedly with Doctor Stratton about foundation conditions found at the present Bureau buildings built under his supervision, and have studied supposedly similar material at excavations in the vicinity. Samples, taken at the elevation of this so-called "firm" rock, after having been exposed to the atmosphere a few weeks, present only slightly different characteristics from the so-called decomposed rock at 8 or 10 feet higher elevation. Samples from both elevations are readily crumbled in one's fingers, and present a more or less granular appearance. In no case does it appear that foundations as proposed by the Bureau staff, will reach really "solid" rock that is not more or less decomposed. It appears from inspection of near-by quarries in this vicinity, and information from engineers and architects acquainted with the material, that the underlying rock below the layer of decomposed material, is broken into relatively small, irregular sharp-edged blocks with fault planes running in all directions. That these blocks of rock may be subject to movement along cracks and joint planes, is indicated by experiences at the new power house. The Bureau's plant engineer states that the power house is founded on this so-called "solid" rock, movement of which has already caused serious cracking of the floors and walls near the east end of this building, such that he believes an overlying cushion of the decomposed rock gives better support. This decomposed rock is a rather dense, closely packed material capable of supporting more than ordinary earth material. It is not subject to slippage. One should not be misled by a casual inspection of the natural ground surface which is a clayey loam and quite slippery when moist. In view of the above conditions it seems logical and wise to keep the foundations on a cushioning layer of the decomposed rock, and that any expense involved in carrying the foundation walls 10 to 15 feet deeper than the structure itself requires, is a needless waste of money that is very urgently needed in the building and equipment.

[21] The ground covered by the Bureau is shown by size of trees to be in the same state (free of dumped material) as when Bureau of Standards was established. The weight removed by excavation to foundation bottom will be greater than that imposed by the new structures; therefore, no settlement is to be feared, if bottom course is properly placed. Actual load on earth in nearly all places will be smaller than it has carried for perhaps thousands of years. The concrete foundation walls of J. R. Freeman design to be specially reinforced for distributing loads. Concrete foundation walls contain a very large amount of reinforcing steel designed to cause them to act as strong girders in distributing the load.

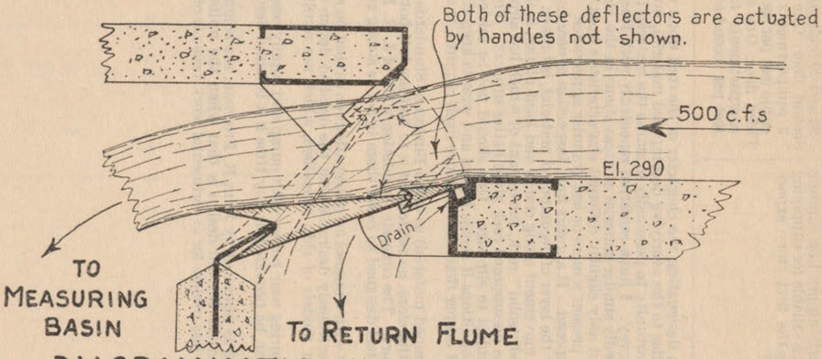
[22] Open access for research.

[23] J. R. Freeman regards it highly desirable that the large centrifugal pump be so placed and so provided with windows for observations on cavitation and turbulence that it can add important practical knowledge helpful to the theory and improvement of such pumps, and regards it extremely desirable that the detailed design of the large pumps be deferred for a year or more until researches can be made with small-model pumps, analogous to those made on models of ship propellers, which are resulting in great improvement in efficiency.

[24] It is proposed to provide several portable individual, self-contained, constant-head tanks and measuring weir boxes, with pump and supply reservoir combined. These units can readily be moved by crane to any desired location. Constant-head tanks of a permanent nature can be provided at any time if it is found desirable, much the same as those proposed in the Bureau design.

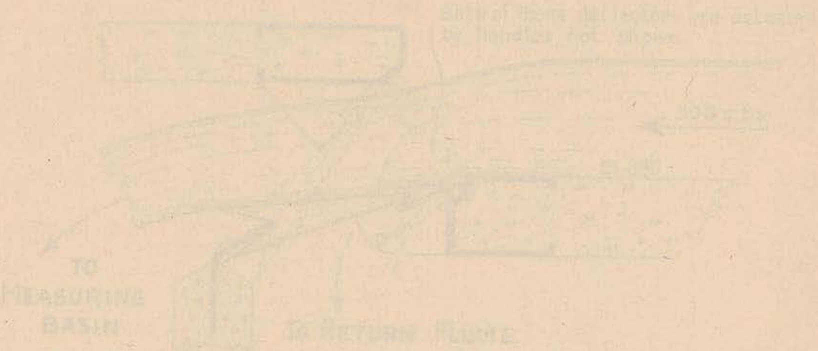
[25] It is understood that one or two of the individual constant-head units (self-contained and portable) as proposed by John R. Freeman, are being considered as desirable pieces of equipment. One undesirable feature of the layout of permanent constant-head tanks as proposed in the Bureau design is that when the units in the third story are being used, one or more of the compartments of the second story constant-head tank are rendered more or less useless for experimental work because of the fact that they are used as supply basins for the third floor pumps.

It seems plain to John R. Freeman, from inspection, that the Bureau of Standards' design No. 2 per plans of February 3, 1931, contained so much more concrete and intricate form work, that it will be more costly (possibly $50,000 in excess of John R. Freeman's design No. 4), and therefore that it will have to be cut greatly from plans as sketched on February 3, thereby rendering the laboratory of the Bureau's design still more inferior in capacity for large-scale fundamental research to the John R. Freeman design.



DIAGRAMMATIC ILLUSTRATION OF THE QUICK-SWINGING DIVERTING GATE AT END OF MAIN FLUME

It seems plain to John R. Freeman, from inspection, that the Bureau of Standards' design No. 4 per plans of February 3, 1931, demands so much more concrete and intricate form work, that it will be more costly (possibly $50,000 in excess of John R. Freeman's design No. 4), and therefore that it will have to be cut greatly from plans as sketched on February 3, thereby rendering the laboratory of the Bureau's design still more inferior in capacity for large-scale fundamental research to the John R. Freeman design.



DIAGRAMMATIC ILLUSTRATION OF THE QUICK-SWINGING DIVERTING GATE AT END OF MAIN FLUME.

ALTON C. CHICK
Engineer
8th Floor Grosvenor Bldg.
Providence, R. I.

February 5th, 1931.

Dr. George K. Burgess, Director. Copy
Dr. L. G. Briggs,
Mr. Herbert N. Eaton,
U. S. Bureau of Standards, Washington, D. C.

NAT'L. HYDRAULIC LABORATORY DESIGN

Gentlemen:

At your request Mr. Freeman relinguished my services, for a period of two weeks beginning Wednesday, January 21st, in order that I might assist you in any way possible in the planning and design of the National Hydraulic Laboratory. As you perhaps know, I have a strong personal interest in this Hydraulic Laboratory, having been associated with Mr. Freeman for the past eight and one-half years, during which time he has been working with untiring effort to promote the idea and secure appropriation from the National Congress with which to build a "U. S. A" laboratory, better than any now in existence in the world.

I doubt if any one appreciates better than myself the great amount of personal time and effort that Mr. Freeman has put into this cause, in addition to the expenditure of large sums of money, inspecting various hydraulic laboratories in Europe on several occasions, the publication of the book "Hydraulic Laboratory Practice" describing laboratories of Europe and their work and in payrolls for designs which he has prepared for the National Hydraulic Laboratory for this country.

I have been acquainted with the results of the conferences of the Advisory Committee in Washington, and I may say that I was somewhat astonished when I reached Washington to find that you had decided to lay aside Mr. Freeman's designs entirely, and proceed along the basis of designs made by your staff, because I had understood it was the almost unanimous opinion of the Advisory Committee at the time of its last meeting, on December 8th, 1930, that Mr. Freeman's plans should be followed.

In view of this situation, I made proposals, upon my arrival in Washington, for modifying the lay-out as planned by your staff, and shown on your blue-prints dated November 28th, 1930, to incorporate the most essential features for which Mr. Freeman has been working; that is, the provision of fixed equipment such as pump supply capacity, size of main flume and measuring basin capacity to meet the conditions necessary for the best possible fundamental research work on weirs, orifices, hydraulic jump, energy absorbing structures, Venturi meters, etc., all of which had been strongly emphasized by Mr. Freeman in the hearings before Congressional Committees, and throughout his work of promotion of this National Hydraulic Laboratory idea.

I found:- (1) that your plans could readily be altered at very slight increase in cost to provide the 15 ft. width and 15 ft. depth of main flume, which Mr. Freeman has been seeking, without altering appreciably the size and arrangement of your structure, and without in any way destroying the flexibility of arrangement claimed by the Bureau staff for their design.

(2) that your pump supply basin would serve tolerably well to meet all conditions of flow required.

(3) that it would be possible to increase your pump capacity by the addition of another pump at some future time, so that you could circulate as much as 400 cubic feet per second very readily.

(4) that you can without difficulty enlarge the size of your measuring basin to accomodate this larger flow.

I discussed with Mr. Eaton various schemes for including this 15 ft. width of flume while at the same time keeping the flexible arrangement of his layout.

Dr. Briggs was called into conference with Mr. Eaton, myself, and other members of the Bureau Staff on January 23rd and finally decided that due to pressure of time, and because of ultimate demands for power, that it would be necessary to follow the lay-out of the Bureau plans as shown in blue-prints dated November 28th, 1930.

I feel that a great mistake has been made not to incorporate this larger flume which would add very little to the cost and provide for all future fundamental research work on a scale of sufficient size to command confidence of engineers throughout the world. Moreover, this larger flume would provide very advantageous space and elbow room for many temporary "set-ups" for research within the flume itself. For this purpose the wider flume would be worth many times more than its added cost.

After the decision of Dr. Briggs, that it would not be possible to make any modifications of the general arrangement and size of your laboratory and fixed equipment, I tried to make it clear to him that although I was not in sympathy with your method of procedure and did not approve your lay-out for the fundamental research work, that I would do all in my power during my stay in Washington to improve your lay-out, both as to arrangement of semi-fixed equipment and as to the hydraulic design of the structure.

There are several items to which I gave special consideration. These will be taken up in order.

(1) FOREBAY

I regret that you are going ahead with the square, concrete forebay. This construction is not as safe, is not as economical, is not as secure against leakage, and is not as adaptible to the many demands for supplying water, which will be made upon it, as would be a tank constructed of steel plate, which would permit the ready attachment of pipes and connections at any point at any time, by the simple process of cutting and welding.

You will undoubtedly find that you have more steel in your reinforced concrete forebay structure than would be required in an all steel tank.

I visited the mine tank at the Navy Yard with Mr. Eaton on January 30th and was very much impressed with the adaptability of such a tank to the needs of the Hydraulic Laboratory. Although the horizontal joints between the plates of this mine tank are secured by a single row of rivets, there is no leakage whatsoever.

I cannot too emphatically impress upon you the seriousness, and the probability, of leaks in your concrete forebay. I invite your attention to the cracks in the reinforced concrete cooling-water tank, at the Bureau of Standards, which shows serious cracks about every 12 feet of its length.

(2) TUMBLE BAY

A study of your plans indicated that you would obtain a very unsatisfactory condition of flow in this tumble bay approaching the entrance to the two return flumes and the pipe lines leading to the Venturi meters. A trial run, in your present hydraulic laboratory, on a model of the substructure of the National Hydraulic Laboratory according to your designs, on a scale of 1 to 32, clearly demonstrated that the above was true. The water in the tumble bay was churned into a high state of irregular turbulence and carried much air into the return channels.

Such a condition would present serious problems of flow control in order to be able to use these return channels for any experiments, also the entrainment of any quantity of air through the Venturi meters would give erroneous and undependable results.

I sketched an arrangement for leading the water from the discharge end of the main flume into the tumble bay with less disturbance, by means of curved passages and guide vanes giving better opportunity for the entrained air to escape. A trial run with the model after changes had been made in the tumble bay according to my sketches indicated a considerable improvement in flow conditions, and showed that when baffles and stilling screens were provided at the entrance to the tumble bay, the velocity of the water could be very uniformly distributed, and that the air could be extracted in a much more satisfactory manner.

It is highly essential that the velocity of flow be distributed as uniformly as possible in approaching the return flumes and the Venturi meter pipes. I believe it well worth while to make further experiments on this tumble bay, and before leaving the Bureau I offered a few suggestions for improving the lay-out as I had sketched it, in order to assure more nearly uniform distribution of velocity.

(3) ARRANGEMENT OF CONSTANT-HEAD TANKS

The location of the constant-head tanks in the second and third stories as shown on your blue-prints was such as to destroy the usefulness of a considerable area of floor space. I made a study to relocate these tanks and prepared sketches showing how this could be done so as to clear up about 4,000 square feet of floor area in the vicinity of the pumps and forebay, which I believe will be found extremely valuable, since it now presents an unobstructed space from one end of the building to the other.

I proposed relocating these constant-head tanks in the extreme eastern end of the building, thus making it possible to support them in part by outside columns of the building. In this way it was possible to omit all columns in the third story, except those along the center line of the building, thus making available a clear floor space in this story approximately 45 ft. wide by 82 ft. long. This can be used very conveniently as a harbor laboratory for such studies as break-waters, beach erosion, harbor currents, etc.

(4) RELOCATION OF SMALL PUMPS

I proposed a relocation of the samll pumps in the first story to economize space and to provide an opportunity for the addition of a future pump, which can be as large as 100 cu. ft. per sec. or more.

(5) DESIGN OF CONCRETE

I learned from the engineer making the designs for the architect that it was his intention to make all reinforced concrete designs on the basis of allowing 18,000 lbs. per square inch stress in the steel, and 800 lbs. per square inch compressive stress in the concrete, and that he was contemplating the use of only about 2/10ths of 1% of steel for taking care of shrinkage and temperature stresses. I believe this is entirely inadequate for the substructure of this laboratory involving the large basins, the main flume and forebay, and the return flumes.

I had a conference, together with Mr. Wright, with Mr. Parsons of your Ceramic Division, at which I presented a theoretical analysis, copy of which I gave Mr. Wright, which showed that based on an assumption of 30 degrees drop in temperature below that at which the concrete set, at least 5/10 of 1% of steel reinforcement would be required to take care of such temperature stresses as would be set-up by the contraction of the concrete. Mr. Parsons concurred with me in this matter as well as in the belief that we should use even more reinforcement than this in order to take care of the greater shrinkage stresses which are set up in the concrete during the process of setting and drying out. It is quite probable that the concrete exposed to outside air will be subjected to a greater drop in temperature than the 30 degrees above mentioned.

During the conference between the Bureau Staff, the architect, Mr. Deming, and the engineer, Mr. Gongwer, at Mr. Marshall's office on January 25th, it was recommended that the concrete be designed on the basis of an allowable compressive strength of 700 lbs. per sq. in., and that steel reinforcement be designed on the basis of the following unit stresses:

(a) For measuring basin, 16,000 lbs. per square inch.

(b) For main flume, 14,000 lbs. per square inch.

(c) For supply basin, 18,000 lbs. per square inch.

(d) For floor slabs, 18,000 lbs. per square inch.

It was recommended that in no case should less than 5/10ths of 1% of steel reinforcement be used for temperature and shrinkage stresses (exclusive of and in addition to structural stresses), and that wherever walls were exposed to the great changes of outside atmospheric temperatures, that even greater percentages of steel should be used.

(6) CONSTRUCTION AND CONTRACTION JOINTS

In all cases where concrete walls and floors are to be used to hold water, it is recommended that great care be taken in the location of all construction joints, and that wherever possible such joints be placed at prearranged locations and treated as contraction joints, which need not be nearer together than about 50 ft.

These contraction joints should be provided with strips of approved metal to act as a water seal. Also, these joints should have proper keys of concrete to take shearing stresses, which may be set up when one portion of the structure is loaded to a greater extent than another.

An inspection of the concrete water cooling tank at the Bureau showed cracks quite regularly at 12 ft. intervals. A study of the blue-prints, in the power house, according to which it is understood this wall was constructed, showed that about 0.36 of 1% of longitudinal steel had been used to resist the shrinkage and temperature stresses. In this wall about 180 feet long, with no contraction joints, this quantity of steel proved entirely inadequate.

(7) ROOFS

I learned at the Bureau that Mr. Doming, the architect, had recommended the use of gypsum poured in a layer about 3½ inches thick, as a supporting cover for the entire roof; that this gypsum would be poured in place on forms of sheet rock, which would not be removed but left to act as a ceiling for the story below. The gypsum would be covered with an ordinary tar and slag roof.

It has been our experience that in a building that is subjected to moisture, the cardboard-like surface of this sheet rock is liable to become loosened in a few years and peel off, leaving a very ugly and undesirable appearance. Moreover, it is very difficult to make repairs to such a roof.

I believe this type of roof would prove entirely unsatisfactory on a building of this nature. Such a roof is barely strong enough for providing the necessary support for a snow load of about 30 lbs. per square foot, and precludes the use of these roofs for any experiment work.

I urge you strongly to provide a concrete slab roof, with either the same type of roof covering or some other acceptable type, and designed to withstand a live load of at least 50 lbs. per square foot.

Concrete will be more economical, it will give almost as good insulation, and from the point of view of strength and usefulness is far superior to gypsum. It should be remembered that if gypsum is used, you cannot even suspend your lighting fixtures, except from the steel beams.

(8) ROOF INSULATION

I do not believe it is necessary to add any further insulation of the roof than that provided by the concrete slab itself. A computation made by your Mr. Beij, based upon the practice recommended in the Handbook of the Heating and Ventilating Engineers, indicated that for the assumptions of the worst possible conditions of outside and inside temperatures and dew point, only about 1/2 inch of cork insulation would at any time be necessary to prevent condensation on the under side of the roof.

This condition is not likely to be obtained, and if it should occur it would be but one or two days in the year. A slight amount of condensation once or twice a year will do no harm. I strongly urge you not to spend money for such insulation, when you need this money so urgently for other purposes.

(9) STEEL FLOOR BEAMS AND DEFLECTION ALLOWANCES

I made a short study of the design of the floor beams for the second story as shown by the blue prints of the Bureau design, and found that these beams contained approximately 50% more steel than actually needed to carry even your excessively large allowances for live loads.

I am glad to be able to report that a study made later by the designing engineer, Mr. Gongwer, showed that the use of slightly deeper beams than shown on your prints, would require a very slight excess of weight over that necessary to carry the allowed live load, in order to provide for your required tolerance of deflection, with the result of a net saving of nearly 1/2 ton of steel per bay for the second floor beams alone.

I do not favor your arrangement of floor beams in this second story, whereby a large portion of the floor loads are transferred directly to beams in the oustide brick wall. While these beams are designed strong enough to prevent undue deflection in the floor itself, if you ever load these floors to anywhere near your live load allowance, you may cause as much as a quarter inch deflection in these outside beams, which would be transferred directly to the brick wall, opening up cracks to that extent, unless this brick wall be so designed as to carry the load and prevent the beam from deflecting. In this case it is unnecessary to provide such heavy beams. Here is a case where I believe money can be saved by further study for economy.

(10) FOUNDATIONS

There appears to be considerable difference of opinion as to how deep you should carry your foundation walls for satisfactory support. I recommend that you secure the services of a competent geologist acquainted with the practical work of foundations to determine the feasibility of erecting this structure without carrying all walls to supposedly "firm" rock.

I inspected the power house at the Bureau, and learned from Mr. Britt, the Bureau engineer, that it was founded on solid rock. There has been, however, a very decided settlement of the eastern end of this building, very seriously cracking the floors and walls. Mr. Britt explained that he believed this settlement was due to movement among the small fault blocks into which this rocky material is broken. He pointed out the fact that one portion of the sidewalk leading to Connecticut Avenue is located on hard rock, and that there has been persistent cracks and settlements in the same spot each time after the walk has been repaired.

With this in mind, Mr. Britt offered the suggestion that it might be better not to carry any foundations onto this solid rock, but to keep all footings in decomposed rock where possible. Wherever it was found necessary to excavate into solid rock, he suggested the desirability of excavating the footing trenches and pits a foot or so deeper, and refilling with a layer of the decomposed material to act as a cushion to absorb whatever movement might occur among these sharp-edged fault blocks below.

This analysis by Mr. Britt appears logical. It is along the same line that Mr. Freeman has been working and I believe agrees for the most part with his recommendations.

Another feature concerning this foundation material which I believe you have entirely over-looked heretofore is that this decomposed rock at the elevations of the footings of the building has for many years been subjected to a much greater load from overburden of material that will be excavated than will ever be imposed upon it by the hydraulic laboratory, even when basins and floors are loaded to their greatest extent. You will not, therefore, have the condition of settlement caused by greatly increased loads on the ground.

If you can save a portion of the $10,000 to $15,000 which would be used in carrying the walls of this building to firm rock, this money certainly can be used to good advantage in other portions of the building. I believe it is by no means necessary in the case of walls supporting no part of the super-structure to carry such walls to firm ledge.

(11) SIZE AND LOCATION OF MEASURING BASIN

I strongly recommend that you relocate and enlarge your measuring basin to have a capacity of approximately 70,000 cubic feet, as shown by a sketch I left with Mr. Eaton. I believe it is entirely a practical and economical matter to provide the walls of this measuring basin to later act as foundation walls for the future west-end extension of the laboratory, although your plans do not provide for this exigency.

I understand it was contemplated by the Bureau designing staff that the measuring basin proposed by them would at some future time be enlarged. I do not believe this would be a satisfactory procedure. One of the most essential features of this measuring basin is that it shall be water tight. If any portion of it is torn down with the expectation of adding more area, I believe you will find it next to impossible to join new concrete to the old concrete in a satisfactory manner for preventing excessive leakage.

No part of the walls of this basin as layed out by the Bureau staff would be in the proper location to act as future foundation walls. The extra expense involved in extending this basin so that the west wall and the north wall will be in position for future foundations of the super-structure will cost but little.

(12) PROVISION FOR INSTALLING AND REMOVING LARGE PUMPS.

I suggested that a hatch opening be provided in the trucking space at the east end of the building to permit lowering into or removing from the pump supply basin the three large pumps. This opening should be provided with a tight hatch cover and a curb to prevent leakage into the supply basin.

(13) ROOF OVER SUPPLY BASIN

The concrete roof over the supply basin, forming the trucking entrance to the laboratory, should be provided with some sort of asphalt material not only as a wearing material but to act as protection against the intensive rays of the sun in preventing cracks.

(14) USE OF HIGH LEVEL RETURN FLUME AS MEASURING BASINS

If you retain your high level return channel in its present size, I recommend that you provide bulkhead grooves about 50 feet apart which will enable you to divide this channel into about four basins, which could serve very well as measuring basins for small experiments located on either the first or second floors.

Any of these basins would hold about 3600 cubic feet of water, and would provide sufficient volume to take care of a flow of 10 cubic feet per second for about 6 minutes.

(15) PROVISION FOR SYPHON SPILLWAY EXPERIMENTS.

I made a study of your lay-out to determine the possibility of making experiments on a syphon spillway under full atmospheric head, and found that this could not be done without some changes in the layout. These changes, however, do not incur great expense and I recommended that the walls of the forebay be raised four feet, that the removable section of the third floor be enlarged to permit the top of the syphon to project through into the third story and that the removable section of the floor of the main flume be relocated immediately downstream from the forebay gate openings, and made sufficiently long to accommodate various possible shapes of the discharge leg of the syphon.

With these changes, it will be possible to build and test a syphon spillway with 15 feet height of throat at the crest, under full atmospheric head. In order to measure the flow through this syphon, it will be necessary to divert the water through the proposed channel under the main flume into the tumble-bay and thence through the Venturi meters.

This is a feasible arrangement which can be improved by extending the walls and floor of this channel under the main flume to connect with the forebay, thus giving a direct, entirely closed channel through which water can be diverted from the syphon spillway, and incidentally from any experiments set up in the main flume, directly into the tumble-bay and thence through the Venturi meters.

I believe it has already been decided by your staff to incorporate the space under the main flume as a part of the supply basin with an opening at its western end, so that the water can be diverted from the tumble-bay directly into this channel.

(16) PROVISION FOR TESTING TURBINES AND DRAFT-TUBES.

I urge you to provide in the wall immediately over the forebay gates and directly under the gate stands a circular opening of sufficient size to take your maximum flow under full head. This opening will serve to supply water to any turbine, draft-tube or horizontal orifice experiment you might wish to set up within the high walls at the upper end of the main flume, and would present means for experiments on turbines of various designs, as well as for running an extensive series of experiments on draft tubes, with the possibility of using the measuring basin or the Venturi meters, or wiers in the return channels, for measuring the flow.

I appreciate having had the opportunity to work with your staff on their design of this National Hydraulic Laboratory. I found them an earnest group of men very much interested in the ultimate success of the laboratory.

I sincerely hope you will find a way to include the essential features for fundamental research on the large scale that has been so strongly emphazied by Mr. Freeman.

Respectfully submitted.

Alton C. Chick

Consulting Engineer.

A.C.Chick/MM

71st Congress, 2d Session — SENATE — Document No. 208

DESIGN OF NATIONAL HYDRAULIC LABORATORY

COPIES OF PLANS, ESTIMATES OF COST, AND MEMORANDA RELATING TO THE NATIONAL HYDRAULIC LABORATORY AT THE UNITED STATES BUREAU OF STANDARDS, WASHINGTON, D. C., PREPARED BY JOHN R. FREEMAN, CONSULTING ENGINEER, PROVIDENCE, R. I.

PRESENTED BY MR. HEBERT

June 28, 1930.—Ordered to be printed with illustrations

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1930

DESIGN OF NATIONAL HYDRAULIC LABORATORY

PROVIDENCE, R. I., *June 24, 1930.*

Hon. JOSEPH E. RANSDELL,
United States Senator.

Hon. ROBERT P. LAMONT,
United States Secretary of Commerce.

Dr. GEORGE K. BURGESS,
Director of United States Bureau of Standards.

GENTLEMEN: Four weeks ago in Washington I learned that plans had been prepared under the direction of a member of the laboratory staff at the Bureau of Standards for the National Hydraulic Laboratory. I called on Doctor Burgess, who gave me a copy of this outline plan, which I understood was about to be turned over to the architect for further elaboration.

On studying this outline design prepared at the bureau, I became greatly disturbed lest the good cause of the National Hydraulic Laboratory for which, with Senator Ransdell, I had worked so diligently for eight years past, was to be imperiled by lack of facilities for fundamental hydraulic research on a large scale, such as I believed were contemplated by the act of Congress, and which had been plainly described by me before the Senate Committee of Commerce, at a public hearing in 1922, and plans presented, which were reproduced in the printed report of the hearing.

Thereupon, I started to revise the plan which I presented to the congressional committee in 1922, in the light of information that I had gained during two subsequent tours of European hydraulic laboratories, in 1924 and 1927, and which are set forth in the book published by the American Society of Mechanical Engineers one year and a half ago, entitled "Hydraulic Laboratory Practice," copies of which book were presented to various members of the United States Senate and to each member of the House Rivers and Harbors Committee.

Unfortunately I have been under very great pressure during the past four weeks, having been compelled to delay my European trip in order to present my testimony before a master appointed by the United States Supreme Court, in the matter of the diversion of the head waters of the Delaware River for the supply of New York City. This testimony made necessary much preparation and rereading of old reports. It was completed on Wednesday of last week.

In the meantime, my assistants have worked diligently over my notes and sketches, with such supervision as I could personally give, and have prepared the plans now presented.

The preparation of such extensive plans in such a short time was rendered possible only by the plans of an equally generous scale, which I presented at the congressional hearing eight years ago, and by a still earlier set of large-scale studies that I had made 17 years ago, and by my familiarity through more than 50 years with hydraulic engineering designs on a large scale.

During the preparation of these plans we endeavored to keep the cost of the principal structures within the congressional appropriation, therefore, I have been much pleased to-day at the result of conferences of my assistant engineer with the estimating staff of Charles T. Main (Inc.) (which is one of the largest and most experienced engineering offices in New England familiar with the construction of industrial plants), and with the estimators of the Turner Construction Co., which built the present industrial building and also the east building at the Bureau of Standards.

The figures from these two independent sources are presented herewith. Those of the Turner Co., total $341,715 were made up on a generous basis of quantity estimates in order to cover any uncertainties, as were the estimates of Charles T. Main (Inc.), which total $354,885 which were based on the same quantities but using slightly different unit costs.

I have not had time to get figures for cost of electrical motors, internal combustion motors, and auxiliary pumps, but I am confident that enough can be saved out of these items, estimated, totaling $341,715, to cover the cost of putting a laboratory into active service.

The ordinary architectural fee of 6 per cent which would amount to about $20,000, need not be expended, because the plans now submitted with the addition of a few details, are sufficient for purposes of a firm bid and for construction purposes. I cheerfully contribute them cost-free for the good of the cause.

I believe no one acquainted with my work, will seriously question my ability to prepare designs of this character.

I have prepared several sets of the blueprints and also several sets of photostats, for the convenient study of Senator Ransdell, Secretary of Commerce Lamont, Doctor Burgess, and members of the advisory committee.

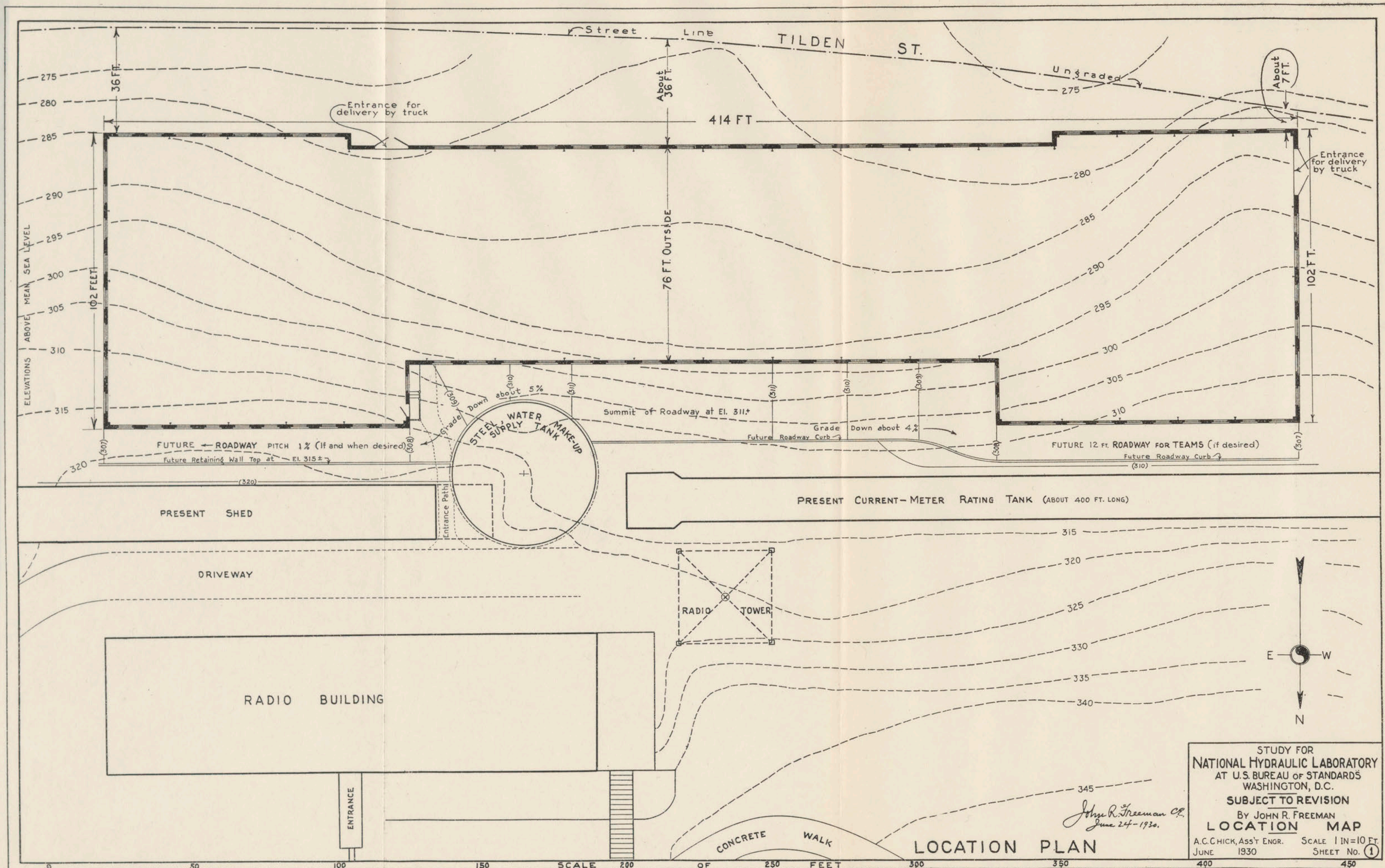
Because of my sailing for Europe next week I regret that I can not be present at further meetings of the advisory committee. I may, however, state that I had previously arranged to meet Professor Gregory, of the advisory committee, in Germany, to inspect some of the larger and more recent laboratories, and that I expect to devote the greater part of the month of July to such inspections and to a discussion of the plans now submitted with some of the most eminent laboratory experts in Europe.

I respectfully submit that the public interests would not suffer by delaying action until Professor Gregory and myself can report on what we find in Europe.

Attached herewith are small-scale photostats of the plans, also copies of the two independent estimates of cost, and some memo randa that I have dictated hastily for the use of the advisory com mittee and Doctor Burgess, as to the motives of the design now submitted.

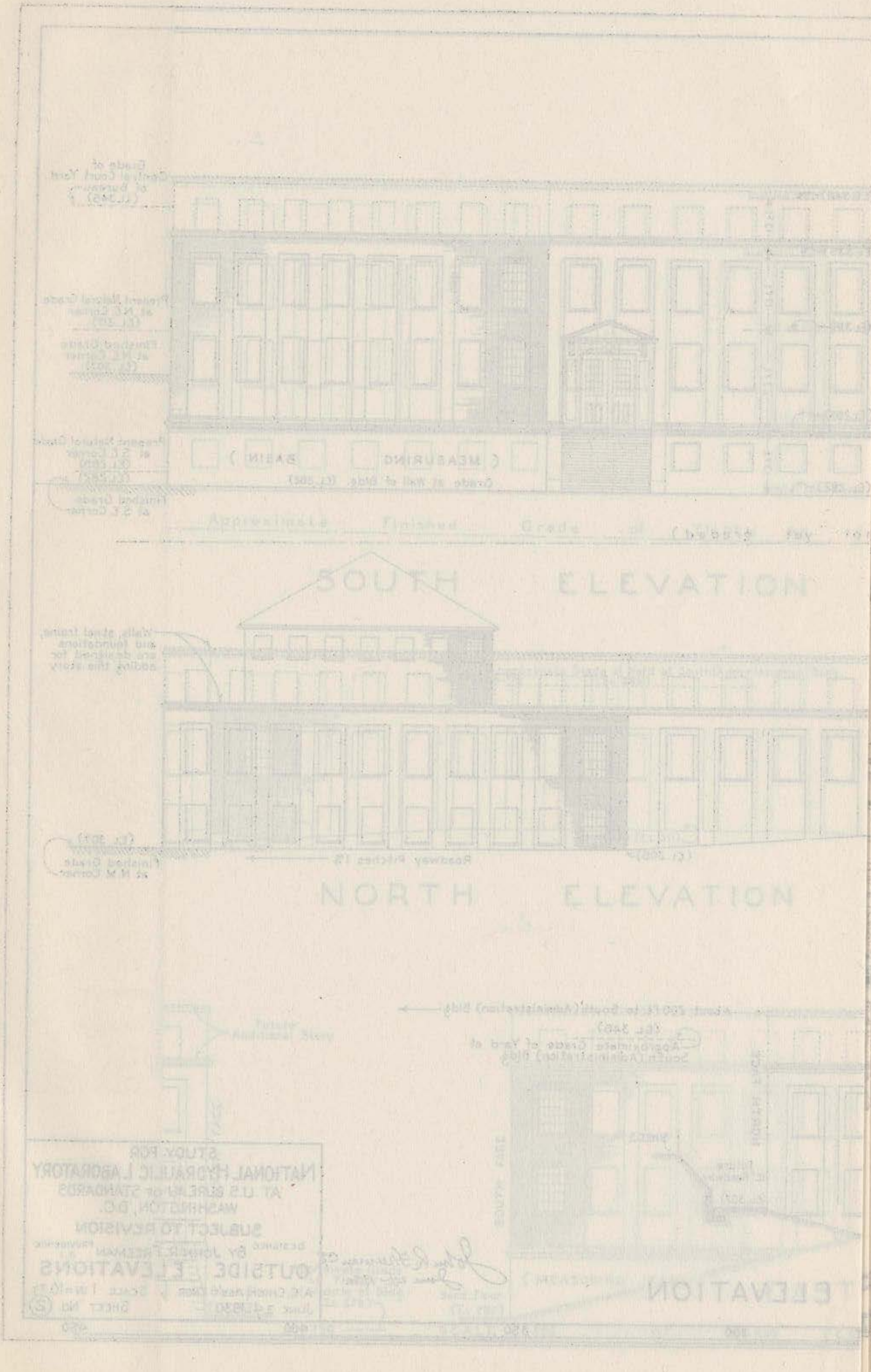
Respectfully submitted.

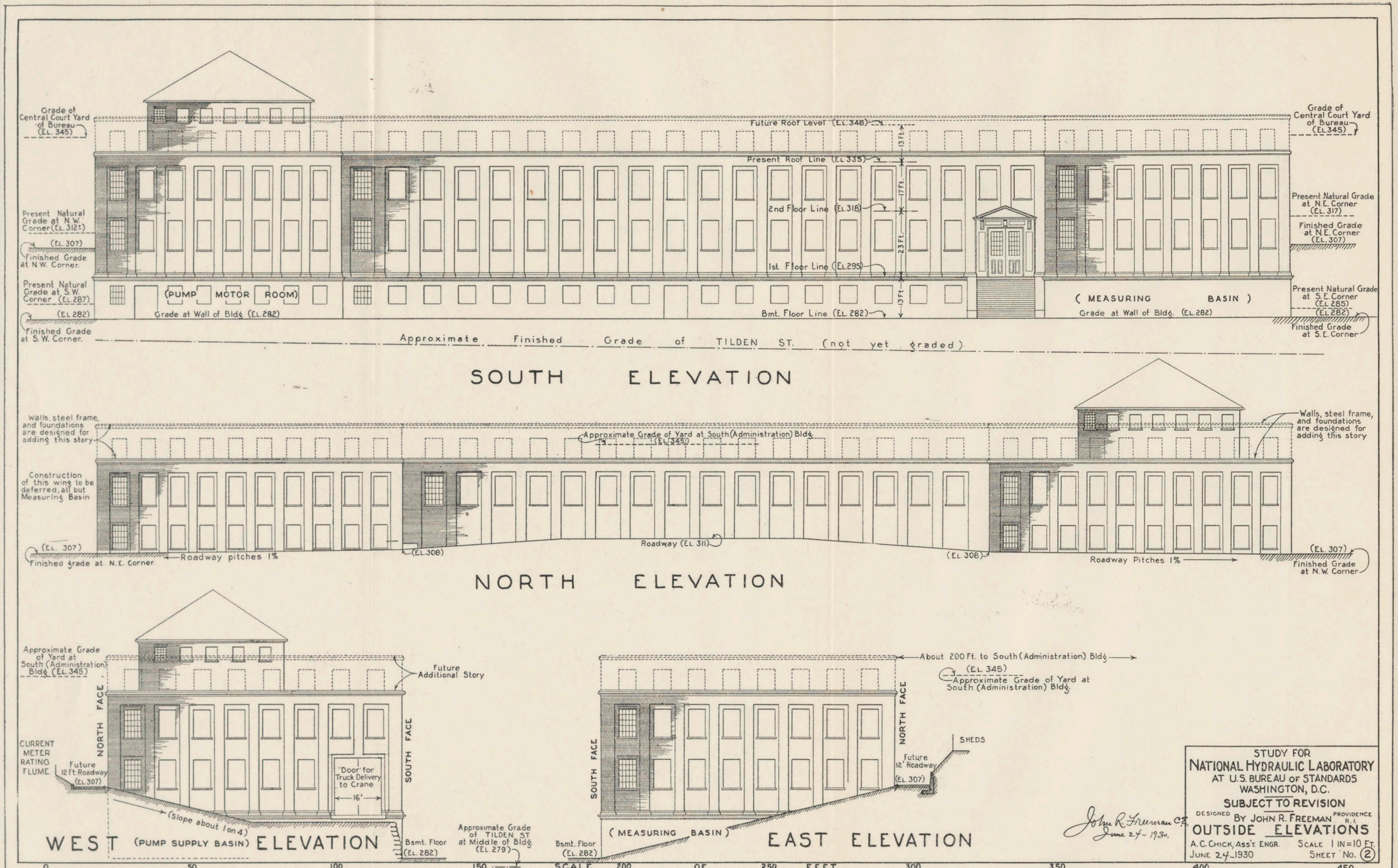
John R. Freeman.



STUDY FOR
NATIONAL HYDRAULIC LABORATORY
AT U.S. BUREAU OF STANDARDS
WASHINGTON, D.C.
SUBJECT TO REVISION
BY JOHN R. FREEMAN
LOCATION MAP
A.C. CHICK, ASS'T ENGR. SCALE 1 IN=10 FT.
JUNE 1930 SHEET No. 1

121057—30. (Face p. 3.) No. 1


SOUTH ELEVATION
NORTH ELEVATION



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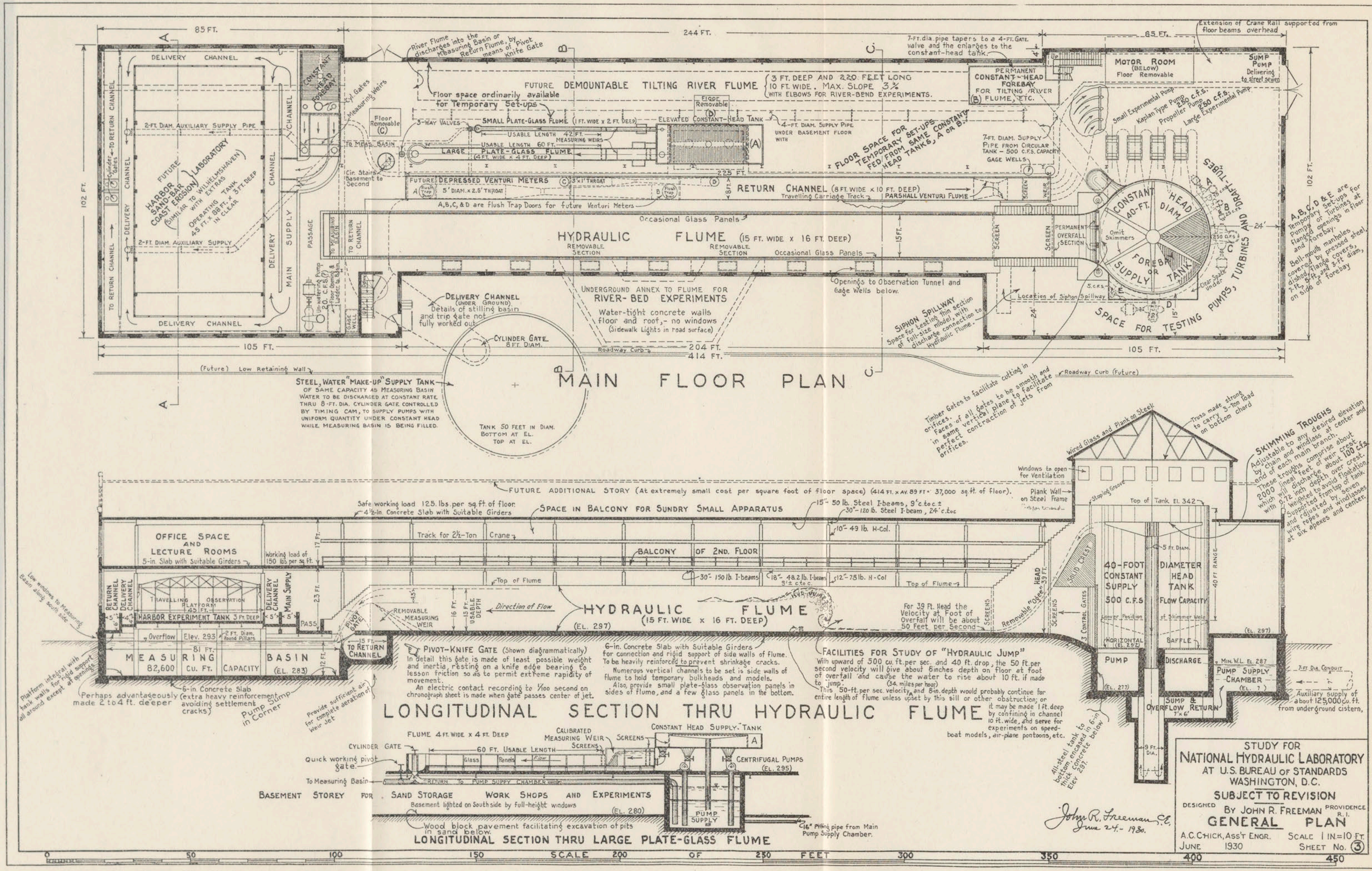

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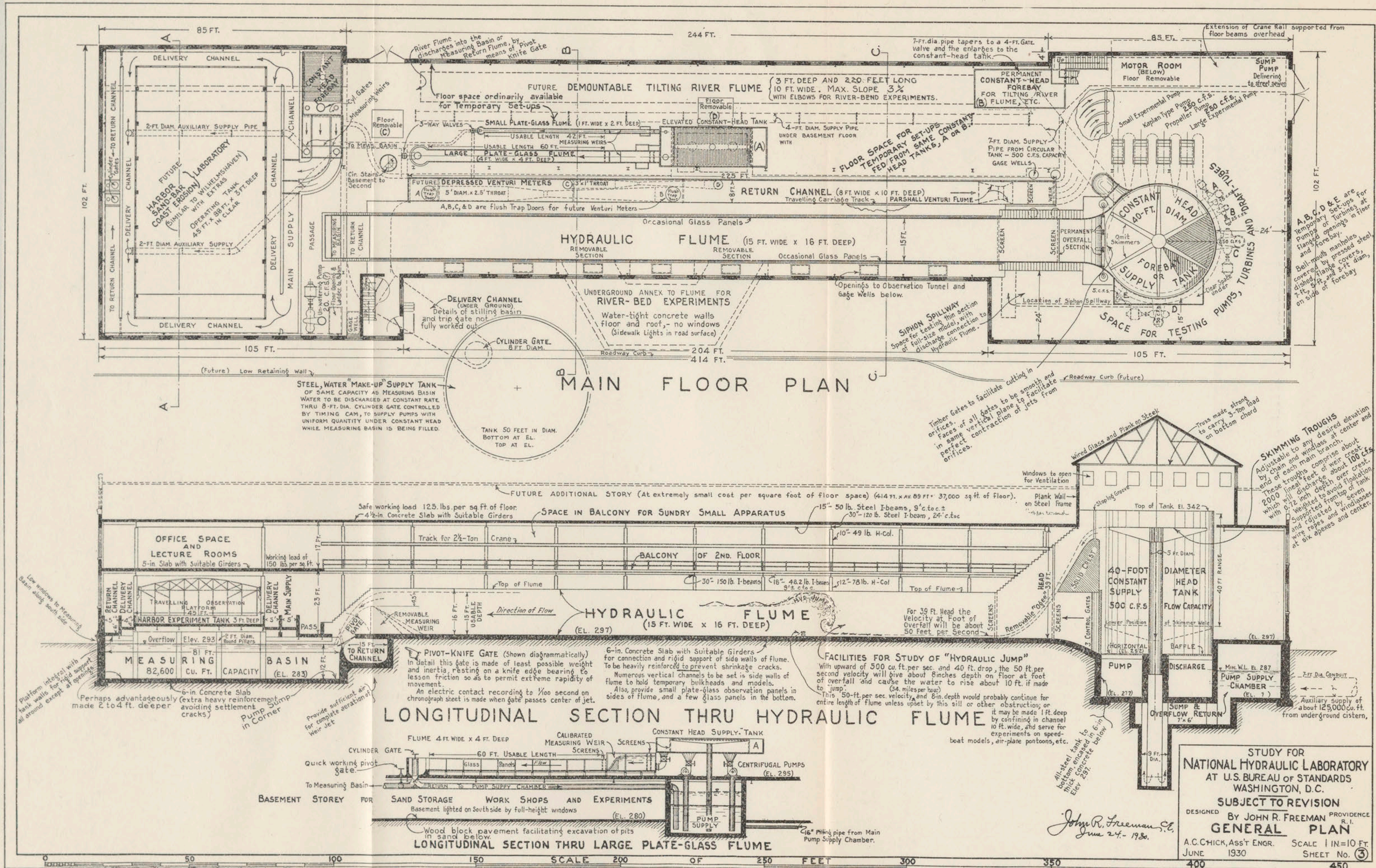
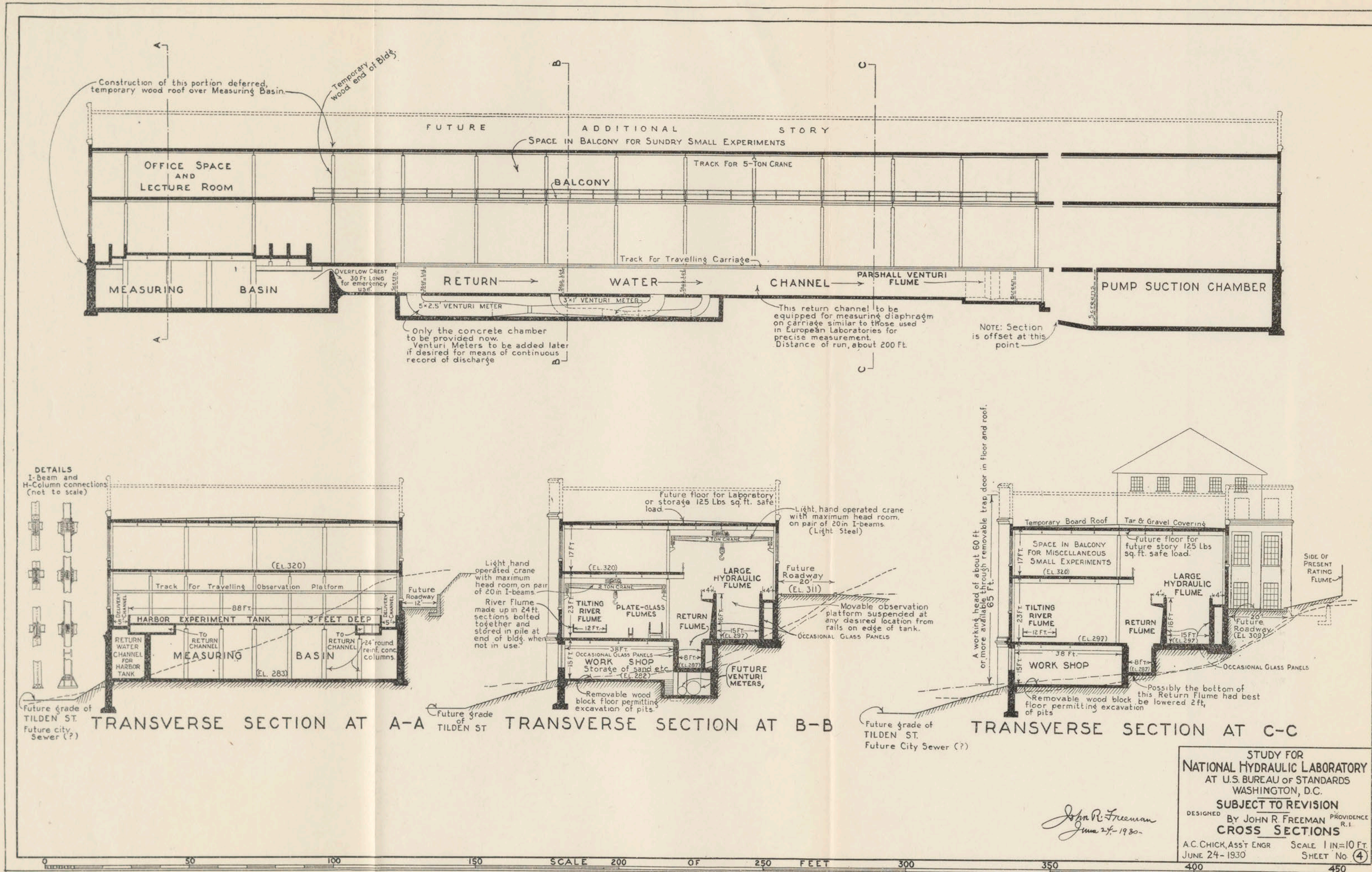


MAIN FLOOR PLAN
FUTURE DEMOUNTABLE TILTING RIVER FLUME
3 FT. DEEP AND 220 FEET LONG 10 FT. WIDE. MAX. SLOPE 3%. WITH ELBOWS FOR RIVER-BEND EXPERIMENTS.
FUTURE HARBOR SAND-BAR COAST EROSION LABORATORY (SIMILAR TO WILHELMSHAVEN) WITH EXTRAS
OPERATING TANK 45 FT. x 88 FT. x 3 FT. DEEP IN CLEAR
DELIVERY CHANNEL
MAIN SUPPLY CHANNEL
TO RETURN CHANNEL
SMALL PLATE-GLASS FLUME (1 FT. WIDE x 2 FT. DEEP)
LARGE PLATE-GLASS FLUME (4 FT. WIDE x 4 FT. DEEP)
ELEVATED CONSTANT-HEAD TANK
FLOOR SPACE FOR TEMPORARY SET-UPS FED FROM SAME CONSTANT HEAD TANKS, A OR B.
PERMANENT CONSTANT-HEAD FOREBAY FOR TILTING RIVER FLUME, ETC.
MOTOR ROOM (BELOW) Floor Removable
SUMP PUMP Delivering to street sewer
FUTURE DEPRESSED VENTURI METERS
RETURN CHANNEL (8 FT. WIDE x 10 FT. DEEP)
A, B, C, & D are Flush Trap Doors for future Venturi Meters
HYDRAULIC FLUME (15 FT. WIDE x 16 FT. DEEP)
Occasional Glass Panels
Removable Section
CONSTANT HEAD 40-FT. DIAM. SUPPLY OR FOREBAY TANK
SPACE FOR TESTING PUMPS, TURBINES AND DRAFT-TUBES
A, B, C, D & E are Temporary Set-ups for Pumps or Turbines at flanged openings in floor and forebay.
UNDERGROUND ANNEX TO FLUME FOR RIVER-BED EXPERIMENTS
Water-tight concrete walls floor and roof, - no windows (Sidewalk Lights in road surface)
SIPHON SPILLWAY
DELIVERY CHANNEL (UNDER GROUND)
CYLINDER GATE 8 FT. DIAM.
STEEL, WATER "MAKE-UP" SUPPLY TANK
TANK 50 FEET IN DIAM.
85 FT.
244 FT.
102 FT.
105 FT.
204 FT.
414 FT.
LONGITUDINAL SECTION THRU HYDRAULIC FLUME
FUTURE ADDITIONAL STORY (At extremely small cost per square foot of floor space) (414 FT. x AV. 89 FT. = 37,000 sq. ft. of floor).
SPACE IN BALCONY FOR SUNDRY SMALL APPARATUS
OFFICE SPACE AND LECTURE ROOMS
BALCONY OF 2ND. FLOOR
Track for 2½-Ton Crane
HARBOR EXPERIMENT TANK 3 FT. DEEP
MEASURING BASIN 82,600 CU. FT. CAPACITY (EL. 283)
HYDRAULIC FLUME (15 FT. WIDE x 16 FT. DEEP) (EL. 297)
Direction of Flow
40-FOOT DIAMETER CONSTANT HEAD SUPPLY TANK 500 C.F.S. FLOW CAPACITY
PUMP
DISCHARGE
PUMP SUPPLY CHAMBER
SUMP & OVERFLOW RETURN
SKIMMING TROUGHS
PIVOT-KNIFE GATE (Shown diagrammatically)
FACILITIES FOR STUDY OF "HYDRAULIC JUMP"
LONGITUDINAL SECTION THRU LARGE PLATE-GLASS FLUME
BASEMENT STOREY FOR SAND STORAGE WORK SHOPS AND EXPERIMENTS
CONSTANT HEAD SUPPLY TANK
CENTRIFUGAL PUMPS
SCALE OF FEET
0 50 100 150 200 250 300 350 400 450
STUDY FOR NATIONAL HYDRAULIC LABORATORY AT U.S. BUREAU OF STANDARDS WASHINGTON, D.C.
SUBJECT TO REVISION
DESIGNED BY JOHN R. FREEMAN PROVIDENCE R.I.
GENERAL PLAN
A.C. CHICK, ASS'T ENGR.
SCALE 1 IN.=10 FT.
JUNE 1930
SHEET No. 3
John R. Freeman C.E. June 24 - 1930.


Construction of this portion deferred, temporary wood roof over Measuring Basin
Temporary wood end of Bldg.
FUTURE ADDITIONAL STORY
SPACE IN BALCONY FOR SUNDRY SMALL EXPERIMENTS
OFFICE SPACE AND LECTURE ROOM
TRACK FOR 5-TON CRANE
BALCONY
Track For Travelling Carriage
OVERFLOW CREST 30 FT. LONG for emergency use
MEASURING BASIN
RETURN WATER CHANNEL
PARSHALL VENTURI FLUME
PUMP SUCTION CHAMBER
5×2.5' VENTURI METER
3'×1' VENTURI METER
Only the concrete chamber to be provided now. Venturi Meters to be added later if desired for means of continuous record of discharge
This return channel to be equipped for measuring diaphragm on carriage similar to those used in European Laboratories for precise measurement. Distance of run, about 200 Ft.
NOTE: Section is offset at this point
DETAILS I-Beam and H-Column connections (not to scale)
(EL. 320)
Track for Travelling Observation Platform
88 Ft.
HARBOR EXPERIMENT TANK 3 FEET DEEP
RETURN WATER CHANNEL FOR HARBOR TANK
TO RETURN CHANNEL
MEASURING BASIN
24" round reinf. conc. columns
(EL. 283)
Future Roadway 12'
Future grade of TILDEN ST.
Future city Sewer (?)
TRANSVERSE SECTION AT A-A
Future floor for Laboratory or storage 125 Lbs sq. ft. safe load
Light, hand operated crane with maximum head room, on pair of 20 in. I-beams. (Light Steel)
2 TON CRANE
Light hand operated crane with maximum head room, on pair of 20 in I-beams
River Flume made up in 24 ft. sections bolted together and stored in pile at end of bldg. when not in use.
TILTING RIVER FLUME
PLATE-GLASS FLUMES
RETURN FLUME
LARGE HYDRAULIC FLUME
Future Roadway 20'
(EL. 311)
Movable observation platform suspended at any desired location from rails on edge of tank.
OCCASIONAL GLASS PANELS
WORK SHOP Storage of sand etc.
(EL. 282)
FUTURE VENTURI METERS
Removable wood block floor permitting excavation of pits
Future grade of TILDEN ST
TRANSVERSE SECTION AT B-B
A working head of about 60 ft. or more available through removable trap door in floor and roof. 65 Ft.
Temporary Board Roof
Tar & Gravel Covering
SPACE IN BALCONY FOR MISCELLANEOUS SMALL EXPERIMENTS
Future floor for future story 125 Lbs sq. ft. safe load.
SIDE OF PRESENT RATING FLUME
Future Roadway (EL. 309)
WORK SHOP
Possibly the bottom of this Return Flume had best be lowered 2 ft.
Removable wood block floor permitting excavation of pits
Future grade of TILDEN ST.
Future City Sewer (?)
TRANSVERSE SECTION AT C-C
STUDY FOR NATIONAL HYDRAULIC LABORATORY AT U.S. BUREAU OF STANDARDS WASHINGTON, D.C.
SUBJECT TO REVISION
DESIGNED BY JOHN R. FREEMAN PROVIDENCE R.I.
CROSS SECTIONS
A.C. CHICK, ASS'T ENGR JUNE 24-1930
SCALE 1 IN.=10 FT.
SHEET No. 4
John R. Freeman June 24-1930
SCALE OF FEET
0 50 100 150 200 250 300 350 400 450

OUTLINE DESIGNS FOR A NATIONAL HYDRAULIC LABORATORY

AT THE

UNITED STATES BUREAU OF STANDARDS

By John R. Freeman

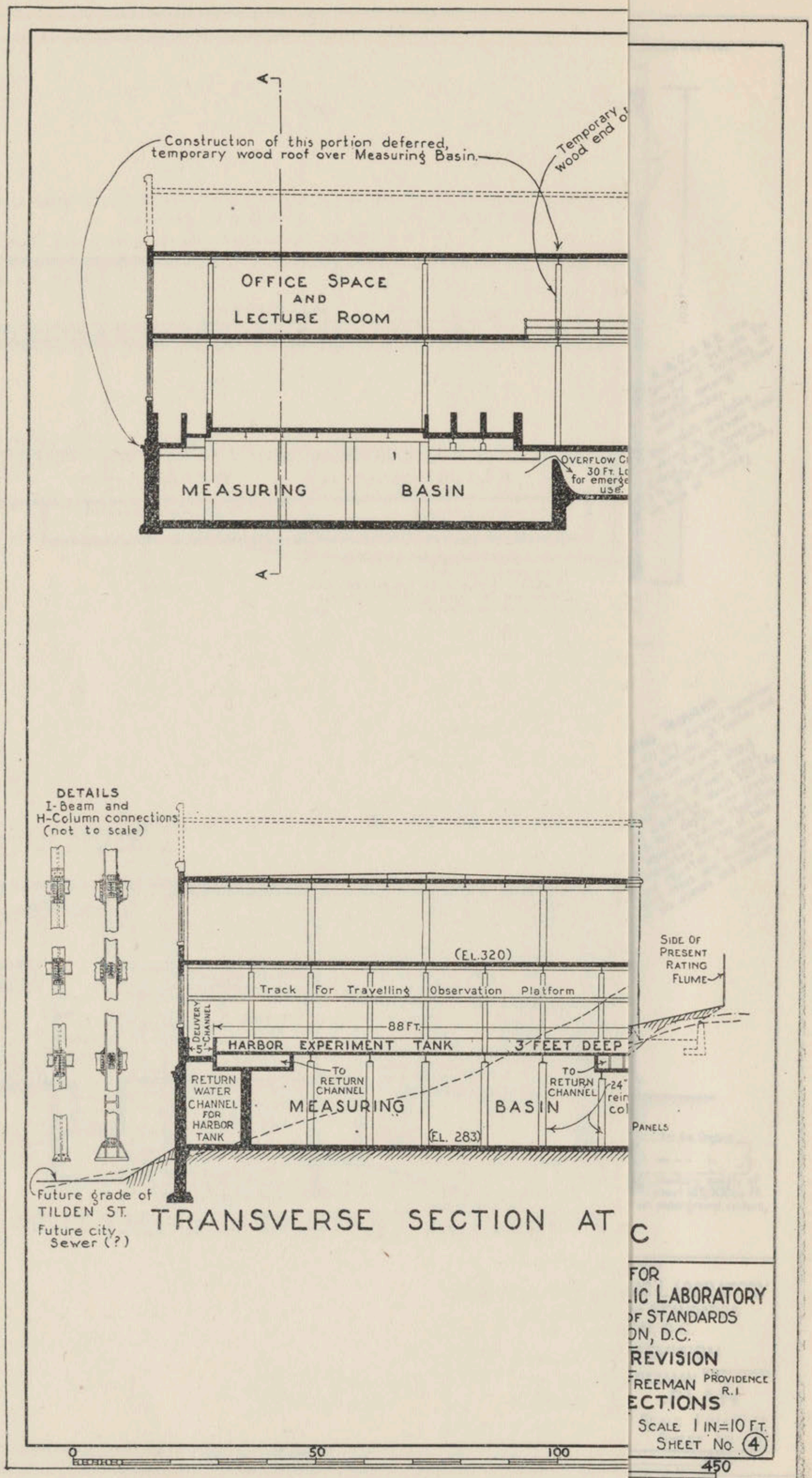
Estimate No. 1

Summary of estimate of cost

[Based upon design by John R. Freeman. Estimate by A. C. Chick, assistant engineer, in conference with Mr. Taylor, chief estimator for Turner Construction Co., of Boston]

	Quantity	Unit cost	Total
Excavation, including, backfilling, and shoring	22,100 cubic yards	$1.00	$22,100
Concrete foundation walk, basement interior walls, basement floor, large hydraulic flume, return flume, etc.:			
Concrete only	4,100 cubic yards	10.50	43,000
Reinforcement, including all reinforcement for entire building.	200 tons	90.00	18,000
Forms (straight work, some specially accurate for flumes)	87,600 square feet	.30	26,300
Curved forms	6,000 square feet	.50	3,000
Granolithic finish for concrete surfaces	15,000 square feet	.12	1,800
Concrete for floor slabs:			
Concrete only	934 cubic yards	10.50	9,800
Forms (allow for use 4 times)	60,000 square feet	.18	10,800
Granolithic finish	do	.12	7,200
Two 2-ton cranes (hand operated), crane track, brackets, etc	30 tons	90.00	2,700
Structural steel, including all beams, columns, etc	430 tons	90.00	38,700
Temporary board roof over third floor (1-inch boards with tar-and-gravel cover).	27,300 square feet	.30	8,200
Outside brick walls, windows, complete with caps, sills, lintels, trim, etc.	28,700 square feet	1.50	43,000
Temporary wood roof over measuring basin (2-inch plank, tar and gravel, on suitable wood timbers).	9,000 square feet	.60	5,400
Steel forebay supply tank	67.5 tons	125.00	8,500
Skimmer weir apparatus			6,000
Roof house over steel forebay:			
Wall area (copper-covered plank on steel)	4,800 square feet	1.00	4,800
Roof (plank on steel, wire-glass skylights)	3,500 square feet	1.75	6,200
2 stairways ($12 per riser)			1,500
Ornamental doorway			500
Heating (radiators and piping only)	1,000,000 cubic feet	.15	15,000
Toilets and washrooms			5,000
Lighting (ordinary equipment)	60,000 square feet	.15	9,000
Underground concrete cistern for 125,000 cubic feet supply water			20,000
Steel make-up water tank, 50 feet diameter			10,000
Kaplan type pump, adjustable blade, 250 cubic feet per second capacity.			8,215
2 small plate-glass flumes, etc			5,000
Total			341,715

Note.—All quantities have been estimated liberally to meet any uncertainties. With more refined design a substantial saving in these quantities can undoubtedly be made.



121057—30. (Face p. 3.) No. 4

OUTLINE DESIGNS FOR A NATIONAL HYDRAULIC LABORATORY

AT THE

UNITED STATES BUREAU OF STANDARDS

By John R. Freeman

Estimate No. 1

Summary of estimate of cost

[Based upon design by John R. Freeman. Estimate by A. C. Chick, assistant engineer, in conference with Mr. Taylor, chief estimator for Turner Construction Co., of Boston]

	Quantity	Unit cost	Total
Excavation, including, backfilling, and shoring	22,100 cubic yards	$1.00	$22,100
Concrete foundation walk, basement interior walls, basement floor, large hydraulic flume, return flume, etc.:			
Concrete only	4,100 cubic yards	10.50	43,000
Reinforcement, including all reinforcement for entire building.	200 tons	90.00	18,000
Forms (straight work, some specially accurate for flumes)	87,600 square feet	.30	26,300
Curved forms	6,000 square feet	.50	3,000
Granolithic finish for concrete surfaces	15,000 square feet	.12	1,800
Concrete for floor slabs:			
Concrete only	934 cubic yards	10.50	9,800
Forms (allow for use 4 times)	60,000 square feet	.18	10,800
Granolithic finish	do	.12	7,200
Two 2-ton cranes (hand operated), crane track, brackets, etc	30 tons	90.00	2,700
Structural steel, including all beams, columns, etc	430 tons	90.00	38,700
Temporary board roof over third floor (1-inch boards with tar-and-gravel cover).	27,300 square feet	.30	8,200
Outside brick walls, windows, complete with caps, sills, lintels, trim, etc.	28,700 square feet	1.50	43,000
Temporary wood roof over measuring basin (2-inch plank, tar and gravel, on suitable wood timbers).	9,000 square feet	.60	5,400
Steel forebay supply tank	67.5 tons	125.00	8,500
Skimmer weir apparatus			6,000
Roof house over steel forebay:			
Wall area (copper-covered plank on steel)	4,800 square feet	1.00	4,800
Roof (plank on steel, wire-glass skylights)	3,500 square feet	1.75	6,200
2 stairways ($12 per riser)			1,500
Ornamental doorway			500
Heating (radiators and piping only)	1,000,000 cubic feet	.15	15,000
Toilets and washrooms			5,000
Lighting (ordinary equipment)	60,000 square feet	.15	9,000
Underground concrete cistern for 125,000 cubic feet supply water			20,000
Steel make-up water tank, 50 feet diameter			10,000
Kaplan type pump, adjustable blade, 250 cubic feet per second capacity.			8,215
2 small plate-glass flumes, etc			5,000
Total			341,715

Note.—All quantities have been estimated liberally to meet any uncertainties. With more refined design a substantial saving in these quantities can undoubtedly be made.

ESTIMATE No. 2

Summary of estimate of cost

Stem	Quantity	Unit price	Total
Excavation	22,100 cubic yards	$0.60	$13,260
Foundation and basement, concrete:			
Main foundation walls, concrete	1,410 cubic yards	18.00	25,400
Floors (all resting on earth) and interior columns of measuring basin.	353 cubic yards	16.00	4,650
Pump-room floors, etc., in west end of building	193 cubic yards	20.00	3,860
Forms for outside basement walls	36,320 square feet	.30	10,900
Interior basement walls	554 cubic yards	18.00	9,970
Forms for interior basement walls:			
Measuring basin	5,080 square feet	.40	2,040
Basement—			
Straight-form work	4,100 square feet	.30	1,230
Curved-form work	6,100 square feet	.50	3,050
Temporary wood roof over measuring basin (2-inch plank on suitable floor timbers).	27,000 board feet	100.00	2,700
Tar-and-gravel covering	9,000 square feet	.15	1,350
Return flume and adjoining tunnels, concrete, etc	510 cubic yards	18.00	9,170
Forms:			
Flume	13,900 square feet	.40	5,550
Adjoining portions	4,290 square feet	.30	1,290
Main hydraulic flume:			
Concrete	1,075 cubic yards	20.00	21,500
Forms—			
Side walls of flume	21,380 square feet	.45	9,600
Upper portion of upper end walls	2,450 square feet	.40	980
Steel forebay or supply tank for large hydraulic flume	134,500 pounds	.12	16,150
Skinner weir			6,000
First floor:			
Concrete	311 cubic yards	16.00	4,970
Forms	16,760 square feet	.25	4,180
Steel beams (12.8 pounds per square foot)	215,000 pounds	.05	10,750
Steel columns	21,800 pounds	.05	1,090
Second floor:			
Concrete	243 cubic yards	16.00	3,880
Forms (use first-floor forms)	15,750 cubic yards		
Steel beams (12.8 pounds per square foot)	189,500 pounds	.05	9,470
Steel columns	9,820 pounds	.05	490
Two 2-ton steel hand-operated cranes complete with track, etc			5,000
Third floor (present roof):			
Concrete	380 cubic yards	16.00	6,080
Forms	27,280 square feet	.25	8,200
Steel beams	292,000 pounds	.05	14,600
Temporary wood roof covering	30,000 board feet	75.00	2,250
Tar and gravel covering	27,280 square feet	.15	4,100
Outside walls of building (13-inch brick)	490,000 brick	60.00	29,400
Windows	7,000 square feet	1.00	7,000
Parapet cap	760 linear feet	1.00	760
Steel for columns in outside wall of building	128,100 pounds	.05	6,400
Temporary wooden end for east end of building	4,000 square feet	100.00	400
Roof house over large steel forebay			15,000
Heating (radiators and piping only)	1,000,000 cubic feet	.15	15,000
Toilets and washrooms			5,000
Lighting (ordinary)	60,000 square feet	.15	9,000
125,000 cubic feet underground concrete cistern for auxiliary pump supply.			20,000
82,000 cubic foot steel make-up water tank			10,000
Kaplan pump, adjustable blade, 250 cubic feet per second			8,215
2 small plate glass flumes, etc			5,000
			354,885

NOTE.—All quantities have been estimated liberally to meet any uncertainties of ground, etc. With more refined design a substantial saving in these quantities can undoubtedly be made.

SCOPE OF DESIGN

(1) The attached drawings speak for themselves, but the following statement will aid in understanding the motives of the design:

The accompanying plans are designed to meet the purposes specified in the act of Congress of May, 1930, and to fulfill the promises of usefulness to the public set forth by Senator Ransdell, of Louisiana, and by various engineers, and others, at the several hearings before committees of the House and Senate, and presented in the printed reports of the hearings:

(2) The bill as passed reads:

> *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That there is hereby authorized to be established in the Bureau of Standards of the Department of Commerce a national hydraulic laboratory for the determination of fundamental data useful in hydraulic research and engineering, including laboratory research relating to the behavior and control of river and harbor waters, the study of hydraulic structures and water flow, and the development and testing of hydraulic instruments and accessories.

Three distinct lines of useful research are authorized:

1. The discovery of fundamental hydraulic data, such as coefficients of weir and orifice discharge, with greater accuracy than now known.
2. Testing of instruments and accessories.
3. Experiments of immediate practical application to the design of structures proposed for the development of water power, flood control, irrigation, domestic water supply, and the improvement of rivers and harbors for navigation, by means of studying the movement of water in relation to small models of the proposed structures, which models may be readily changed in trying out different ideas.

From observations upon these models the action of the proposed full-size design may be accurately foretold, and changes made for improving its efficiency or lessening its cost.

(4) The accompanying plans are designed with a view to presenting facilities for hydraulic research on models, and for developing formulas for estimating the discharge in proportion to depth, form, or velocity for many forms of weirs, orifices, and channels on a large scale, and with a high degree of precision, better than can be found anywhere in the world, and for redetermination of many fundamental hydraulic coefficients with such certainty and accuracy that they may stand unchallenged for a hundred years.

(5) They have been prepared in the light of my experience of more than 50 years in large problems of hydraulic engineering, and after many months of personal experience in several hydraulic laboratories in years gone by; also they are designed after personal inspection and review of substantially all the foremost hydraulic laboratories in Europe, as they existed three years ago. Laboratory research has since made large advances abroad, and very possibly I might change certain details after the tour of the three latest and largest European laboratories, on which I start next week, and after conferences with the eminent engineers in charge.

(6) In general, the fundamental hydraulic laws, coefficients, and constants for weirs, orifices, open channels, and pipes, now chiefly relied upon, have not been determined with the precision, nor over the range, required by present-day engineering, but have been developed piecemeal from apparatus of small capacity and often of imperfect adjustment. For example, the data on coefficients of orifices were largely determined by Poncelet and Lesbros 100 years ago, with precision marvelous for the times, with orifices only 2 decimeters (8 inches) in width and heads only up to 2 meters (6.6 feet). That these old researches leave much to be desired is shown by the critical review of Hamilton Smith, jr., Hydraulics, New York, 1886, page 27, et seq.

It is of particular importance that new tests be made upon water measuring weirs—rectangular, sharp-crest, round-crest, and V-notch—of many forms and large dimensions.

(7) The very small scale of most of the apparatus with which many important hydraulic constants and coefficients now in use were determined requires for their extension to modern practice, wonderful faith in the laws of hydraulic similitude, which may not be fully justified. Recent admirable experiments under the supervision of Professor Thoma at Munich, for developing the effects of changes in weir crests, reported in 1929 under the title "Sources of Error in Weir Measurement," are extremely instructive, but were made with great precision on extremely small apparatus, with a length of weir crest of only 6 inches and a depth over the weir of from 1½ inches to about 4 inches.

CONFIDENCE VERSUS DISTRUST

(8) I believe there is a growing feeling of distruct among engineers familiar with the movement of water about the precision obtainable in applying coefficients, constants, and hydraulic laws, derived from apparatus and in depths of these small dimensions, to practical problems where the depth may be thirty or forty times as great, and the discharge a thousand times greater.

(9) In the paper to be presented during the present week at Toronto, before the summer convention of the American Institute of Electrical Engineers, Mr. Karpov, the chief hydraulic designing engineer of the Aluminum Co., which is now building the largest hydroelectric station in the world, on the Saguenay River, and another large station in Tennessee, reports after a recent tour of European power developments and hydraulic laboratories:

> Two different opinions predominate [in Europe] in the question of the scale on which models such as of rivers, channels, locks, dams, etc., should be made and tested.
>
> One opinion that is best represented by the hydraulic laboratory of the Prussian State in Berlin is that the models have to be as large as possible; the other opinion, best represented by the hydraulic laboratory of the Technical University of Karlsruhe, is that the models are to be reasonably small, depending on the character of the problem to be studied.
>
> The Berlin laboratory in logical development of its idea went so far as to start to build an out-of-doors laboratory outside of Berlin, in order to remove the limitations that are put on the scale of the models by the size of a building. In this laboratory models as large in scale as 1:40 are built and tested.
>
> In order to work on still larger scales, this laboratory goes so far as to build and test models with different horizontal and vertical scales.
>
> The Karlsruhe laboratory stresses the importance of the refinement of measuring and observation methods, and believes that a small model can be tested out much more thoroughly, by making a larger number of tests under different conditions, a procedure that would be prohibitive on account of time and cost in a large scale model.
>
> Both laboratories have the support of outside technical opinion. The Berlin laboratory is starting a number of model tests on river regulation problems in Soviet Russia which are to be run on out-of-door models of large scale.
>
> The Karlsruhe laboratory is finishing a special building where the regulation problems of the Rhine River are to be solved on models of much smaller scale (1:200). The tests are to be run on a number of separate models, each representing consecutive stretches of the Rhine River about 10 km. long.

The out-of-door hydraulic laboratory recently completed at the Walchensee, near Munich, was promoted largely because of doubts about accuracy with very small models.

IT IS HIGHLY IMPORTANT TO HAVE FACILITIES BY WHICH "SCALE-EFFECT" CAN BE TESTED, AND A PROPER DEGREE OF CONFIDENCE GIVEN

(10) Illustrating this, I may say the recent measurements of the flow, about 11 feet deep, over the actual crest of the dam across the Mississippi, at Keokuk, Iowa, recently measured with great care by a group of engineers from the hydraulic laboratory of the University of Iowa, resulted in finding a discharge nearly 10 per cent greater than that which I had deduced about 20 years ago from the best experimental data then available.

FACILITIES FOR RESEARCHES FOR BOULDER DAM—UNITED STATES GEOLOGICAL SURVEY, DEPARTMENT OF AGRICULTURE, UNITED STATES ARMY AND HARBOR ENGINEERS, ETC.

(11) In the design now presented for a national hydraulic laboratory, in addition to facilities for determining fundamental laws and coefficients, facilities also are provided for other practical experiments and tests with models on smaller scale, in great variety, so as to fully meet the conditions prescribed in the hearings before Congress, and fulfill the promises made which led Congress to grant the appropriation, and for fullest cooperation with the United States Army engineers.

(12) The general layout is shown in the accompanying plans of a building, not all of which is to be built at once. The foundations of the whole should be planned from the beginning, so as to contain the flumes, supply tanks, and measuring tanks necessary for future large scale operation, in determination of fundamental laws and coefficients.

(13) The drawings now presented have been worked up in a great hurry to fit the site at the bureau, and are subject to revision. I believe that by conferences with eminent hydraulicians in my prospective tour of the largest, latest, and best European laboratories during the next two months, I could learn how to substantially improve many details.

(14) Once more I emphasize that the entire structures shown are not all to be built immediately. After a more precise estimate of construction costs, possibly I would desire to readjust some features so as to surely keep within the appropriation of $350,000 for buildings, plus $50,000 per year for operation and apparatus.

(15) The present outline design has been assembled to fit the local conditions, with the elements of flumes, tanks, pumps, and measuring basin laid out with the purpose of first of all making these elements of the maximum size desirable for the greatest possible utility of the laboratory.

My assistant engineer, Mr. Chick, has carefully estimated the quantities of excavation, concrete, steel, brick, roofing, windows, etc., and has discussed cost of the various elements with the chief estimators of C. T. Main (Inc.) and the Turner Construction Co., concerns particularly experienced in the design and construction of industrial buildings, and has thus reached the figures shown in the attached table. There has been insufficient time to precisely work out all details, or to get firm prices on pumps and electrical apparatus.

The experienced Swiss engineer, Doctor Meyer-Peter, spent more than six months, with a corps of experienced structural designers, on the details of design of the hydraulic laboratory very recently completed at Zurich.

An architect in the ordinary sense is the last man needed in planning a laboratory of this kind. The external shell is the smallest and least difficult part of the work, and its planning naturally comes after the layout of the big apparatus has been all worked out.

(16) If I had another month, subsequent to getting firm contract prices on the present building plans and apparatus, I would probably slightly modify certain features, and change some dimensions of the building, but from many years familiarity and several previous designs I believe these are about right.

SCALE OF MAGNITUDE AND PRECISION

(17) The design contemplates the discharge of water in quantities as large as 500 or 600 cubic feet per second on rare occasions, and the layout is designed so that quantities even up to this large size can be measured with certainty such that the margin of error will not be greater than one-tenth of 1 per cent, which is fivefold to fiftyfold better than heretofore commonly attained.

(18) These very large quantities will very rarely be used under more than 20 feet head on the pumps. The heads of 40 feet are for rare and brief experiments on full size syphon spillways, hydraulic jump, energy destroyers, pontoon models, etc. Possibly in order to get uniform distribution of velocity throughout the cross section, the discharge for pontoon models will have to be made from a bell-mouth gate, instead of over the ogee.

The quantities of water to be circulated by the pumps in the main flume ordinarily will be from 2 to 5 cubic feet per second, under only about 15 feet total head, including friction, thus requiring but a small amount of electrical power and a small pump.

MEASURING EFFECT OF IMPERFECTIONS UPON DISCHARGE

(19) It is proposed to create definite disturbances on weirs, orifices, channels, and dams, and accurately measure the effect. Practical conditions often prevent the perfection of form assumed in the application of ordinary formulas. For example, the edges of the orifice, or the crest of the weir, may be slightly round instead of precisely sharp. Also the walls of the orifice or weir may have the roughness of ordinary masonry, instead of the polished surface of the original apparatus, and of even greater importance is turbulence, vortex motion, or inclined approach in the channel feeding the measuring weir or orifice.

(20) There are almost no data by which the effect of these disturbances can be estimated, but certainly these apparently minor defects sometimes lead to important errors in estimates.

For illustration, I have been told that when the discharge of the 24-inch Venturi meter in the mechanical engineering laboratory of the Massachusetts Institute of Technology was tested by the Francis type weir into which its conduit leads, an error of about 8 per cent was found. This subsequently was traced to the disturbance immediately upstream from the Venturi, induced, first, by the turbulence from the pump, and, secondly, by a right-angle elbow.

The type of current meter most commonly used by the water resources branch of the United States Geological Survey and by the Reclamation Service is well known to be subject to error caused by turbulence, or twist, in the approaching current. Also it is known that certain other types of meter, the Haskell meter used by the United States Army engineers, and the Ott meter used in Germany, are less subject to these errors due to turbulence and twisting currents.

I am told that in Germany the American type of meter is ridiculed in some quarters because of this imperfection. It continues in use in American because of its remarkable ability to resist deterioration from rough usage in transportation, and the gritty water necessarily encountered in field service.

I believe that given opportunity for mechanical improvement of current meters by tests with running water, in which turbulence and twisting currents can be introduced to any desired extent, also in the irregular currents over cobblestone stream beds, these defects can be remedied.

GUIDES FOR COLLEGE LABORATORIES

(21) There is a strong forward movement among American engineering colleges toward establishing hydraulic laboratories for purposes of instruction and also for research, but obviously, as with the great majority of laboratories at the engineering colleges in Europe, the scale of operations of these new American college laboratories will be necessarily cramped by financial and architectural considerations.

(22) It has seemed to me of the highest importance that this national hydraulic laboratory should be laid out with a scope sufficient to settle many of these important questions about scale error, "Reynolds number," wall friction, etc., for a hundred years to come, and I believe this can be done under the present appropriation of $350,000, with $50,000 per year provided for management, operation, and new apparatus if the original layout is properly made.

(23) The plans now submitted are with the above facts in view.

This national laboratory could derive the precise coefficients and formulas for the most exacting work, leaving to the college laboratories such tests as can readily be made on smaller scale.

BACKGROUND OF THESE TENTATIVE DESIGNS

(24) I may add that my own hydraulic laboratory experience began actively more than 50 years ago in two of what were at that time doubtless the best hydraulic laboratories in America, where I worked off and on for 10 years, and continuously for many months, on very precise researches on developing apparatus for measuring the water drawn from canals of the power company by the factories at Lawrence, Mass., at Manchester, N. H., etc., and in supplementary researches on the accuracy of piezometers, and upon the flow of water in pipes, penstocks, sluiceways, flumes, and open channels. I have myself conducted researches on discharge over models of dams at Cornell University, and had charge for nearly 10 years of measuring the water drawn for power by all of the factories at Lawrence,

and for a time at Manchester, N. H., and have supervised the making of designs for several large water-power developments and municipal water supplies, having to provide for enormous flood discharges, etc.

I also made a long series of experiments on gage errors due to capillarity.

I have personally made the most extensive series of researches ever made on height of jets, discharge of nozzles, and hydraulics of fire protection.

Some years ago I carried out the most extensive and precise series of researches on the flow of water in pipes that has yet been attempted anywhere in the world, but which unfortunately remain unpublished because pressure of other matters has prevented the desired critical review of the results.

My uncommon experience in laboratories and in practical work have made me painfully aware of many of the difficulties involved in great precision of hydraulic measurement, because of air traps, capillarity, turbulence, pulsating heads, etc., and I have tried to take advantage of this experience in the layout now presented.

Above all I have sought to avoid cramping the scale of future research, by building foundations with proper regard for scale effect.

ESTIMATES OF FLOOD FLOW OVER RIVER DAMS

(25) In dozens of problems of water-power development, municipal water supply, irrigation, flood relief, etc., the best information available about flood flows that can be stored in great reservoirs, when traced back, rests on some sort of an estimate of discharge over a dam corresponding in depth, and the determinations commonly are of doubtful accuracy. New experiments over dam crests of great variety of form are greatly needed.

The tests made 25 years ago at Cornell University on a few typical forms of dams, are of doubtful precision.

LARGE MEASURING BASIN

Particular attention is called to the large measuring basin, the elevation of water within which can be measured with certainty to within 0.0001 part of a foot by Hook gage, or to within less than 0.05 of a foot by a 1-inch glass-tube gage.

It is designed to base quantities discharged upon this previse cubical measurement in connection with a chronograph recording to hundredths of a second of time, and by these means to calibrate or test other water measuring devices, such as the standard weir, the V-notch weir, the Venturi meter and standard orifices, which will thereafter be used with greater facility in the ordinary course of experimenting and testing in this laboratory.

CONSTANCY OF HEAD

Unusual precautions are taken for great constancy of head in the forebay, or supply tank, by means of a skimmer weir presenting about 2,000 feet in length of overfall crest, by which any momentary increase of delivery and head by the pumps will be "skimmed off" and returned to the suction chamber. It is estimated that a sudden increase of 100 cubic feet per second in pump delivery could not increase the operating head by more than 1 inch.

The designer's many personal experiences in various hydraulic researches have taught him the difficulty and the necessity of extreme precaution in matters of providing constant head, if one would measure depths over weirs and upon orifices and pipes with the utmost precision.

TURBULENCE AVOIDED

Precautions against eddies and turbulence in the approach to apparatus under experiment has been the most common source of error in precise hydraulic research. Therefore, I have taken great precautions to provide means by which one can screen out all such irregularities, by adjustable screens, beyond which uniformity of distribution of the current throughout the cross section will be insured, and by a forebay and connecting channels of ultragenerous size.

LARGE DISCHARGE CAPACITY

The water-discharge capacity of 500 second-feet is more than double that understood to be available at the latest and largest laboratory in Europe (the Walchensee), and is nearly four times that available at the newest large indoor laboratory at Zurich, the designer of which assured me of his opinion that most of the then existing laboratories were cramped in the quality of certain important researches by lack of adequate scale of operations.

I believe from experience that this large capacity is not an extravagance. So much will rarely be called for, and then only for brief periods.

To circulate 500 cubic feet per second of water with 20-foot total lift, including friction losses, will call for 1,500 horsepower on pumps, at 75 per cent efficiency, but this large power demand will be only for a very few hours.

In the laboratory for which I made tentative outline designs for the Massachusetts Institute of Technology 17 years ago, I also provided for 500 to 600 cubic feet of water discharge per second, mainly for the purpose of establishing coefficients of weir discharge at great depths, with high accuracy for important conditions often met in practice.

This 500 cubic feet per second on a sharp-crest weir, without end contractions, 15 feet in length, will develop an overfall of about 4.5 feet in depth; or, if the channel is narrowed to a 10-foot length of weir, will present a depth of about 6 feet. Should the pumps prove capable of 600 cubic feet per second, a depth of about 6.8 feet can be maintained over a weir 10 feet long.

The Francis standard weir of 75 years ago had a maximum crest length of 10 feet, and a maximum discharge depth of about 1.6 feet. The many experiments of later years by Fteley, Stearns, Bazin, or those at Karlsruhe, Cornell, etc., have mostly been with smaller dimensions and smaller depths. The caution by Mr. Francis that his formula was not expected to be accurate for depths greater than 2 feet, or less than 0.5 foot often has been forgotten.

The slightly more complicated Bazin formula is now preferred by many careful engineers for use outside these narrow limits.

The best brief discussion of limitations of weir formulas that I have seen is that by Hazen and Williams in their admirable Hydraulic Tables, pages 63 to 75. An earlier, excellent discussion of the uncertainties in weir discharge is presented in Hamilton Smith's Hydraulics, page 89 et seq.

Both of these critical reviews fail to deal with the most common source of error, which is turbulence or twisting motion in the approaching channel, and scant depth.

The recent European experiments by Rehbock and others, and the recent Cornell experiments, fail to agree within about 1 per cent.

LARGE APPARATUS FOR DETERMINING SCALE EFFECT

One most important purpose of the great range of size of models and quantity of discharge permitted in the proposed design, is for thoroughly testing the question of scale effect, about which there has been much doubt in the minds of practical men.

It is important to settle this question for all time, also to discover rules of percentage allowance necessary in transferring from one scale to another, and rules controlling the accurate use of distorted scales.

ORDINARY ROUTINE WORK WILL BE IN SMALL FLUMES

Glass flumes similar to those in Professor Rehbock's laboratory at Karlsruhe are provided for researches upon models which will permit the scale of experiment common in the European laboratories. These smaller flumes will service for three-quarters of the routine experiments.

Ample floor space is provided for temporary tests on models, or on structures of many kinds similar to those made at Charlottenburg on temporary models.

In any of these experiments it is obvious that quantities of water can be used as small as desired.

TESTS WITH SMALL DISCHARGE

It is expected that research in the large flume, with full capacity of apparatus, will, in most cases, be preceded by experiments on a small scale in either the Rehbock flume or in small special apparatus temporarily erected on the floor and supplied from any one of the numerous outlets on pipes connected with the main fore bay, which will give pressure under extremely uniform head.

The first work of the laboratory will doubtless be with the small flumes—the Rehbock flume and small, special apparatus—on problems for the Boulder Dam, Reclamation Service, Geological Survey, and the Department of Agriculture, in which no great discharge of water will be needed, and no extreme precision.

Nevertheless, this laboratory, being of national scope, should be laid out in its flumes, foundations, large supply tanks, and measuring basin on a scale for determining fundamental hydraulic coefficients competent for service in designing the largest engineering works and the most exacting researches.

In order to provide the United States Army engineers, whose cooperation in this laboratory is expected, with facilities for laboratory researches upon sand-bar formation in harbors, or at their entrances, space is provided for the duplication of the harbor-model tank at Wilhelmshaven, Germany, which was Germany's great naval base, and presented particularly difficult problems of shoaling by drifting sand. So far as I could learn this particular laboratory (the second near the same site) is the best special tool for this kind of problem ever yet built. It was designed after long study of other laboratories, and seems to have served its purpose well. (See Hydraulic Laboratory Practice, p. 374.)

MEASURING ERRORS DUE PRACTICAL DEFECTS

One of the most important features of the present laboratory design is the provision for testing the percentages of error caused in the discharge of weirs and orifices, by various disturbances of measured dimensions, such as turbulence, inclined or twisting currents, roughness of crest or wall of orifice, etc. Often these defects of form are unavoidable in practice.

Shear boards for producing definitely inclined or twisting currents in the approach to various types of weir (sharp crest, notch weir, and round crest) can be introduced as desired, and the effect noted in percentage of error due to incomplete contraction of jet, etc.

The proposed new form of standard round-crest weir is expected to show much less error due to such causes.

The effect of various definite degrees of roughness in the side walls of orifices or in the crests of dams will be measured as produced by covering these surfaces with expanded metal lath, etc., thus simulating the rough surface of masonry.

The Fteley and Stearns experiments on effect of slightly rounding the weir crest and on various breadths of weir sill, and the Bazin experiments on various depths in front of weir and various velocities of approach, and on correction for various velocities of approach will be greatly extended.

NEW FORM OF ROUND-CREST STANDARD WEIR

Since my personal tests 30 years ago at the hydraulic laboratory of Cornell University for determining the rate of flow at various depths over a full-scale model of the Croton Dam and since my researches of 40 years ago upon "the nozzle as an accurate water meter" I have been convinced that a form of weir crest giving greater precision of measurement under ordinary practical conditions than the common sharp-crested weir now in use and less liable to error due to turbulence or shallow channel of approach can be made.

The layout presented for this laboratory is adapted to determine this particular matter, once and for all, up to the large depths of 6 feet on crest and with precise measurements of the effect upon accuracy of disturbing conditions.

FURTHER DESCRIPTION OF DETAIL

The attached plans show a laboratory layout comprising:

(*1*) *Large flume.*—This is a very large flume about 16 feet deep by 15 feet wide, within which experiments can be made with a discharge of large volumes (500 cubic foot-seconds) of water over weirs of various types and dam models of various shapes.

Current meters can be rated at various velocities in currents purposely disturbed to definite amounts.

Venturi meters up to 3 feet or more in diameter can be set up downstream from a bulkhead built within the flume at any convenient point, and tests made on disturbed currents from elbow and other causes. Also, experiments can be made upon the limiting conditions of maximum efficiency as determined by the upstream and downstream Venturi taper. Experiments on effects of bell-mouth and curving tapers, both upstream and downstream, can also be made to advantage, for use in confined situations.

(*2*) *Fore bay.*—At the upstream end of this large flume stands a steel tank fore bay, about 40 feet in diameter and 40 feet high. This has been designed with an adjustable skimmer-weir for maintaining, with the utmost precision, a constant head on apparatus fed from this fore bay, while also avoiding turbulence in head and velocity due to possible variations in rate of delivery of the pumps. An adjustable horizontal perforated screen stops eddies from the discharge of the pumps.

The forebay is made of this large diameter in order to permit a new series of fundamental determinations of the coefficient of discharge from large orifices of various kinds opening from the flat, smooth, vertical surface of its wooden bulkhead, comprising the three gates which close the three main openings.

(3) *Deep erosion and revetment research.*—The large flume will present an excellent opportunity for certain types of experiments on river-bed erosion, both in straight and crooked channels, and to uncommon depths. It is believed that by this means much valuable information can be obtained relative to rip-rap revetment deposited in a mass along the bank in readiness to roll down and give protection as undermining and undercutting of the bank occurs, as has been practiced from time immemorial in river bank protection in China and Italy.

The large flume also will afford better opportunities than ever believable for researches on the transportation of large-size gravel and boulders, along river beds, at high velocities.

An observation platform carried by rails on the top edge of side walls of the large flume permits convenient observation at low-water levels.

(4) *Small return flume.*—The return current from the large flume is brought back to the pumps by a small flume at the lower level, which also can be used to great advantage for a large number of experiments with current meters, etc. In many cases two simultaneous sets of observations can be maintained, one at relatively low velocity in the large flume, and another at three or four times the velocity in the small flume.

The small flume is to be fitted for the moving diaphragm method of measuring, common in the European laboratories, and excellently described in the bulletin of the Engineering Experiment Station at the University of Wisconsin, Paper No. 672, June 10, 1914, by Mr. C. R. Weidner. It will be of interest to compare precision of measurement and facility of measurement by moving diaphragm, with other standard methods.

(5) *Pitot tube researches.*—Within both the large and small flume the Pitot tube as a water-measuring instrument can be developed and tested. This was highly developed by Darcy about 70 years ago, and was further greatly improved by the late Hiram F. Mills, of Lawrence, Mass., 50 years ago, who developed various forms for regular use in measuring the large quantities of water drawn from the canal by the various factories. These forms developed by Mr. Mills have never been publicly described, and some, doubtless, are capable of great practical utility.

(6) *Ogee dam model.*—Attached to the forebay is an ordinary section of ogee dam, 15 feet in length of crest, over which the water can be discharged and flow down the ogee, presenting at the bottom a velocity of about 50 feet per second and presenting excellent opportunities for large-scale experiments on the hydraulic jump as an energy absorber, and on various other forms of energy absorbers. This will permit a testing out of the scale effect for various types by means of similar tests on small models.

It is highly possible that this swift current would continue with a shallow depth for nearly the whole length of this flume, unless interrupted by some low form of sill for starting the jump. This sill can be placed at any desired point.

This current of swift velocity will also serve the useful purpose of testing models of speed boats and models of pontoons for naval airplanes. For this purpose, the discharge can be made through a bell-mouth orifice of the full width of the bottom of the flume, and at any velocity desired, up to about 50 feet per second.

(7) *Bottom orifice discharge.*—By temporarily narrowing the bottom of the flume to a width of 10 feet or less, greater depth can be obtained. This discharge through a smooth bell-mouth orifice will present a very advantageous condition of uniform distribution of velocity throughout the cross-section useful in many researches on boundary-layer effect.

It is believed that much useful data can be obtained by experiments similar to those made with air currents in wind tunnels.

(8) *Venturi meters for continuous use.*—Beneath this small return flume a space is provided in which two Venturi meters of widely different size can be installed in future, whenever desired, and maintained as a convenient ordinary means of automatically recording the rate of discharge, while experiments on river models, etc., are going on in either the large or in the small flume.

(9) *Measuring basin.*—This measuring basin comprises a large concrete tank permitting precise cubical measurement of volume for the precision of approximately 0.01 per cent, although commonly there would be no need of precision more than 0.1 per cent, which is the general limit aimed at in the design. An outside gage pit permits the quick use of a glass-tube gage of 1 inch internal diameter, quickly read by a vernier for avoiding capillarity, and also permits arrangement for Hook gage.

By means of a pivot gate of small inertia, capable of instantaneous movement and chronographic record, the water can be diverted into and out from this measuring basin in a fraction of a second, and the time of filling precisely recorded by the chronograph, to within less than 0.02 second.

This large and precise means of measurement will permit more accurate rating of discharge over new standard forms of weir, either horizontal, sharp-crest, round-crest, or V-notch types, with far greater depth than have ever yet been made, and can reconcile the differences now found between the researches with small apparatus made by many experimenters.

The large scale of the measuring basin, flume, and forebay, are all adapted to the precise measurement of quantities up to 500 cubic feet per second.

(10) *Auxiliary make-up tanks.*—One of the chief difficulties encountered in the design, for accurately controlling and measuring such large quantities, when delivered from a pumped supply, is found at the time of deflection of current into the measuring basin, because immediately thereafter the lessened delivery into the return channel supplying the pump increased the pump suction head which would quickly cause some variation in the rate of flow. This obstacle can, I believe, be successfully overcome by a supplementary supply tank 50 feet in diameter by 40 feet in height, located near the measuring basin, which is to be provided with a trip gate interlocking with the pivoted diversion gate, so as to be opened wide in the return flume to the pump supply tank at the instant following the diversion into the measuring basin. I have not had time to work up the final details of this device, and the tank as shown is subject to modification.

The rate of discharge from this make-up tank will be made substantially constant by means of a cylinder gate, previously adjusted so as to give a discharge substantially equal to that in the experiment, and raised automatically by the action of a large float during the descent of the level in the make-up tank, so as to give substantially a constant discharge. The distance away from the return channel of the disturbance caused by this switching of one current away from, and of another into it, is so far away from the pumps that it is believed that no important disturbance of constant head upon the weir, or orifice, under experiment, need be caused by the switching.

In order to fill the big forebay, or supply tank, in some few experiments, with this filled near its top, another outside auxiliary tank or cistern will be needed, of somewhere near the capacity of a cylindrical tank 40 feet in diameter by 40 feet deep. A circular cistern 80 feet in diameter by 10 feet deep near the west end of the main building would serve this purpose.

(11) *Water supply.*—The total quantity of water for filling the auxiliary tanks, the pump suction chamber, the large hydraulic flume, the forebay, and the make-up tank, and all accessories, for those few experiments demanding the largest quantities, will be about 200,000 cubic feet, or 1,500,000 gallons, which can be slowly drawn from the present city water mains through pipes not necessarily more than 6 inches in diameter, which at a draft of only 500 gallons per minute, or 30,000 gallons per hour, would fill the tanks in about 50 hours, and would cost, at an ordinary charge of 10 cents per 1,000 gallons, only about $150. This water would be used over and over again,

so that the tanks would not need to be refilled more than once or twice a year, and possibly less often.

(12) *Pumps.*—It is expected that the large quantities of water will be supplied by the use of propeller pumps, in order to save cost of apparatus.

In observing the marvelous efficiency of the speed-boat propellers developed during the last few years, the writer believes that pumps can be developed for this type, useful in many situations and to a greater extent than heretofore. It is proposed that one of these large pumps shall be of the Kaplan type, a sort of reverse Kaplan turbine with its high-speed propeller blades, adapted to have their angle of advance changed while in operation as in the turbines.

Ample space is also provided for many varieties of centrifugal pump.

It is proposed that some of these experimental pumps be driven by extremely high-speed internal combustion engines as used in airplanes. The demand for experiments with extremely large quantities of water will be infrequent and brief, and it is desirable to save the cost of an unnecessary plant for pumping these large capacities.

The fore bay and pump room also permit a great variety of experiments relative to the efficiencies of pumps or turbines which can be attached to bell-mouthed openings, ordinarily closed by flanges. Apparatus for studying cavitation similar to some of that recently found in European laboratories can be attached to one of these.

(13) *Harbor flume.*—Arrangements have been made for duplicating the apparatus developed at Wilhelmshaven, Germany, through many years of experiment, for the special study of harbor problems. From inspecting this special harbor laboratory, I believe that it has a wide adaptability, and that it might be extremely useful to the United States Army engineers in studying various problems of sand-bar erosion, of channel straightening, of effects of groynes, retards, etc., and many other devices pertinent to harbor improvement.

From all that I have been able to learn, this special German laboratory was found of great utility in saving cost of dredging continuously at the entrance to the great German pre-war naval base, (harbor of Wilhelmshaven), and in improving the harbor entrance at Helgoland. I believe it well worth while of further study, and am proposing to again visit the Wilhelmshaven laboratory the coming summer, although, since the war, its activities have greatly declined.

(14) *Tilting flume.*—The original Engel's river flume, which I saw at his first laboratory about 17 years ago, was of the tilting variety, his later flumes are of the fixed variety, but I note that as large a tilting flume as space permits has been installed in the new Zurich laboratory.

I believe that an exceptionally long flume of this kind can be made of great utility for determining accurately the hydraulic laws governing the flow in open channels. Also, that a series of much needed experiments on partially filled conduits can be made therein; therefore, I have provided for it. I have designed it to be in sections of steel plate that can be stored in small quarters when not in use, or be bolted together, presenting a channel 220 feet in length, capable of being turned to any angle from zero up to a 3 per cent slope. Still greater length could be provided; also a somewhat greater angle of slope.

When not in use, and piled up in storage, the large vacant floor area adjacent to its site, would be open and free for other experiments.

Large size is of no important disadvantage, except first cost. The large pump would not be run, except rarely, for large-scale experiments. The large dimensions of the tilting flume and of the hydraulic flume are of no disadvantage, all permit temporary structures to be built inside to meet various special conditions. Access by the observers can very readily be had for studies of small depths flowing at the bottom of the flume from a platform suspended either from the traveling crane or from a light carriage traveling on the top edge of the flume.

This great depth in the hydraulic flume permits additional experiments on the laws controlling the hydraulic jump, which is a principle largely discussed during the past 10 years and not yet fully solved, which one may judge from a paper received June 19, 1930, from the Technical University at Charlottenburg, comprising extended experimental studies by Dr. Ingr. Kurt Safernez, of the construction firm of Julius Berger, and supervised by Professor Ludin, entitled "Untersuchungen Uber Den Wechselsprung." (Researches on the Hydraulic Jump.)

SAND AND SILT EXTRACTOR

While inspecting conditions on the silt-laden Colorado River at the irrigation canal intake near Yuma, Ariz., on several occasions, and also while studying conditions along certain silt-laden rivers in China, I have been impressed by the great importance of developing simple, effective, and cheap apparatus for extracting the major part of the burden of silt from the water by means of an apparatus involving very little mechanism and small loss of head.

I have also been greatly impressed while watching the marvelous performances of certain cyclone-dust extractors in extracting fine cotton-lint discharged with large volumes of air from napping machinery, by the application of the principles of centrifugal force, and have been led to believe that the useful device for this purpose could be designed for extracting the principal burden of sand and silt at intakes from rivers carrying a large silt burden, and have provided space in this national laboratory, wherein such apparatus of large dimensions and capacity can be conveniently set up for trial. (A pencil sketch of this has been prepared, but there has not been time to trace it.)

VENTURI FLUME AND PARSHALL FLUME

Nearly 40 years ago, I made many experiments on the discharge of hydraulic nozzles with a view to utilizing them for metering water, and was greatly impressed by their merit for certain conditions, and by the relatively small effect which turbulent approach had in modifying their discharge. On the other hand, I noted the errors caused by turbulence in the discharge of sharp-crested measuring weirs.

At that time I desired opportunity for the development of a measuring flume on the Venturi principle, but the opportunity did not present itself. Some years later my former chief, Hiram F. Mills, chief engineer of the water-power developments at both Lawrence and Lowell, Mass., made what, so far as I know, were the earliest experiments on a crude sort of a Venturi flume, and showed me the results.

His experiments had reference particularly to the design of certain new sluiceways at the head gates of one of the Lowell canals, with a view toward lessening the loss of head at entrance. These were intended as merely preliminary to further experiments on a more elaborate and precision scale which I discussed with Mr. Mills, but which were never carried out.

Eight years ago I suggested Venturi-flume development as one of the objects of the hydraulic laboratory. I have since been greatly interested to read of the admirable progress made by Mr. Parshall in developing a measuring flume for irrigation purposes on this principle, which for certain situations is better than any measuring instrument for this purpose heretofore devised.

The Parshall flume is designed first of all to be cheaper, and of such simple outline that it can be put together by any ordinary carpenter and used for measuring as accurate as is needed by the ordinary farmer. I believe that the principle could be applied with great advantage in a more refined form, which would give greater precision, and that this offers to be a useful adjunct in hydraulic engineering. I have, therefore, provided for experiment with Venturi flumes of various form and various sizes up to one of large dimensions conveying 500 cubic feet of water per second and for determining the discharge of each with great precision. Meanwhile, tests would be made by various forms of disturbances, twisting, and of turbulent currents, and of the effect of obstructions of gravel accumulated at the upstream side of the sill in case this were elevated above the general bottom.

The large hydraulic flume also permits of a wide range of experiments upon the erosion and transportation of river débris, such as sand, gravel, and cobblestones, and would permit a most useful extension of the partially completed researches by the late Carl G. Gilbert, made some 15 years ago at the Institute of California, with the assistance of Mr. Gerard Matthes, in small flumes with small quantities.

Professor Meyer-Peter, the eminent engineer and professor of hydraulics at the Technical University of Zurich, Switzerland, has told me of his earnest belief in the necessity of experiments on the hydraulic laws covering the transportation of gravel and small bowlders with much larger flumes and with much larger quantities and velocities of discharge than have heretofore been available in laboratories. I have sought to make ample provision for this in the hydraulic flume.

EROSION EXPERIMENTS

The most difficult and important question in economic control of the Mississippi River lies in the subject of erosion and deposition of sand and gravel after considering various plans of relief at various times, after observing erosion effects left at some of the great crevasses on the Mississippi, particularly at the site downstream from the Weecama crevasse of 1922. I have come to believe that fundamental experiments relative to rip rap are greatly needed, which experiments will fail of their untility unless carried out in a flume of about the size and depth here provided.

Along the Yellow River (Hoany Ho) in China and along the Po River in Italy as developed by centuries of practical experiments, I have observed precautions against the undermining of levees comprising, in brief, a deep mass of irregular fragments of stone and from one-half to 3 cubic feet in size deposited at the foot of a sloping bank with the expectation that when, if ever, a current should cut deeper and threaten the undermining of the bank at this point, this mass of stone would gradually roll down the steepened slope and deposit itself so as to prevent further erosion. I am led to believe that experiments on this made at the laboratory on a gradually increasing scale, would develop the principles under which the experiment within the river itself on full, natural scale, could be much more effectively carried out.

TILTING FLUME

A tilting flume of a large size and length is regarded in several of the leading European laboratories as a very desirable piece of research apparatus, but in nearly all cases they are much smaller and shorter than would be most advantageous. In Professor Engel's earliest laboratory, which I saw in connection with the Leipzig Exposition, about 17 years ago, a tilting flume was his principal apparatus for the study of river hydraulics, and his new laboratory at Dresden at first contained a large apparatus of this kind, which could be quickly adjusted to any convenient angle.

In his later remodeling of his laboratory at Dresden, the tilting flume has been omitted, and his models are built upon the bottom of a fixed flume, similar to the hydraulic flume now proposed, but very much smaller in width, depth, and hydraulic capacity.

I noted with great interest that in the new laboratory at Zurich Professor Meyer-Peter was planning as large a tilting flume as his floor space would permit.

It has seemed to me, during much consideration of problems of river regulation in China and in the United States, that a tilting flume could be made an extremely useful instrument for many kinds of research, and therefore I have reserved ample space for one of large dimensions, which would, however, not be installed until the special demand comes for research with its aid. Primarily, this will be extremely useful in studying the possibilities of making cut-offs in river bends in the Mississippi and other meandering streams. Also useful in studying the best form of groyne or dike for deflecting an erosive current away from a bank which it threatens to otherwise undermine.

The tilting flume can also be useful for estimating on a more firm and precise basis than is now given in the textbooks, or that has ever yet been possible, the fundamental laws of flow in open channels of various shapes of cross section and with various hydraulic radius.

FLOW IN PARTIALLY FILLED CONDUITS

Large conduits for drainage, sewage, and water supply of the cut and cover type carry their discharge without being completely filled. For some purposes, as for the conveyance of sewage and storm water highly charged with sedimentary material, it has been found to be advantageous to give these an ovate cross section diminishing toward the bottom so that in periods of low flow the velocity should not be abnormally diminished beyond that which would move the sediment.

The hydraulic laws covering such conditions are very poorly established; this tilting flume would permit establishing them once and for all, and very possibly would develop facts of much economic importance.

WATER CUSHIONS BELOW OGEE DAM

One of the subjects as yet very much unsettled and greatly discussed in current technical literature is that of the most effective and economic means for distributing surplus energy at the foot of the overfall of a high dam.

Much research with small models in European laboratories has been devoted to this subject, and there is some uncertainty in the application of these model experiments to practical conditions on a very much larger scale and with extremely variable depths of discharge. I have therefore provided an overfall similar to a dam crest at the top of the main supply tank, in which conditions governing flow and the discharge over a high dam can be simulated. The upper portion of the slope is made permanent, the lower part is made removable so that it can quickly be changed in form, either being taken out or put in by the overhead crane.

At the foot of this slope various forms of baffle piers can be used, such, for example, as those similar to the piers downstream from Gatun spillway, which I have from the first believed were not as advantageous a type as could be devised by laboratory experiments.

By means of continual cutting and trying I believe the most advantageous form of baffle pier could be developed once and for all.

Also, a large depth of the hydraulic flume at this point, the large quantity available, from 300 to 500 cubic feet per second, and the high fall of about 40 feet, permits a great variety of experiments on different so-called water cushions and energy absorbing basins, which would supplement the experiments on the hydraulic jump made by Professor Woodward for the Miami conservancy and other similar experiments.

THE SIPHON SPILLWAY

This is a device of very great economic importance in the development of water-storage reservoirs, which has never yet come into such great use as its importance justifies. I believe that I have supervised the design and construction of the largest battery of siphon spillways ever yet constructed. To get some of my data I had experiments made by Professor Smrcek in his laboratory at Brno, Czechoslovakia, which foreshadowed experimentally the results attained in a practical test of the completed structure. But I believe that I certainly could have prepared a still better design with laboratory facilities.

The spillways just mentioned had a height of 8 feet in the contracted area, six in number side by side, over the crest and a width of 10 feet, and each discharged approximately 2,000 cubic feet per second. Each was provided with an automatic flashboard device at the throat. I have since designed others which were not built, in which the established discharge of each unit was 4,000 cubic feet per second, and with 20 of these units side by side, the head of the contracted area over the crest being 10 feet. I have reason to believe this depth could readily be increased to 12 or 15 feet. Small-scale models are incapable of indicating this maximum, because of complications relative to the atmospheric pressure.

These large siphons, just mentioned, present great advantage in permitting the passage of driftwood, trees, even of logs 40 feet in length, and their use gives a safeguard not dependent on human control in case of sudden flood or the bursting of a dam or reservoir farther upstream. It permits waste of storage space now almost universally requisite for flood discharge over a thick, permanent dam crest, and permits the reservoir to be normally used for storage up to within 1 foot of the maximum flood height.

I have deemed this matter of such great importance for the conservation of this country's water resources that I have devised means for making practical tests with a siphon throat up to the maximum possibilities, 12 or 15 feet above the permanent crest, and over a section equal to the whole atmospheric pressure.

PROPELLER PUMPS

The laboratory has been laid out for extensive research on single pumps with motor blades ranging from multiblades to a single pair of blades like those in an airplane propeller. Pumps of the propeller type, of great capacity and a lift of about 10 feet, as I remember it, were introduced nearly 40 years ago by the E. P. Allis Co. for promoting circulation in a canal at Milwaukee, but the type has never yet received the professional attention which I believe it merits. The type can be further developed in the form of a reversal of the Kaplan turbine, with adjustable blades, and I have provided that the propeller pump for large quantities and low lifts in the laboratory should be of this type, permitting a wide range of research on the controlling principles.

There has been a remarkable development of the propeller type of turbine water wheel, particularly of the Kaplan type in Europe during the past five years with very great economic advantage in permitting the use of high-speed, electric generators directly attached to turbines acting under very low heads. There is good reason to believe that high-speed low-head pumps on the propeller principle have great economic merit, and I believe this laboratory could be of great service in developing the principles of design.

I have been much impressed with these possibilities while a passenger observing the performance in various light, high-speed skiffs, provided with outboard motors, and more recently in observing the propeller in a speed boat belonging to my son, capable of about 35 miles per hour, at from 2,500 to 3,000 revolutions per minute, driven by a gasoline motor of about 125 horsepower. This application of extremely high speed to boat propellers is a most remarkable development, and the reverse application merits immediately earnest attention.

It is possible that with various modification of the apparatus much could be learned useful in the aeronautic propeller from the hydraulic propeller, because the controlling principles of hydrodynamics and aerodynamics have much in common. One of my friends, eminent in aeronautics and a great mathematical genius, assures me that the design of aeroplane propellers could be helped by studies of small model propellers immersed in mercury.

CENTRIFUGAL PUMPS

Ample opportunity for testing single-stage centrifugal pumps up to heads of 40 feet has been provided for, and with discharges up to about 300 cubic feet per second.

About 40 years ago, I became greatly interested in the design of centrifugal pumps in connection with a factory organized for their manufacture at Lawrence, Mass.; subsequently, 35 years ago, I induced Mr. Carson, chief engineer of the Boston metropolitan sewer system, to modify his proposals for pump equipment, which had been drafted as solely enormous reciprocating pumps, so as to admit of the centrifugal design, and myself bid and tend red on four large pumps of this type. I was slightly underbid by the Allis-Chalmers Co., and so lost the opportunity for engag ng in pump manufacture. But the results demonstrated the principle of superiority of the centrifugal pump, which now, 35 years la er, has become well established.

Many years ago, while on engineering work in Mexico, I had opportunity to experiment with a small centrifugal pump made, as I recollect, by Sulger Bros., in Switzerland, which developed such great discharge capacity for its size and weight that it convinced me that here was a great field for research.

I believe that the national hydraulic laboratory could do a great service by developing the true principles of design for obtaining either maximum discharge or maximum economy with a minimum quantity of cast iron.

Therefore I have provided ample space around the main forebay where pumps of various types can easily be set up.

Obviously, these same outlets and inlets, which ordinarily would be covered by simple, dished-flange plates held on by bolts, could be utilized for the testing of turbines of various types and sizes under heads of up to 40 feet.

COMPARISON OF PRESENT PLANS WITH THOSE PRESENTED AT HEARING BEFORE SENATE COMMITTEE EIGHT YEARS AGO

(1) These earlier plans were described in the report of the hearings of September 8, 1922, calling attention to the drawings following page 40, reproduced on a small scale from those which I presented at the original hearings.

This original report contemplated: (1) A discharge of about 600 cubic feet of water per second; (2) about 1,167 brake-horsepower, on rare occasions for brief time; (3) a weir flume 15 feet wide by 15 to 20 feet deep by 245 feet long; (4) a tilting flume about 200 feet in length; (5) a concrete measuring basin of about 50,000 cubic feet capacity; (6) a supply basin of about 50,000 cubic feet capacity; (7) several large Venturi meters; (8) many items of large-scale fundamental research.

(2) The present layout is substantially for the same scope of operations as that of eight years ago, with provision for 500 second-feet of water instead of 600, and with building slightly larger in plan and

design especially to fit the site on the steep hillside at the southerly side of the bureau grounds near Tilden Street.

(3) In my plans now submitted, the design has been modified to fit the ground, and also modified to meet conditions developed during the eight years since the first hearing, and improvement found during my two tours of hydraulic laboratories in Europe, and in course of my compilation of the book entitled "Hydraulic Laboratory Practice."

But in my later plans I have taken scrupulous care to provide for research on the same scale set forth in my report to Congress of eight years ago and in subsequent reports.

In the report of eight years ago the appropriation asked for was $200,000.

(4) The appropriation in the bill recently passed being nearly double, permits more stories and more floor space than recommended eight years ago; but in my recent designs scrupulous care has been taken to keep within the limits of this appropriation of $350,000 intended to cover building and the fundamental apparatus, comprising flumes, supply tanks, and pumps sufficient to immediately begin work on a most comprehensive scale, in meeting the objects set forth in the bill recently passed and the hearings precedent thereto, for both fundamental research and the practical tests desired immediately by other departments of the Government. I have not included the cost of tilting tank distinctly marked as "future," nor the "future" Venturi meters. Otherwise substantially all problems suggested at original and later hearings can be studied by means of the apparatus now provided.

(5) To make certain of thus fulfilling the promised researches by an expenditure within the appropriation, I have had detailed estimates of cost prepared by estimating the quantities in foundations in great detail, including the principal flumes, measuring basins, supply tanks, pumps, etc., so that a far closer estimate of cost can be had than by the very rough method based on an assumed number of cents per cubic foot of total cubical space contained in the buildings, which cubic method is extremely unreliable for a special structure of this class, in which the building foundations, etc., are integral with the chief apparatus, or flume and measuring basin, etc.

(6) These estimates did not include the construction of the harbor laboratory in the east wing for special research for the United States Army Engineers, which I proposed to study further in Germany during the coming summer after conference with the Chief of Army Engineers, and after further studies to be made by Lieutenant Kramer of his corps, arrangements for whose studies of laboratories in Europe have already been made.

(7) The estimate did, however, include foundations of an exceptionally heavy character, sufficient to support one or two additional stories at some future time, giving additional convenient floor space for the use of any of the varied purposes of the bureau, at the extremely small additional cost of about $1.50 per square foot of floor space, by reason of the roof in the present plans being designed as a future floor suitable for carrying a working load of 125 pounds per square foot; this floor roof to be temporarily covered by a watertight and weatherproof roofing material of standard Barrett specifi-

cations, upon temporary boards, cost of which is included in this estimate.

(8) Because of the peculiarities of this hillside location, the one of two future stories provided for in strength of foundations, walls, and columns might properly be considered as not wholly a charge on the laboratory appropriation, since these one of two additional stories are peculiarly advantageous in their location close to the administration and other buildings, and being at very nearly the upper courtyard level, the hydraulic laboratory proper being mainly below the top of the hill. No other location on the bureau grounds will give floor space for general at so low a cost.

(9) The drawings now submitted have been worked out in such detail that work might immediately be begun under an ordinary form of cost-plus contract, frequently used by industrial corporations, or they can quickly have further details added, within from two to four weeks' time by one or two skilled designers, at an additional expenditure of, say, $1,000 for wages, including forms of contract and specifications suitable for the competitive bidding now required on Government buildings.

(10) From much experience I have entire confidence that with a moderate amount of trimming and reshaping certain features (such, for example, as substituting a steel tank at a cost of only about half that for the underground reinforced-concrete reservoir at the west end, carried in the present estimate at $20,000), that the structure can be put into working shape so that within the limits of the appropriation several important lines of research could be started within eight months from the present time.

(11) It was not at any time expected during the recent hearings that all cost of all future apparatus would be covered within the $350,000 appropriation, because a large part of this apparatus will be made by the bureau's mechanics, especially to fit the research in hand, under the annual allowance of $50,000 per year.

(12) Most of the laboratories in Europe had been badly cramped in their scope of operations by insufficient laboratory space and by having to crowd apparatus into rooms that were too small and were ill adapted in shape. It is of the highest importance that first attention be given to having the fundamental apparatus of proper size and built integral with, or prior to, the outside walls.

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