Reprint "S. 1710 ... establishment of a national hydraulic laboratory..." April, 1928

NATIONAL HYDRAULIC LABORATORY

HEARINGS

BEFORE THE

COMMITTEE ON RIVERS AND HARBORS
HOUSE OF REPRESENTATIVES

SEVENTIETH CONGRESS

FIRST SESSION

ON

S. 1710

AN ACT AUTHORIZING THE ESTABLISHMENT OF A NATIONAL HYDRAULIC LABORATORY IN THE BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE AND THE CONSTRUCTION OF A BUILDING THEREFOR

APRIL 26, 27, 1928

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COMMITTEE ON RIVERS AND HARBORS

House of Representatives

SEVENTIETH CONGRESS, FIRST SESSION

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NATIONAL HYDRAULIC LABORATORY

HOUSE OF REPRESENTATIVES,
COMMITTEE ON RIVERS AND HARBORS,
Thursday, April 26, 1928.

The committee met at 10.30 o'clock a. m., Hon. William E. Hull presiding.

Mr. HULL. We are called here to-day to take up S. 1710, reading as follows:

[S. 1710, Seventieth Congress, first session]

AN ACT Authorizing the establishment of a national hydraulic laboratory in the Bureau of Standard of the Department of Commerce and the construction of a building therefor

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, the development and testing of hydraulic instruments and accessories.

SEC. 2. A board to be known as the National Hydraulic Laboratory Board is hereby created, the three members of which shall be the Secretary of Commerce, the Secretary of War, and the Secretary of the Interior, or in lieu thereof such other officer of each department as the Secretary thereof may designate. It shall be the duty of the board to determine from time to time a program of the projects to be undertaken and the manner in which the work is to be performed.

SEC. 3. There is hereby authorized to be appropriated, out of any money in the Treasury not otherwise appropriated, not to exceed $350,000, to be expended by the Secretary of Commerce for the construction and installation upon the present site of the Bureau of Standards in the District of Columbia of a suitable hydraulic laboratory building and such equipment, utilities, and appurtenances thereto as may be necessary.

This bill has passed the Senate, and Doctor Burgess is here from the Bureau of Standards. We will call on him to make a full explanation in connection with this bill.

Mr. O'CONNOR. Will you permit me to say at this time that Senator Ransdell told me yesterday that he was going to try to be here this morning, but in all probability he is taken up with flood control over yonder, which is of paramount importance at pres nt, but he is going to be here if it is at all possible.

Mr. HULL. We will notify his office that we are taking this up and would like to have him come over.

Before Doctor Burgess takes the floor, the secretary informs me that there are a number of telegrams, addressed to Mr. Dempsey, supporting this bill. They seem to be from engineers or from secretaries of associations.

If there is no objection, we will put all of them in the record.

Mr. HUDSON. I have four here that I would like also to insert in the record.

Mr. HULL. All right; and if there are any others they may be put into the record.

(The telegrams referred to are as follows:)

DETROIT, MICH., *April 25, 1928.*

GRANT M. HUDSON, *Rivers and Harbors Committee:*

Hydraulic laboratory in Bureau of Standards extremely necessary. Please support Senate bill 1710.

S. H. STEPHENSON,
President Detroit Section, American Society of Civil Engineers.

DETROIT, MICH., *April 25, 1928.*

GRANT M. HUDSON, *Member of Congress:*

Local section Mechanical Engineers desire your support in passage of Hydraulic Laboratory bill, 1710.

S. H. LOW, *Chairman.*

DETROIT, MICH., *April 25, 1928.*

GRANT M. HUDSON:

Detroit Engineering Society favors passage Hydraulic Laboratory bill. Please cooperate.

CHAS. J. PECK, *President.*

DETROIT, MICH., *April 25, 1928.*

GRANT M. HUDSON,
House of Representatives:

Wired Chairman Dempsey urging support of hydraulic laboratory in Bureau of Standards, Senate bill 1710. Appreciate your support.

G. C. DILLMAN,
President Michigan Engineering Society.

DETROIT, MICH., *April 25, 1928.*

S. WALLACE DEMPSEY,
Chairman House Committee on Rivers and Harbors:

Anxious for passage of Senate bill 1710, hydraulic laboratory in Bureau of Standards. Desire your support.

S. H. STEPHENSON,
President Detroit Section of American Society of Civil Engineers.

DETROIT, MICH., *April 25, 1928.*

RIVERS AND HARBORS COMMITTEE,
House of Representatives:

Attention Mr. Dempsey, chairman. Request passage of hydraulic laboratory bill, Senate bill 1710, placing laboratory at Bureau of Standards. Appreciate support.

G. C. DILLMAN,
President Michigan Engineering Society.

DETROIT, MICH., *April 25, 1928.*

S. W. DEMPSEY,
Rivers and Harbors Committee:

Local section, mechanical engineers strong for hydraulic laboratory in Bureau of Standards. Want your support.

S. H. LOW, *Chairman.*

DETROIT, MICH., *April 25, 1928.*

S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives:

Detroit Engineering Society desires establishing Hydraulic laboratory in Bureau of Standards.

CHAS. J. PECK, *President.*

SAN FRANCISCO, CALIF., *April 26, 1928.*

S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee:
House of Representatives, Washington, D. C.:

I strongly urge passage of hydraulic laboratory bill, S. 1710, as such a laboratory will be of material assistance in solving problems of river flow on Mississippi River. The laboratory should be in charge of the Bureau of Standards to get proper scientific investigation.

J. D. GALLOWAY,
Consulting Engineer.

PHILADELPHIA, PA., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives, Washington, D. C.:

The board of directors of the Engineers' Club of Philadelphia urge your favorable consideration and action in the matter of Senate bill 1710 with regard to hydraulic laboratory, and especially urge the desirability of the placing this laboratory under the Bureau of Standards.

CHAS. E. BILLIN, *Secretary.*

SAN FRANCISCO, CALIF., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY:

We are advised that the hearings on hydraulic laboratory bill, S. 1710, is coming before your committee Thursday morning. We request favorable consideration of this bill and believe laboratory should be placed under the Bureau of Standards.

A. EMORY WISHON,
Vice President and General Manager
Great Western Power Co. of California.

CHICAGO, ILL., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY:

Representing our 2,800 engineer members, our board of direction approve and urge passage of Senate bill 1710 providing for hydraulic laboratory under direction of Bureau of Standards. A prompt favorable report by your committee is desired.

WESTERN SOCIETY OF ENGINEERS.

ANN ARBOR, MICH., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House Office Building, Washington, D. C.

As an engineer interested in hydraulic science, I urgently request your support of the Ransdell hydraulic laboratory bill, S. 1710, and particularly its location in the Bureau of Standards.

LOUIS E. AYRES, *Consulting Engineer.*

SAN FRANCISCO, CALIF., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives, Washington, D. C.

The Engineers' Club of San Francisco, with a membership of over 800 engineers in or about the San Francisco district, strongly recommends the passage of hydraulic laboratory bill S. 1710 and wishes specially to emphasize its opinion of the great desirability of placing the laboratory in the Bureau of Standards.

R. A. KINGSLAND, *President.*

SAN FRANCISCO, CALIF., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives, Washington, D. C.

San Francisco section of American Society of Mechanical Engineers, numbering approximately 400, strongly recommend favorable action hydraulic laboratory bill S. 1710 and consider it particularly desirable to place this laboratory in Bureau of Standards.

DENNISTOUN WOOD, *Chairman.*

SAN FRANCISCO, CALIF., *April 26, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbor Committee,
House of Representatives, Washington, D. C.:

The interests of the hydraulic division American Society Mechanical Engineers are strongly favorable to the passage of the hydraulic laboratory bill S. 1710, and wish to emphasize the importance of placing laboratory in the Bureau of Standards. Favorable action of your committee accordingly is respectfully urged.

ELY C. HUTCHINSON,
Chairman Executive Committee,
Hydraulic Division American Society Mechanical Engineers.

SAN FRANCISCO, CALIF., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives, Washington, D. C.:

The San Francisco section of American Society of Civil Engineers recommends passage of the hydraulic laboratory bill, S. 1710, with provision included placing the laboratory in the Bureau of Standards.

W. H. KIRKBRIDE, *President.*

CAMBRIDGE, MASS., *April 26, 1928.*

WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee:

Affiliated Technical Societies of Boston, organization of 3,500 engineers, recommend establishment of national hydraulic laboratory, Senate 1710. Believe it should be placed in Bureau of Standards.

J. B. BABCOCK, *Executive Secretary.*

ITHACA, N. Y., *April 25, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Rivers and Harbors Committee,
House of Representatives, Washington, D. C.:

May I express myself as strongly favoring laboratory bill S. 1710, providing for national hydraulic laboratory. Believe such laboratory essential. In fact, it

should have been established long ago. Am strongly in favor of placing laboratories in Bureau of Standards.

D. S. KIMBALL.

PALO ALTO, CALIF., *April 26, 1928.*

Hon. S. WALLACE DEMPSEY,
Chairman Committee on Rivers and Harbors,
House of Representatives, Washington, D. C.:

Would request favorable action on hydraulic laboratory bill S. 1710, and that laboratory be placed under jurisdiction of Bureau of Standards.

ARTHUR B. DOMONASKE,
Executive Head Mechanical Engineering Department, Stanford University.

SAN FRANCISCO, CALIF., *April 26, 1928.*

S. WALLACE DEMPSEY,
Chairman Rivers and Harbor Committee,
House of Representatives, Washington, D. C.:

Your support and favorable action is strongly urged upon hydraulic laboratory bill, S. 1710. Am of the opinion also that the bill should definitely provide for placing the laboratory in the Bureau of Standards. Permit me therefore to urge the consideration of your committee and to hope for its favorable action accordingly.

M. M. OSHAUGHNESSY, *City Engineer.*

Mr. HULL. As I understand this bill, and from the limited knowledge I have of it in connection with flood control and different bills that are being put forward at the present time, there is a demand for this hydraulic laboratory, and it seems that if this would answer the purpose for all things it would be better to have it in the Bureau of Standards, and therefore Doctor Burgess is here, who will give you a full explanation, and if nobody else wants to appear ahead of him we will call on him now.

Mr. MANSFIELD. Before we begin, I wonder if General Jadwin wants to appear before the committee? Do you know?

Mr. HULL. I do not know a thing about it.

Mr. MANSFIELD. He requested its reference to this committee.

Mr. HULL. I think we could take him on later.

Mr. MANSFIELD. Yes.

Mr. HULL. We probably will not decide this to-day.

STATEMENT OF DR. G. K. BURGESS, DIRECTOR BUREAU OF STANDARDS

Doctor BURGESS. Mr. Chairman and gentlemen, I have with me, who would also like to appear before the committee, Mr. Gano Dunn, who is past president of the Society of Electrical Engineers, and in his executive capacity as president of the J. G. White Engineering Corporation has had a great many power plants under his responsibility for erection; Mr. W. F. Durand, past president of the Society of Mechanical Engineers, who has had large experience in hydraulic and similar problems; Mr. C. E. Grunsky, past president of the Society of Civil Engineers; Mr. John R. Freeman, twice past president of the Society of Civil Engineers, who is the father of the hydraulic laboratory idea; Mr. J. L. Harrington, of the Society of Mechanical

Engineers, also a past president; Mr. L. W. Wallace, the Executive Secretary of the Engineering Council, representing the united activities of the engineering societies of the country; and President S. W. Stratton, the first director of the Bureau of Standards and now president of the Massachusetts Institute of Technology.

For the record, I would like first to read a letter.

Mr. HULL. Before we begin, we have quite a list of speakers here and we only have an hour to give to this matter. So I would like to have you confine yourself to about five to eight minutes, if you will.

Doctor BURGESS. All right; we will do so.

This letter is from General Lord to the Secretary of Commerce and reads:

> In reply to your letter of the 7th instant inclosing a proposed revision of the text of bill S. 1710, authorizing the establishment of a National Hydraulic Laboratory in the Bureau of Standards of the Department of Commerce and the construction of a building therefor, I have to inform you that the proposed legislation, if amended in accordance with the revision submitted by you, is not in conflict with the financial program of the President.

This bill, Mr. Chairman, as now before you in its amended form has unanimously passed the Senate and was reported to the Senate unanimously by the Commerce Committee of the Senate. The original bill, introduced by Senator Ransdell, has been changed, the changes being made at the suggestion of the Budget Bureau after consultation with General Jadwin, who felt concerned that the War Department was not given any authoritative control over the proposed laboratory.

In the bill as printed, and passed by the Senate, there are three sections.

The first section sets up the laboratory function of hydraulic research and testing in the Bureau of Standards.

The second section, and this is the important one from the point of view of the cohesion of the three departments mainly concerned, sets up a board of three Secretaries, the Secretary of Commerce, the Secretary of War, and the Secretary of the Interior, which will comprise the control board to lay down the program of work. This, then, gives the War Department a third interest in the control of the work that is going on.

The third section authorizes the appropriation for the purpose The Budget Bureau itself increased the appropriation from $300,000 to $350,000 to take care of the permanent equipment.

This laboratory as proposed will be a laboratory in a scientific center in which there are at the present time some 900 men working in very varied fields of work. We have found from experience that it is highly desirable to have any highly technical projects in such a center, and the Bureau of Standards is such a center.

The method of operation will be that the projects originating in the field, whether it be in the Geological Survey, the Reclamation Service, War Department activities, Agricultural Department activities, or elsewhere, will be brought to the laboratory and the field data supplied, and the experimental work then carried out in the laboratory by the staff of the Bureau of Standards in consultation with the field representatives, and then the field representatives of the various services will take back the problems to their own departments to execute the work.

It has been found in practice, particularly in European practice, that there are often times several alternate solutions to a hydraulic

problem. If you try to make a single solution in the field of a project such as a harbor or a river project, you can only have one answer, because it costs several million dollars. If that is put into the laboratory, you can make studies in the laboratory of three or four modifications of a project and you can get the most probable answer and then carry back your best solution and execute it in the field.

We have been behind in this country in work of this kind. In Europe they have some 10 or 12 such laboratories and are adding new ones. A new one is just being started in Switzerland, which has no large rivers or harbors; nevertheless they are putting some $250,000 into such a laboratory.

In Czechoslovakia they are just putting in a second new laboratory of large dimensions.

We feel that this laboratory at the the Bureau of Standards will be of very great use to the engineers of the country and to the responsible State officials as well as national officials, and of great advantage also to consulting engineers and construction engineers in all kinds of hydraulic projects.

In Senate Report 718 there is given a letter of indorsement by Secretary Hoover, followed by an analysis of the need for such a laboratory in question and answer form. I will not go into the details of that, but in effect it sets up the desirability of a laboratory in a civilian institution, with a staff of permanent, civilian personnel in an institution, the Bureau of Standards, which has had 27 years' experience in the way of cooperation with other departments of the Government and the public most successfully, with a background of scientific workers in science and engineering, which gives us a free consulting group and also groups which can carry out experimental work which is correlative to but not a part of the laboratory itself.

So I am asking you for this laboratory and for prompt action, and the reason I am asking for prompt action is that if your committee recommends it favorably and the House passes this bill in time, we will be able to come in on the deficiency bill with an appropriation to construct the laboratory.

Reverting again to the Budget Bureau, I think I should emphasize the fact that the Budget Bureau has had this matter under consideration since November. It has gone over the thing very carefully indeed. It has considered the Ransdell original bill and it has proposed the compromise which gives the three departments mainly concerned—War, Interior, and Commerce—jurisdiction in the control of the laboratory.

Mr. HULL. Doctor Burgess, the flood control bill as we passed it in the House the other day refers, I think, to the same proposition. Do I understand that if this bill is passed and this is set up in the Bureau of Standards, it would be unnecessary to have that set-up separately for flood control?

Doctor BURGESS. We feel that a single national laboratory, in view of the fact that there are at least six national services, to say nothing of the State organizations which would be interested—that a national laboratory under civilian control, with an organization which can consult with and do work for all of these field services, including the Mississippi River Commission and the Chief of Engineers of the Army, is most highly desirable.

Mr. HULL. I understand, but what I am trying to get before this committee is whether or not we could eliminate that out of the flood control bill if this passes.

Doctor BURGESS. As I read the bill, Mr. Chairman, there is no provision for a laboratory, although in the report presented before the House there was a statement, including General Jadwin's original suggestion, which did contain a project for a laboratory.

Mr. HULL. It contemplates setting this up; I know that.

Is there anything else that the gentlemen of the committee would like to ask Doctor Burgess?

Mr. CARTER. In connection with this cost of $350,000, have you any of the detail on that?

Doctor BURGESS. $300,000, roughly, of the total would be for the laboratory building itself. The European experience has been that they are going to larger and larger laboratories of this type. This will permit us to erect a building 456 feet long and 63 feet wide.

The $50,000, approximately, is for permanent equipment in the shape of pumps and other auxiliaries which are in effect a part of the building.

M. CARTER. Where do you propose to locate this building?

Doctor BURGESS. The location for the building is on Bureau of Standards grounds, parallel to Tilden Street, in effect at the lowest part of the ground. There is a 50-foot drop from the high point of the adjacent land in the grounds to the bottom of the laboratory, so that we can work vertical problems as well as horizontal problems. We have the water, and we have all the facilities otherwise necessary, such as shops and scientific men.

Mr. HUDSON. This is to be in that low, unimproved section?

Doctor BURGESS. Yes.

Mr. MANSFIELD. Some of the members of this committee are only laymen, from a scientific standpoint, and would it not be well for the doctor to explain just what a laboratory is and what they propose to do there?

Doctor BURGESS. Of course, this is all answered in the report, and I expect Mr. Freeman and Mr. Dunn to go into that in some detail.

I can answer the first question by reading the first two paragraphs of the Senate Report 718, on page 4:

> A hydraulic laboratory is a building especially arranged for investigating the physical laws which define the motion of water, and for studying, by means of models and other special equipment, engineering problems arising in connection with the measurement, control, and disposition of large quantities of water, and the utilization of water for irrigation and power purposes.
>
> The fundamental conception underlying experimentation by means of models in a hydraulic laboratory is this: If the model demonstrates that the conditions existing in a harbor, for example, can be reproduced typically by the ebb and flow of tides in the model, then it is possible, by placing regulating works in the model, to show the changes that will be brought about in the harbor if these regulating works are built. The effectiveness of proposed regulating works can this be determined in advance by means of model experiments at small expense, and the most efficient and economical design selected from a number of proposed plans.

Further along in the report you will find, for example, beginning on page 14, a list of 64 problems that are in effect urgently needed to be solved in the hydraulic engineering field, which are laboratory problems but which, nevertheless, can be carried into the field for

execution and to which the laboratory will be expected to give an advance answer of great advantage to the constructing engineers.

Mr. HULL. This building costing $300,000 could not come under the building program that they have laid out, could it?

Doctor BURGESS. There is a technical situation involved which I might explain. I had to come in something over a year ago for a power plant building. Under the law it requires a special act for each building of the Bureau of Standards, because there is a "south of the Avenue" rule in the general act.

I would like to insert one other letter into the record, Mr. Chairman, from the Director of the Geological Survey to the Director of the Bureau of Standards, inclosing the memorandum of the Secretary of the Interior to the Budget Bureau on the question of this bill.

(The letter referred to is as follows:)

DEPARTMENT OF THE INTERIOR,
GEOLOGICAL SURVEY,
Washington, March 3, 1928.

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

MY DEAR DIRECTOR BURGESS: The letter addressed to the Director of the Bureau of the Budget by Secretary Work to-day contained the following expression of views:

"The Geological Survey and the Bureau of Reclamation in this department are interested in having a national hydraulic laboratory established. The Geological Survey, in connection with problems related to the study of the water resources of the country, frequently needs research work of a kind that can only be done in a well-equipped hydraulic laboratory. Such necessity arises in the design and testing of instruments and equipment for measuring river discharge, in seeking the sources of error, and in determining the degrees of accuracy obtained by various instruments and methods. There is increasing need for the use of water turbines as water meters and for recording the discharge through gates of various kinds and over the crest of dams of various shapes. All these matters must be studied in a properly equipped laboratory in order to obtain information as to the best designs to be adopted, the appropriate coefficients to be used and the necessary precautions to be taken.

"The construction work of the Bureau of Reclamation frequently involves the design and erection of irrigation structures embracing unusual requirements as to size or function and considerably in advance of current practice. In order to supplement existing hydraulic data applicable to these structures, experimental work has been undertaken from time to time by the field engineers on structures already built and considerable original data have been accumulated which have been of great value in improving existing practice and in aiding economical design. Gratifying reductions in the cost of structures have been effected by this bureau in a number of instances as a result of this experimental work and a comprehensive program of further necessary investigations has been outlined by their engineers. Due, however, to the very small amount of funds that can be made available, it is impracticable in their construction organization to provide equipment and employ specially trained research workers to carry out such a program in a consecutive and orderly manner. The investigations that have been so far undertaken therefore have been restricted to those which could be carried out by the regular engineering force as time could be spared from other duties and there are several important lines of investigation that it has been impossible to take up at all.

"The establishment of a national hydraulic laboratory would be of great value to the Bureau of Reclamation by providing facilities for carrying on this research work without interference or interruption with suitable facilities and under the direction of specialists in investigation lines, and it is certain that the results that may reasonably be expected would permit increased efficiency and economy in the design and operation or many important irrigation structures and other hydraulic work.

"It is the opinion of the officials of this department that a national hydraulic laboratory is much needed, that it should be placed in the Bureau of Standards—a research bureau with a stable personnel of scientists and engineers qualified for

the work to be done and with established and satisfactory cooperative relations with other bureaus and departments—and that S. 1710 makes reasonable provision for such laboratory."

Yours very cordially,

GEORGE OTIS SMITH, *Director.*

Mr. HULL. Are there any other questions?

Mr. HOUSTON. What is the attitude of the Secretary of War as well as of the Secretaries of the Interior and of Commerce?

Doctor BURGESS. The attitude of the Secretary of Commerce is shown in the letter on pages 2 and 3 of the report, in which he most highly and emphatically and as strongly as possible indorses this laboratory.

The Secretary of War, under date of March 7, on the original Ransdell bill, before the provision was put in setting up the three-Secretary control—Secretary of Commerce, Secretary of War and Secretary of the Interior—gave out a press release opposing such a laboratory, which statement appeared in the United States Daily of March 7, and I understand that the last paragraph of it at least is practically the answer he gave to the Director of the Bureau of the Budget.

Mr. HULL. Will you read that?

Doctor BURGESS (reading):

A recent proposal to establish a national hydraulic laboratory does not meet with approval of the Secretary of War, who has been informed by the Chief of Engineers that measures and observations on our largest rivers supply the best hydraulic data on the flow of such streams, since actual experiments with full-sized structures are preferable to experiments with small scale models. Laboratory experiments are likely to lead to erroneous conclusions. The Secretary of War, therefore, feels that studies and experiments pertaining to river and harbor and flood control works should be under the direction of the authorities who are charged by law with planning and executing those works.

I may say, Mr. Chairman, that that statement, in part at least, is in direct contradiction to the whole European experience on that subject.

Mr. CHALMERS. What is the date of that letter?

Doctor BURGESS. March 7. The approval of the Bureau of the Budget and of the President is as of date of March 16.

Mr. CHALMERS. Does the Secretary of War still hold to that position?

Doctor BURGESS. That I do not know. This is previous, as I have already stated, to the final form of the bill.

Mr. HULL. The War Department has asked for a day of hearing on this, so we can bring that out at the proper time.

Is there anything else to ask the doctor?

Mr. HOUSTON. He has not stated the attitude of the Secretary of the Interior.

Doctor BURGESS. I submitted for the record a letter which discloses that. It is favorable to having the laboratory at the Bureau of Standards.

Mr. O'CONNOR. If this laboratory were established would this organization make investigations on its own motion, or would it consider only such data and reports as may be submitted to it?

Doctor BURGESS. I would expect this laboratory to consider only those things that the board itself, consisting of the three Secretaries, Commerce, War, and Interior, would bring in. Those Secre-

taries, representing in the case of two of them the field work and in the case of the other the laboratory and also field work, as of the court survey, would only bring in problems of interest to them, and there are a host of such problems. We would work on problems submitted to us by the interested field services through the board. The program could also include problems originating outside the Federal Service, if of general interest.

Mr. O'CONNOR. Do not understand that I am opposed to the bill at all, because I am the author of the O'Connor bill, which is nothing more than the old Newlands bill, and it occurred to me that the results sought to be achieved through the creation of this board would be in the direction of the results designed to be accomplished under my bill, to investigate the water resources of the country.

Mr. HULL. Are there any other questions? If not, I will call on the next gentleman, Mr. Dunn.

STATEMENT OF GANO DUNN, PRESIDENT J. G. WHITE ENGINEERING CORPORATION; CHAIRMAN NATIONAL RESEARCH COUNCIL OF WASHINGTON

Mr. HULL. If you can confine yourself to about eight minutes, it will help us get through in time.

Mr. DUNN. Mr. Chairman, my name is Gano Dunn; I am president of J. G. White Engineering Corporation and chairman of the National Research Council of Washington. These two positions give me a peculiar experience, Mr. Chairman and gentlemen, in this subject, and I am firmly of the belief that the cost of a hydraulic laboratory would be saved perhaps every year and that the time in which improvements in rivers and harbors construction will be put into effect will be reduced by years and years.

I note from the questions asked here that the issue is perhaps in two parts, one whether it is desirable to have a laboratory of this kind, and second, where it should be put.

Just a word on the desirability. There has been a quotation that I wrote down as it went by, that actual experiments with full-sized structures are preferable to experiments in a laboratory. It is the old argument that we are familiar with. It is the argument that nature's own laboratory is the best.

Now, nobody will deny that. It has been true for very many years, but it is only true when you have the opportunity of asking nature the questions you want to ask and paying nature for the cost of the answers. If you ask nature a question on a full-sized river, on what that river wants to do, it is going to cost you three, four, and five million dollars to ask that question and you have got to wait four, five, and six years for the answer.

Now, the answer in the hydraulic laboratory may not be as good an answer, but it will be gotten quickly and it will be gotten cheaply.

Somebody was interested in what this laboratory is. One of the principal things in it is a big trough 350 feet long and wide enough to hold a good stream of water, capable of tilting to any angle you want, and you have water flowing in it, and if you tilt it up a little bit the water flows slowly, and by putting into that trough materials of the same kind you would put on dikes and by breaking the current in that trough you would arrive in a few weeks at answers to these

questions and at an almost insignificant cost, whereas it would take you much longer to arrive at it if you did it on the real structures.

There is a big word used by all engineers, but it is a word used more and more in the last few years, that is the key to this whole question. It is the principle of similitude. That sounds like a high-brow statement, but it is becoming so much used now by everybody that I venture to use it here, where I know you will all understand it.

That means this that if you reproduce a natural phenomenon on a reduced scale in the laboratory, the things that happen in the laboratory are found to follow exact laws in relation to the big phenomena that take place in the world itself. It does not mean that the proportions in which you have reduced it in your laboratory are followed in all respects. For instance, if you make a laboratory in which the size is one one-hundredths in respect to the size of the river, the flow of water must be only one-tenth, but if you have the flow of one one-tenth in a laboratory, then you will find happening in the laboratory reproduction just what you find happening in nature's laboratory, only quicker and cheaper.

In my early career as an engineer one of the first things I did was in connection with one of the first applications of the principle of similitude in Washington. When they were designing our early ships in the Navy, they started a towing tank here. What is a towing tank? It is a long body of water with a ship capable of being driven in it with an electric motor, so that you can take a reduced model of a ship just like the ship you are going to build, but smaller, and drag it through this water.

Mr. MANSFIELD. They have something of that kind in the navy yard.

Mr. DUNN. That is what it is, and that is one of the first things I did as an engineer, to calculate the power required to do that towing, and the results have been beyond all expectation. It would have otherwise cost millions of dollars more.

I also had the privilege of building equipment for Langley Field, and there the same principle came in. It was in connection with the wind tunnel. What does everybody now do in aviation? Not to build an airplane to find out how it works, but a man goes to a wind tunnel and he takes his designing features from that.

The application of the principle of similitude to hydraulic problems has been successful in connection with those things, and this laboratory is merely a place where you would apply the principles of similitude to a type of problems that in this country it has not been applied to before; and the answers they are getting abroad show that the cost of the laboratory is simply picayunish and nothing at all compared to the enormous savings made by quickly putting into effect the principles they want to use in the rivers, and if they do not work, modifying them, and then with the data at hand giving those principles to the engineering corps and the other engineers who actually do the work of the rivers, and they know what they are doing and their work is successful.

Now, as to where the laboratory should be located. In this report there is stated the number of departments and bureaus of the Government that would use this laboratory—the Mississippi River Commission, the Federal Power Commission, the Coast and Geodetic Survey, the Board of Engineers for Rivers and Harbors, the Geolog-

ical Survey, the Reclamation Service, the Department of Agriculture, and many others. If it is not located in the Bureau of Standards, it can not be a central service for all those departments. The awkwardness and inconvenience of putting it in any one of them would be very great, and no one of those services is adequate to bring to the service of the laboratory all the knowledge and facilities that the Bureau of Standards can bring.

At first sight it would look as if this hydraulic problem was a civil-engineering problem. In the old days it was, and the wonderful work that has been done by the civil engineers in this country needs no description and no apology; but to-day the march of science is so rapid that no one branch of engineering is competent to cover even its own field. In this very laboratory which we started to think of as a civil-engineering laboratory, problems will come in from other branches of science, such as chemistry, in connection with the condition of the soils and sediments; such as physics, in connection with colloids and deposits and things of that kind; such as metallurgy, in connection with the rate at which corrision will take place; and in many of the other sciences. To-day no one engineering problem is ever a problem in one's subject alone.

The Bureau of Standards is the research institution of the United States Government. That is where you will find men skilled in all these different arts and branches, and only there will you find that symposium and consensus of information and knowledge on all scientific subjects that is necessary to a successful solution of this problem, and no man can say that to-morrow is not going to bring a new branch of science that will be called into a thing of this kind.

The Bureau of Standards has a site where there is already a flume built, and there are many reasons in addition to the ones I have given why that would be a desirable location.

It seems to me, therefore, in view of the testimony almost universally favorable on the part of engineers given a few years ago when this question was up—and the only opposition to it, and that was only partial, that I read at that time was Mr. Ockerson's—and in view of the increasing confirmation of the value and the accuracy of this principle of similitude developed since that time, the argument, if you would go into it, for the existence of a laboratory is simply unanswerable, and I think the only thing remaining is where is the best place to put it.

Mr. HULL. What is your answer to the opposition of the Secretary of War?

Mr. DUNN. My answer to the position of the Secretary of War is that it is based upon this quotation which I referred to, which is that actual experiments on full-sized structures are generally likely to give better results, etc.

My answer to that is that if you poll any leading 10 engineers you will probably find 9 of them differing with that opinion.

It is not so, gentlemen. It is not so, and this country is way behind the progress of other countries abroad, because they have thrown over that old idea, and they are introducing these hydraulic laboratories.

I happen to know, for instance, that the development of the River Shannon in Ireland, which has a number of peculiar problems in

hydraulics, is being studied in a hydraulic laboratory in Stockholm, where those problems are to be settled.

The answer is that it simply is not so, and the preponderating weight of engineering opinion will not confirm it, and I only suggest that you invite that opinion.

Mr. HULL. You spoke about this trough 350 feet long. How is that trough constructed? Is it a wooden trough, or a metal trough?

Mr. DUNN. It is not fully designed, but I believe it will be a steel trough, lined with wood, arranged with two long girders in it and arranged so that it can be tilted, which will require some crane supplies and other accessories of that kind, and it is also going to have a side to it so as to imitate where a river comes into it.

There are often peculiar problems introduced that on a small scale can be studied in this manner, but I do not want to take up the time of my associates who are going to speak.

Mr. O'CONNOR. Is the purpose sought to be accomplished by the creation of this board the coordination of all the governmental activities charged with investigating the water resources of the country for the purpose of coordinating them into one whole and getting the best out of our water resources relating to irrigation, power, reclamation, flood control, navigation—is that the ultimate purpose of this?

Mr. DUNN. Yes, sir; because to leave any one of those services without this service would be unfortunate, and they will have equal opportunities to have the benefit of the laboratory. That is why this tripartite commission is formed.

Mr. HULL. Will this laboratory be able to determine the problems in reference to the reclamation works in the Great Lakes?

Mr. DUNN. Mr. Chairman, it is very heard to predict what kind of a scientific answer you are going to get when you ask the question. Sometimes you do not get any answer; sometimes you have to ask the question in two or three different forms, and the best way to get the answer to those questions is to go to the laboratory first.

Mr. HULL. That is a little indefinite.

Mr. DUNN. I can not make a definite answer; there is no definite answer.

Mr. HULL. We will hear from Doctor Durand.

STATEMENT OF DR. WILLIAM F. DURAND, PROFESSOR EMERITUS OF MECHANICAL ENGINEERING AT STANFORD UNIVERSITY, PAST PRESIDENT OF AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Doctor DURAND. My name is William F. Durand; I am professor emeritus of mechanical engineering at Stanford University, and perhaps I should say for the record that I am past president of the American Society of Mechanical Engineers.

For about 30 years I have been occupied in the investigation of scientific and engineering problems, and in very large degree these problems have been such that they have involved the application of this law of similitude which Doctor Dunn has just spoken of and which I need not more especially describe.

I do wish, however, to state most emphatically that——

Mr. HULL (interposing). I think there are several of us who do not know what that word "similitude" means. I wish you would explain that before you go further.

Doctor DURAND. Let me give a very simple illustration. We have the drawings for a large ship which is going to be 500 feet long. Those same drawings are used to construct a model which is geometrically similar in every respect, with special reference to the underwater form to its full-sized ship. It might be one-twentieth size, one-thirtieth, or one-fortieth, depending on the size of the laboratory and the conveniences available for the investigation with the model.

Then it is known, by principles of the mechanics of fluids, which I can not go into here, that if this model is moved through a body of still water at a speed which is proportional to that of the speed of the full-sized ship in the relation of the square root of the linear dimension, then the physical configuration and the physical relation between the full-sized ship and the ocean in which it moves will be geometrically similar and dynamically similar to the situation in the tank and to the model and to the water in which the model is, and it develops as a result of the application of these same laws that the relation between the resistance of the full-sized ship and the model will be in exact proportion to the volumes of the displaced water in the two cases. In other words, that develops a very simple numerical relation between the resistance of the full-sized ship——

Mr. HULL. In other words, as I understand it, it is to show the relation between the model and the full-sized ship—is that the idea?

Doctor DURAND. If the conditions, as Doctor Dunn said, in nature are reproduced in the laboratory on a reduced scale, then by the application of the known principles of mathematics and mechanics, tested out by experience——

Mr. MANSFIELD (interposing). Then the principal reason for this laboratory is that by using these models and other appliances at small expense, comparatively small expense, in a limited time you can reasonably test out what might otherwise cost millions of dollars and require perhaps many years?

Doctor DURAND. Precisely. We may not be able to get quite as good an answer as if we were to take many millions of dollars and many years of time to answer the question on a full scale of nature, but we can get a sufficiently good answer, and I say without hesitation, without danger of successful contradiction, that the recent progress of marine construction during the last 50 years has been made possible only by the application of this law. No shipbuilder, no naval architect, would for a moment think of designing a ship at the present time without utilizing the principles of similitude. No designer of an aircraft, of an airplane, or of the propeller to drive that airplane, would think for a moment of carrying forward his design without first submitting it to the test of the results which have been developed by exactly these methods of utilizing the principles of similitude.

Mr. HULL. I would suggest that you confine yourself to your regular speech, because your time is limited.

Mr. O'CONNOR. In view of the fact that we have only general debate going on on the floor, I would suggest that we give these gentlemen time enough to present their views.

Mr. HULL. Yes; go ahead.

Mr. O'CONNOR. A hearing is a hearing.

Mr. HULL. We will give you more time.

Mr. CARTER. There is another day to be given to this also. I think we ought to give these gentlemen time.

Mr. HULL. We will give them plenty of time.

Doctor DURAND. I speak with some emphasis, Mr. Chairman, because I have myself for over 30 years been working on these problems and I have been testing out for myself appliactions of this law of similitude largely with reference first to problems involved in naval architecture, and more recently to problems involved in general hydraulics and power hydraulics and aeronautics, and I have a profound and abiding conviction that the principles and the use of the application of those principles of similitude are the best and the cheapest and the most direct way to obtain the information which is desired.

So much with reference to the broad significance of the laboratory. I should like, however, to add one point, and that is simply this, that as much as we honor and respect the achievements of mathematics, that application of mathematics to the phenomena of nature, it results that when we attempt to answer in detail the problems of nature, to investigate them in detail through the aid of mathematics alone—in other words, I mean, with a pencil and a pad of paper—we very soon come to its limitations and we simply can not do it, primarily because we do not know enough about the intimate constitution of matter and the relation in particular of the moving fluid to the surrounding and nearby solid body to permit us to express those relations in mathematical form, and the only possible way in which we can meet the requirements of the problem is to go to some kind of an experiment to ask the question of the configuration itself, to get some liquid and some solid and put them together and see how they behave, and it is either a question of doing it full scale or on a reduced scale, and so as these conditions develop we are able to reach results which are reasonably satisfactory in consequence of these methods employed in the laboratory.

Now, with regard to the second question, that of the location of the laboratory, I should like to emphasize in particular two of the reasons which have been mentioned by Mr. Dunn. I may say that I am entirely in favor of and indorse most heartily the 10 reasons which are adduced by the Secretary of Commerce in support of the location of the laboratory at the Bureau of Standards, but these two stand out, in my opinion, paramount in importance, and the first is this, that this laboratory should be a laboratory for the entire country, for the entire Nation, for all States and for the width of the country from one ocean to the other and from the northern boundary to the southern; and, furthermore, for all types and character of services and problems; and, second, that only by the location of a laboratory in a center of scientific and engineering activity can we obtain that cooperative feature which has so well been brought out by my precedessor.

With regard to the variety of problems, I should like to emphasize this point, that we have lagged behind, as has been said, in the application of this method of the use of models to engineering problems, particularly in the matter of what we may call river problems. We have been reasonably forward in the application of this principle to problems arising in naval architecture, to problems arising in aero-

nautics, and we are coming again to investigate problems in structures in the structure of dams, in articulated structures, in this same way, through the use of small models.

We have lagged, however, sadly in the application of this principle to what we may call river problems, and there Germany has gone far and away beyond us and, in fact, the rest of the world in their recognition of the utility of this particular method, and this is a particularly opportune time for the United States to delay no longer in going forward with reference to the organization and establishment of such a laboratory, because now we can take advantage of all that Germany has done.

There is really no doubt about what we ought to do and how we ought to do it, and there is no doubt about what the laboratory should contain, how it should be built, what its characteristic feature should be, and as to the problems which can be successfully treated in such a laboratory and as to the degree of accuracy and the reliability of the results which can be reached therein. We can benefit by all this experience which has been accumulating in continental Europe, particularly in Germany.

Now, with reference to the breadth of the problems, I wish to point out, in addition to river problems, that there are many other problems, particularly in power hydraulics, in the provision of water supply to large cities and in other directions which are of vast importance the country over, which could have immediate and successful study in a laboratory of this type.

I wish, furthermore, to call attention to one particular problem in which I am personally interested, because this illustrates the point of what I am saying just now. I have recently been brought into close contact with the problem connected with the Colorado River, and I recently submitted a report of some considerable extent to the Secretary of the Interior on the problems connected with the reclamation and control of the lower Colorado River.

Now, suppose that the Boulder Dam should be built. There now lie in the bed of the Colorado River, below the site of the Boulder Dam, 200 or 300 miles of river varying from 300 feet in width to 1,000 in width, with a deposit of silt anywhere from 15 to 20 feet deep to 30 or 40 feet deep and aggregating millions upon millions of tons of silt lying in the bed of that river below the site of Boulder Dam.

If and when Boulder Dam is built, what is to become of that silt? At the present time the river has reached a condition of equilibrium by and large throughout the year between the flowing river and the silt in the bed. When the dam is built the water passing the dam will be desilted. What is going to be the condition of that river bed after Boulder Dam is built and this relatively clear water flows down? It is a most fundamental and important problem which relates to the Colorado River and to the southwest territory, distinctly and restrictedly, and it is a problem which must be studied, and I am confident that many useful indications regarding the study of this problem could be brought about through the aid of a laboratory such as is proposed here.

Mr. CHALMERS. Will you permit a question?

Doctor DURAND. Yes.

Mr. CHALMERS. As to how much water would be desilted by Boulder Dam?

Doctor DURAND. The silt would be deposited in the reservoir above the dam.

Mr. MANSFIELD. And remain there?

Doctor DURAND. And remain there, and the water which flows on will be substantially clear.

Mr. CHALMERS. When the water passes through, when it has been desilted, it will pick up until the point of saturation is reached again and go on with this burden of silt?

Doctor DURAND. Exactly. It will pick up until it has reached the burden which it can carry to the gradient determining velocity, the point of saturation.

Mr. HULL. Will that water, after it goes over the dam, be clear, or will it still be yellow?

Doctor DURAND. It will be substantially clear.

Mr. HULL. After it goes through the dam?

Doctor DURAND. The reservoir will be some 100 miles long and the silt will be deposited as soon as the velocity becomes still. It will at least first be deposited in the upper reaches of the reservoir far from the dam, and the water, as it goes through the power plant, will be at least largely desilted, relatively clear.

Mr. HUDSON. In connection with the location of the laboratory here, with some of the immediate problems ahead of us like the Mississippi flood-control problem, you have not the elements of soil handy to make the tests that would have to be made that you would have at hand if the laboratory were perhaps in the central Mississippi Valley.

Doctor DURAND. So far as that particular item is concerned, of course the soil could be more immediately made available at St. Louis than at Washington, but to my mind that is in a sense a trivial advantage; also amounts of soil sufficient for the purpose can easily be shipped to the laboratory.

Mr. MANSFIELD. To carry that advantage out fully, you would have to have a laboratory at every point where you made a test.

Mr. HUDSON. I understood that that was largely the element of opposition.

Doctor DURAND. The experience in Europe does not seem to confirm that. As my predecessor has pointed out, the present control of the River Shannon is being studied in a laboratory in Stockholm, and likewise problems are being studied in Germany, as Doctor Freeman, I am sure, will tell us later, which relate to other countries in various parts of the world.

The better plan seems to be to carry the problem to the laboratory located under the best conditions for the prosecution of that kind of work, and certainly the Bureau of Standards here in Washington does seem to be the proper place.

I want also in closing to emphasize a point which my predecessors made, and that is the necessity of placing a laboratory of this kind in a focus of scientific and engineering activity. I do not think myself that I ever have come in contact with a problem in engineering, and I have been dealing with them practically all my life, that did not impinge upon other elements of science, and it is exceedingly important that there should be available facilities for the construction of accurate and fine apparatus, that there should be available colleagues in other branches of scientific activity in order that these

collateral and incidental problems may be all brought together and that all of this intellectual activity may for the time being be focused upon this one particular problem, and nowhere else in the United States than here can such a place be found other than at the Bureau of Standards.

Mr. O'CONNOR. Would not the effect of this legislation be to coordinate all of these governmental activities that are investigating water resources of the country and make them a great asset instead of a liability, which they are now?

Doctor DURAND. That is exactly the idea, and I believe that would be the consequence.

Mr. HULL. Does anybody else wish to ask any questions? If not, we will hear from Mr. Grunsky.

STATEMENT OF C. E. GRUNSKY, CONSULTING AND CIVIL ENGINEER, PAST PRESIDENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Mr. GRUNSKY. My name is C. E. Grunsky, consulting and civil engineer in private practice, educated in my technical profession in Europe, in Germany; assistant State engineer of California for 10 years, dealing with flood control, hydraulic mining, irrigation and related problems.

Mr. HULL. Where do you reside now?

Mr. GRUNSKY. In San Francisco. Later I was a member of the examining commission on rivers and harbors for California; still later city engineer of San Francisco for four years, dealing with run-off hydraulic problems of various kinds connected with city affairs. Then I was appointed on the Isthmian Canal Commission by President Roosevelt as one of the engineer members of that board. Thereafter I was consulting engineer in the United States Reclamation Service and advisor to the Secretary of the Interior, and since that time, 1907, I have been in private practice.

Mr. HULL. Now, Mr. Grunsky, go ahead and give us about 5 or 10 minutes.

Mr. CHALMERS. There is no doubt about the fact that the doctor has qualified as an expert.

Mr. GRUNSKY. I thank you.

I wish to emphasize what has already been said by my fellow engineers, and I am going to take very little of your time because I consider it of great importance that you hear very fully from Mr. John R. Freeman, past president of the American Society of Civil Engineers.

Mr. HULL. Do not understand that I am limiting your time. I am only trying to get through and to give all of you a chance to be heard.

Mr. GRUNSKY. I had opportunity last year of visiting the laboratories of Germany. I did it at my own expense, for information that would be of value to me and my profession, and I was very much impressed by the value thereof and by the necessity of having laboratories or, at least, one major laboratory in this country where experiments can be carried out on a larger scale than in the ordinary laboratories that are provided at our various universities.

It is very important that problems connected with rivers and harbors be studied on a small scale so that a large number of tests and

experiments can be made so that what is done is done most efficiently. If our Panama Canal were to be built to-day and locks were required, every feature connected with a lock would be studied in a laboratory first. The advantage of the results from that goes without saying.

Engineers are becoming bolder and bolder every day. They meet with success in building these structures. They build their dams; they make them thinner; they are acquiring more and more confidence in the reliability of the materials with which they build until they get to the danger line and an accident happens. That should be forestalled by the experiments in a laboratory.

When it comes to spillways on the Mississippi River and a structure is erected over which some of the surplus water is to flow, how shall the ground lying back of that structure be best protected? Along those lines experiments are being made at the present time in the European laboratories, because water falling over a weir or a dam has great energy which is expended upon the rock or the other material upon which the structure stands.

I have in times past had occasion to examine a dam under which I could run a pole 15 or 20 feet. The water had undercut the structure and there was danger. Danger of that kind can be avoided by first making tests.

Now, reading this measure that is before this committee, it occurred to me that there might be a little improvement in the language in order to make it somewhat broader. If I have a correct copy before me, I might make this suggestion to the committee for its consideration——

Mr. HULL. What copy do you have? Is it dated April 17?

Mr. GRUNSKY. No; this is dated December 15.

Mr. CARTER. Here is a copy.

Mr. GRUNSKY. I find it inconvenient to suggest offhand an amendment that would apply to the language as at present in the bill, but my thought is this, that the problems that are to be studied in a laboratory of this kind should not be restricted——

Mr. HULL. May I suggest to you that if you have something that you think ought to go into this bill, you put it in writing and give it to the reporter.

Mr. GRUNSKY. I will very gladly do that, but my suggestion relates to this, and I think it is a matter of importance, that a laboratory of the kind that is proposed here should be at the disposal of the engineering profession of the United States, and any engineer, even though he be in private practice, should be permitted to bring his problem to the laboratory and have the necessary studies there made. It should not be confined to merely the engineering activities of the various departments of the Government.

Mr. HUDSON. That is true now of the Bureau of Standards, is it not, and would it not be true of this laboratory?

Doctor BURGESS. That is generally true for many of our activities. Such language was written in the bill originally, but it was thought not necessary to leave it in, so it was cut out. I think there is no question at all but that problems coming from associations such as, for example, the American Society of Civil Engineers, could be studied n such a laboratory as well as problems coming from a Government

bureau such as the Reclamation Service. The board composed of the three Secretaries would decide such questions.

Mr. HULL. Would you not be overloaded with problems if you left it to every single engineer to submit them to you?

Mr. GRUNSKY. I would suggest in connection with that that no problem should be considered in a laboratory of this sort unless it has the approval of the three Secretaries that have been mentioned. There would be no danger whatever of overloading the laboratory with work, but any private engineer may have a problem that is large enough to deserve investigation.

I want to emphasize the necessity of the laboratory. There is no question that it is needed, and no expense should be spared in creating a laboratory that will be as good as the best in the world.

I thank you.

Mr. HULL. Is there any question that any gentleman would like to ask?

Mr. SEGER. If such tests as you tell us about could have been made in connection with the St. Francis Dam, would that dam have gone out?

Mr. GRUNSKY. The situation at the St. Francis Dam is a peculiar one. It is not a question of the structure alone. The structure that was built there was a gravity section dam. Its failure resulted from a combination of the foundation condition and the crack.

Mr. SEGER. But such an investigation of the structure could have been made as you speak of?

Mr. GRUNSKY. In that case no investigation could have been made excepting on a scale as large as the dam itself. Whether or not the dam should have been built there in the first place should have been determined by a proper investigation.

Mr. HULL. Do we understand that if we should have this laboratory, it would not be serviceable in connection with the St. Francis Dam?

Mr. GRUNSKY. There are some problems connected with that that could not be answered in a laboratory.

Mr. HULL. The next speaker is Doctor Freeman.

STATEMENT OF DR. JOHN R. FREEMAN, TWICE PAST PRESIDENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Doctor FREEMAN. My name is John R. Freeman, of Providence, R. I., a consulting engineer. I have been engaged in hydraulic work for somewhat more than 50 years and in many parts of the country and abroad, in Canada, in China, in Mexico.

I am heartily in favor of this bill and very strongly in favor of its being located at the Bureau of Standards. This opinion is the result of a great deal of study going back quite a number of years.

It has been my habit to go abroad once every few years to see what the engineers are doing abroad, in Germany, in France, in England, particularly to study what is going on in the technical schools.

The year before the Great War, I saw the first of these laboratories. It was at Dresden, and the idea was not particularly prominent then, but immediately I saw that it was a great idea.

I called there again four years ago and I was amazed to find that the laboratory had been entirely rebuilt. Then I visited other

laboratories and I visited the laboratory at Karlsruhe in Germany, and I found that they had torn down a laboratory better than any that we had in the United States in order to build a new one, and Doctor Rehbock, the professor of rivers and harbors engineering in charge of the laboratory, told me that every major experiment that he had undertaken had brought about a saving in the cost of structures that was enough to entirely represent the cost of the laboratory and all the apparatus in it.

I visited also a laboratory in connection with the great engineering school just outside of Berlin, and I found there experiments going on for the drainage of the Zuyder Zee in Holland, and I found experiments just completed on a navigation lock for the new North Sea Canal, to be about the same size as those at Panama, and the gentleman in charge, Doctor Krey, told me that the savings from those experiments in building that lock would amount to an equivalent of $600,000 simply from taking the problem into the laboratory and studying it there.

I came back three years ago very enthusiastic about the idea that we ought to have more of those laboratories in this country, and while I was there I said to one of my friends, the secretary of the National Society of German Engineers, a Doctor Mutschoss, the professor of rivers and harbors engineering at the great engineering school in Berlin, this:

"If you can prevail on some of your friends who have been showing me their laboratories to have each one write a description of his laboratory and the researches he had been engaged on in it, I will find some way to get these articles translated into English and published in America. You are 25 years at least ahead of us in America, and the scientific men of the two countries ought to get together again and exchange information in a friendly way."

They took hold of the idea very nicely. They said, "We will not make this exclusively a German book; that would look like propaganda, but we will invite the engineers in charge of that kind of work all over Europe to each make a contribution."

The result was this which I have here (showing the book "The Hydraulic Laboratories of Europe"), and we have completed the translation and it is published under the auspices of the American Society of Mechanical Engineers. If you are interested, I will leave it with you and it will give you a good idea of what a laboratory is like.

Mr. HULL. Do you want to put that in the record?

Doctor FREEMAN. No. I left a copy of it with Senator Ransdell some months ago and he told me he would find it very interesting to show to some of his colleagues. I thought some of you might like to see it.

Mr. HULL. Just so we get the record clear here, do you want to offer that book to go in the record, or just leave it here?

Doctor FREEMAN. Not to go in the record; simply to leave it here for examination.

Mr. O'CONNOR. Is there a copy of it in the Congressional Library?

Doctor FREEMAN. I do not know. I will leave a copy there, if there is not a copy in their files.

Mr. HULL. I think it ought to be. If you will leave it with the chairman of the Committee on Rivers and Harbors, it will be available to us, but it is a little long to put into the record.

Doctor FREEMAN. Absolutely.

This doctrine of models, the doctrine of similitude, has a very curious history. Sir Isaac Newton, in his great treatise on natural philosophy, hinted at it, but it was in such involved language that practically no one got its full force until comparatively recently. It was tried out in a small way in some experiments for the Manchester Ship Canal. Then there was an engineer of rivers and harbors in France who made a few experiments, but it remained for Doctor Engle, at the University of Dresden, to prove its application to practical work. He started perhaps 20 years ago, and the great growth of the idea in Germany and in Europe has been in the last 10 years.

After the Mississippi River floods I prevailed on some of my friends in the American Engineering Society to establish some fellowships of traveling engineers, with a small stipend under which they could go over and study, and there were six of them, mostly junior professors in some of the leading engineering schools, and I went over again last July and helped those men get started and get introduced, and then I visited six or eight of these modern laboratories and I was amazed to see the progress that had taken place in the three or four years since my previous visit.

I was surprised to find that, from their original attention to rivers and harbors, they were getting more into the problems of water power development and into other problems connected with rivers and the problems of turbine design, to getting the last half of 1 per cent in the efficiency of water turbines and getting higher efficiency from pumping machinery.

That is, I found that in each of these great laboratories, perhaps two-thirds of all of their problems to-day are not problems of rivers and harbors, but problems of water power development, of irrigation, of protecting river beds, and problems of that kind.

At the laboratory at Berlin, I found during the summer vacation that it was being occupied wholly for experiments on a power development in Ireland. I found that at Karlsruhe they had five major researches going on, one in reference to the highest dam in Europe, in Spain, and in connection with another investigation, they had a model of the section of a river where they were going to undertake some further improvements for navigation and they were trying to change the course of the river. I found that they had been experimenting on a flood reservoir for the city of Nuremburg, and they made five different models before they arrived at the one they thought would give the best solution of the problem. I have forgotten the saving in cost, but it would be very large, but they were certain they were going to get very much efficiency out of the flood spillway.

At Dantzig I found them experimenting on wave erosion, on a beach similar to that along the New Jersey coast or part of the Massachusetts coast, near Cape Cod. They were imitating waves on a small scale or on a small beach within the laboratory, and it was amazing to see how they could duplicate on this small scale the action of the waves.

All of the authorities there told me that they are becoming more firmly convinced of the application of this method. It was received with a great deal of doubt and hesitation at first, but now practically no important engineering problem, if it has anything to do with rivers or turbine design is taken up by the German engineers or the engineers

of Czechoslovakia or Austria without first putting the problem through the laboratory.

I think the trouble with the statement of the Secretary of War is that they are not posted on the enormous advance going on in those matters during the past 5 or 10 years.

Mr. HULL. Right there, I would like to have you make a statement whether you think the Secretary of War is correct in his statement against this proposal?

Doctor FREEMAN. I think he is wholly incorrect in his statement. I do not know that I could state the matter any better than it has been stated by Mr. Dunn, Doctor Durand, and Mr. Grunsky, but I am very firmly convinced that the Secretary is wrong, and I also know that if he does not take his share of one-third of the problems to the laboratory there will be plenty for the laboratory to do on problems of the Reclamation Service, and if they can be admitted, with the problems of the engineering profession from all over the United States.

Mr. HULL. Do you think that this appropriation will be sufficient to take care of the War Department, or would it be better if we had a larger appropriation and built a larger laboratory?

Doctor FREEMAN. I think that this is all right for a starter. This will give us a laboratory better than anything in Europe to-day.

I found at Zurich, in Switzerland, that they are just starting on a laboratory on which they were planning to spend $250,000, and in general I would say that this appropriation, after making account of the difference in price and the cost of labor, will give us a better laboratory than anything they have there to-day.

Now, I do not believe that any laboratory of this kind is a fixture for all time. They are completely rebuilding those laboratories in Germany and going to a larger scale in some places, and, in some cases, to more intricate apparatus. For instance, at the great laboratory near Berlin, they found that they wanted to attack those new problems. The laboratory has simply outgrown the problems having to do with canal improvement and river improvement, so they are establishing additional laboratories, but the final work, the more precise work, in the doctrine of models will still be carried on——

Mr. MANSFIELD. Are those laboratories Government institutions, or are they in connection with institutions of learning?

Doctor FREEMAN. In nearly every case they have been located at some engineering college, but under Government control, so as to get the advantage of consulting with scientists in the different branches. At Karlsruhe they showed me a photographic apparatus they had developed with the aid of the optical department in the university, but in every case except one or possibly two, those laboratories have been put at some center of scientific research so they could bring to bear on the problems at hand the opinions of scientists on how, for example, to devise a new apparatus or how to treat a certain problem. The one exception to that is a laboratory at Wilhelmshaven, which is purely a harbor laboratory.

Mr. MCDUFFIE. What has been done in this country so far as our greater universities are concerned along that line? Have we not some laboratories similar to that which is here to be constructed by the Federal Government in our greater universities throughout this country?

Doctor FREEMAN. No; I am familiar, I think, with every important college laboratory of hydraulics in the country, and we have nothing that compares with these laboratories in Germany. Our laboratories here are designed mainly for the instruction of students, and they are on a relatively small scale. There are a few admirable ones. There is one at Cornell University. I have worked in that laboratory on researches for the water supply at New York.

There is another good one at the University of Iowa, and they are enlarging it now, but nearly all are on a small scale for this kind of work.

Mr. MCDUFFIE. Will you indicate what will be the approximate annual cost of the upkeep of this laboratory?

Doctor FREEMAN. That is estimated at $50,000 a year, giving them a good start. There has been an estimate made in detail by Doctor Burgess and his assistants as to just how that will be made up.

Mr. MCDUFFIE. Do you think that $350,000 would equip a laboratory with all the apparatus you would need to make your investigations?

Doctor FREEMAN. It would make an excellent start.

Mr. MCDUFFIE. Do you think $50,000 would secure the services of the type of experts that you would necessarily have to have in a laboratory of that kind?

Doctor FREEMAN. I think it will, because I think a great many engineers will come and offer to give time without any thought of compensation just to help the good cause along. I think Doctor Burgess can get all the consulting service of that kind he needs, just as the Bureau of Standards got such services during the war.

Mr. MCDUFFIE. Will you give us your idea as to how many will comprise the personnel necessary to operate such a laboratory as is proposed here?

Doctor FREEMAN. Doctor Burgess has an estimate on that.

Mr. MCDUFFIE. If the Doctor is coming on, we can get his estimate.

Mr. HULL. He has made his statement.

Mr. MCDUFFIE. If I am asking questions asked before, just eliminate them from the record. I was in another committee and could not be here.

Doctor FREEMAN. There is to be one senior mechanical engineer at $5,200; one physicist at $3,800; five associate engineers at $3,000, $15,000; five junior engineers at $1,860, $9,300; one senior laboratory mechanic on instrument construction, $1,860; one laboratory mechanic on model construction, $1,680; two assistant laboratory mechanics at $1,500 each on model construction, $3,000; one minor scientific helper, $900; one junior laborer, $900; one engineering draftsman, $1,500; one junior clerk-stenographer, $1,500; a total of $44,640, and the balance, to $50,000, is made up for material for constructing models.

Mr. KINDRED. On the fundamental question of costs, you have already provided for a sufficiently equipped laboratory, probably, and you have provided for the personnel in that statement you have just read, for experts to begin the work, but have you in mind the rapid development of this institution which would bring about a situation which practically exists in the Veterans' Bureau, in the medical department? I am a physician, and happen to know of that situation, that the medical service is insufficiently paid. Here you are providing for experts, scientific workers——

Mr. McDUFFIE (interposing). At $1,800 a year.

Mr. KINDRED (continuing). And for some engineers. Are you not providing an entirely inadequate amount for the large personnel which you should have and for the best personnel that we can get in this country if we are to compete with the progressive nations which are working along the line of scientific engineering?

Doctor FREEMAN. A great many young men, when they get out of college, are very glad to take positions in the Bureau of Standards as a sort of a post graduate course in completing their education. I think it is true that Doctor Burgess, by some means or other, is able to get good assistants at about half the price they are paid on the outside.

Mr. KINDRED. Are they the best?

Doctor FREEMAN. There are some most excellent men there working for the love of that kind of work, taking their pay in the love of doing that kind of work.

Mr. MANSFIELD. These men do not initiate the work they are doing. They are carrying out the work of others, of the Chief of Engineers of the War Department or somebody of that kind.

Doctor FREEMAN. Yes; and I imagine that if the Department of the Interior had a hydraulic problem, they would take their best hydraulic engineer and send him over to advise with these other men and tell them what he wanted them to do.

Mr. HULL. In other words, the departments would use their own men in this situation and it is not necessary to have these high-priced men because they have already got them?

Doctor BURGESS. The list of personnel is in accordance with the classification act.

Doctor FREEMAN. Yes.

Mr. McDUFFIE. And the probabilities are that this little board we are beginning to create now will not develop into a very huge organization in the future?

Doctor FREEMAN. No; I have no idea of that.

Mr. CHALMERS. It is all under the direction of the Bureau of Standards?

Doctor FREEMAN. Yes.

Mr. SEGER. And the Budget.

Doctor FREEMAN. Yes. I take it it would be handled just as the Bureau of Standards is carrying on a great deal of work for the War Department, Navy Department, and many other departments, and in collaboration with some of our large commercial organizations which send over a research associate.

Mr. HULL. On rubber tires, and things of that kind?

Doctor FREEMAN. Yes.

Mr. O'CONNOR. Would not the effect of this bill, if enacted into law, make for a great survey of the water resources of the country from every imaginable standpoint and ultimately coordinate them into a great system whereby we would secure beneficial results?

Doctor FREEMAN. My impression is that the people at this hydraulic laboratory would answer the questions asked them and they would not be looking for new worlds to conquer.

Mr. O'CONNOR. Would not the result of their investigations result in more beneficial uses of the water resources of the country?

Doctor FREEMAN. Absolutely; it would tend to better development of our water resources.

Mr. HULL. Is there anything further that you want to state?

Doctor FREEMAN. Nothing, except that I said that the Engineering Society had sent over half a dozen young men, mostly junior professors, to study in these European laboratories, and I happen to be on some of those committees and those men make monthly reports and I have here some of the monthly reports. This one is from a young man studying at the hydraulic laboratory at Stockholm, Sweden, and there are a good many photographs of the problems in operation there.

Mr. HULL. Would you like to leave that with the committee?

Doctor FREEMAN. I will.

Mr. HULL. We would like to have anything you care to leave here.

Doctor FREEMAN. I would like to get it back later. I might say that at Stockholm they are carrying on investigations for a large irrigation power project in India. The whole world now is coming to Germany, and, later, to Stockholm, to carry on these problems.

Mr. CHALMERS. Where in India?

Doctor FREEMAN. I do not remember the name. It is given here, but this modern method of taking hold of these problems, to build a model and then by this mathematical doctrine of similitude, or dimensional analysis—that is another name for it—it is a new tool in the hands of the engineer and one which permits you to try half a dozen variations.

Mr. HUDSON. You and others have mode most interesting statements here, but we are confronted immediately with two or three very large problems in which, it seems to me, this matter of hydrualics is very largely concerned. We have the Mississippi River flood control project before us, and we have a compensating problem, to somehow or other stop this so-called diversion—some of us call it the stealing—of the waters of the Great Lakes.

Mr. HULL. I move that that be stricken from the record.

Mr. HUDSON. We have the St. Lawrence deep waterway project. Will the establishment of this laboratory at this time be of service in connection with any of those projects?

Doctor FREEMAN. It will help every one of them. I happen to be the engineer who was called on particularly to make a report on the regulation of the Great Lakes. You will find a copy of it in the Library of Congress; perhaps you have a copy, and in order to design one of the structures that I put into that I got them to patch up their apparatus the best they could at the Institute of Technology and make experiments on one piece of apparatus that I felt was needed in that work, and I think that this projected laboratory would help in every one of these problems.

It was the fact of the Mississippi River flood which induced our American Engineering Society to send these men abroad to study for a year in these laboratories.

Mr. HUDSON. Then we ought to have started the construction of this laboratory immediately after the flood last year, instead of wasting all the time we did in the discussion of some of these things.

Doctor FREEMAN. We would have been just so much farther ahead.

I may say further that Mr. Grunsky and I are members of a committee appointed by the American Society of Civil Engineers to come here and urge the passage of this bill, and that the laboratory be established in the center of scientific activity.

Mr. HULL. If there are no further questions of Doctor Freeman, we will call on Mr. Harrington.

STATEMENT OF JOHN L. HARRINGTON, OF KANSAS CITY, MO., PAST PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mr. HARRINGTON. My name is John L. Harrington; senior member of the consulting firm of Harrington, Hart & Ash, Kansas City, Mo.

Mr. HULL. It is now pretty close to 20 minutes after 12 and we have two other men to hear. If you can confine yourself to eight minutes, go ahead.

Mr. HARRINGTON. For the record, I am the past president of the American Society of Mechanical Engineers, and appear here both in an individual capacity and principally for the American Engineering Council, which has for its function service of this kind.

My principal personal work is the building of large bridges, of which I have to my credit something more than 400 in the rivers of the United States. I have four under construction at the moment on the Mississippi River, and I have, therefore, to deal with the hydraulic problems that are involved in our large rivers and in situations of that kind, and I wish to address myself, rather than to the theoretical side, to some direct and pertinent points which illustrate the service which such a laboratory would offer to the country.

In the year 1903, there was a flood in the Kansas and Missouri Rivers simultaneously at Kansas City, which caused an unprecedented condition and a loss of something like $15,000,000 or $20,000,000. Immediately there was a drainage district organized to levee and protect the Kansas River; a member of the United States Army Engineering Corps was employed as its consultant, and it proceeded to reconstruct the Kansas River for the purpose of preventing the damage resulting from such a flood again.

It was the dictum of that board and its adviser that some of the bridges than on the river should be removed because the number of piers in the river were such an impediment as to cause overflow and serious damage. The bridge of the Kansas City Southern Railway was removed and replaced at a cost of about half a million dollars, on the theory that three piers in the river would cause great damage whereas two piers would pass, and the matter went through the courts and the bridge was removed.

A corresponding order was issued to the Missouri Pacific Railway to remove its bridge which had six piers in the river. Fortunately for the Missouri Pacific Railway, who were my clients, a flood came in the meantime and we were able to determine by actual measurements what was the increase in the elevation of the water due to the presence of those piers in the river, rather than to rely upon theoretical matters, and that bridge is still in the river because it was demonstrated by actual measure that there was no real impediment there by those piers, and half a million dollars was saved to the railroad company.

The half million dollars was lost in the case of the other railroad company because it could not be demonstrated to a court by mathematical means that that water would not be raised. The presence of a flood which came at intervals, of course, enabled us to make the check.

I might cite another instance of a practical character. A few years ago a large causeway was destroyed at Corpus Christi, Tex., by reason of the typhoons in the territory. It became my function a few years ago to build a bridge in the upper end of Mobile Bay in which we were subjected to the same conditions and had to build a large causeway which had to be topped by the water unless we were to drown the city of Mobile. The investigation into how to build that causeway so that the water may roll over it at intervals and still not suffer damage was a pretty expensive one. It went to the measurement of corresponding slopes in Florida and investigation of the Corpus Christi disaster and the investigation of many points along the coast where structures had or had not stood, and finally to the adoption of slopes for that causeway to resist that condition. They have had a typhoon over it and they have resisted the condition, but it was a matter that could have been settled in comparatively short order in a laboratory had we had a laboratory available.

The question of the materials used, of the soils employed, has been raised here as pertinent to the matter. The soils along the Mississippi River are about as various as the humans. There is every known kind of soil. A soil may be used in a laboratory at Washington that would meet the conditions at one point on the Mississippi and would not meet them at another point 5 miles away. It has got to be done with the materials particularly involved at the point in question.

Mr. HULL. Let me ask you a question. Do you think that when they get into this question of flood control on the Mississippi River, they will have to establish some kind of a laboratory out there to determine what soils they will meet, or would they bring the soils in here?

Mr. HARRINGTON. They could bring the soils here just as well as to any other point. The soils are varied along the various parts of the river.

Mr. HULL. What quantity of soil would you have to bring here?

Mr. HARRINGTON. A very modest quantity to use in a laboratory, because you would be conducting your investigation on a small scale.

Mr. HULL. A carload?

Mr. HARRINGTON. That would be abundant for that sort of purpose. The conditions of the soil at Vicksburg, for instance, where we are putting in a bridge at the present time, are totally different from those at Cape Girardeau, at New Orleans, or at Alton.

Mr. O'CONNOR. The Army engineers and the Mississippi River engineers are familiar with that fact, are they not?

Mr. HARRINGTON. Surely they are; they have lived there. I make these comments regarding this broad problem because it is a broad problem of "cut and try" at the present time. The "cut and try" should be taken out of it as far as possible by a determination which I believe could be satisfactorily made in a laboratory of this kind.

I am heartily in accord with my predecessors in the view that a laboratory of this kind should serve a broad and not a narrow purpose. It is suitable for serving a great many purposes and not

simply the purpose of assisting rivers and harbors work. Of course, that is a very important function; I can not stress it too highly.

Mr. HULL. Do you think that this bill, as it is written, will provide a laboratory large enough and extensive enough to go ahead?

Mr. HARRINGTON. I think it will do to begin with. I do not think it will be large enough in the end. I think it will grow, and this will be a comparatively moderate beginning, because the direction of its growth should be determined by the development of the work. I think it would be a mistake to provide too large an equipment to begin with, because you would not know how wisely to use it. I think that a moderate beginning is a wise beginning. I will say frankly that I think you will go very much further. I think you will spend many times this amount on the laboratory before you are through.

I want to answer the question asked by this member here——

Mr. CHALMERS. That is Mr. McDuffie, from Mobile, Ala.

Mr. MCDUFFIE. I am the fellow that nearly got drowned.

Mr. HARRINGTON. There is this question that may be answered, as to the character of service that may be obtained by the small sums available here. I want to say frankly that governmental agencies are accustomed to paying pretty small salaries to its men, and you can not get, as you well understand, the highest type of talent for that kind of a salary.

Mr. CHALMERS. You can not get the highest type of experience, but you may have the talent here.

Mr. HARRINGTON. You will have here in this laboratory the men who will carry out the work which men of large experience and broad experience plan. Neither can you ever employ for service in this laboratory men of the highest type of experience, of the kind that you ought to have, but, fortunately for you, you are able to draw upon the ability of those men from the beginning without charge, and you can call upon such men as Mr. Freeman and Mr. Grunsky and a dozen others that I might name who have had a very large experience and who will gladly give their time and services to the setting up of these problems and the planning.

Mr. MANSFIELD. And they benefit from it.

Mr. HARRINGTON. They benefit from it. They want these things solved. They know what the problems are; they know how to state them and to organize the work.

Mr. HULL. In other words, you consider this laboratory a builder of science for these men?

Mr. HARRINGTON. Exactly, sir; that is why we want it; that is why we are here.

Mr. MCDUFFIE. What does the Chief of Engineers of the United States Army think of this project?

Mr. HULL. We are going to have to continue this hearing and we will have the Chief of Engineers here. The Army wants to be heard, and we will hear them to-morrow.

Mr. HARRINGTON. I want briefly to make this suggestion. Regardless of what the Chief of Engineers of the Army thinks, and I have a very great admiration for the Army engineers; I am in contact with them constantly in connection with my bridge work; they are a fine group of men, who know their business and are doing it well, and I have nothing but commendation for work of the engineers of the

Army, but this field is a good deal broader field and it demands a very broad service. It will serve only one phase of the problem if it serves only the work of the United States engineers.

Mr. HULL. Will you be kind enough to give your name and your address?

STATEMENT OF L. W. WALLACE, EXECUTIVE SECRETARY AMERICAN ENGINEERING COUNCIL, WASHINGTON, D. C.

Mr. WALLACE. Gentlemen, the American Engineering Council is an organization composed of about 25 national, State, and local engineering societies, having a combined membership of 43,000, an organization set up for the avowed purpose of having a means through which engineers may express their views regarding engineering questions of a national character, as an instrument through which that professional group is endeavoring to render a public service, and all of these men who have testified this morning are associated with the American Engineering Council through their representative organizations.

Mr. HULL. We will give you about eight minutes.

Mr. WALLACE. I shall take less, I hope. The American Engineering Council, some three or four years ago, was somewhat instrumental in getting Mr. Freeman and Senator Ransdell together on this question of the national hydraulic laboratory, so the council has given three or four years' careful study, under the guidance of Doctor Freeman, to this question. We come to you, therefore, as a result of careful, engineering study and investigation into this question, and I think, gentlemen, at this point that it is quite proper to say that Mr. Freeman was too modest to say that the five or six young engineers are in Europe to-day under scholarships through money that Mr. Freeman has given for that purpose.

Mr. Freeman has contributed to three of the leading engineering societies of this country something in the neighborhood of $100,000 to defray the expenses of these scholarships, and the engineering societies are back of that movement; all a manifestation of the fact that the engineering profession fully appreciates and realizes the great need for such a scientific laboratory as is proposed in this bill; and the American Engineering Council therefore wants to go on record very emphatically in favor of the establishment of such a laboratory and that its establishment be in the Bureau of Standards, and that concludes my remarks, Mr. Chairman, with this request, to save your time, that I may be permitted to submit for the record a list of numerous indorsements for this laboratory.

Mr. HULL. We would be very glad to have them.

Gentlemen, we have one more doctor here. Do you want to remain and hear him?

STATEMENT OF DR. S. W. STRATTON, PRESIDENT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. HULL. If you will confine yourself to about 8 or 10 minutes, it will help us to complete our program for to-day in a short time.

Doctor STRATTON. I will confine it to about two or three minutes.

Mr. HULL. You need not be in a hurry.

Doctor STRATTON. My name is S. W. Stratton, formerly director of the Bureau of Standards and now president of the Massachusetts Institute of Technology.

Mr. HULL. Your home is in Boston?

Doctor STRATTON. At Cambridge, Mass.

I once heard a lecture in college that I never have forgotten, and that is if you want to know how to plow, ask a farmer. You have had here this morning the men of this country who are best suited by experience to tell you what is being done and what is needed in this country. They know, and I wish to indorse most heartily every word they have said.

There is this one point that I would like to add something to, which has been touched upon by nearly every speaker, and that is the great importance of having work of this kind done in a scientific atmosphere, where you can bring to bear upon it workers in almost every line. There is no question whatever as to the bureau getting cooperation and consultation of the engineers, but it is another thing to have close by it and working with it the practical men, with the group of scientific investigators. It is essential, absolutely essential, and the location in a scientific center is vastly more important than the geographical location. That is insignificant.

Another thing that has not been brought out about the Bureau of Standards is that this work largely consists of measurement after the problem has been established, and you have at the bureau the best institution, perhaps, in all the world in the field of physics, chemistry, and engineering. It is their business to know how to measure and to measure well, and they will do this problem correctly with the assistance of engineers.

Now, gentlemen, I can not say much in addition to what these men have already said so well.

Mr. O'CONNOR. Under the terms of this bill, would not the Secretary of Commerce, and the Secretary of the Interior and the Secretary of War be permitted to assign to the service of the board the eminent engineers that they have?

Doctor STRATTON. Certainly. The Bureau of Standards has many illustrations of that kind. The bureau has always had the very best cooperation with all departments in the Government service.

Mr. SEGER. Does the Massachusetts Institute of Technology have much of a course on hydraulics?

Doctor STRATTON. No, sir; a course in the usual kind of hydraulics to which Doctor Freeman has referred. It is now considering the addition of this sort of hydraulics to its course. It should have done so long ago. If so, it will be the addition of equipment of this kind. on a smaller scale, which is intended to teach the men who will go into this laboratory and other laboratories, and will be limited, of course, in the scope of its work to those problems which are necessary to teach men.

Mr. HULL. Gentlemen, the War Department will want to be heard, and we have our colleague, Mr. Lineberger, who would like to address you for a few minutes, and if you remain we will get through with him and then we will adjourn until to-morrow morning at 10.30.

STATEMENT OF WALTER T. LINEBERGER

Mr. LINEBERGER. My name is Walter G. Lineberger, consulting civil engineer, a member of the American Society of Civil Engineers and American Institute of Mining Engineers, and for four years a member of this committee.

I will be very brief.

I followed this bill and this idea for several years. I am heartily in favor of the bill. It seems to me that it is an opportunity to substitute that which every engineer and every citizen wants to substitute in asking engineering problems, practice as against theory.

The engineering problems of the country in the maritime, industrial and other fields, in the age in which we are now living, are more complex than ever before. The structures are larger than they were in the earlier development of the country. More money is involved and a larger number of lives are at stake in the case of the failure of a large engineering structure. All of that is aside, or course, from the economic question involved.

Europe is much more advanced than we are in this thing. I was very much interested in what Doctor Freeman had to say, because I happened to have been through the great engineering laboratory just outside of Berlin a few years ago in company with one of the great German professors in charge of that laboratory there, and I believe that this is the proper and scientific way to attack this problem.

Now, I had a thought that perhaps will not be of value, but I think that by studying these problems in model—and that is what the doctrine of similitude is; it is a similar thing, only on a much smaller scale where it can be studied and observed on a laboratory basis—would perhaps be of great value indirectly and directly to this committee. The problems of the silting of harbors, which is certainly a very fundamental question in the consideration of all river and harbor projects in this country, because it involves the question of maintenance, might be studied with great advantage in such a laboratory as this, and by having this in the Bureau of Standards it would be the proper place for such an activity, because it is already a vast scientific laboratory, as has been brought out, and there the physicists and scientists connected with the Bureau of Standards would be available for the study of collateral problems which would develop in connection with this particular laboratory.

I might say that the rank of the engineering schools is pretty generally predicated upon the facilities which they have in this regard. The Massachusetts Institute of Technology and Rensselaer Polytechnic Institute, in which I was formerly a student, and all the greater engineering schools of the country have long since realized that their reputations, the records of their graduates, depend largely upon the laboratory facilities which are available to them in connection with their engineering course.

Now, engineering is just like any other profession. The work must be continued on through life, because engineering problems are changing all the time. We are in the heart of the nation, where engineers foregather and where the activities of this bureau would be available to the various committees of Congress as well as to the citizens of the country, and it seems to me that this bill should receive

not only serious but favorable consideration at the hands of this committee.

Mr. HULL. Now, gentlemen, it is growing late.

Mr. CHALMERS. May I make a brief statement? I am not sure that I can be here to-morrow.

I think that this is one of the most important projects that has ever been before our committee and, as Doctor Burgess has said, the time is short. They are now holding hearings on the deficiency bill, and this bill has passed the Senate and, Mr. Chairman, if we pass a resolution to-morrow after hearing the Chief of Engineers, you, as acting chairman of the committee, could call it up any morning and have it pass the House, so as to get the matter before the Committee on Appropriations in the deficiency bill.

Mr. HULL. It has been my thought to have the Army engineers here to-morrow and Senator Ransdell and, if it is the wish of the committee, I would suggest that we adjourn until 10.30 to-morrow morning and that you all be on hand and help to move this thing along. We would like to adjourn at noon.

Mr. HUDSON. Would it not be wise for Mr. Burgess to be here?

Mr. HULL. I will ask them all to be here.

I think the committee ought to extend a vote of thanks to these gentlemen for the information we have received this morning.

(Whereupon, at 12.45 o'clock p. m., the committee adjourned until Friday morning, April 27, 1928, at 10.30 o'clock a. m.)

HOUSE OF REPRESENTATIVES,
COMMITTEE ON RIVERS AND HARBORS,
Friday, April 27, 1928.

The committee met at 11 a. m., Hon. William E. Hull presiding.

STATEMENT OF HON. JOSEPH E. RANSDELL, A SENATOR FROM THE STATE OF LOUISIANA

Mr. HULL. Senator Ransdell, we will be glad to hear from you.

Senator RANSDELL. Gentlemen, I appreciate this opportunity of saying a few words to you about this in my judgment very important matter.

Mr. HULL. Perhaps General Deakyne would like to hear your statement.

Senator RANSDELL. Yes. I think this matter is of very great importance to the War Department.

I will preface my remarks by saying that I have been interested in this matter for several years. I received my principal inspiration from Mr. John R. Freeman, a very eminent man, who, I understand, testified before you yesterday, and I am sure he made a good impression upon you. He has always made a wonderful impression upon me.

I introduced a similar bill to this in the Senate several years ago, and at that time had rather elaborate hearings in support of the measure which are embodied in the report which is attached to the Senate bill which is now under consideration by you gentlemen, which

passed the Senate some days ago. Those hearings were held in September, I believe, 1922, in January, 1923, and May, 1924. They were in the main favorable to the idea of a hydraulic laboratory. The bill was favorably reported at that time, but no action was taken.

I have continued my interest in this measure, and it was intensified very naturally by the terrible flood of last spring in the Mississippi Valley, about which we have all heard so much. When this bill was reintroduced we did not consider it necessary to hold any elaborate hearings, as we had already gone so fully into it three and a half or four years ago, but we did ask the Commerce Department, which is in charge of the Bureau of Standards to look into the matter as fully as possible and to make an elaborate report on the bill. Mr. Hoover wrote to Senator Jones a letter endorsing the project in very strong language and I assume that letter was read to you yesterday.

Mr. MANSFIELD. It is published in the report.

Senator RANSDELL. Yes, it is published in my report, but I assume it was read. If not, I want to embody it in my remarks.

Mr. CARTER. It was referred to, Senator, yesterday, but not read.

Mr. HULL. We read all three of those letters from all three of the Secretaries.

Senator RANSDELL. Then I do not care to take up your time, gentlemen, about what you already know. Attached to that letter was what I would call a catechism relating to the needs and purposes of a hydraulic laboratory. It was attached to Mr. Hoover's letter, and if that has not been embodied in your report, I would like to have this, because it is very clear. It starts out by this question, "What is a hydraulic laboratory?" And then it answers it, and then it says, "What Federal field services would be interested in the establishment of a national hydraulic laboratory?" And so on. There are several printed pages, beginning at page 4 of the report, in support of the bill. It comes nearer being an A, B, C proposition in regard to this important matter, than anything I have ever seen.

Mr. HULL. If you would like that to go in the record——

Senator RANSDELL. I would like to have that go into the record. There are four or five printed pages.

Mr. HULL. Then we will make that a part of the record.

Mr. MANSFIELD. Also Mr. Hoover's letter.

Senator RANSDELL. Yes; Mr. Hoover's letter, with this attached to it.

Mr. HULL. Mr. Hoover's letter was read yesterday.

Mr. CARTER. Mr. Chairman, you are in error about Mr. Hoover's letter being read in full. It was only an extract or two which was read.

Mr. HOUSTON. It is my recollection that the 10 reasons were read.

Mr. CARTER. The 10 reasons were not given. They were referred to.

Mr. HULL. What did we have about that, Doctor Burgess?

Mr. BURGESS. We did not read the letter, Mr. Hull, from Hoover.

Mr. HULL. Then you mark the things the Senator wants to put in, and we will not duplicate it.

(The matter indicated by Mr. Burgess for the record is as follows:)

The Secretary of Commerce has indorsed the bill with the changes above noted, and his report thereon is printed below:

DEPARTMENT OF COMMERCE,
Washington, March 18, 1928.

Hon. W. L. JONES,
Chairman Committee on Commerce,
United States Senate.

MY DEAR SENATOR: In reply to your request for a report on bill S. 1710, authorizing the establishment of a national hydraulic laboratory in the Bureau of Standards of the Department of Commerce, I inclose a revision of S. 1710, which I am informed by the Director of the Bureau of the Budget is not in conflict with the President's financial program.

The revised wording provides for a board with the three Secretaries of Commerce, War, and Interior to determine projects for the laboratory, and also increases the estimate from $300,000 to $350,000 to provide for permanent equipment.

There is an urgent need for a national hydraulic laboratory equipped to carry out hydraulic experiments on an adequate scale. I am satisfied that such a laboratory at the Bureau of Standards would be of great service to the Nation and that it would soon repay the investment many times over through the savings effected in the cost of hydraulic structures resulting from the information gained through laboratory tests. Such savings have already been demonstrated by the work of several hydraulic laboratories in Europe, where great emphasis is being placed upon the value of the results obtained from experiments with models.

A national laboratory of this kind would be of direct value and assistance to all Government field services concerned with hydraulic questions, such as the Mississippi River Commission, Federal Power Commission, Coast and Geodetic Survey, Board of Engineers for Rivers and Harbors, Geological Survey, Reclamation Service, and the Department of Agriculture.

I wish to emphasize the fact, however, that the work of the hydraulic laboratory is primarily and essentially of a laboratory nature. The various services named above are, so far as hydraulic problems are concerned, essentially field services, and for this reason I believe that the work of the hydraulic laboratory could be most effectively carried out at the Bureau of Standards, working in close cooperation with the field services.

It should be pointed out that there is a fundamental difference in point of view of the engineer and scientist. The engineer is charged with the execution of material projects and the handling of men, the scientist's duty is to study and discover principles in science and its applications, which may be taken over by the engineer.

Under the proposed scheme of a hydraulic laboratory at the Bureau of Standards, the field services would bring their problems to the laboratory which would then, from several possible alternatives, determine from their experiments what is the best solution scientifically, and the one which gives the most promise from the economic and financial point of view. The field services would then take the solutions of problems and apply them in the field. The two groups, scientists and engineers, are thus doing those things for which they are best qualified by training and experience. There is no interference, but on the contrary, the most effective kind of cooperation.

It is desirable that the national hydraulic laboratory should be under civilian control, staffed by professional men with civilian status and permanent tenure.

General Jadwin in his report on flood control to the Secretary of War, December 1, 1927, states, paragraph 143:

"Measurements and observations on our large rivers supply the best hydraulic data on the flow of such streams, since actual experiments with full-sized structures is preferable to experience with small-sized models. However, on occasions questions relative to the flow of water can be worked out by small-scale experiments. Such experiments may be useful in some of our lock and dam design, etc."

Experience abroad has shown that on the contrary the quickest, most effective and least expensive method of answering many river problems is to put the problem first into the laboratory. It may be expected that in general it will take several years and several million dollars for the river itself to answer a question, whereas in the laboratory an answer may often be obtained in a few weeks

at a cost of a few thousand dollars. It is not proposed that this laboratory shall be a toy, but it will be a building 450 feet long, containing facilities based on European experience, adequate to answer in a satisfactory manner many problems relating to water flow.

The advantages of establishing the hydraulic laboratory in the Bureau of Standards may be summarized as follows:

1. The bureau already possesses a large concrete flume, 400 feet long, which can be made an integral part of the hydraulic laboratory. This flume has already been extensively used for testing water current meters for the various field services mentioned above.
2. A suitable site for the laboratory is available at the Bureau of Standards, involving no additional expenditure for land.
3. Power facilities for driving the pumps and other equipment are adequate.
4. The water supply at the bureau is adequate because the steadiest working conditions are obtained by recirculating the water.
5. The facilities for developing the necessary instruments used in hydraulic measurements are excellent and the shop equipment for such work is adequate.
6. The hydraulic staff of the laboratory if located at the bureau would have the great advantage of close contact with men in other branches of science and engineering. The European experiences have demonstrated the advantage of a laboratory located in a scientific center.
7. The underlying principle of the proposed hydraulic laboratory is research, which is in entire accord with the organization and purposes of the Bureau of Standards.
8. Civilian direction and staffed by professional men with civilian status with permanent tenure.
9. In the Bureau of Standards the laboratory will be centrally located, accessible to the other departments, and will be a service laboratory for them.
10. The bureau has had a long and successful experience in cooperating with other Government establishments and the public.

I am inclosing herewith a memorandum in the form of questions and answers in which the need for a national hydraulic laboratory is more fully set forth.

Yours faithfully,

HERBERT HOOVER.

THE NEED FOR A NATIONAL HYDRAULIC LABORATORY IN THE BUREAU OF STANDARDS

WHAT IS A HYDRAULIC LABORATORY?

A hydraulic laboratory is a building especially arranged for investigating the physical laws which define the motion of water, and for studying, by means of models and other special equipment, engineering problems arising in connection with the measurement, control, and disposition of large quantities of water, and the utilization of water for irrigation and power purposes.

The fundamental conception underlying experimentation by means of models in a hydraulic laboratory is this: If the model demonstrates that the conditions existing in a harbor, for example, can be reproduced typically by the ebb and flow of tides in the model, then it is possible, by placing regulating works in the model, to show the changes that will be brought about in the harbor if these regulating works are built. The effectiveness of proposed regulating works can thus be determined in advance by means of model experiments at small expense, and the most efficient and economical design selected from a number of proposed plans.

WHAT FEDERAL FIELD SERVICES WOULD BE INTERESTED IN THE ESTABLISHMENT OF A NATIONAL HYDRAULIC LABORATORY?

The office of the Chief of Engineers, which includes the Mississippi River Valley Commission, the Board of Engineers for Rivers and Harbors, and the various district engineer offices; the United States Geological Survey; the United States Coast and Geodetic Survey; the United States Reclamation Service; the Federal Power Commission; and the United States Department of Agriculture.

General Jadwin in his report on flood control of the Mississippi recommends the establishment of a hydraulic laboratory in the office of Chief of Engineers. Many other Federal field services are, however, actively concerned with hydraulic problems. Furthermore, many States and municipalities are confronted with

special hydraulic problems relating to river control, municipal water supply and sewage disposal. Finally, the civil and mechanical engineers of the country are in urgent need of a suitable laboratory for the study of water-power development projects and conservancy systems. All of these needs could be advantageously met by the establishment of a national hydraulic laboratory on an adequate scale. The research carried out in a hydraulic laboratory is essentially different in character from engineering field work. It is in fact laboratory work, and as such could be most advantageously carried out at the Bureau of Standards where the facilities of the laboratory and the services of a skilled staff would be available to all concerned.

WHAT HYDRAULIC LABORATORIES ARE THERE IN THE UNITED STATES?

The Engineering Foundation in 1922 published a descriptive directory of the hydraulic laboratories in the United States (Publication No. 5) in which these laboratories are described in some detail. Most of these laboratories are located at our colleges and universities and are designed primarily for collegiate instruction. There are a few commercial hydraulic laboratories; some of these, such as the Allis-Chalmers Manufacturing Co. and S. Morgan Smith Co., give their attention entirely to the development and testing of their own hydraulic machinery and take in no outside work; others, such as the Holyoke Waterpower Co., make outside tests of hydraulic turbines. A number of the university laboratories have contributed substantially to hydraulic research along lines for which they were equipped. In general, the university laboratories are of very modest dimensions and the equipment has been selected primarily for purposes of instruction. There is not among them at present a single laboratory equipped to carry on experiments in river or harbor hydraulics.

WHAT KIND OF EQUIPMENT WOULD THE HYDRAULIC LABORATORY HAVE?

In the first place, it should be emphasized that the building itself must be adequate in size. In the hearings before the Senate subcommittee in 1922–23 the fact was emphasized that the work needs to be undertaken on a scale of magnitude and a scope of inquiry that are not practicable for the comparatively small hydraulic laboratories of the universities of the country. The proposed laboratory is about 450 feet long and 60 feet wide. These dimensions are necessary to provide room for the large equipment to be installed and to provide adequate floor space for the numerous special models of hydraulic structures that will be built for test purposes. A proposed plan of the laboratory equipment is shown in drawings in Report 1240 from the Senate Committee on Commerce (67th Cong., 4th sess.). The plan includes two large flumes, a river flume, and a hydraulic flume.

The river flume is a tilting tank 250 feet long 20 feet wide and 3 feet deep, hinged at one end, with provisions for a wing extension on one side. In the river flume a model to scale of some part of a river which it is desired to study could be built up. The general laws governing erosion and deposition of sediment could be studied, the effect of various kinds of bank protection could be investigated, the proper location of spur dikes could be determined, and the relative merits of various shapes for the ends of spur dikes and the inclination of the dikes to banks could be tried out.

Adjacent to the river flume there would be a hydraulic flume 240 feet long 15 feet wide and 15 to 25 feet deep, which would be used in tests of models of hydraulic engineering structures, such as weirs, dams, spillways, "fall increasers," various types of energy absorbers and hydraulic jumps, baffle piers, sluice gates, tunnel entrances, bridge piers, etc. Plate-glass panels set in the walls in the hydraulic flume at intervals will provide special opportunity for studying the circulation.

Provision will be made for a large measuring tank for use in the accurate determination of the coefficients of discharge of the weirs and other special water-measuring equipment used in the experiments on models. A large supply tank will also be provided and so arranged that any required head up to 40 feet may be maintained with precision. A group of circulating pumps of graduated sizes will provide a total flow when required of 600 cubic feet per second.

In addition to the above equipment, a large space will be available for the installation and study of special models of various engineering projects. These models will be of temporary construction and will be taken down when the study is completed and replaced by other models as the work progresses.

IN WHAT WAYS WOULD A NATIONAL HYDRAULIC LABORATORY BE USEFUL TO THE FEDERAL FIELD SERVICES ENGAGED IN HYDRAULIC WORK?

Hydraulic laboratory experiments would be of value to the following services:

(*a*) The Office of the Chief of Engineers, in connection with the design of dams, locks, spillways, diversion works, bridge piers, and hydraulic-power installations and in the development of works to reduce the erosion of river banks, increase the scour of river beds and similar problems; in brief, in connection with all projects or changes in projects for engineering works designed to improve rivers and harbors.

(*b*) The Federal Power Commission, in connection with such laboratory research as may be required in its field investigations of water-power projects, and the effect of one water-power development upon another.

(*c*) The United States Geological Survey, in connection with the development, through laboratory research, of more accurate methods and instruments for the measurement of the flow of streams and the effect of turbulence and variable direction of flow on such measurements; the experimental determination of the laws governing the transportation of débris, such as stones, sand, silt, and clay, down river channels; the laws governing the carrying capacity of streams for the transportation of débris in relation to slope, depth, width, and curvature of the stream.

(*d*) The United States Bureau of Reclamation, in connection with the design of engineering structures used in the development of national irrigation projects, such as dams, spillways, and hydraulic-power installations; the determination of coefficients for measuring the flow of water in channels and canals, and the coefficients of discharge through head gates and for overflow dams; transition losses in canals where a change in size or shape occurs; intake and outlet losses for flumes and canals; and the form and method of construction of drops of various kinds, where water must be dropped to a lower level and provision made for dissipating the power thus developed.

(*e*) The United States Coast Survey, in connection with the interpretation of tidal action along our seacoasts, the formation and movement of bars in navigation channels, the measurement of the velocity of tidal currents, and the erosion resulting from wave action on our seacoasts.

(f) The Department of Agriculture, in connection with the determination of the discharge coefficients of drain tile; the effect of size, shape, roughness, and slope on the carrying capacity of canals, ditches, and flumes used in distributing water for irrigation purposes; improved means for the measurement of water supplied to the individual farmer for irrigation purposes; the development of more economical methods of pumping water to higher levels for use in irrigation; methods of designing bridge piers for Federal highways to insure against undermining, and to provide the least resistance to the flow of water and the free movement of ice.

IS THE BUREAU OF STANDARDS NOW COOPERATING WITH THE FEDERAL FIELD SERVICES WITH REFERENCE TO HYDRAULICS?

The Bureau of Standards now calibrates all the water-current meters which are extensively used by the field services for measuring the velocity of river and tidal flow. Special equipment has been installed at the bureau for this work the major feature of which is a flume or testing tank 400 feet long in which the meters are towed through still water at known speeds. Much work of this kind is done every year for the Mississippi River Commission, the various district engineer offices, the Reclamation Service, the Geological Survey, the Coast and Geodetic Survey, and the Department of Agriculture. The Bureau of Standards also tests cement and other structural materials employed by the Reclamation Service, Department of Agriculture, district engineers, Panama Canal Commission, and other services in building dams, spillways, bridge piers, and other hydraulic structures. It has also made many tests for the Federal field services regarding the strength of concrete, steel reinforcing rods, cables, hawsers, chain and other engineering supplies, as well as special investigations, such as the effect of alkali on concrete.

HOW WILL RELATIONS WITH THE FIELD SERVICES BE SET UP?

The purpose of the hydraulic laboratory is to help the field services in the analysis and solution of their problems. This cooperative relationship can probably be most effectively established and maintained by the aid of an advi-

sory committee on hydraulics, consisting of representatives of all the Federal services concerned with hydraulics, and, perhaps, including one or more prominent outside hydraulic engineers as well. This committee could determine which problems were of most pressing importance and the order in which they should be undertaken. Advisory committees of this character have been of decided assistance and value in other lines of work at the Bureau of Standards.

In the case of any particular project the field service would supply the laboratory with the necessary data concerning the topography at the site of the project, together with plans of the proposed installation. The staff of the laboratory would build a model to scale in accordance with these plans, study its performance, and determine the effect of any modifications that gave promise of improving the performance or of lessening the cost of construction of the full-scale structure. The engineer in charge of the project would have every opportunity to witness the model in operation and the effect of such modifications in the original design as might be made and would have a complete report upon the performance of the models. He would then be in a position to make the most effective use of this information in the design or development of the full-scale project. The laboratory work would be carried out by men experienced and skilled in the measurements of models of hydraulic projects. The application of the results of this study to the full-scale project would be the function of the hydraulic engineer in charge of the project. The work of the laboratory staff thus supplements the work of the engineer but their fields of activity stand clearly apart.

WHAT ARE THE VIEWS OF AMERICAN ENGINEERS REGARDING A NATIONAL HYDRAULIC LABORATORY?

The testimony of a number of prominent American engineers engaged in hydraulic development was given at the hearings held September 8, 1922, and January 10, 1923, pursuant to Senate Joint Resolution 209 to establish a national hydraulic laboratory. The following excerpts are made from their statements:

John R. Freeman, Providence, R. I.:

"To-day there does not exist on the American continent even one laboratory for the study of river-training problems.

"I have come here to speak in favor of such a laboratory mainly because of my observations of the terribly threatening conditions during a tour of inspection along the lower Mississippi a few months ago during the highest flood ever known and because of my profound belief that such a laboratory would be extremely helpful toward better, cheaper, and broader protection against flood disaster by giving to American engineers more precise scientific knowledge than they now possess upon the operation of water currents in eroding, transporting, and deposing sediments; in causing river banks to cave and thus breaking down levees, and in creating bars of sand and gravel which obstruct navigation.

"The chief objects of this proposed laboratory are the promotion of economy in certain large expenditures and greater safety to life and property. * * *

"Tests with models in the laboratory are proposed to be used hand in hand with observations in the field or river, 'on the full-sized specimen,' as a means of obtaining the underlying scientific fact or law of nature with greater precision. The river training problems to my mind are just now the most important among the many for which this laboratory would be useful. * * *

"And, entirely apart from these matters of flood protection and river training, there are many problems of great importance in municipal water supply, in conservation of water for power development, in the safe design of bridge abutments and piers; problems in design of canals and pipe conduits for irrigation, in tests for improving the shape of boats, in developing more accurate apparatus for measuring velocity of currents, in the more precise formulation of certain hydraulic theories, etc., in which such a laboratory could be extremely useful. * * *

"Hydraulic laboratories as a means for the study of problems of river training are highly esteemed among the skilled engineers of Europe."

Morris Bien, Reclamation Service: "I know that it (a national hydraulic laboratory) would be of great advantage to the work, as it would assist us in making more economical use of water and, directly or indirectly, reduce the cost to the settlers who, by law, are required to repay it. So we are strongly for it."

J. A. Ockerson, Mississippi River Commission:

"After 43 years of active work by a corps of scientific men in nature's own laboratory, the river itself, it is believed that the commission has accumulated a volume of data covering practically all of the varying phases of the physics of

the Mississippi River which are necessary to a full understanding of the regulation and control of the river. There is no 'woeful lack' of data, as has been charged.

"It is believed to be wholly impracticable to obtain any further useful data regarding the Mississippi River problems by the use of laboratory models, and the reason for this belief is to be found in the following briefs of conditions to be met with.

"When I speak of 'models' I speak of the whole scheme of hydraulic laboratory work. * * *

"As far as the hydraulic laboratory experiments are concerned, I can not conceive of anything that it could do that would materially modify the plans that are now under way. * * *

"My statement is not an objection to a laboratory; it is simply a statement to the effect that we do not think it would help our problem materially."

Clemens Herschel, New York City. "My argument is, and long has been, that there are needed in the United States several endowed hydraulic laboratories in which experiments and observations may be made and taken continuously, and by trained observers making this their life work: * * *; and I am hoping that the United States Government will make a beginning in this direction, principally for the use and benefit of its Government departments. * * * The conclusion that I wish the subcommittee to come to is that a United States hydraulic laboratory should be made one of the permanent institutions of the country. * * *"

John C. Ralston, Spokane, Wash.: "It is peculiarly the province of government to develop through its trained agencies those scientific criteria which must be ascertained in some manner if its greater hydraulic problems are to be solved expeditiously and economically."

John L. Harrington, Kansas City, Mo.: "I feel that the more exact, more satisfactory, more scientific knowledge would enable us to design works with greater accuracy, with greater certainty, and with greater economy, and therefore the work is well worth while. There is no wisdom, certainly, in a nation of this magnitude, having problems of this magnitude before it, leaving in the unknown matters of such consequence to it. We have too long overlooked scientific matters of this kind."

Gardner S. Williams, Ann Arbor, Mich.: "As I conceive it, the greatest purpose of this laboratory will be to make a study of the handling of the floods and flows of these rivers, which vary from very low flows to very high ones; and that is something that nobody has attempted yet."

H. C. Ripley, Detroit, Mich.: "In the improvement of our harbor entrances it is a matter of the greatest importance to determine the relative merits of the various systems which are being used. * * * This is a matter that could be definitely settled in a laboratory at small expense.

"I think the statement is entirely conservative to affirm that, had the most suitable plan been adopted for the deepening of our bars, 50 per cent of all the money expended by our Government for this purpose in the past 50 years could have been saved, and in the future many millions of dollars can be saved annually by the definite solution of this problem."

C. C. Williams, Urgna, Ill.:

"This work needs to be undertaken on a scale of magnitude and a scope of inquiry that are not practicable for the comparatively small laboratories of the universities of the country.

"Not only in flood control and river training is this investigational work in hydraulics needed, but also in irrigation engineering, hydraulic power development, and in navigation. * * *

"Experimentation and trial of devices can be carried forward in such a laboratory as that proposed at a cost that is negligible compared with the cost of trial and error in actual construction."

Arthur E. Morgan, engineer for Miami flood-control works: "I have long contended that the Government needs just such an institution."

R. D. Johnson, New York City: "I wish I might transfer to you the mental picture, such as I have acquired during my years of practice, where there is portrayed a great array of blunders running into enormous expense, due for the most part to a lack of sufficient understanding of the vagaries of water in its flow, and propagation of pressure waves."

J. M. Howells, San Francisco: "Such a laboratory would be of particular value for gaining exact knowledge of the laws applying to the flow of water in rivers and their erosion and deposit of material forming their beds."

C. E. Grunsky, San Francisco:

"In the matter of facilities for research work there should not be the slightest hesitancy in providing the desired facilities, provided only that the reasonable need for the same can be demonstrated and that there be not unnecessary duplication. * * *

"While I am here calling attention to the need of such a laboratory as an aid in the solution of river problems, it goes without saying that in such a laboratory there should be facilities for the study of all hydraulic problems with adequate appliances."

W. F. Durand, Stanford University, California:

"In my opinion Mr. Freeman, as the initiator of the measure, has made out, in the hearing on September 8 last, a clear and convincing case for the laboratory and one which is not in the least shaken by the expressed skepticism of Mr. Ockerson.

"I am familiar with many of the problems mentioned by Mr. Freeman as adaptable to study in the laboratory and with the great need which exists for extending or rechecking much of the now available information regarding these problems.

"In my opinion no finer contribution could be made to the general study of many of our most important hydraulic problems than through the provision of a laboratory of the general character as proposed, and I am satisfied that, having in mind the vast sums of money which the Federal and State Governments must inevitably spend on hydraulic problems during the coming years, the provision of such a means for their study will be found a measure of genuine economy."

A. T. Safford, Lowell, Mass.: "I wish to favor the national hydraulic laboratory along the lines suggested by Mr. John R. Freeman, not only because of the many and difficult problems which it would help to solve, but because of the utter inadequacy of private and school laboratories to do this work."

F. L. Stuart, New York City:

"Within the last few years, in connection with some problems of a hydroelectric project, costing $65,000,000, with which I was connected as consulting engineer, it was found necessary to make a model of the proposed discharge of a large canal into a forebay, which in turn discharged direct to the turbine tubes, in order to cut down friction, etc. For lack of precedent or scientific knowledge intake models and other models had to be made for experimentation, which cost a considerable amount of money.

"It is a fact that, while great strides have been made in late years in certain branches of hydraulics, the field needs just such research as is proposed. From my own professional experience I know the field of usefulness to the public for such laboratory is very great."

L. W. Wallace, secretary Federated American Engineering Societies, Washington, D. C.: "The Federated American Engineering Societies has become actively interested in the passage of the proposed bill. It earnestly hopes that Congress will realize the great need and will make available the necessary facilities for meeting the need."

A. H. Markwart, San Francisco, Calif.: "Hydraulic studies and investigations should be encouraged when we consider the importance of hydraulics in connection with water-power plants. The work of a national hydraulic laboratory of broad scope, such as I understand is proposed, would be very valuable in this connection to say nothing of the many other extremely important branches of hydraulics which would be benefited by it."

B. F. Groat, Philadelphia, Pa.: "Only certain ideal cases of flow can be attacked mathematically. Actual cases have been attacked with success only by experiments upon models, and it is remarkable how few engineers know what laws have been established in relation to models and their full-size prototypes. In most of the tests on models the experimenter has been ignorant of the laws and has gone ahead with his tests in his own way, frequently to find that he must repeat with correct proportions before he can get exact results. One of the most valuable functions of the national hydraulic laboratory will be to stop all this misdirected effort and render it unnecessary for each engineer to study his model before he can study his problem by means of his model."

C. F. Rand, New York City:

"A number of leading hydraulic engineers of our country, men of wide experience in several branches of hydraulic engineering, have repeatedly requested engineering foundation to undertake studies on a practical scale of a number of important hydraulic problems. * * *

"In view of this interest and experience in the hydraulic science and the importance to the country and its industries, commerce, navigation, and agri-

cultural interests, engineering foundation believes that such a national hydraulic laboratory as is proposed could be made to contribute benefits for which the cost of the laboratory and its operations would be a small expenditure."

Thaddeus Merriman, New York City:

"I desire to heartily indorse this project and to say that in my judgment it would lead to a much needed advance in the art of hydraulics not alone in all matters related to the flow of rivers but also on every public work and private undertaking which has to do with water in motion.

"This proposed national hydraulic laboratory would, in effect, constitute an additional department in the Bureau of Standards and would extend the activities of that bureau into a field where new information and data are most urgently needed. This field reaches out and includes every city and hamlet of our own country where water is used or where the destructive effects of floods are sought to be minimized.

"On page 47 of the printed proceedings of the hearing, Mr. Ockerson, in referring to certain experiments on models of the Gilboa Dam, which dam we now have under construction stated that '* * * variations in the relative proportions gave quite different results.' In order that an erroneous conclusion may not be drawn from this statement, I would say that the results of the experiments in question were most satisfactory and that without them we could not possibly have carried the design to a satisfactory conclusion.

"I may say further that in order to perfect the design of the spillway of the Ashokan Reservoir we found it necessary to experiment with scale models and that these models were more helpful than all of the theoretical considerations that we could bring to bear.

"Twenty years ago I was connected with the construction of the Boonton Dam for the water supply of Jersey City, and the design for the spillway of that structure was also based on experiments with models. Without these experiments the design could not have been brought to the state of perfection which was actually attained.

"The establishment of a national hydraulic laboratory would, from every point of view, be more desirable. By adding to the sum total of hydraulic knowledge and information, it would begin to pay dividends from the start, and at a merely nominal cost would contribute more toward the economic development and control of the waters of the Nation than could any other agency.'

WHAT IS THE SITUATION REGARDING HYDRAULIC LABORATORIES IN EUROPE?

In comparison with the United States, the hydraulic laboratory situation in Europe presents a remarkable contrast. Despite the unfavorable economic conditions which have prevailed since the war, several of the hydraulic laboratories in Germany have either been completely rebuilt or greatly enlarged. This is due to the appreciation of the fact on the part of continental engineers that hydraulic laboratories are not luxuries but absolute necessities. In other words, engineers have come to realize that a great deal can be learned about a proposed installation by means of carefully conducted experiments in a hydraulic laboratory, and that it is simply common sense to utilize this information in designing hydraulic engineering works.

The work in the German hydraulic laboratories is by no means confined to German projects. For example, to the Karlsruhe laboratory have been brought problems from Brazil, from Peru, from Egypt, from Italy, and from Holland.

A new hydraulic laboratory on a large scale is now being built in Switzerland at a cost of over $250,000.

WHAT IS THE NATURE OF THE WORK BEING CARRIED ON IN EUROPEAN HYDRAULIC LABORATORIES?

A comprehensive statement regarding this subject will be found in a recent German book on the hydraulic laboratories of Europe, published in 1926. This work contains a description of the hydraulic laboratories at Darmstadt, Dresden, Stockholm, Graz, Charlottenberg, Berlin, Wilhelmshaven, Braunschweig, Karlsruhe, Vienna, Danzig, Brunn, Munich, and Leningrad, together with an account of the experiments which have been carried on at these various institutions as well as some of the work which was in progress at the time the book was written. There is also an account of some American researches in hydraulics by Mr. John R. Freeman. It was through Mr. Freeman's initiative and support that this volume on the hydraulic laboratories of Europe was prepared, which contains over 400 copiously illustrated quarto pages written by the leading

hydraulic engineers of Europe. The following list, which is by no means complete, will serve to give an idea of the nature of the problems which have been investigated in these laboratories:

1. Experiments on the protection of bridge piers against undermining: Experiments showed that scour occurred at foot of upstream face, instead of below the piers as formerly believed. On this basis a method for protecting piers was successfully developed.
2. Effect of low water training walls on the deepening of the navigable channel of rivers.
3. Formation of the bed of straight or slightly curved streams with shifting bottoms.
4. Currents on sandy bottoms of rivers under the influence of cross dikes. Material was found to be deposited principally during high-water stage. Thus the fundamental law was established that cross dikes must be so arranged that the currents carrying sediment can enter dike openings with least possible interference from the river.
5. Formation of mud deposits at old entrance of Kaiser Wilhelm Canal.
6. Investigation of flow phenomena accompanying the closing of the Zuider Zee by a dam. This is probably the most comprehensive hydraulic investigation ever undertaken. Still in progress.
7. Designing of the flood-water discharge structure for the Friedland power plant on the Alle. The original design was much simplified and the cost of construction materially reduced. Full-scale structure was carried out in accordance with experimental results. The same is true for the Sihl Weir in Zurich.
8. Prevention of scour below flood spillways of Friedland plant on the Alle. Good agreement of all phenomena with models on different scales. Constructed on basis of model experiments. Behavior wholly satisfactory during great floods of 1924.
9. Determination of the proper construction of a brush-closing dam.
10. Flow through drainage sluices.
11. Distribution of detritus in river branches.
12. Protection of stream beds against scour below drops and weirs: Experimental results show that best protection consists of a depth of water downstream sufficient to allow the formation of a stationary surface eddy. Rehbach discovered from his experiments that the formation of such surface eddies is greatly facilitated by the use of a toothed sill, with the vertical faces of the teeth upstream. This toothed sill has since been widely used in Germany and Peru.
13. Development of structures of diverting water from streams.
14. Experiments on models of river Weser.
15. Experiments on models of the Elbe River.
16. Improvement of the river Jade.
17. Canal model research.
18. Ship locks for canals.
19. Dams across valleys.
20. Harbor engineering, involving the ebb and flood of the tide; use of moles to increase scour of channel; shoaling of channel.
21. Beach erosion by waves in successive tides.
22. Effect of ebb and flow on an unprotected river mouth; shoaling of river mouth.
23. Spacing of bridge piers.
24. Location of breakwaters for the harbor of Heligoland. Experimental results were fully confirmed by good results obtained with completed structures.
25. Location of jetties in fourth channel entrance at Wilhelmshaven.
26. Stability of permeable earthen dams; hydraulic gradients within earthen dams; high earth dams.
27. Motion of water in steep flumes.
28. Motion of water in groin bays.
29. Corrective wash sill at canal intakes to prevent entrance of sand and gravel.
30. Rock-fill dam across the Moldau above Prague: Experiments showed that the proposed construction would endanger the safety of the city of Prague.
31. Experiments on the absorption of energy at high weirs or dams, by means of (*a*) tumble bays; (*b*) projecting stones on downstream face; (*c*) concrete baffle piers in stream bed; (*d*) baffle sills; (*e*) cascades.
32. Wave erosion due to raising level of Lake Siljan. Changes taking place during ice-free season of year, amounting to 230 days, could be represented in model in 80 minutes.
33. Investigations of Stockholm Harbor. Salt water at bottom makes a difference in the currents.

34. The discharge of a suppressed weir for different heights of tail water.
35. The elasticity of clay.
36. The Influence of the width of tank on the rating of current meters.
37. The design of the harbor for Larvik, Norway. (International competition won by researches conducted here.)
38. The study of erosion produced by waves.
39. The pressure of ice against dams.
40. The flow of water in sand.
41. The influence of the diameter of the rod on rating current meters.
42. The pressure of waves against vertical walls.
43. A study of the currents in the harbor of the city of Stockholm, Sweden.
44. A pilot tube study of the distribution of the velocity in a pipe.
45. Verification of Rehboch formula for suppressed weir of 0.5 meter length.
46. The discharge of a 90° V notch.
47. Model tests to show the best means of passing timber through dam at Hammarforsens Kraftwerk.
48. Model tests on discharge from Sikfors power plant.
49. The Bann River project in Ireland, model tests.
50. Study of discharge coefficients of Portna Dam in Ireland.
51. A comprehensive study of the Chendorch Dam in India using model scales of 1:36, 1:42, and 1:96.
52. Tests and critical studies of current meters.
53. The loss of head through trash racks.

WHAT SAVINGS HAVE BEEN EFFECTED BY HYDRAULIC EXPERIMENTS?

Experiments connected with the design of a large ship lock, carried out by the hydraulic laboratory in Berlin, led to a saving as reported by the contractors amounting to $500,000. A simplified construction for the emptying and filling of another lock, which was developed through experiment, led to a saving approaching $100,000. A model experiment in connection with two ocean-going vessels resulted in an improvement which according to the owners saved $25,000 of coal each year. In remodeling the third entrance to Wilhelmshaven to prevent the channel from silting up, a submerged groin was decided upon as the result of model experiments. An expenditure of $30,000 for this groin saved in five years $110,000, which would otherwise necessarily have been expended in dredging to keep the entrance open.

In the Swedish hydraulic laboratory at Stockholm studies have been made of the Hammersfarsen Dam to find the most effective way of discharging logs over the dam. A form of construction was finally developed in which the "logs" in the model would not jam under any conditions, no matter which way the wind was blowing. The model was on a scale ratio of 1:200, and the model and experimental work cost about $1,000. The engineer in charge estimated a direct saving in cost of $70,000 through the elimination of a large part of the original design, aside from the great advantage of securing a satisfactory installation.

Professor de Thierry states the work done in European hydraulic laboratories has already effected economies in engineering construction that exceed the total cost of establishing all the laboratories. At Karlsruhe a number of practical problems of large magnitude have been taken from out of doors into the hydraulic laboratory, and the saving in structural cost due to the information gained is said to have exceeded in each case the total cost of the laboratory and the research. This laboratory has thus paid for itself many times over. But these savings, great as they are, are small in comparison with the savings which ultimately result from building hydraulic structures in accordance with the best design that can be developed from laboratory tests and field experience, for most hydraulic structures are built for centuries to come. If the design is adequate they give efficient service with minimum interruptions and minimum expenditures for upkeep. Herein lies the great economy.

ARE MODEL EXPERIMENTS RELIED UPON IN OTHER BRANCHES OF ENGINEERING?

The great value of model experiments in the related fields of aerodynamics and naval ship design has long been recognized. The War Department, the Navy Department, the National Advisory Committee for Aeronautics, and the Bureau of Standards all have large wind tunnels devoted to model experiments on aircraft and related structures. Great advances in the efficiency, stability, and safety of aircraft have resulted from model experiments made in wind tunnels in this country and abroad. No aeronautical engineer would think of building a full-

scale airplane or airship involving new departures in aerodynamic design without first thoroughly testing the performance of a model of his craft in a wind tunnel. Experience has taught that the omission of such model tests may result in useless costly structures, if not in disaster.

Again, in the field of naval engineering, model experiments have long been recognized as a means of effecting large economies. From the results of the experiments on models, it is possible to select the form of hull which requires the minimum power to drive it through the water at a given speed. A saving of coal is thus made on each day's run during the whole life of the ship. No naval engineer would now lay down a hull of new form without the results of model tests to guide him in the design. A number of great testing basins have been constructed for this specific purpose, including the famous Froude tank at Teddington, England, the great German tank at Hamburg, the large naval basin at the Washington Navy Yard, and a similar basin at the University of Michigan.

The wide application of model tests in these fields and the extensive employment of the results of such tests in the design of full-scale structures speak convincingly for the value and usefulness of model experiment. The same underlying principle, the law of dynamic similarity (hydraulic similitude), is equally applicable to hydraulic problems.

WHAT IS "HYDRAULIC SIMILITUDE"?

The term refers to conditions which must be observed in experiments with a model in order to reproduce faithfully the phenomena occurring in full-scale performance. If, for example, the model has been constructed to a linear scale of 1/100, the proper velocity of the water in the model is 1/10 of the full-scale velocity, while the volume used per second in the model is only 1/100,000 of the full-scale volume. The roughness of the surface of the model should be reduced in proportion to the reduction in linear dimensions, and the friction due to débris carried by the stream must also be taken into consideration.

A complete analogy between model and full-scale structure is never attainable, but the agreement will as a rule be sufficiently close for practical purposes if model experiments on different scales lead to the same conclusion.

As the flow of water under field conditions is almost exclusively turbulent in character, it is important not to reduce the scale to the point where the flow in the model takes on a filamental character. In other words, the model must not be too small. Filamental flow in the model is sometimes avoided by exaggerating the vertical scale of the model in comparison with the horizontal scale. The frequent necessity of using exaggerated models in small-scale experiments emphasizes again the great desirability of providing one hydraulic laboratory in the United States in which models may be built to suitable scales.

ARE LABORATORY EXPERIMENTS USEFUL IN CONNECTION WITH RIVER-CONTROL PROBLEMS?

Concerning this question Professor Engels, director of the oldest river-hydraulics laboratory in Europe, says:

"The regulation of the larger débris-carrying streams now ranks in all countries among the most important of problems in river hydraulics. It affords one of the most profitable and at the same time one of the most difficult undertakings and one in which experimental models are found to be especially elucidating. Such experiments as have been made in this direction point to the desirability of further experimentation, preferably on as many different scales as possible, and especially on as large scales as possible. A complete analogy between model and stream is never attainable. Nevertheless, even for the small-scale models, and with appreciably exaggerated scales, the shape of débris deposits appearing in models bears a close relation to débris deposits as found in nature. It is necessary, however, to undertake this most important problem with larger models than have been used heretofore, and hence with ampler funds commensurate with the value of the results to be expected. It is advisable also to investigate the movement of débris in some of its phases by means of separate experiments which are not confined to any given scale. It should once more be emphasized that in the transference of any flow that is affected by friction, it is necessary to exercise the greatest of care."

The experiments on models made by Osborne Reynolds, the English physicist, on the River Mercy have demonstrated that the characteristic natural configurations of river bottoms may be reproduced in the model even though the model is exaggerated as regards scale. Reynolds's models had a horizontal scale

of 1 to 31,800 and 1 to 10,600, while the vertical scales were 1 to 960 and 1 to 396, respectively. Concerning the larger model Reynolds says:

"The calculated period of this model is 80 seconds, and experiment bears this out, any variation leading to some tidal phenomena, such as bores or standing waves, which are not observed in the estuary.

"On one occasion the model was kept going for 6,000 tides and a survey was then made of the state of the sand. And this will be seen to present a remarkable resemblance to the charts of the Mersey (illustrations not shown); in fact, the survey from the model presents as great a resemblance to any one of these charts as they do to each other.

"This method of experimenting seems to afford a ready means of investigating and determining beforehand the effects of any proposed estuary or harbor works; a means which, after what I have seen, I should feel it madness to neglect before entering upon any costly undertaking."

There was at this time a divergence of views as to whether a canal for deep-draft seagoing vessels from Liverpool to Manchester was to be preferred to regulating the Mersey. A controversy arose particularly as to whether certain training works for the upper mouth area would cause the lower mouth area to silt up, and thus injure navigation from Liverpool to the ocean. Finally there was a question whether the outer bar, in its existing location, could be deepened by means of training works. Vernon-Harcourt undertook the answer of these questions by model experiments. After the existing conditions had been reproduced in his model, the training works proposed for the upper mouth area were installed. These works, under the action of tides in the model, resulted in the deposition of an extensive bank near the mouth of the Mersey and the formation of a bar opposite Liverpool.

After the model had again been restored to its original state, training works were installed in the lower mouth area, and these works brought about an improvement in the navigable depths over the outer bar. The practical outcome of these experiments with models was the rejection of the proposed training works for the upper portion of the Mersey and the construction of a ship canal along the southern bank.

The improvement of the mouth of the river Seine was another problem undertaken by Vernon-Harcourt with the aid of models. Surveys of the mouth of the Seine were available which showed the conditions that prevailed before the building of existing training works; also surveys that were made subsequent to the construction of these works. Vernon-Harcourt said:

"If the model succeeds in demonstrating that the originally existing conditions will reproduce themselves typically; and if, moreover, by placing regulating works in the model, the same changes can be reproduced that were brought about by the engineering works actually built, then I am sure that I can take the third and most important step, namely, to investigate with every promise of success, the prospective action of the proposed work for extending the training dikes toward the mouth."

He satisfied himself that the model complied with the requirements imposed, and then proceeded to test out in his model 10 different plans that had been submitted, all aimed at bringing about material improvement. His experiments led to the practical conclusion that none of the proposed projects would accomplish the desired results, and in consequence all of them were rejected. While a successful solution of the problem was not reached in this case, the experiments prevented the expenditure of large sums for engineering works which would have been found useless on completion.

WHAT ARE SOME OF THE PROBLEMS TO BE STUDIED IN A NATIONAL HYDRAULIC LABORATORY?

The national hydraulic laboratory would be directly and immediately useful in connection with problems arising in the flood-control program of the Mississippi River. General Jadwin in his report of December 1, 1927, to the Secretary of War has indicated his belief that hydraulic laboratory experiments may be useful in connection with lock and dam design on the Mississippi. Experiments would also be of value in connection with the design of the proposed great spillways near New Orleans, especially with reference to the protection of the foot of the spillway to prevent erosion and undercutting. Any proposed changes in the present path of the river (river training) should also be studied in the hydraulic laboratory by means of models before work on the river is actually undertaken.

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Experiments in Germany on models of the River Rhine have shown such experiments to be of great value.

But a national hydraulic laboratory would not be limited to studying the problems of the Mississippi alone. The recent disastrous floods in New England, resulting in loss of life due to the sudden failure of dams, reservoirs, and spillways shows the great necessity for the broader study of such problems. The lower reaches of the Colorado River present problems of outstanding importance. Our harbors and harbor entrances, subject to the ebb and flow of tides provides another class of problems, such as silting of channels, formation of sand bars, and methods of inducing scour. Finally, there is the important class of problems which will be presented by hydraulic engineers in connection with the commercial water-power developments of the Nation, including dams, spillways, tunnels, conduits, canals, forebays, gates, penstocks, and tailraces as well as the development of more efficient water wheels and turbines.

In general, each specific problem in river or harbor control or water-power development requires detailed individual study and treatment, depending on its particular local conditions. It is the concensus of opinion of both European and American hydraulic engineers that this preliminary study of the project can be most effectively carried out by means of models in an adequately equipped laboratory. (See Senate hearing on S. J. Res. 209, September 8, 1922, and January 10, 1923.) Not only do such experiments aid in establishing the most efficient and economical design, but large savings in cost of construction are often accomplished.

The above presentation has dealt broadly with the problems which would be presented to a national hydraulic laboratory. The following list (see Rept. 1240, Senate, 67th Cong.) gives in more detail the character of the problems which could be studied to great advantage in a national hydraulic laboratory:

1. An investigation of Thompson's theory of scour at river bends due to spiral flow.
2. An investigation of the path of material scoured out from the concave shore at a bend, whether moved across the river or to a downstream sand bar.
3. Study of straight versus curved river channel for Missouri River conditions.
4. Study of curved versus straight channel for a deeper river, as for certain bends on the lower Mississippi.
5. Best inclination to bank and best shape of end for spur dikes in a straight river channel for producing minimum scour at ends of spur and best shape for preventing undermining a submerged spur by scour.
6. Relative merit of permeable and impermeable spur dikes of various forms.
7. Best form for subsurface dike reaching from bed to slightly above lower water but submerged at high water, and thence extended up the bank by thicket of willows or other trees.
8. Development of shape and construction of cross section of spur dike faced with stone riprap for minimum cost.
9. Necessary distance between spur dikes in relation to width of river for maintaining straight alignment and protecting shore between spurs.
10. Formation and travel of sand waves in straight and curving rivers and relation of same to navigable low-water channel.
11. Study the effect of the coarseness of grain as between fine sand and coarse gravel in its relation to the upbuilding of cross-over bars on curved rivers.
12. Study the action of the Haupt reaction jetty and its limiting curvature for efficient action.
13. Study for economizing cost of bridging a river by construction of "Bell-Bunds" similar to those developed in India, with study of minimum distance between abutments and proper curvature of alignment.
14. Investigation of obstruction and backwater caused by bridge piers and of tendency to undermine same by swift current.
15. Form of bridge-pier base and abutment for producing minimum scour on the bed, combined with a maximum of stability.
16. Miscellaneous studies in training a river like the Missouri or Platte, within erodible banks and bed, in the most economical way for flood relief, by causing it to dig itself deeper, so as to minimize the need of levees, and to carry its sediment forward to the sea with minimum deposition en route.
17. Best form of harbor jetties to minimize obstruction of entrance by littoral currents by carrying sand.
18. A study of maximum bottom velocities consistent with the stability for various sizes of sand grain and various qualities of adhesion.

19. Transportation of larger débris by rivers, and extensions of the Gilbert California experiments to broader conditions, larger pieces of débris, and higher velocities.

20. Investigation of the truth of Kennedy's law on movement of sand and silt in suspension.

21. Develop the law of back-water effect from dams and obstructions in straight or curving channels.

22. Investigation of fluid-filament theory of parallel flow versus vortex motion near sides at various velocities.

23. Distribution of velocity for various qualities of roughness of surface, particularly near sides and bed of stream of flume.

24. Study of vortex motions and boils caused by obstructions at bottom or by collision of currents.

The following experiments, which could be made in the river flume, relate to flow in artificial channels, such as canals, flumes, sewers, culverts, and large pipes partly filled.

25. An extension of the Darcy and Bazin experiments of 60 years ago to other shapes of channel and to greater velocities of flow and with various definite forms of roughness or surface.

26. Effect of twisting or spiral currents upon loss of head.

27. Loss of head with water carrying nearly a maximum load of sediment, in comparison with clear water.

28. A test of the Eads theory as to the maximum percentage by weight of sediment of various sizes of sand grain which can be transported at a given velocity. The probabilities are that nowhere on the Mississippi or even upon the Missouri is the water saturated with sediment, and that much higher percentages of sediment could be carried in a regular channel, if only it could be dug up from the bottom by the velocity and kept moving, in a straightened river.

29. Determine the relative propositions of sediment that can be carried in suspension at various high velocities when walls of conduit are relatively smooth and when roughened or thrown into eddies by spur dikes.

30. Determine more precisely the relations of roughness to laws of flow. (This can be readily done by tilting trough, over a wide range of velocities, by changing the depth, or the speed of pump, or by control by its discharge valve.)

31. Develop formulas of discharge for sewers, or conduit pipes, partially filled to various depths.

32. Effect on velocity or loss of head caused by various percentages of the wetted perimeter much smaller than the whole, being rough.

33. Laws of loss at sudden enlargements.

34. A study of tidal rivers in which the action of the rising tide on the river flow is simulated by water introduced at downstream end of flume.

35. Test the effect of wave transmission for various depths and forms of channel, and study effect of pulsations of flow upon said waves and sand-bar formation.

36. Determine the law of flow for the "bore," or "cloud-burst" type of flood wave, at various inclinations of bed.

37. Repeat the J. B. Francis "whitewash experiment" under various conditions, for determining course of threads of current.

38. A model of the mouths of the Mississippi on a horizontal scale of about 1 to 100 might prove very instructive in studying out the most efficient means of making the South Pass available for deep-draft steamers with a minimum of dredging.

39. Possibly also some extremely useful information could be had by experiments on the model of the spillway proposed 6 miles below New Orleans, from the Mississippi to Lake Borgne, as to the results that would be achieved in flood relief and subsequent silting or absence of silt in the river mouth.

40. From the printed descriptions of what has happened and is liable to happen again in the delta of the Colorado River below Yuma, Ariz., in relation to a change of the river's course that might endanger the Imperial Valley, some experiments on a model of a portion of this river, with a dike protected by "groynes" or "retards" might be very useful for determining the cheapest and most resistant form.

For the weir flume the following immediately suggest themselves:

41. Extend the Francis Weir formula by new experiments to greater depths up to 5½ feet with crest 15 feet long, or to higher depths with shortened crest.

42. Try out in great variety the effect upon accuracy of measurement of swirls and irregularities of flow in the current approaching a standard weir.

43. Determine the coefficient of discharge for various forms of round-crest weir, and, incidentally, experiment to develop a new standard form of weir for measuring water discharge which shall be less subject to error from disturbance in approaching currents and disturbed contraction than is the sharp-crest weir.

44. Determine form of crest for maximum discharge, or least depth over a dam.

45. Test effect of submergence and backwater on weirs at various depths and proportions of backwater to a depth of 5 feet on crest. More extended experiments on this are greatly needed for practical use.

46. Test thoroughly the new Herschel type of weir and depth measurement.

47. Determine the coefficients for discharge over models of many dam crests actually in use and now utilized for metering the flow of American rivers.

48. Check up and extend the deep-waterway dam-crest experiments made some years ago at Cornell University.

49. Determine coefficients for various types of sluiceway, some of which are utilized in gauging the discharge by the hydrographic department of the United States Geological Survey.

50. Make a series of experiments on ordinary canal headgate sluices of different forms, for determining the coefficient of discharge for various heights.

51. Test the effect of various forms of twisting and disturbed flow in channels upon the precision and accuracy of measurement by current meters of various types. There is great need of additional data on this. Certain types of current meter are much more accurate than others in disturbed currents.

52. Develop best type of current meter for accuracy in the disturbed currents found over a cobblestone or other rough bottom.

53. Develop and test an improved portable type of pitot-tube velocity meter and study the errors that may be caused on this under practical conditions by waves and twists of current.

54. A study of the hydraulic jump or standing wave phenomena.

55. A study of "fall increaser," for use in economizing water power on rivers subject to high backwater in floods.

56. Study of various types of energy absorber for the foot of overfall dams, to lessen danger of scour on soft river beds downstream therefrom.

57. Develop best type of baffle piers for foot of an ogee overfall.

58. Develop a Venturi type of sluice gate for the head gates of irrigating canals and other waterways.

59. Develop the best form of bell mouth for tunnels for the by-pass of dams.

60. Determine the most efficient angle of divergence for a Venturi tube, both with smooth current of approach and with disturbed and twisting currents of approach, as in the draft tube of a water wheel. It is possible these studies would aid in the economics of power development.

61. Study the limiting conditions for precision of measurement with Venturi meters of various types with disturbed currents in the approach.

62. Experiment on the laws of centrifugal pump discharge over a wide range of velocities and with throttled inlet and throttled outlet.

63. Determine the overturning effect of currents at various high velocities upon bridge piers and similar structures of various shapes.

64. The weir flume would be useful as a naval test tank for certain conditions of currents, where holding the model still while the current flowed swiftly past. It would be particularly instructive for cases of high velocity and too brief a run in the ordinary naval tank.

WOULD IT NOT BE PREFERABLE TO HAVE THE HYDRAULIC LABORATORY NEAR THE MISSISSIPPI RIVER?

There are unquestionably some arguments so far as the Mississippi problem alone is concerned in favor of locating the hydraulic laboratory near the river: (1) Materials typical of the river banks could be obtained more readily; (2) the laboratory staff would be nearer to the field engineers; (3) the staff would have an opportunity to observe the river in action.

But the fact must not be lost sight of that a hydraulic laboratory is needed not for the Mississippi alone. The Missouri, the Colorado, the Ohio, the Connecticut all have their own problems. Nor is the field of useful and necessary work by any means confined to river problems. The protection of shore lines against wave action, the protection of harbors from deposits of sediment, the prevention of bars at narbor entrances, the determination of the proper size and location of breakwaters are all matters of grave concern to many of our coastal cities. Finally, the myriad of problems arising in the design of engineering structures for generating water power and for irrigation have a just and economic claim

for consideration. The need for a hydraulic laboratory is thus seen to be of nation-wide importance. Its function is hydraulic research carried out by laboratory methods, and it is believed that this could be realized most effectively by establishing a national hydraulic laboratory at the Bureau of Standards.

That the importance of the proper laboratory surroundings and the proper personnel far outweighs the advantages of proximity to the work may be illustrated by the experience of the Karlsruhe laboratory in Germany. To this laboratory have been brought problems in harbor construction from Rio de Janeiro in Brazil, problems in irrigation canals from the Puira River in Peru, problems in river construction from the Lisi River in Italy, and problems in canal spillways from the Nile in Egypt.

These, however, were problems for which it might not have been profitable to construct a local laboratory and it might seem that where a long series of experiments were to be carried out over a number of years the obvious advantages of contiguity to the problem might be the major consideration. Here again the experience of the Karlsruhe laboratory is informing. The closing of the Zuider Zee involving the expenditure of over $100,000,000 by the Dutch Government brought with it problems in hydraulic engineering of a magnitude unprecedented even in the experience of Dutch engineers familiar for years with similar problems of reclamation of land from the sea.

The investigations were of such magnitude and the program of tests so large that it might well have seemed that the best thing to do would be to erect a hydraulic laboratory near the site of the work. This, however, was not done. In Karlsruhe there existed a group of men familiar with similar types of investigation, and to Karlsruhe—several hundred miles away and in another country—the work was taken.

There, from 1922 to date, one model experiment after another has been carried on, two at a time and sometimes three or four, solving one problem after another in connection with the locks in the canals, the outflow channels for the pumps, and the methods of closing the great dike.

No more striking illustration could be given that in the establishment of a hydraulic laboratory the proper surroundings of laboratory facilities and experimentally trained men are of more importance than the minor advantages of closeness to the work.

WHAT ARE THE ADVANTAGES OF LOCATING NATIONAL HYDRAULIC LABORATORY IN THE BUREAU OF STANDARDS?

There are a number of advantages in locating the proposed national hydraulic laboratory in the National Bureau of Standards.

1. A suitable site is available, involving no additional expenditure for land.
2. Power facilities for driving the pumps and other equipment are adequate.
3. The bureau already possesses a concrete flume 6 feet wide, 7 feet deep, and 400 feet long, used for testing water-current meters, which can be made an integral part of the hydraulic laboratory.
4. The water supply at the bureau is adequate, because the steadiest conditions are obtained by recirculating the water.
5. The hydraulic staff would have the advantage of contact with men engaged in related lines of work, such as aerodynamics and structures.
6. The facilities for the development of instruments are excellent. Three different types of strain gauges, which were extensively used in the measurements made on the Stevenson Creek Dam and its model, were designed by members of the bureau staff. Shop facilities at the bureau are adequate.
7. The underlying idea of the proposed hydraulic laboratory is research. Furthermore, it is essentially research of a laboratory character, as distinguished from field work. For its most effective development, a continuity of thought and action on the part of the staff is essential. The staff should have the advantage of the inspiration, the incentive, the suggestions that come from contact with research workers in allied fields. These conditions are found in the Bureau of Standards, and here the work of a national hydraulic laboratory can be carried out to the advantage of the Federal services and the Nation.
8. In the Bureau of Standards the laboratory would be under civilian direction and would be staffed by professional men with civilian status and permanent tenure.
9. In the Bureau of Standards the laboratory will be centrally located, accessible to the other departments and will be a service laboratory for them.
10. The bureau has had a long and successful experience in cooperating with other Government establishments and the public.

While the control of floods and the problems of river training have called forth stupendous efforts on the part of mankind since the early ages, these activities are unusual among engineering works in that the scientific side of their development has not kept pace with progress in the art of building the physical structures with which rivers have been controlled and utilized. The object of this resolution is to provide for intensive research work on hydraulic problems, principally those of river hydraulics.

The country has had in the last few years such a striking example of what may be accomplished by research in the development of radio communication that it is apparent we should not wait longer to pay more attention to the scientific study of the many problems which arise in the control and utilization of rivers. Such vast sums are expended by the Federal Government each year in the building of structures for the control of rivers and for the utilization of water that it would seem to be the businesslike procedure to study some of the fundamental problems connected therewith. At the present time, as doubtless has been the case always, the urgency of meeting immediate problems is so great the tendency is to devote all available funds to project works rather than to research. Because of the absence of fundamental scientific data, there is great conflict of opinion.

A painstaking search made by Prof. Hardy Cross, formerly of Brown University, but now at the University of Illinois, of practically all literature on the science of river control developed the fact that diametrically opposite opinions are held on almost every important question by equally eminent authorities. There have been marvelous developments in the art, according to John R. Freeman, one of the country's foremost hydraulic engineers, but in his words "the science slumbers and should be awakened to guide improvements in construction." At this juncture it is appropriate to insert a very pertinent letter from Mr. Freeman, dated February 24, 1928, telling about the researches being made in European laboratories.

FEBRUARY 24, 1928.

Hon. JOSEPH E. RANSDELL,
United States Senate, Washington, D. C.

MY DEAR SENATOR RANSDELL: I listened with great interest to the statement of Secretary Hoover this morning at the hearing before Senator Jones and the Committee on Commerce, relative to flood control on the Mississippi River.

I have since been reading the committee print of the bill introduced by Mr. Jones and its recommendation in section 6 authorizing the establishment of a hydraulic laboratory, for which it is proposed to authorize the Secretary of War to allot from annual river and harbor and flood-control appropriations the necessary funds for expenses and publication of scientific data.

For about 15 years past, I have been carefully following the progress of development in various hydraulic laboratories in Europe, and last summer made a tour to investigate their present status and the problems on which they are working—this supplementing previous visits.

I find that these laboratories are coming to be a great factor in leading the way to more efficient means of water-power development, solving problems that arise in municipal water supply, and such as those often confronted in the work of the United States Reclamation Service, the United States Geological Survey, and the United States Department of Agriculture.

I found, for example, at the great laboratory of the Government Engineering College at Karlsruhe, Germany, five major problems in progress, only one of which related to a proposed improvement of the River Rhine for navigation, while the other four had to do with water-power development, the prevention of erosion downstream from river dams on soft foundations, the design of great sluice gates, a reclamation project in Spain, etc., and I was told that whereas these laboratories which I visited at Karlsruhe, Dresden, Charlottenburg, Danzig, etc., had been founded originally to aid in river and harbor work; engineers in general practice had come to recognize the value and economy of experiments in the laboratory with relatively small models prior to building the great and costly structures in the field to the extent that more than half of their work now relates to other matters than those of rivers and harbors.

At Charlottenburg, Munich, Dresden, Stockholm (Sweden), Trondjhelm (Norway), and other great institutions for research and the instruction of engineers, the perfecting of the design of hydraulic turbines has come largely to engage their attention.

It is found that on a model of a turbine wheel not larger than a foot or a foot and a half in diameter the problems of developing proportions in designing turbines as large as the largest yet built anywhere in the world can be solved with great facility.

I have been told of a recent case at the laboratory in Stockholm, Sweden, where an extremely large sum has been saved by finding out in the laboratory the defects of a proposed design for a log sluice to accommodate lumbering operations on one of their great rivers, so that a better design was worked out which has proved very successful in practice.

At the great engineering college maintained by the Government at Zurich, Switzerland, I found them just starting on plans for a new laboratory building estimated to cost the equivalent of $235,000, and Switzerland has no seacoast to present harbor problems, and only two rivers of much importance.

It may interest your committee to know that because of these remarkable developments in hydraulic laboratories as an aid to industry, three of the principal engineering societies in America have established traveling fellowships, under which junior professors and matured students are sent abroad for a year of study in these European hydraulic laboratories. Among those at present enjoying this privilege are junior professors from the Massachusetts Institute of Technology, the University of California, Purdue University in Indiana, and two exceptionally able postgraduates from the University of Illinois.

As a member of the committee supervising these fellowships, I receive monthly reports full of enthusiasm at what they find going on. For example, at Stockholm investigations have recently been in progress for a large reclamation project in India. At Charlottenburg, near Berlin, I found the laboratory occupied on researches for the great power development now being made on the Shannon River in Ireland.

From intimate contact with European professors in charge of this work and from personal observations, I am convinced that Secretary Hoover was absolutely correct in his judgment that the place where a laboratory of that kind could do the most good for the industries and agriculture, as well as river and harbor work, would be at the Bureau of Standards, where it could be utilized by all departments of the Government and could also undertake many research problems for municipalities, public-service corporations, and engineers charged with the design of model structures.

Very respectfully,

JOHN R. FREEMAN.

The idea of establishing a national hydraulic laboratory originated with Mr. Freeman. Mr. Freeman is a civil engineer who has specialized in hydraulics for more than 50 years. He has been the president of the American Society of Civil Engineers and is conceded to be one of the greatest civil engineers in this country. The Federated American Engineering Societies, made up of more than 40 of the prominent organizations of engineers of the country, has undertaken to put Mr. Freeman's idea into practical effect. The federated societies have been very active in the collection of data to demonstrate the practical utility of this laboratory. It is very evident that the engineers of the country are almost a unit in their belief that this legislation is wise.

Senator RANSDELL. This bill, I would say, contemplates a study of all hydraulic problems in which the people of our Republic are interested, and we have endeavored as closely as possible not to tread on the toes of any one department or bureau of the Government, but to give them all a chance at it. For instance, the bill provides that a board, to be known as the National Hydraulic Laboratory Board, is hereby created, the three members of which shall be the Secretary of Commerce, the Secretary of War, and the Secretary of the Interior. Those three great department heads are to be at the head of this board, to regulate it, and control it. It shall be the duty of the board to determine from time to time a program of the projects to be undertaken and the manner in which the work is to be performed.

Mr. MANSFIELD. Would it disturb you if I asked you a question there, Senator?

Senator RANSDELL. Not at all.

Mr. MANSFIELD. Would not the Secretary of Agriculture be equally interested in some of these problems?

Senator RANSDELL. He has a good deal of interest, but it is awkward to have too large a board, and we thought that a board of this

kind would certainly place the facilities of the laboratory before all the departments of the Government. That is the spirit of it, that it shall be made by the Government, and controlled by these Cabinet officers and used for the benefit of the citizens of this Republic.

The only really great scientific investigational bureau that I know of that is doing general work is that at the Bureau of Standards. Perhaps I exaggerate that some, but it has done a great deal of scientific research along practical lines, and it was thought for many reasons that this laboratory should be located in the Bureau of Standards. It is true the Bureau of Standards is under the Department of Commerce, but that does not mean that it is going to favor the Department of Commerce any more than the War Department or the Navy Department or the Interior Department or any other department.

I am under the impression, from my study of the subject, that problems of a hydraulic character will be constantly arising under practically every department of the Government, unless possibly the Post Office and Department of Justice. There will be a number of practical problems not relating to the thing so dear to my heart right now—flood control—many problems not relating to that, but relating to structural works of various and sundry kinds; problems in connection with the reclamation of the lands of the West, where you have to build great dams and where in many instances the waters pour over dams created by nature, or great falls occur, and those rushing waters must be studied in a most elaborate manner to determine the effects thereof. I imagine the engineers went into these things and I am not going to take your time to talk about the various and sundry things which a hydraulic laboratory could be helpful in.

I am an American who is very, very proud of his country, and I assume all of us in this room are, and if my information is correct we have been extremely backward in this very problem of the establishment of hydraulic laboratories for pure scientific research. The people of the Old World have done a great deal more along this line than ourselves, especially Germany, and even little Switzerland, I understand, has a fine hydraulic laboratory where problems of this kind are studied. They have not been studied in our country except in a small way at some small laboratories connected with colleges, the principal one of which is at Cornell. I remember the testimony given before us, the very interesting statement made by one of the engineers, that although it was thought everything humanly possible had been found out about the turbines, the scientists have been using turbines for almost time immemorial, and yet, as a result of that small laboratory at Cornell, a slight change was found in the structure of the turbine which made it, I think, 5 per cent more efficient. That is my recollection. Was it 5 per cent, Doctor Burgess?

Doctor BURGESS. I do not remember, Senator.

Senator RANSDELL. You will find it in this record. That was only a few years ago, and was one of the direct results of this small laboratory at Cornell University.

I am especially interested just now, gentlemen, in flood control, as you gentlemen know. In the report of General Jadwin, Chief of Engineers, known as Document No. 90 in the House of Representatives of this session, on page 33 appears this passage:

> The establishment of a hydraulic laboratory similar in some respects to such research organizations carried on by certain European governments has been considered.

Now, those European governments, if my information is correct, have had laboratories of the same character as we have designed here, not out in the field but in buildings and under the general plans such as we are trying to follow.

Measurements and observations on our large rivers supply the best hydraulic data on the flow of such streams, since actual experience with full-size structures is preferable to experiment with small-scale models. However, on occasions questions relative to the flow of water can be worked out by small-scale experiments. Such experiments may be useful in some of our lock and dam designs.

In addition, the organization in charge of a hydraulic laboratory may well be charged with the coordination of field data relative to the flow of the Mississippi and other rivers. For instance, it could advantageously take charge of the discharge measurements, silt measurements, slope and velocity measurements, etc., and make studies and draw conclusions therefrom. It could be a clearing house for such engineering data and publish the same.

Right there I would like to say that my hope is that this hydraulic laboratory will be a clearing house for all engineering data relating to water, not alone water in connection with navigable streams or water in connection with floods, because we have many floods on streams which are not navigable, notably those recent awful floods in New England did not come from navigable streams, as I understand it. We have had some great floods in the last few days in the South on streams which were not very navigable, but they furnish an immense amount of water at times, and they do a great deal of destruction, and I would like this laboratory to be a clearing house for all of these projects and not alone on navigable streams.

It is therefore recommended that the Chief of Engineers under the supervision of the Secretary of War, be authorized to establish a hydraulic laboratory, and that the Secretary of War be authorized to allot the necessary funds from annual river and harbor and flood control appropriations to pay the expenses of such a laboratory and for the necessary printing to publish the scientific data collected.

Now, I am in accord absolutely with the suggestion made by General Jadwin in this report of his concerning the hydraulic laboratory, except I believe it should not be under the War Department and confined, as this report contemplated, very largely to flood control and to problems of navigation, but it should be of a general character, such as this bill contemplates, where all problems, not alone those of flood control and of navigation, but of structural materials, problems connected with the great irrigation dams out West, and many, many others which I can not even dream of, gentlemen, but which will develop and which are explained in the data I am placing in the record here.

I think I do not need to tell you gentlemen that I am interested in flood control on the Mississippi River. I have spent my life there. Every dollar that I have got is invested there, and my own property overflowed last year from 2 to 8 feet deep, and the people of the State which I have the honor to represent in part in the Senate suffered a great many millions of dollars of loss of property and lives from those floods. So I am tremendously interested in anything relating to flood control. I have lived on the banks of the river since September, 1882. That is a good long while ago, nearly 46 years. Part of that time I was a member of the levee board of my district, the local board in charge of matters relating to flood control, and for 29 years now I have been a Member of Congress, all of which time I have studied this matter. I have done the best I could to

hold up the hands of the War Department and its agency, the Mississippi River Commission which was created by act of Congress in 1879, to control floods on the Mississippi River. That commission has done the very best it could during those 49 years, with the very limited sums at its disposal. It has studied a great many hydraulic problems. I have observed at my home in the little town of Lake Providence, which is right on the bank of the Mississippi River in northeast Louisiana, the growth and development of a number of these hydraulic problems carried on by the Mississippi River Commission. One of our very, very troublesome things, and which I take it the hydraulic laboratory will have to study, is the stabilization of banks of streams. Make them stable, put them in the same fashion artifically if you can, in which the God of Nature placed those streams which have permanent banks, streams which flow through a rocky country where the banks do not cave. There are many streams where the banks do cave, and that destroys the lives and destroys the towns.

Just yesterday before the Senate Commerce Committee, we had two powerful appeals made to us to protect the banks of the Missouri River in South Dakota and in Nebraska, in one instance to keep an immense bridge from sweeping away that had been built there for the use of the general public, a great highway bridge, and another to save a little town from a caving bank.

The problem of making permanent the banks of a stream is a very great one in many places outside of the lower Mississippi Valley. There it is absolutely essential for two purposes, first, to preserve the navigation of the river. If the banks cave in, immense volumes of earth cave in and flow on down the stream, fill up the bars, the channel is clogged, great bars form, boats can not pass over these bars, and it results in a complete stoppage of navigation in the lower stages of the river—the summer time. There is a very great destruction of private property, but I won't discuss that.

Second, we have a great levee system, as you gentlemen know, on that river, a system the beginning of which was way back in 1717, when the first levee was constructed in front of the then village of New Orleans. That is considerably over two centuries ago, and we have been building levees since to protect our property from the annual floods of that great river.

Now, it costs a very large sum to build a levee. You gentlemen, many of you, have seen levees. You know what levees are. The cost of constructing these levees is extremely great, and every dollar of it was borne by the Federal Government prior to the creation of the Mississippi River Commission in 1879. So it seemed imperative, when this commission was created, that one of its most important works was to protect the caving banks to make them permanent so that the levees would not cave in. If a levee caved in, there was only one thing to do, build another one back of it, build another one back of that, and build another one back of that, and in that connection I would like to tell you a story of something I witnessed.

When I went to Lake Providence late in September, 1882, my sister, Mrs. Tom Montgomery, was living about 2 miles below Lake Providence at the Deeson plantation. They had a wonderfully fine house, one of those so-called southern antebellum homes, a magnificent structure, and the levee was just at the corner of the front porch, or gallery, as we call it in the South. I immediately asked

my brother-in-law, Captain Montgomery, why his house was built so close to the levee. "Why," he said, "Joe, this house was built here by Mr. William Deeson in the early forties, and it was so far back from the river that his neighbors laughed at him. They said 'Mr. Deeson, what do you mean by putting your house so far back from the river? You can not see the boats pass.' This hard-headed old fellow says 'All right, I can see the smoke; that is sufficient for me, and my children will see this property cave into the Mississippi River.'" The property has passed into the hands of my brother in law. That was in September, 1882. The river had caved up very considerably over a mile to that time, and, gentlemen, I have seen that levee move back of the Deeson house, as we call it, twice. This river kept on caving and kept on eating in, and eating in, and eating in, and the house was certainly eventually a half mile or more farther back than where Mr. Deeson had located it originally in the forties, and then it was so far back that about all he could see was the smoke of the boats. The continuous caving in of the levees on the bank of the river has resulted in enormous losses. The Yazoo Delta section of Mississippi, which you gentlemen have heard a great deal about, has many wonderful cities. A report was made recently by one of the engineers that they had lost considerably over 200 miles of levees.

Mr. McDuffie. May I ask you a question there, Senator?

Senator Ransdell. Yes.

Mr. McDuffie. With a hard substance, cement or these mats, or whatever they put down, I think they perhaps did have a system of using a mat weir and willows or trees of some kind—is it a fact that the river caves under those? In other words, wherever it has been fixed by the engineers by the use of hard material, the water will not erode or tear away? There has been no caving behind those fixtures, has there?

Senator Ransdell. To a very great extent, no.

Mr. McDuffie. Then it resolves itself into a question of getting money enough to do that?

Senator Ransdell. Absolutely.

Mr. McDuffie. The point is this, how do you expect this laboratory to be helpful in this regard?

Senator Ransdell. I was coming to that.

Mr. O'Connor. Mr. Hudson suggests that a good deal would depend on the materials used.

Mr. McDuffie. They have already found a material.

Senator Ransdell. I am coming right to that, if you will permit me.

I was trying to show you gentlemen the necessity of the Mississippi River Commission solving the different problems before them. I had reached the point that it was essential to hold the banks of the river. I was about to tell you that some thirty-odd years ago—yes, it is nearer 40 years ago—I saw a number of great piles driven into the channel, great trees driven into the channel near my home and extending quite a little distance out into the channel. The banks caved around them and destroyed them and did the very thing you said this other would prevent.

Later on they began to put in mattresses, as they called, made of small willows, 60 or 70 feet long, that grow very close together and very long on the bank of the river. They lashed them together with

wire cables and a great mat of these willows would be built at the head of a caving bend, and they would string them along until they got a mat about half a mile long in some instances, and, a third to a half mile long, extending from the bank of the river out, say, 250 or 300 feet into the channel, every string anchored to the bank by big cables, great big fellows, and of course floating on the surface of the water. One mat was built after another, one after another, two or three hundred feet long and extending out, away out until you got about 250 to 300 feet into the river, right along above this caving bend. When the raft, as they called it, was completed, they anchored barges loaded with heavy stone just on the outer edge, piled the stone on them very rapidly, with hundreds of men just throwing it on as rapidly as possible, until the whole mat sunk, and they would have them all sink at the same time. They had a number of these barges unloading the stone, and as it sank it struck the contour of the bed in the river. Then they would go on down and build another and another and another, and in some instances those caving bends were revetted for several miles, and that accomplished the purpose.

Mr. MANSFIELD. Would those willows take root and grow?

Senator RANSDELL. No. They are underneath the surface. This was done as nearly as possible at extreme low water.

Mr. HULL. Do those mats exist to-day?

Senator RANSDELL. Yes, sir.

Mr. HULL. How long have they been in the river?

Senator RANSDELL. Some of them have been in the there over 30 years. That was one of the hydraulic experiments, I should say No. 2 is a very important way.

Later on they found that the willows were getting scarce and you could not get all trees just the same size, and it was a little more difficult to work them. So some great men connected with the Mississippi River Commission conceived the idea of making material of concrete, reinforced concrete blocks, as I recall about 4 feet long and about 2 feet wide, and they are lashed together exactly the same as this willow proposition, except that they do not have to be weighted. They have great barges there, and when they slip them over from the barge, down they go. They are lashed to the bank in the same way, and it is thought that they will be perpetual. In fact, they never will decay, and they will stay there forever.

Mr. MANSFIELD. Until the cables rust out.

Senator RANSDELL. Possibly so, but the only purpose of the cable is to get them fixed in this bank.

Mr. MCDUFFIE. After they hit the bottom they will never move.

Senator RANSDELL. Let me say this: As soon as the bank is coated with these willow mats or these concrete mats, the river bearing a great deal of sediment in solution deposits that sediment. The sediment in some instances will become many feet deep over the mats. The current sweeping around strikes that mat. It is like striking a rocky bank, it bounds off and goes over to the other side. It can not destroy it. Formerly it just cut that alluvial soil almost like you would cut a big cheese with a knife, and it would cave and cave and cave, but when it strikes that mat it is bound to go off. So they have controlled many, many of the cave-ins of that river and controlled them successfully. But you probably stated the situation, it has been a lack of funds.

Mr. McDUFFIE. Sure. In other words, there have not been any need, Senator, as I take it, of any further experiments. We have found how to do it, and all we need is money enough to do it?

Senator RANSDELL. That to some extent is true, but as a result of experiments conducted by the Mississippi River Commission, they have a much better method than they have ever had in the past. My contention is that any further experimentation in connection with the floods of the Mississippi River can be carried on under the great flood control bill we are about to pass. I understand—well, I know—that this bill, if it becomes a law, will have the work done by the Mississippi River Commission, the same board that has been studying it all of these years, it will be under the general jurisdiction of the Chief of Engineers, and the present Mississippi River Commission, and either one or two civilians, but the general work will be carried on in a big way, and just as in the past, wonderful experiments were carried on from time to time of a hydraulic character similar to experiments which will be carried on in this laboratory for flood control, not on the Mississippi River, because, heavens above, they can not carry on much better than they have carried on down there in the great laboratory of nature itself.

Mr. HUDSON. Right there, Senator, if I may be permitted a question. I asked yesterday if the construction of this hydraulic laboratory would be of use at the present time in solving the Mississippi flood-control problem. What is your reaction to that?

Senator RANSDELL. My reaction, sir, is that it may. I do not know whether it would or not, but I do know that we have been trying for considerably over two centuries to solve the flood problems on the Mississippi, and I do know that they are not yet solved. Absolutely, gentlemen, they are not yet solved, and the problem involved is so enormous in its value, it is so costly that I do not think we ought to hesitate to give any assistance that can be given. I do know that the study of people in other lands indicate that they have received aid from hydraulic laboratories such as we have got here in this bill, and I am very hopeful that on the lower Mississippi we will receive aid. At the same time, I would say that the engineers in charge of that river ought not to confine their efforts simply to the laboratory we would have here in Washington, but they ought to carry on their experiments in the field. Why, gentlemen, the problem now is the greatest one in the hydraulics of humanity, in my judgment. The commission figures that this work will probably cost $775,000,000 before it is finished. The opinion of the Chief of Engineers is that the engineering features will cost some $297,000,000, and that does not contemplate compensation for lands taken. So it is a perfectly enormous, a collossal problem.

Why should we hesitate five minutes to do anything that may help to solve the problem?

I would like, right at this moment, to say that one of the men in Washington that all of us have had to run up against occasionally and get a black eye from him is the Director of the Budget, General Lord. I was perfectly delighted when General Lord not only approved in toto the bill as prepared by me and presented but went $50,000 better and suggested that we ought to have $350,000 to start this laboratory instead of $300,000. I think that was a tribute, as far as he was concerned.

Mr. MANSFIELD. He raised you $50,000?

Senator RANSDELL. He raised us $50,000.

Mr. MCDUFFIE. I think the committee is in accord with you about the gravely serious problem on the Mississippi River and we should give it every attention possible we can from the standpoint of making an investigation of these things. The point I am making is, as far as the Mississippi is concerned, that it was not a lack of knowledge as to what to do, but it was a question of lack of funds with which to do it, and the question is whether this laboratory or any laboratory can improve on the methods we know can control the river. But, after all, it is a question of getting more funds to control it with.

Senator RANSDELL. That is possibly true, but, gentlemen, we have not scratched the surface of scientific research in our country. I do not think we have begun to scratch the surface, and this is a great scientific research institution. It is to be made available for every branch of the Government, and there are many things which are not related to flood control, as I said before you came in, Mr. McDuffie, that would be reached by this laboratory, and they ought to be studied and studied carefully.

Mr. MCDUFFIE. As to the flow of water, hydraulics, generally speaking, do not the great power companies, the hydroelectric power companies, do experimental work, so far as power is concerned?

Senator RANSDELL. I suppose they do, but if there is any hydraulic laboratory in this country that amounts to anything I do not know it. I stated before you came in that there was a little laboratory at Cornell University that had done pretty good work, and these power companies need just such a place as this where they can go and have experiments conducted, and we are all tremendously interested in the development of hydro electric power. We ought to have a place where experiments can be conducted, and in this laboratory here an agency, a disinterested highly intelligent, independent government agency will be created where all reasonable problems will be worked out.

Mr. CHALMERS. It seems to me, Senator, that there is great merit in your bill, and I can not conceive of our committee failing to report it out. It seems to me that there has not been anything that has come before our committee since I have been a member of it that is as promising as the project you are after.

Senator RANSDELL. I thank you very much for that.

Mr. HUDSON. I would like to say this too, Senator. I did not ask a question with reference to the Mississippi flood control in any sense of indicating I was unfavorable to it, but I think, regardless of that, our entire coast line, the line of our Great Lakes, our commerce, are entitled to this great hydraulic laboratory, for determining the result of wave action. On Lake Michigan they spent a hundred thousand dollars creating what they thought was going to stand for eternity, to save the resort property from the action of the waves, but the waves came right over, and before we knew it a hundred thousand dollars worth of cement was out in the Lake.

Mr. CHALMERS. We have not yet heard from our professional adviser, the Chief of Engineers, as to whether or not this laboratory will be of service to him, but I am very sure, from the presentation here yesterday, which was a very interesting one, that it will be of interest to the other departments of the Government and to the general public of the country, whether it can be used by the War Department or not.

Senator RANSDELL. They certainly can use it, along with every other department. In connection with your statement I would like to remark that when the original bill was introduced in the Senate by Senator Jones of Washington it contained a provision for a hydraulic laboratory as suggested by General Jadwin in his report. I discouraged that idea because I thought it was too limited. I have always believed that we should look out for all the interests of the Republic—not one interest. This suggestion contemplated what seemed to me to be a limited use of the hydraulic laboratory, and that it was from my knowledge, from my connection, with the Mississippi River Commission that they would use in the future, as they had in the past, and would conduct all manner of experiments relating to field work of the hydraulic laboratory, and in a great Government institution here in Washington for the use of all of the departments they would get the benefit of any experiments they themselves desired to make, especially as the Secretary of War is one of the three members of the board that controls and directs everything.

Mr. MANSFIELD. The question I wanted to ask was in regard to the stabilizing of the banks of the Mississippi River where those caves occur.

Senator RANSDELL. Yes, sir.

Mr. MANSFIELD. Isn't it a fact that when there is a great change in the course of the stream on account of those caves at one place, that it changes the course of the stream below that and causes other caving places?

Senator RANSDELL. It does. In connection with that may I tell another story. The great author, Mark Twain, was once a pilot on the Mississippi River, and he says that when he first started piloting there he was told that a few years before there had been a big caving and that a bend had caved in and saved 15 miles. There was a point down below, you see, and the points came together and saved 15 miles, and then some distance down the river another bend caved off and 20 miles was saved, and so on down, and he said he got a pencil out and figured it up and thought that if this caving was going to be continuous in the future as it had been in the past, it would not be many years before Cairo and New Orleans would be on opposite banks of the river, but yet he said, "I found by measuring it that the distance was the same," and he discovered when there was a big cave at one bend and a saving of distance, the river regulated itself by caving somewhere else.

Mr. O'CONNOR. Senator, I know that one of the hopes of your legislative life has been to see a system put into operation whereby the water resources of the country could be used for beneficial purposes for the entire Nation.

Senator RANSDELL. That is true.

Mr. O'CONNOR. Don't you think, or do you think, that if this bill were enacted into law, that ultimately, as a result of this experience and its investigation and the wisdom that would be gained as a result of a study of these matters, that we would have that very result that you have longed for; that is, for the use of the waters of the country from the standpoint of investigation, of flood control, irrigation, power, and all of that which would make a great system of the greatest possible use and the greatest asset to the country.

Senator RANSDELL. I think it would be very helpful toward that end.

Mr. O'CONNOR. With reference to the stabilization of the banks and the revetment of the river, with which both of us are familiar from living on the banks of that river, for so many years, don't you think that continuous study and experimentation would constantly improve the methods which are now used, and 25 years from now, the methods of to-day may be regarded as primitive?

Senator RANSDELL. There is no question about it. I have seen wonderful improvement changes since I have lived there.

Mr. SEGER. Don't you believe also that the revetting and the building of levees is not the only solution of the flood problem?

Senator RANSDELL. I do.

Mr. SEGER. You think that further study should be made for the relief of the river?

Senator RANSDELL. I absolutely do think so. We have not solved it, I am sorry to say. This bill that we are talking about will go a long ways toward the solution, but I am afraid it will not be a completion solution.

Mr. HULL. Gentlemen, here is a communication to Mr. Dempsey. It says:

I have the pleasure of handing you herewith copy of resolution adopted by the board of direction of the American Society of Civil Engineers at its meeting held on April 24, 1928, in the city of Washington, relative to the national hydraulic laboratory.

The President of the society appointed past president John R. Freeman and past president C. E. Grunsky a committee to present the same on behalf of the society before the Rivers and Harbors Committee which it is my understanding they did on Thursday, April 26.

That is signed by Mr. George T. Seabury, secretary, and attached to it is the resolution which they have adopted. I think that should appear in the record.

RESOLUTION ADOPTED BY THE BOARD OF DIRECTION OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS APRIL 24, 1928

Whereas it has come to the attention of the board of direction of the American Society of Civil Engineers that a bill authorizing the establishment of a national hydraulic laboratory in the Bureau of Standards of the Department of Commerce and the construction of a building therefor has been passed by the Senate of the United States; and

Whereas some consideration has heretofore been given by some Members of the Congress to the thought that the national hydraulic laboratory should be placed under the direction of the Corps of Engineers of the United States Army rather than in the Bureau of Standards: Be it

Resolved, That the board of direction of the American Society of Civil Engineers, holding firmly to the opinion that the proper place for the proposed laboratory is under the direction of the United States Bureau of Standards, urges favorable action on the bill as passed by the Senate; and

Resolved, further, That the president of the society be authorized to appoint a committee to present the foregoing resolution to the Rivers and Harbors Committee.

GEORGE T. SEABURY, *Secretary*.

Mr. HULL. General Jadwin will want to come before the committee on this subject, and I have told him, on account of his being tied up on flood control matters at present, that we would hear him at a later meeting. So we will adjourn, subject to the call of the chairman.

I think we all ought to give a vote of thanks to Senator Ransdell for his remarks here this morning.

(A vote of thanks was given.)

(Whereupon at 12 o'clock noon the committee adjourned.)

HOUSE OF REPRESENTATIVES,
COMMITTEE ON RIVERS AND HARBORS,
Tuesday, May 15, 1928.

The committee met at 11.45 o'clock a. m., Hon. S. Wallace Dempsey (chairman) presiding.

The CHAIRMAN. Now, General Jadwin, we will hear you for a few minutes.

Mr. HUDSON. Mr. Chairman, I suggest that the General be allowed to make a complete statement before being interrupted.

The CHAIRMAN. Yes; I agree with you on that.

STATEMENT OF MAJ. GEN. EDGAR JADWIN, CHIEF OF ENGINEERS

General JADWIN. Mr. Chairman and gentlemen of the committee, I understand that you called me before you to give the views of the Engineer Department on the subject of the establishment of a hydraulic laboratory. You all know that I recommended the establishment of such a laboratory in the report of the Army engineers on the subject of flood control in the Mississippi Valley. The report was submitted December 1, 1927. The recommendation there is short, in three paragraphs, and I will read it:

> The establishment of a hydraulic laboratory similar in some respects to such research organizations carried on by certain European governments has been considered. Measurements and observations on our large rivers supply the best hydraulic data on the flow of such streams, since actual experience with full-size structures is preferable to experiment with small-scale models. However, on occasion questions relative to the flow of water can be worked out by small-scale experiments. Such experiments may be useful in some of our lock and dam designs.
>
> In addition the organization in charge of a hydraulic laboratory may well be charged with the coordination of field data relative to the flow of the Mississippi and other rivers. For instance, it could advantageously take charge of discharge measurements, silt measurements, slope and velocity measurements, etc., and make studies and draw conclusions therefrom. It could be a clearing house for such engineering data and publish the same.
>
> It is therefore recommended that the Chief of Engineers, under the supervision of the Secretary of War, be authorized to establish a hydraulic laboratory, and that the Secretary of War be authorized to allot the necessary funds from annual river and harbor and flood-control appropriations to pay the expenses of such a laboratory and for the necessary printing to publish the scientific data collected

That recommendation has received additional force by the action of the Congress in placing the Mississippi River Commission, over which we have heretofore had only veto power, under the direct orders of the Chief of Engineers and the Secretary of War in the bill which has passed the Congress, and I understand has been or is about to be signed by the President.

It has also received added force from the fact that you have directed us to make surveys from the flood-control standpoint, including the allied and related questions of power and irrigation on practically all the streams in the United States that have a flood-control problem. This work is giving rise—will give rise—to new investigations which we wish now to initiate and get under way and are getting under way as rapidly as possible. We will have additional laboratory experiments, what may be called "laboratory experiments," to be made in that connection.

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The essential of a hydraulic laboratory which will be capable of dealing with the problems of the Mississippi and the similar great alluvial rivers throughout the country is that it be located on the Mississippi, where experiments can be carried on with the types of alluvium and sediment characteristic of the valley, and where a laboratory force can be in immediate contact with the field forces which are executing the actual river work, and can check its theoretical conclusions against their practical observations. It is an error to think that a few barrels of sand can be shipped from the Mississippi Valley to a laboratory in Washington and made to represent actual conditions. You know how barrels of sand are gotten when you send out to a field force for them. If the laboratory is established along the Mississippi, we will get the exact material, the exact mud and water there that is to be reckoned with, and we will not have the Potomac River water as you would in a laboratory placed on a hill near Washington. If we attempt to being water up from the Mississippi in jugs here, it is going to settle and you are not going to get at all the composition of sediment and water and alluvium that you will get if you carry the experiment on where the problem exists that is to be solved.

Mr. MANSFIELD. General, if it will not disturb your argument, your theory is that you ought to test with the same water that you have in the Mississippi?

General JADWIN. With the same water and the same mud. Mud is a big factor out there, what is carried in suspension in the water and what is rolled along on the bottom. Those things all have a bearing on a good many of our problems. They have a particular bearing on the question of discharges and the determination of them with meters, the reading of the meters, and with the soundings, getting the volume of flow.

The proposed bill, by violating this fundamental rule, would set up an arrangement which would be fraught with the greatest peril to the best interests of the citizens of the Mississippi Valley, and to the progress of river navigation and flood-control work throughout the country.

In the light of this, it is desirable to examine the 10 alleged arguments for locating the laboratory at the Bureau of Standards. These appear on page 18 of Senate Report No. 718, Seventieth Congress, first session. Below I have summarized the reasons and given in brief the answer to each.

Reason No. 1: "A suitable site is available involving no additional expenditure for land."

Answer. A suitable site on the Mississippi River can be purchased for probably $1,000 or $2,000, a very small sum when you consider the discussion that we have had on the value of land and the amount of land to be acquired in connection with the flood-control problem on the Mississippi River. We already have quite a lot of land there, and it may be that we can put one on a site that we have, but if we need a site the cost will be an insignificant matter compared with the great advantage to be obtained from it, as compared with the heavy expense that you would have if you attempted to transport water and sand from out there, and people from here out there, and people back and forth, in order to get the scientific mind in touch with the field mind.

Reason No. 2 "Power facilities for pumps, etc., are adequate."

Answer. No great amount of power is necessary, and such as is necessary can be readily manufactured or purchased from ordinary commercial sources at many suitable sites on the Mississippi. I have been giving a good deal of attention to the best location for it, and am pretty well settled in my mind that it ought to be somewhere between Memphis and New Orleans, probably about half way down, because there we are not so far from the lower river, where the water moves slowly and where the levees have to be moved only about once in 75 or 80 years, or from the upper river, where many times the levees have to be moved sometimes as frequently as once in 20 years.

The CHAIRMAN. Will you be good enough to give me that second heading again?

General JADWIN. "Power facilities for pumps, etc., are adequate." That is, at the Bureau of Standards they already have power. The answer is that no great amount of power is necessary, and such as is necessary can be readily manufactured or purchased from ordinary commercial sources at many suitable sites on the Mississippi. Most of those that I have in mind already have wires there, and the power would have to be paid for, and power costs money in either case.

Mr. O'CONNOR. Will you permit me to ask a question, General? Would not the same argument that you have made for the location of that laboratory between Memphis and New Orleans apply to the location of the commission that is to administer the flood-control provisions?

General JADWIN. Not necessarily, Mr. O'Connor. Its headquarters ought to be fairly close. But you have to make these measurements at exactly where the physical proposition is.

Mr. O'CONNOR. I have often wondered why the Mississippi River Commission is located in St. Louis instead of in Memphis or Vicksburg or New Orleans.

General JADWIN. That question has been up many times, and has been brought up several times recently, and there are things to be said on both sides, but it is not exactly the same condition that would control in both cases, necessarily.

Mr. MANSFIELD. General, such a laboratory as you speak of, would that require a building down there, or would it be in the open?

General JADWIN. I was counting on doing both, Judge. We will have to have a building. It would not necessarily be a very expensive building, but I am counting on having it down there for another reason, that there are a great many small streams that are tributaries of the Mississippi and tributaries of the tributaries. The Yazoo, for example, has some features that seem to hold out a great deal of benefit, that duplicate in miniature already many of the conditions on the river, and they possibly duplicate them even better than they could be duplicated by a model in a building, but we want to be able to build those models in a building, and I want to give special attention to several things that are coming up now as we are going into this new flood plan. For many years the engineers worked on the theory of raising the levees three feet above the last flood. That was arbitrary, as I think you all know, but it was the best that could be done in the light of the funds that were available for the work. Now we have gotten to the point where Congress has indicated perfect

willingness to do whatever is necessary for the physical solution of the problem, and we are going to have to give quite a good deal of attention to careful studies to know exactly what the flood line will be under various possible conditions, and we will want to simulate that as far as we can and have studies on it, and we will do part of the work out of doors and part of it in a building.

Mr. CHALMERS. What is the overall expense for the problem you want to solve down there, General?

General JADWIN. We had in mind a very small allotment to start with, Mr. Chalmers, probably $50,000 to get going, and we will have—it would be hooked up with the work of the surveys. It would be field work, determining velocities, etc., and computations of rate of flow and volumes of flow. That amount we thought would take care of us certainly for the establishment of the building and initial appliances. If we found we needed more later, we could add to them if and when and as needed.

Reason No. 3: "The Bureau of Standards possesses a concrete flume."

Answer. A flume adequate for all purposes connected with investigations on alluvial rivers can be constructed for a very limited cost. We also would probably make use of some of the small streams which are there and which are not here—at any rate carrying anything like the same character of alluvium.

Reason No. 4: "Ample water supply at the Bureau of Standards."

Answer. The water supply of the Mississippi River is unlimited—I think you all understand that—and this water, taken directly from the river, will contain all the various degrees of sediment, studies regarding which are an essential item in the work. The water supply here in Washington we filter. The Engineer Department does that before it goes to these users, and they get water which is different from the water of the Mississippi.

Reason No. 5: "The staff of the proposed laboratory could have contact with men engaged in such lines of work as aerodynamics and structures."

Answer. The essential thing for the staff of a successful laboratory is to have immediate personal contact with the men who are doing the field work, so that the research can really go hand in hand with the field work.

Reason No. 6: "The Bureau of Standards has adequate instruments and facilities for developing them."

Answer. Adequate instruments for the purpose can be obtained readily at limited cost and had best be tested under the actual conditions obtaining in the Mississippi River to avoid possible very serious errors in the results obtained from them.

Reason No. 7: "The proposed laboratory is essentially for research of a laboratory character, as distinguished from field work. Conditions for this are satisfactory at the Bureau of Standards."

Answer. The whole weakness of the proposal is revealed in the above. The laboratory is essentially for research, but it is a grave mistake to speak of this research as being "distinguished from" and separate from field work. Laboratory experts isolated from contact with field experts often come to grossly erroneous conclusions, and their conclusions are therefore likely to be discredited in the eyes of the field agencies.

Reason No. 8: "The laboratory at the Bureau of Standards would be directed and staffed by civilians with permanent tenure."

Answer. A laboratory on the Mississippi would likewise be staffed and operated almost entirely by professional men of civilian status and permanent tenure. Being an integral part, as it should be, of the great work of controlling the Mississippi and other rivers—and they are now coming into the problem, and we will have to make experiments and research concerning them, and the Mississippi River is centrally located with regard to them, whereas Washington and the hill on which the Bureau of Standards is located is far removed from the great majority of them. Such a laboratory would and should be under the direction of the civilian and Army agencies which by law have charge of that work.

Reason No. 9: "The Bureau of Standards laboratory would be centrally located with respect to the other departments of the Government."

Answer. A Mississippi River laboratory would be centrally located with respect to the entire Nation, and the rivers of the Nation, and would be directly on the particular river which presents the greatest problem. It would also be more satisfactory for certain theoretical studies which might be found advisable regarding jettied channels, on account of the use of regulating structures of a quite similar sort on the Mississippi, and also because of its proximity to the Gulf coast, where some of the largest systems of this sort are located. More probably, however, most studies of this sort would be carried on at the site of the works, since, for example, the jetty problems of the Pacific coast harbors and of the Gulf coast harbors differ in many particulars.

Reason No. 10: "The Bureau of Standards has had long experience in cooperating with other agencies."

Answer. The Bureau of Standards might well conduct investigations which deal with filtered water, and with the class of problems which enter into such matters as municipal water supply, etc. The problems, apparatus, and technique facing a laboratory to deal with the flow of alluvial rivers are entirely different. The problems of these rivers are unique and their solution is almost exclusively in the hands of agencies operating under the War Department. It is essential that the theoretical study of these problems be carried on hand in hand with the practical field work.

Mr. MANSFIELD. General, would it be practical to have a moving concern that you could load onto a Government barge and move from New Orleans to Pittsburgh, to test under different conditions?

General JADWIN. I think that we could do that for some of the experiments, Judge.

The practice of testing power wheels, and so forth, in a way is an intermediate subject, and I just want to say on that point that possibly it may not be so important right now for the reason that there are three large manufacturers of that class of machinery in the country, and that each of them has a very fine laboratory for testing those things, and they are right out in the forefront of the procession, technically, in matters of that kind. So that, so far as I understand it, there is probably no great necessity for appliances of that kind or the establishment of a laboratory for that purpose on the part of the Government at present.

It is apparently the thought of certain proponents of this bill that the scientific study of hydraulic problems by Government agencies is a new thing in this country, and that such studies as have been made in America have been done by, and on the initiative of, universities and other civilian technical agencies.

The exact contrary is the case. The science of river hydraulics in America, both theoretical and practical, as a whole is more advanced than that of any other nation in the world, and this advance is due almost exclusively to the activities of the Army engineers.

For over a century the Army engineers have been in charge of Federal improvements on waterways. During that time they have espended over a billion dollars on work of the most varied character. It should be self-evident that this could not have been carried out without the most extensive theoretical studies. The amount of such studies by the Army engineers has in the total been enormous. It represents a specialized and highly technical literature appearing in books, in Government publications, in memoirs and contributions to periodicals and to learned societies, and in special reports of all descriptions. An illustration from a matter fresh in the mind of Congress is the data contained in the pamphlet by the Mississippi River Commission on depth, width, velocity, discharge, etc., of crevasses; information which is invaluable in determining the characteristics of water flowing out of the main channel of the river; and in spite of this we hear theorists telling us how to learn this from laboratory experiments. That book has a record of practically every crevasse and the flow that has taken place, I believe, in the last 50 years. Studies of the sort described cover the field of river flow, river regulation, fixed and removable dams, locks, power dams and power machinery, dredging and many others.

In developing these studies the Army engineers have investigated and digested the technical literature of all the leading European countries, such as France, Italy, Germany, Russia and the countries bordering on the Danube; and have moreover visited these countries and studied exhaustively the works of all characters constructed in them. You have heard testimony from some gentlemen, I believe, who have visited over there and seen some of those laboratories. I have had some little experience over there myself and I want to say that—and I may say that I had charge of a large number of men, about four or five times as many as I am in charge of at present, and I know somewhat of the way they work over there and the way things are done, and I want to say that in the matter of waterways the United States is just as far ahead of them—we want to take and to use all they have that is useful, just as this country is largely populated by people who have come from Europe, but we are just as far ahead of them in the matter of improvement of waterways as this country is ahead of them in the matter of general development.

I will give an experience or two that I had, if you can bear a digression. It gives an idea of what was done over there. I had charge over there for quite a time of the bulk of the construction for General Pershing, and we ran up against the methods of those gentlemen. We were allies with them and it was up to us to get along, and we did get along, and all worked well, but their methods were somewhat different from ours in many cases. I remember one case where we had to cut a switch in, soon after we got over there, so that we could

get off the main line of the railroad and get out and develop a large yard and tracks out there, which would not do us any good unless we were hooked on to the main line. Now, permission to cut a switch in on a main line is quite a formal proposition over there. It has to go through many hands before you get your authority. The officer in charge sent up to headquarters his application for this authority, and headquarters was having quite a time getting it. You know, they are more formal in many ways than we are. Instead of using just plain railroad spikes and driving them in as we do, they have screws and they screw those things in very carefully to hold the rail down. It is a good plan and all right, but it costs lots more to do and it takes time. That general principle applies all along. We were a long time getting permission, in fact, I am not sure whether it has ever been granted yet. I think it has, because subsequently we got a great many others. But one day the colonel in charge down there telephoned up that we need not worry about that any more; that a foreman of his in charge of a track gang was out there and had gotten busy unexpectedly and without any proper authority at all had cut in that switch. Then the question was raised: "What are we going to do with it? Will we have to take it out?" And he was told, no; if there was a switch in, it required just as much red tape to get it out as it did to put it in in the first place. [Laughter.]

We had another experience there in another matter. Among the work that I had charge of, besides constructing the railroad and the hospitals and the buildings, I had also the port work. We had to do some dredging and we had to prepare a great many berths. We built about 20 berths ourselves from the bottom up, in order to increase facilities in harbors where the depth of water was all right, and we took over 65 or 66 others and modified each of them to whatever extent was necessary to adapt them to our uses.

We had some trouble down at the port of Saint Nazaire, where they had their docks built out of concrete and stone, very carefully and very expensively built and very accurate measurements, but a little small, and they had small hoists up on top of them that I had read many documents about, how wonderful they were, and what their practice was in unloading stuff, but we were not unloading fast enough and it was costing too much to unload it, so we had to have a new dock. I ran a double track trestle just as you have seen here hundreds of times in America, out from the shore, cut away from those docks and ran out into 30 feet of water, built a wooden wharf there on piles, and we started in unloading. The actual unloading came under General Atterbury. We built the works for them, the tracks and wharves, and they unloaded there for 40 per cent in cost and labor of what they were unloading over at these fancy places that the Frenchmen had constructed at great expense and many years of time.

After the armistice the boys wanted to see some of our work, and General Harbord took them around on a special train, men who had charge of corresponding things for the British Army, fine fellows, and when they came down and looked at this they stuck around for a long time. I did not know what in the world was bothering them. I thought it must be they had discovered something wrong that I did not know about. Later on General Harbord got me off to one side and said: "Here, Jadwin, what is there so wonderful about that

dock you built out there? These fellows seem to think that is a marvel." I said: "There is nothing wonderful about it, General. That was suggested to us in the first place by a man who had been building docks for railroads"—I think he was working on the Flagler Terminal going out to Key West. The idea came up, came to me, and I immediately adopted it. I said: "It is the kind of thing we are doing in our country right along, and any engineer officer who has had a district would know what to do, and so would any civilian railroad engineer who had had experience around a port." I said: "There is nothing wonderful about it at all." "Well," he said, "these Johnnies seem to think it is marvelous." General So-and-So, who had charge of that class of work for them, said: "You know, General, our boys would never have thought to do that."

We afterwards took the French around. General Atterbury went around with them. He had a special train this time and wanted me to go with them. We worked together, just as I worked with the man in charge of the hospitals, you know, building his hospitals for him. We had to build for all those people. We had with us the cabinet minister who had charge of such construction in the French Government, Monsieur Claveaux. Things went all right with him on the inspection until he got out on this wharf, and he looked at it a long time back and forth, and he asked General Atterbury a lot of questions and asked me and asked my people there who had been building, and the other fellows who were operating it, and finally he came up to me, a great big fellow, 6 or 8 inches taller than I was, and put his arm around my neck and said: "Ce est marvelleux Mon General, mais ca ne dura pas plus que cinquante annees."

Mr. MANSFIELD. What did you tell him?

General JADWIN. He said: "Those things won't last more than 50 years." [Laughter]. I said: "My God, General, I will be thankful if they last seven years." He says: Ce est terrible, terrible." I said: "What is terrible, Mr. Minister?" "Why," he says, "we can't use it after the war is over." "Well," I said, "we are not here to build things for you to use after the war is over. We are here to help win the war, and we calculate getting it done inside of seven years."

So that was that. But it represented their point of view as compared with ours. They are all right and they are fine fellows, but we are way ahead of where they are and we are getting ready right now to jump off at a greatly increased pace with these increased appropriations which are given to us for the Mississippi and for other rivers.

The result of all these activities is that we lead the world in our hydraulic achievements. We have undertaken and carried to successful completion river canalization, river regulation, and the dredging of waterway channels on a scale far beyond that achieved by any other nation. We have developed the most efficient dredges in the world. We have improved on the best French designs for movable dams. We have constructed in Panama the greatest and the most efficient lock canal in the world.

The Army engineers are directly responsible for these achievements. They have been the leading hydraulic scientists of the country for over a century, and in many fields they represent practically the only body of organized hydraulic scientists which now exists in this country. Of course, we admit also the equal responsi-

bility of Congress for furnishing the funds to do this. We do not want to take any of that credit away from you. The Army Engineer School gives a thorough course in this, and is the only educational center in the Nation which does so.

These facts are perhaps not as widely known as they should be, since it has been the policy of the Army engineers to do their work and let someone else do the talking. But it is truly astonishing that anyone purporting to have any knowledge of the science and technique of hydraulics should be unaware, or appear to be unaware, of the facts. Space does not permit me to give a full detailed statement of the works to which I refer; such a statement, indeed, would be in the nature of a history of the Corps of Engineers. Merely to cite a few which are common knowledge to the general public, I may mention the following: The structures and lock gates and valves of the Panama Canal, an extraordinarily intricate design problem. And may I say that we carried on experiments down there for a long time before we settled on those points. They were carried on immediately under the direction of Mr. C. M. Seville, who had a desk in the same room with me.

The CHAIRMAN. You did not carry them on here?

General JADWIN. No; we carried them on down there at Panama. We built in miniature a type section of Gatun Dam, using the various kinds of material that are around there, building it to get the proper ratio of sand, rock, water, and other material through there, and got the hydraulic gradient, and that is what determined the cross section of the dam. It was made to fit in with the headwaters on the upper side of the elevation and the water on the lower side; the character of the material that was available and out of which we had to build it by some combination of material. We also did the same in connection with the spillway there. The question of the hydraulic jump was quite an important one and required experiments in miniature with these little blocks at the foot of a slope, which were set there with the idea of catching the water that came down and turning it in so that it would be divided against itself, work against itself, and kill the head and jump.

Then the locks and movable dams on the Ohio River. May I say, as you all, I think, well know, they exceed in size anything—that system exceeds in size anything of that type anywhere in the world, Europe not excepted at all. We have seen practically all that they have over there. The height of our movable gates on the Ohio—and we got the idea, by the way, from France—we are willing, and glad to take everything they have to offer—we got the wicket or gate from there, but we have increased the size and value of them. The dam, locks, and power installations of the Wilson Dam at Muscle Shoals; the bank protection and regulating works on the Mississippi and Missouri, evolved after years of the most careful practical and theoretical investigation; the various dredges designed, constructed, and operated by the department, of the pipe line, dipper, and seagoing hopper types, which are admitted to be the most efficient and economical machines of their kind in the world. I think those machines, many of them, have been seen by many members of this committee.

These great works were undertaken only by a close correlation of theoretical and practical study. The formulæ and computations

which went into their making would cover acres of paper and fill enough volumes to stock a library.

The immense field of theoretical knowledge thus covered is available to all officers of the Corps of Engineers; it represents a portion of the instruction given to them as a part of their preparation for their career; and it forms a background for their work, when they have attained sufficient knowledge and experience to be placed in responsible charge of the great tasks which the corps undertakes. I speak entirely impersonally of this.

The CHAIRMAN. Does this study begin in West Point or in some school subsequently?

General JADWIN. It starts at West Point and then it goes on at the Engineer School down at Fort Humphrey. And I may say in addition that we send practically all of our young officers for a year to various civilian colleges to get anything that they may have bearing on the subject.

The CHAIRMAN. Boston Tech and Troy Tech?

General JADWIN. Boston Tech and Troy Tech and Cornell and even Stanford University.

Mr. MANSFIELD. Do you send any of them abroad for that purpose?

General JADWIN. We have two men abroad now—three, rather—they are in Oxford University, but they are in there as Rhodes scholars, and I may say that all three of those young men won those Rhodes scholarships by competitive examination taken after they left West Point. We have another one who has been designated by Leland Stanford College, after taking his year there, to fill a scholarship, the filling of which was offered that university by a German university, and we will probably arrange for him to go over there.

I may say further that when we get started on this laboratory it is my intention, although we have many officers who have been through and have seen what they have in these laboratories in Europe and have read what people have written on them, I intend to send an officer over there to get the latest up-to-date information that they may have, such as it may be, to use in connection with the establishment of our laboratory. That is, I do not mean to say we are going necessarily to follow what they have, but we want to have just the latest information so that we may do the best possible for this great work that is ahead of us.

Mr. HULL. Will it be necessary to pass legislation for you to establish your laboratory?

General JADWIN. No, sir. We have made these studies at different times; I am putting it in here because it is pertinent to the flood subject, but we feel that we have the legal authority now, Mr. Hull.

The superficial character of certain criticisms launched against us in this line should be evident from a consideration of the alternative plans advocated by such critics, and of the lack of knowledge of the elements of sound river engineering betrayed by these critics. In the recent past, for example, we have heard a comprehensive attack on the principle of reservoirs, and the allegation that reservoirs can be of no benefit as an integral part of river engineering. Such a statement betrays at once the superficiality of knowledge of anyone responsible for it. As a basis for irrigation, as a source of power, and as an element in local flood control, reservoirs have immense possibilities. While it is true that investigation has shown them not to be the

soundest method of solving the specific problem of floods on the lower Mississippi, no greater mistake could be made than to assume them on that account to be discredited for all purposes. The Corps of Engineers is now undertaking a comprehensive study of rivers throughout the country, a large part of which will be an investigation of reservoir possibilities.

We have also listened to proposals, made in the face of the experience of 1927, for solving the Mississippi flood problem on the exploded basis of "levees only," using this time a double line of levees, and thereby more than doubling the cost, sacrificing great areas of valuable land, and demonstrably failing to obtain a solution of the problem. We have been opposed by so-called hydraulic experts who are on record as favoring the straightening of the Mississippi by cut-offs across its loops, a procedure whose fallacy is known to any layman at all familiar with the river. We have been given treatises on bank revetment, which are obviously merely hasty copies of our own reports on the subject, and which contain recommendations for cheapening the work without any practical suggestion as to how this end shall be accomplished.

It will be very dangerous to take seriously proposals from such sources. The impracticality of such suggestions as those I have outlined above is in itself a conclusive comment on the soundness of any new suggestions from the same sources.

The proposal for a hydraulic laboratory, made by the Chief of Engineers in his report on Mississippi flood control, is nothing in any way revolutionary. It is simply a further step in systematizing one particular branch of the theoretical researches which the Corps of Engineers has been carrying on for many years, and the records of which, I repeat, form the basis for the science of river hydraulics in this country, and compare favorab,y with similar studies anywhere else in the world. When necessity arises, we have done precisely this type of work in the past. For example, in designing the Gatun Dam and the complicated Gatun spillway in Panama, we constructed working models and made very careful theoretical tests with them. Heretofore, however, we have handled such laboratory tests at the site of the works in question. The same principle, applied to the Mississippi, pointed to a laboratory at some central point on the lower river. And I may say further about that site, there are several that we are considering. There is one possibility of going just below Memphis, where we will get river conditions and where we can get power and supplies easily.

Another one that we are considering, not quite so seriously, is near Greenville, just back of Greenville a little way. The Yazoo has so many tributaries filtering in.

Another one we have considered is on the other side of the river at Lake Providence, where we are figuring that possibly new conditions will arise in time of flood that will call for probably extensive measurements there with the necessity of determining the cross section of the levee and its height.

Mr. O'CONNOR. May I suggest, Mr. Chairman, at this point that Senator Ransdell, the author of this bill, lives at Lake Providence.

General JADWIN. Well, that would not prevent us from doing it. [Laughter.].

We also are considering a site up at Arkansas City. There are certain advantages there. There are certain advantages and disdvantages with each of them. Arkansas City has the big advantage that they are pretty sure to get a lot of water around there It is a very critical point as it is right near where the Arkansas River joins the Mississippi. That is a very critical point in the study of the river, and while we have got a general plan and you have adopted it, we will have to make many studies as we go along on the question of the exact type of levees above and below the flood line, and we want to compare them concurrently, and while we are studying the levees it has been suggested by a member of this committee that New Orleans might be a good place for that laboratory, and we might give consideration to that also.

Mr. O'CONNOR. General, I am very serious about the locus of that administering body to flood control. Frankly, if I may be permitted at this time, while having great affection for St. Louis, I can not understand—but I am a layman and probably I would take the same position as these civil engineers do with respect to this laboratory—but I never could understand why a great body of that kind should be located at a point that is not seriously affected by the flood waters, instead of being located where they could study flood waters, and that seems to parallel your view that the Mississippi ought to be studied from a hydraulic standpoint, from the banks of the river, rather than in Washington.

General JADWIN. Well, that question has been up a good many times, Mr. O'Connor, but it is different now from what it has been in the past. It is up again. A gentleman was in talking to me about it yesterday and asked for my reaction, and I told him I had heard a great deal of it lately.

Mr. HULL. Is it because the mosquitoes are not so bad in St. Louis as they are down below? Is that the reason they are stationed at St. Louis? [Laughter.]

General JADWIN. I do not know just how it got there, but that was the big city at that time. I suppose it has been largely a matter of inertia. But they are interested there in navigation up to St. Paul, they are interested in going up the Missouri, and they are interested in the work over toward Chicago. If you take a geographical view of it and consider the tributaries, it is central, but the bulk of this work that we are starting on now, this $300,000,000, as Mr. O'Connor says, is south of there, and I think that question will probably be up very acutely before the Secretary and myself. I have sort of hoped that it might not be stirred up until we got the real work going down the river, in other words, got quite a few changes in development on our hands there, but if it is forced on us we will have to dig into it and make a recommendation on it, I suppose.

Mr. O'CONNOR. May I suggest to Senator Ransdell that you have suggested the probability of the laboratory being erected, constructed and put into operation in his own town of Lake Providence?

General JADWIN. The possibility; no guaranty. I want to consider them and weigh them on their merits. But that seems to be the general location, where it ought to be for the nature of the problem.

The CHAIRMAN. Those two general locations, Senator Ransdell's home and on the Arkansas, each have the advantage in making of measurements along that channel conveniently.

General JADWIN. That is the very serious, critical part of the system. The biggest break, you know, of all happened at Mounds Landing, right where the Arkansas comes in. That is right near Arkansas City, and there has always been an argument about the height of the levy line there, and that has got to be gone into and we will have to make a model of some kind and will have to carry it right along. But there is no reason for stopping the main work; it is just a question of a few feet in the height of the levee, and then we want to figure also, and I say we may, if you want to know more about those problems, we want to figure further on the cross section of the levee. When we started with the levees they were small; they just grew up as mounds of earth, and if you had a party out there building, it was simply a question of giving them the lines and let them build the same cross section for a long distance, because you could not tell just what kind of material they were going to get, as they just came from the borrow pit and took it, sand, clay or whatever mixture it was.

We are going to make the levees higher and wider. Particularly we are going to strengthen them, increase the width. That is going to call for more material and it is quite probable that we may be able to effect a saving in cost by making a different cross section, where we have different materials, where we have clay, for example, as compared with material where we have largely sand. For proper engineering you really need a bigger cross section. They have rather gone on the theory in the past, the levees not being any too big or any too wide, of making them all practically as they made the biggest one. Now, I think we will have to get a little closer on that and will have to make some models of these things and put the water on one side and develop gradients, just as I told you we did in Panama, and determine the cross section in general with regard to the material there. You can not, of course, when you have got parties out in the field working, just control what the material is. You have got dredges working, you have got a lot of teams working, and the material does vary somewhat as you go along, but in a general way, if you can find a long run of clay we would make it smaller than if we had to take sand, and we would make the cross section accordingly.

Mr. MOONEY. I would like to ask just what you mean when you use the term "cross section" in that connection.

General JADWIN. Here is the cross section of this book, Mr. Mooney [indicating]. It is the end of the book as you see it there. The levee, you know, comes out like this on that side and on this side, and then we have a berm which comes out here. Now, the cross section is the part cut by a vertical plane across the levee.

Mr. MOONEY. That is the width of the levee?

General JADWIN. The width and height and exact location of it.

Mr. MANSFIELD. An end view of the levee.

General JADWIN. Just where a plane going through there vertically would cut the levee.

Mr. MANSFIELD. General Jadwin, Senator Ransdell made this point in regard to the location of this laboratory in the Bureau of Standards: That it would serve the purpose of various other depart-

ments of the Government as well as of the War Department, the Department of the Interior and others.

General JADWIN. We were aware of that argument, Judge. I did not intend to say anything about it, but I will as long as you have brought it up. It is set forth in the book here, the previous testimony, that they will have there one man, a scientist, who is familiar with water, with hydraulics, and they will have under him some young men out of college, and then he in turn will work under the direction of the Bureau of Standards, which is also charged with testing cement—and we have cement tested there—and it is done satisfactorily—and testing steel and brick. His time will be divided, this one man, between looking after the laboratory and these other things. He is not a man who will be in touch with field conditions, and he will have under him these young college boys, and he will also take care of us. We are to tell him about this problem on the Mississippi; then we go in and he is going to fit us in with some jobs that he is doing for the reclamation people and some jobs that he is doing for the Geological Survey and some jobs that he is doing for some private corporation. We will go on when we get our turn, and our problem will be handled in the way that he wants to handle it, and it will be done with these three barrels of sand that are to be brought in there, and with this jug of water, and perhaps it will not suit us at all nor move along at the rate that we expect to move in order to get this information to carry right along with the work.

Mr. MANSFIELD. Your department would have far more use for it, perhaps, that any other department of the Government?

General JADWIN. We have charge of practically all of the river improvements, with one or two exceptions, for navigation and for flood control.

The CHAIRMAN. Let me ask you two or three questions, General. As I understand it, you have testified that your department is advised that you already have authority to establish the laboratory in question here?

General JADWIN. Yes, sir.

The CHAIRMAN. So if the committee here by its action approved another laboratory, it would be a duplication, would it not?

General JADWIN. If you permit them to go on with anything connected with rivers, the improvement of navigation, flood control, yes, sir.

The CHAIRMAN. As I understand it, one of your main arguments is, is it not, General, that you can bring the men to the condition which makes the problem here, very much easier than you can bring the conditions to the men at a distance, a long distance from where the conditions exist?

General JADWIN. That is better stated than I stated it, Mr. Chairman.

The CHAIRMAN. Now, third, General, you have already, have you not, officers in all of these fields where your problems arise?

General JADWIN. Yes, sir.

The CHAIRMAN. And they are trained officers who have studied at West Point, who have gone on in an afterstudy at these various places, like Leavenworth or Humphreys, and perhaps in Troy or Cornell or Boston Tech?

General JADWIN. Correct.

The CHAIRMAN. And have completed in that way their education, and who would be in charge in the field of the operations and of the studies at the same time; the studies and the operations would be conducted simultaneously, practically simultaneously and in the field?

General JADWIN. Yes, sir. He would be one of the best officers that I have, technically, and we have 15 or 20 officers especially qualified for such work and a leaning that way—Colonel Pillsbury sitting here is one of our chief ones, and we have developed quite a number of others. You will find in a book here that is written by a prominent civil engineer many references to the excellence of our work in that respect. He speaks particularly of one officer that is down in my office now, and I will take one of these officers and put him in charge and have him work under the Mississippi River Commission, because we are going to handle all that flood business in that way. They come under me now, you know. And then the president of the commission will coordinate between this man and the people in charge of the work right there in the field, so that they will get prompt action.

The CHAIRMAN. And the officers up and down the Mississippi and the Missouri and the Ohio and other tributaries, where these problems arise, would all be within easy distance of this laboratory, and where they could keep in constant touch and where the man in charge of the laboratory could also go to the individual commissioner.

General JADWIN. That is correct. And Judge Mansfield suggests we might find it advantageous to put it on a boat, or we might put a movable one there that go up some of the rivers on some substudy.

The CHAIRMAN. That is, part of your outfit could be transportable that way to the actual scene of operations throughout that region?

General JADWIN. Yes. I had not thought of that before, but I think that that may be an advantage for part of the tests and studies.

The CHAIRMAN. Then, General, let me ask you this: Would the placing of this in another agency be or not be something like the proposition presented to us by this bill to place engineers in the Interior Department instead of the War Department?

General JADWIN. It would be bound to result in red tape and delay and slowing up of the work. We have to take our turn with our priority, and after a while they would have their ideas as to how these things should be done, be governed largely by their studies, and get out of touch with the field, and we would have more or less constant conflict, which would result in great disadvantage to the work.

The CHAIRMAN. Now, General, we have had that bill under consideration for some time, as you know. We have also had presented to us recently—you may not know it—the question of whether the water-power bureau should be made practically an independent bureau. I do not know whether you know the history of that or not.

General JADWIN. Yes, I am thoroughly familiar with it, Mr. Chairman.

The CHAIRMAN. I want to tell you the history of it the way it went through, the legislation. It got on the floor. It was reported by a committee and supported by a committee, the Committee on Interstate and Foreign Commerce, one of our greatest committees, supported by, I think, a united committee. One of the gentlemen on the floor who was very familiar with that kind of matter offered

amendments which struck out every vital part of the bill. Senator Burton, who has been here this morning, supported the bill.

Mr. McDUFFIE. It was his bill. He introduced the bill.

The CHAIRMAN. He made the leading argument. He got 15 minutes in which to make the argument.

Mr. McDUFFIE. And the House voted it down after they had heard the speeches.

The CHAIRMAN. After the Senator had made the argument for 15 minutes and after the committee had supported it unanimously, on amendment to strike out the vital part of the bill the vote of the House was about 2 to 1. Then with the vital parts out, we fellows who had made the fight were perfectly willing to vote for the bill, but we could not stop the procession. The bill itself was defeated as well as the destructive amendments adopted 2 to 1. I thought perhaps that might throw some light upon what might happen if we got into the House from this committee with this situation.

Mr. MORGAN. Might not a situation arise, Mr. Chariman, like the gentleman explained arose in France in the matter of placing the siding, that conflicts might result in delays and emergencies?

General JADWIN. I am quite sure it might.

Mr. HUDSON. General Jadwin, after listening to your very able exposition of your side of this question, would you be willing to state that you think there is a field for a hydraulic laboratory exclusive of the needs of the Board of Engineers?

General JADWIN. I am not quite willing to say that, Mr. Hudson. I will tell you why. We ought to have it for this river project. Now, then, there comes in the power business. There is need for a laboratory, but my understanding is that this manufacturing of machinery is concentrated in three large concerns, and they have very extensive laboratories and their expermentation is in A No. 1 shape. I do not see any occasion for the Government to step in and assist them on that.

Then you come to the questions of the flow of water in pipes and in connection with water supply of cities. That has been done somewhat in the colleges. I am not sure whether they really need much of that. We do not, so far as we are concerned.

Mr. HUDSON. In other words, if there is a need it is not a pressing need, at least in your view?

General JADWIN. Not to my knowledge. They have been establishing water works for many, many years, and the colleges do carry on those experiments. Now, I am not well enough up on that arm of the profession to say whether or not it would pay the Government to put in a laboratory that would make tests in connection with water supply, sizes of pipe, and things of that kind. There has been a great deal of work done on that, and largely all the formula we already have are based on those small amounts, and we have had to do our own work in getting up to these larger amount in rivers. And again, our rivers are bigger than any of those rivers in the other countries where they have done that work.

Mr. O'CONNOR. So far as the Mississippi and its tributaries are concerned, you do not consent to the doctrine and theory of similitude?

General JADWIN. The doctrine of hydraulic similitude has some points, Mr. O'Connor, and some things have been determined by

tests. I showed you where we had done some. But I will say this: That has to be done with reason. You have to keep your feet on the ground and watch the actual things. For example you make the model such a percentage smaller in length and width; then comes the question whether you are going to make it the same percentage smaller in depth. Then you get your sand in there, are you going to reduce that by the same denominator, and having got that, having reduced everything but that, shall you take the velocity just as it is in the river or shall you cut that down and call that one-tenth? Those things all come up and they have to be taken within reason. Sometimes you can get a valuable indication; other times if you tie to it too closely you will get completely lost. I can point out cases where men who have been very successful in one branch of the engineering profession, who in the prime of life have done magnificent things, who have gotten out and gotten interested in other branches when they got past their prime and have written books about it, have gotten in things that are pretty bad from a professional standpoint.

Mr. HULL. Will you tell us what similitude is, General?

General JADWIN. Similitude is derived from the Latin word meaning similar, and this model is similar to the thing in real life, but it is on a much smaller scale. Hydraulic similitude means that reduction in connection with water, and it is a question—you have got a problem in there each time you reduce it, whether you cut everything down a tenth, or if whether you cut one thing down a tenth and the other a hundredth, and so on.

Mr. CARTER. Is there not some way they can determine that? Can they not work out those formulas?

General JADWIN. That has been experimented with a good deal, Mr. Carter, and progress has been made on it, but it is just prophecies on election, for example, it depends a good deal on the equation which you use, and you have to keep watching. You have to keep watching things on the ground, and the nearer you get to it the better off you are.

The CHAIRMAN. General, I will give you the best illustration there is in the United States that I know of, in fact, in the world, of the kind of problem that you want to work out and how successfully to work it out. Go up to Niagara Falls with me and go right to the power house just above the cataract and you will see there a model of Niagara Falls.

General JADWIN. I have seen that.

The CHAIRMAN. And you know that Niagara Falls, on the horse shoe side, the Canadian side, has a water fall down in the center of that 3,000 feet, and it erodes and largely destroys the cataract and impairs enormously its beauty.

General JADWIN. Yes, sir.

The CHAIRMAN. Now, John Harper was a great engineer.

General JADWIN. Yes, I knew Mr. Harper very well. I had a great admiration for him. I went over that model with him.

The CHAIRMAN. He worked out the problem of how to correct that erosion and that destruction of the falls and how to control the flow of the water, but he did it right on the edge of Niagara Falls and with Niagara Falls water. His model is right on the edge of the river. He

brings the water in from the river. He has created a miniature Niagara Falls, exactly in proportion to the thousandth part of an inch, and he takes the river as his model presents, as it is. Then he has his concrete blocks and he places them in the river, in this miniature river, and shows just how you can correct the erosion, how you can prevent it, how you can spread the flow of the water, how you can have a very much more beautiful Niagara than any white man has ever seen, and how at the same time you can withdraw additional water for practical purposes.

Mr. McDUFFIE. Just as he says, Mr. Chairman, that they did down at Gatun Dam.

The CHAIRMAN. Now, if there are no further questions, I think we have finished with the General.

Mr. McDUFFIE. Has General Jadwin completed his statement?

General JADWIN. I did not complete it altogether. I was saying, I think, when we digressed, that the proposed laboratory could, in all probability, have been established without additional legal authority, just as, under the general provisions of other acts of Congress, we have carried on the multitude of similar technical and theoretical studies which are at the root of our practical achievements. The Chief of Engineers, however, thought it advisable to bring the matter to the attention of Congress and incorporate it formally in a law. There is no more reason why this particular branch of study should be removed from the control of the department, than there is reason for similarly removing any of the other numerous activities of the same sort which it now carries on.

There is not only no reason for doing it, but there is a very grave danger in doing it. The laboratory which I propose is intended primarily to further the technical studies to be made in connection with the improvement of the Mississippi and other alluvial valleys. Such study must be undertaken in immediate connection with the agencies which are handling the field work, and at a locality which will permit investigations of the actual phenomena. To take a simple illustration: The phenomena of sand boils and percolation, which vitally affect the safety of levees on the Mississippi, turn on the fact that along the river the alluvial soil extends to great depths. Water may seep through scores of feet below ground level, and come to the surface hundreds of feet from the river bank. Manifestly we can not reproduce this condition, with a thin layer of sand and mud spread over an impervious foundation fabricated in a laboratory in Washington.

It would be extremely dangerous to the Mississippi Valley, and to the cause of river improvement and flood control, to have its problems studied theoretically, with a few barrels of sand, at a point remote from the Mississippi, by men in no way familiar with the problems of the Mississippi; men who would be out of contact with the agencies working on those problems, save as such contact can be obtained through the formalities and red tape of interdepartmental correspondence, or by the expensive and cumbrous method of traveling back and forth across the country. The people of the Mississippi Valley do not desire to see their river studied in a remote laboratory in Washington, and no one who has their interest at heart should advocate such a course.

The CHAIRMAN. General, the silt and the bottom of the river differs just exactly as much as the soil differs in a given county or on a given farm?

General JADWIN. That is correct, and at times, you know, it moves along. The bottom works along, tumbles over in waves, and above that it is thick in suspension and presents an ever changing problem, and we have got to get works that will deal with it, whatever its conditions may be.

The CHAIRMAN. Now, gentlemen; we have a great deal of work ahead of us and we only have a very short time, and my own notion is that we have heard all that is necessary to enlighten us on this subject. I am ready to hear more, if any member of the committee wants more, but as far as I am concerned I am ready to go into executive session on this. What do you say?

Mr. MANSFIELD. Mr. Chairman, I would suggest that Doctor Burgess is here from the Bureau of Standards, and we might see if he has anything further to suggest, since hearing General Jadwin.

The CHAIRMAN. Very well.

Mr. MOONEY. General, will you be here this afternoon?

General JADWIN. I am at your service.

Mr. MOONEY. There is one other matter that I would like to hear the General on.

The CHAIRMAN. General, you heard Senator Burton this morning, and we want to hear you on that Fairport Harbor, and we will not have time before we adjourn. I would like to talk with you about it and get your views, and we may want to have you heard this afternoon on that.

General JADWIN. All right.

The CHAIRMAN. General, let me ask you this question. Suppose that the committee should reach the conclusion that a laboratory should be established and that there might be some question as to your having present authority, and we concluded to report this bill, but to report it with a recommendation, report it as part of the rivers and harbors bill and with no jurisdiction of the War Department?

Mr. MOONEY. In the omnibus bill?

The CHAIRMAN. Yes. Now, how would you feel about that, whether it would aid the department to have the bill reported and passed in that way?

General JADWIN. If I understand you correctly, Mr. Chairman, if you do establish one that has anything to do with the rivers, we would like to have it under our charge.

The CHAIRMAN. Suppose we concluded that we would not establish it in the Bureau of Standards, which would meet the views of your department better: To simply vote against the bill, or to report the bill as a part of the War Department work under the engineers?

General JADWIN. Whichever you thought best in your wisdom. We can get along with it either way. If we thought you did not want the laboratory established we would not do it, but we feel that we ought to go on with it.

Mr. HULL. As I understood you a while ago, you do not need the bill, do you?

General JADWIN. No, as we understand it we do not.

The CHAIRMAN. Now we will hear you, Doctor Burgess.

STATEMENT OF G. K. BURGESS, DIRECTOR BUREAU OF STANDARDS

Mr. BURGESS. Mr. Chairman, I regret that you were not present on the 26th of April when we heard six very distinguished engineers. I hope you will read the record, because as I see it, practically, if not every, statement that General Jadwin has made this morning was anticipated and answered by these several gentlemen, all of whom, with the exception of Doctor Stratton, are members and past presidents of the several engineering societies, electrical engineers, mechanical engineers, and civil engineers. The engineering fraternity of the country, the civil fraternity of the country, is unanimously in favor, Mr. Chairman, of this hydraulic laboratory at the Bureau of Standards.

I may recall for your benefit, Mr. Chairman, that I stated at the previous hearing that this bill was given very careful consideration by the Budget Bureau and the President, bearing in mind the situation as it exists in the corps of engineers. I understand that the chief of engineers was consulted by the Budget, and the bill as originally presented was modified to take care of the War Department's interests, such as in section 2 of the bill before you, to set up a board of three secretaries, Commerce, War, and Interior, and the duties of that board are to map the program before the laboratory. For instance, if the War Department is in at the start on anything that is going on, if their problems are the most important, of course they will get first and primary consideration.

I think it is possibly pertinent to ask, Mr. Chairman, why has not the Corps of Engineers had a laboratory in the last 50 years in which they have been established, if they have the general authority, as I understand from the general's statement they have?

Mr. HULL. I think that they get that authority in the last bill.

Mr. BURGESS. Only from the last bill?

The CHAIRMAN. Yes. And I think the substance of what the general said was that in effect they have had what has been a laboratory in the field. For instance, such laboratories as they had down at the Panama Canal where they made these studies and tests with the surrounding conditions to meet the practical operation which they had before them.

Mr. BURGESS. I would recall in that connection, Mr. Chairman, the statement that Senator Ransdell made to the effect that there is nothing in this bill that prevents the War Department from doing anything it chooses in the way of experimentation along the river banks. That is wholly within their jurisdiction.

There is total and absolute disagreement among the civilian engineers who testified here the other day and the Chief of Engineers as to the desirability of having a central laboratory and having it located in a scientific engineering center, such as the Bureau of Standards. Also, the other departments concerned, who have field services, are also unanimously in favor of having such a central laboratory under civilian control and in, as I say, a scientific atmosphere.

Regarding the question of a laboratory itself on the Mississippi River——

Mr. MANSFIELD (interposing). May I disturb you for a question there before you get to another subject?

Mr. BURGESS. You can not disturb me but you can ask me a question.

Mr. MANSFIELD. Suppose that the engineers of the War Department act independently and have laboratories wherever they need them on the ground, would the other departments of the Government have activities sufficient to authorize this in the Bureau of Standards for their benefit and not to have any connection with the War Department?

Mr. BURGESS. I would consider, Mr. Mansfield, that there are unquestionably a very considerable number of problems that would very properly come into the central laboratory, problems other than those of the War Department. We have, for example, the problems of the Coast and Geodetic Survey, the Geologic Survey and the Reclamation Service, the Power Commission, the Bureau of Roads and others in the Agricultural Department. So that there is a very considerable feature of availability of such a laboratory in any case.

Regarding the laboratory on the Mississippi River, if you put up a large laboratory it is at one place. I doubt if you can do very much in the way of a portable unit for any very serious work of a laboratory nature that you will have to carry out.

Regarding the transportation of material of the river and mud and so forth, if you have a laboratory here, 50 miles down the river or 100 miles down the river, as the case may be, you have an entirely different soil condition. You will have to transport material anyway. I think that is absolutely clear and definite. You can have a laboratory but you must transport the material anyway.

The statement was made that it would be set up under one man and some boys, but you heard the testimony the other day to the effect that we can have at the Bureau of Standards the best possible engineering advice and get it freely from the engineering profession outside the Government service as well as within the Government service. Just as the engineer corps executes problems of river control on the rivers themselves with advice they get from the Mississippi River Commission, if it be on the Mississippi River, so in the case of a laboratory of this kind the actual work is done by the laboratory people but the problems are set up by the engineers who are experienced in hydraulic work.

Mr. HUDSON. Doctor Burgess, may I there do what my colleague said, disturb you a moment? Men are detailed from the War Department to various activities, are they not? Could they not detail engineers to this laboratory for work?

Mr. BURGESS. We have had very large experience in that sort of thing at the Bureau of Standards. We have had Army officers, Naval officers, members of other departments, detailed for specific work in problems for a large number of years. We also have had a great many problems put into our laboratories from those several departments and we have been able to give them the results they wanted. Very frequently we have a case coming up of an engineering service which needs cientific and engineering data which they themselves did not have first-hand. They actually go so far as to transfer money to us to carry out the work. They get back the answer that the laboratory can give them and then they apply that answer in any way they please.

As was stated the other day by the very eminent gentlemen who testified, this laboratory would be unquestionably of very great use to not only the War Department but the other departments. I took it on myself, if I may repeat a part of the conversation which I had with General Jadwin sometime ago—I will repeat it to the committee

if it is in order; if not, we will strike it out: That is, that I told General Jadwin that I believed he would get better and more effective service from a laboratory at the Bureau of Standards in the atmosphere that we have there of scientific research than if he had it under his own control. And I stand by that statement.

Mr. O'CONNOR. May I be permitted to ask you a question at this time? I do not want to disturb the trend of your thought, but under existing law has not the Bureau of Standards the power to make investigations in every imaginable field of science?

Mr. BURGESS. We have, Mr. O'Connor, the authority to carry out the investigations in a very large field of science and engineering. The thing that inhibits us usually is the money available for investigating any particular project. Our appropriations, of course, are specific appropriations.

Mr. O'CONNOR. That is not what is in my mind. Have you not got sufficient authority to enable you to go before the committee on the budget and the committee on appropriations now and ask for a sufficient amount to carry out any proper purpose that you may have, that falls within the scope of your powers as legally defined?

Mr. BURGESS. The technical situation here, Mr. O'Connor, is this: This requires a building in the District of Columbia, and to get authorization for a building you have to have a separate act.

Mr. O'CONNOR. Then you are lacking. That falls within my question. There is a lack under existing law.

Mr. MORGAN. Right along that line, Mr. O'Connor, does it require a specific statement of the use of the building, or have you authority in case you ask for an additional proposition for a building for scientific research?

Mr. BURGESS. In general we do not necessarily have to state a specific object, but this particular proposition is one involving other services than ours. It involves the field services of the several departments in addition to the public, so that it seems wise in putting up this bill to make provision, not only for the building, but for the specific cooperation, and under this board of three secretaries who are most interested in this matter.

Just another word regarding the question of a laboratory being in a central location. The Zuyder Zee is no little piece of water, but the problems of the Zuyder Zee they took over to Karlsruhe, to that laboratory. And I may repeat, Mr. Chairman, that the work done at Karlsruhe in all major problems is shown in that book in the center of the table there, and that every major problem they have put in has more than paid for the cost of the laboratory.

I will finish with just one sentence, Mr. Chairman, and that is this: That I believe that your committee can do a most constructive act in reporting out this bill. It will be a benefit to the several departments of the Government, it will be a benefit to the War Department in particular, and it will be a benefit to the public, and will be a money saver and will act as a help in the more economical administration of all matters connected with waterways.

The CHAIRMAN. Thank you very much, Doctor. We will adjourn until 3.30 this afternoon.

(Whereupon, at 1 o'clock p. m., the committee adjourned until 3 o'clock p. m. this day.)

EXTENSION REMARKS BY DR. H. K. BURGESS, DIRECTOR BUREAU OF STANDARDS

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, May 25, 1928.

Hon. S. WALLACE DEMPSEY,
Chairman Committee on Rivers and Harbors,
House of Representatives, Washington, D. C.

MY DEAR MR. DEMPSEY: In view of the limited time available for my statement before the Committee on Rivers and Harbors at the hearing held on May 15, 1928, I respectfully ask permission to have the following extension of my remarks included in the record:

In the hearings held before the Committee on Commerce of the Senate in 1922 and 1923, the proposal to establish a national hydraulic laboratory was unanimously indorsed by a large number of prominent engineers in this country engaged in hydraulic work and by most of the field services of the Government concerned with hydraulic operations. The only dissenting voice was that of Mr. Ockerson, representing the Mississippi River Commission, who said:

"It is believed to be wholly impracticable to obtain any further useful data regarding the Mississippi River problems by the use of laboratory models * * * When I speak of models I mean the whole scheme of laboratory work."

Mr. Ockerson's statement may be fairly assumed to be the attitude of the Mississippi River Commission at that time and there was no evidence brought forth to show that during the 43 years' activities of the Mississippi River Commission there had ever been a single serious attempt to determine whether laboratory experiments would give useful information in guiding the enormous outlay of public funds on the Mississippi River. As clearly set forth in Mr. Ockerson's testimony, the Mississippi River Commission was not at all in sympathy with the laboratory method of attack.

The Chief of Engineers (General Beach) was present at the hearings and the position taken by the representative of the Mississippi River Commission evidently met with his approval. Nevertheless, the testimony presented was so overwhelmingly in favor of a national hydraulic laboratory in Washington that the Senate Committee on Commerce reported favorably on the project February 28, 1923. This was five years earlier than any recommendation of the Chief of Engineers for a laboratory on the Mississippi River.

In the Annual Report of the Director of the Bureau of Standards for the year ending June 30, 1927, I urgently recommended that authorization be obtained and funds be granted for the building and equipping of a national hydraulic laboratory at the Bureau of Standards. This recommendation was made with the deep-seated conviction that such a laboratory would repay its cost to the country many times over in providing information on specific problems for the various governmental and civil agencies engaged in hydraulic work. My recommendation was duly approved by the Secretary of Commerce and submitted to the Bureau of the Budget in September, 1927. The project received the approval of the Bureau of the Budget and the President with the proviso that the program of the projects to be undertaken should be under the control of a national hydraulic laboratory board consisting of the Secretary of Commerce, the Secretary of War, and the Secretary of the Interior. This provision was duly incorporated in Senate bill 1710, which passed the United States Senate unanimously.

In his report to Congress, dated December 1, 1927, the Chief of Engineers recommends that a hydraulic laboratory be established under his direction. In this connection he states:

"Measurements and observations on our large rivers supply the best hydraulic data on the flow of such streams since actual experience with full-sized structures is preferable to experiments with small scale models. However, on occasion questions relative to the flow of water can be worked out by small scale experiments. Such experiments may be useful in some of our lock and dam designs.

"In addition, the organization in charge of a hydraulic laboratory may well be charged with the coordination of field data relative to the flow of the Mississippi and other rivers. For instance, it could advantageously take charge of discharge measurements, silt measurements, slope and velocity measurements, etc., and make studies and draw conclusions therefrom. It could be a clearing house for such engineering data and publish the same."

I wish to emphasize the fact that discharge measurements, silt measurements, slope and velocity measurements, etc., are made on the river itself, and do not have to be made by members of the hydraulic laboratory staff. They are field

measurements. Perhaps the best evidence of this is the fact that the Mississippi River Commission has been carrying out such measurements for years without any hydraulic laboratory. The results of some of these field measurements on the river would naturally be used in laying out the experiments in the hydraulic laboratory. But the laboratory experiments and the field measurements do not have to be made by the same group of men. If fact, it is far preferable to have the two lines of work carried on by different groups, each skilled and experienced in its particular line, but working of course in the friendliest cooperation. The effectiveness of specialization in research has been demonstrated so often as to require no further emphasis. In particular, experiments in the hydraulic laboratory, if they are to be effective and helpful, must be carried out with the precision and care and attention to detail that is demanded by such work. It is a specialized job just as the job of a construction engineer on a great project is a specialized job. Neither can take over the work of the other effectively, but working together, each contributing the knowledge and experience in his particular field, they form an effective combination which provides the maximum protection against costly mistakes in designing and building full-scale structures.

I should like to answer in some detail General Jadwin's comments on our summary of reasons for locating the national hydraulic laboratory at the Bureau of Standards. It should be recalled that the statement from which he quotes was largely a summary statement and that the underlying arguments were in the body of the accompanying report. (S. Rep. 718, 70th Cong., 1st sess.).

Reason No. 1: "A suitable site is available, involving no additional expenditure for land."

To this General Jadwin replies:

"A suitable site on the Mississippi River can be purchased for probably $1,000 or $2,000." * * *

This statement shows that General Jadwin is not considering the national hydraulic laboratory at all, but has in mind only his own immediate work and immediate requirements. The proposal in this bill is for a national hydraulic laboratory.

Reason No. 2: "Power facilities for driving the pumps and other equipment are adequate."

General Jadwin replies:

"No great amount of power is necessary and such as is necessary can be readily manufactured or purchased from the ordinary commercial sources at many suitable sites on the Mississippi." * * *

The fact is that we have been urged to undertake important measurements in the proposed hydraulic flume which would involve the expenditure of 1,200 horsepower, or more, for short periods of time. By working after regular hours this power could readily be supplied from existing equipment at the Bureau of Standards without interfering with other work. Furthermore, the testing of large pumps will require on occasion the use of relatively large amounts of power for short periods. The location of the national hydraulic laboratory at the Bureau of Standards would make it possible to carry out such tests.

Reason No. 3: "The Bureau of Standards already possesses a concrete flume 6 feet wide, 7 feet deep, and 400 feet long, used for testing water current meters, which can be made an integral part of the hydraulic laboratory."

General Jadwin's answer is:

"A flume adequate for all purposes connected with investigations on alluvial rivers can be constructed for a very limited cost." * * * Here again General Jadwin obviously has in mind only the immediate needs of the Corps of Engineers and has lost sight entirely of the fact that the proposal is for a national hydraulic laboratory. This flume, owing to its size, length, and volume of water stored, will be of great value in connection with the work of the national hydraulic laboratory.

Reason No. 4: "The water supply at the Bureau of Standards is adequate because the steadiest conditions are obtained by recirculating the water."

Regarding this, General Jadwin states:

"The water supply of the Mississippi is unlimited."

Our answer is that we do not need an unlimited supply. As is stated, our supply is adequate. General Jadwin also states that the water supply in Washington is filtered whereas the water from the Mississippi River would contain sediment. As a matter of fact, filtered water is essential for a great many hydraulic laboratory experiments, and it would seriously hamper the work not to have a filtered water supply. Potomac River water does not carry any precipitating agents as is evident from an inspection of the river itself in times of

flood. It is a simple matter to get into suspension such clay and silt as may be required in hydraulic experiments, but it is not so simple to get this material out of suspension when clear water is required.

Reason No. 5: "The hydraulic laboratory staff would have the advantage of contact with men engaged in related lines of work, such as aerodynamics and structures."

To this General Jadwin answers:

"The essential thing for the staff of a successful laboratory is to have immediate personal contact with the men who are doing the field work so that the research can really go hand in hand with the field work." * * *

I agree with General Jadwin as to the importance of laboratory men having personal contact with men engaged in field work where the two groups are working together on a common problem. But this does not mean that the laboratory man must be located at the site of the field problem in order to get such contact. The Bureau of Standards has innumerable contacts with industry. We have some 80 advisory committees concerned with technical problems in various lines of industry. The members of our staff are kept continually in touch with industrial problems in their particular fields through the visits of men in industry at the bureau, through occasional field trips, through meetings of technical societies, and through the visits of our advisory committees. We enjoy the fullest cooperation of industry and the engineering professions. If the proposed national hydraulic laboratory is established at the Bureau of Standards, I am confident that the most eminent hydraulic engineers in the country will be glad to contribute their advice and counsel when called upon as other engineers have repeatedly done in the past. In fact, a number of the distinguished engineers who appeared before your committee expressed their willingness to assist in any way possible. There is no question about contact with the field services. That will be amply provided for, but the fact that I have tried repeatedly to emphasize is that the job of the staff of the hydraulic laboratory is a laboratory job as distinguished from a field job. The staff is working upon a problem brought in from the field, but it is attacking that problem by laboratory methods. It is a practical problem and it is being worked upon in a practical way, but that way is not the way of a field engineer but the way of a scientist in a laboratory with proper appreciation of the method of procedure and the precautions to be observed in order that the solution may be a practical solution. Such work can be most effectively conducted in an organization devoted to the investigation of engineering problems by laboratory methods, surrounded by adequate facilities for such work and in contact with specialists in related fields where similar methods of investigation are employed. It is under such conditions that laboratory research reaches its highest state of fruition as regards sound, practical results.

Reason No. 6: "The facilities for the development of instruments are excellent. Three different types of strain gauges which were extensively used in the measurements made on the Stevenson Creek Dam and its model were designed by members of the bureau staff. Shop facilities at the Bureau of Standards are adequate."

To which General Jadwin replies:

"Adequate instruments for the purpose can be obtained readily at limited cost, and had best be tested under the actual conditions obtaining in the Mississippi River to avoid possible very serious errors in the results obtained from them." * * *

This statement has elements of humor in view of the fact that the Engineer Corps has for years been sending hundreds of water current meters to the Bureau of Standards for calibration before using them in the Mississippi River in connection with their measurements. As a matter of fact, much of the instrumental equipment in a hydraulic laboratory is of a very special character and has to be built especially for the purpose. In the design of this equipment the hydraulic laboratory staff at the Bureau of Standards would have the advantage of being able to consult freely with men skilled in the design and use of electrical, optical, and engineering instruments, and to secure their advice in applying such instruments to precise hydraulic measurements.

Reason No. 7: "The underlying idea of the proposed hydraulic laboratory is research. Furthermore, it is essentially research of a laboratory character, as distinguished from field work. For its most effective development, a continuity of thought and action on the part of the staff is essential. The staff should have the advantage of the inspiration, the incentive, the suggestions that come from contact with research workers in allied fields. These conditions are found in

the Bureau of Standards, and here the work of a national hydraulic laboratory can be carried out to the advantage of the Federal services and the Nation."

Regarding this General Jadwin says:

"The whole weakness of the proposal is revealed in the above. The laboratory is essentially for research, but it is a grave mistake to speak of this research as being 'distinguished from' and separate from field work. Laboratory experts isolated from contact with field experts often come to grossly erroneous conclusions, and their conclusions are therefore likely to be discredited in the eyes of the field agency." * * *

I am glad to have this comment from General Jadwin because it defines his position more clearly than anything he has said. He has read into our statement an interpretation which the statement does not justify. Laboratory research must inevitably be distinguished from field work conducted on the river itself. The laboratory research is based upon laboratory measurements conducted as far as possible in accordance with the principles of hydraulic similitude from data supplied from field observations. We have never said that it was "separate from" field work. Throughout the report emphasis has been placed upon the necessity of the fullest cooperation between the laboratory and field staff. There is no difficulty in securing such cooperation. Precisely the same plan has been followed at the Bureau of Standards in carrying out laboratory research in connection with other lines of engineering work, and the procedure has been found to be most acceptable and satisfactory. For example, the Bureau of Standards investigated for the Navy Department a large number of duralumin latticed girders such as were used in the Shenandoah. The method of investigation was determined in conference with officials of the Navy Department and the results of the research were supplied to the Navy Department with our comments and suggestions. The results of this investigation were effectively used by the engineers of the Navy Department in designing the Shenandoah, but the Bureau of Standards had no part in the construction of the ship itself. The final design and construction of the ship was the "field" job carried out by men experienced in that line of work.

Again, at the request of the Delaware River Bridge Commission, the Bureau o Standards carried out an extensive investigation to determine the safe load which could be carried by wide-web columns without danger of buckling. These columns were crushed in our great compression testing machine, involving loads of 2,000,000 pounds or more. They represented part of the structure supporting the great suspension cables. The results of this work were again incorporated into the design of the towers of the bridge, but the "field" job, consisting of the final design and construction of the bridge itself, was carried out by the Delaware River Bridge Commission. Numerous other similar examples could be cited in which important laboratory investigations have been intrusted to the Bureau of Standards, in full recognition of the fact that such researches could be most effectively carried out at the bureau. The examples cited are illustrative of the procedure which would be followed in the investigation of hydraulic problems and, incidentally, show the application of the principle of similitude in other engineering fields.

Reason No. 8: "In the Bureau of Standards the laboratory would be under civilian direction and would be staffed by professional men with civilian status and permanent tenure."

General Jadwin says:

"A laboratory on the Mississippi would likewise be staffed and operated *almost entirely* by professional men of civilian status and permanent tenure." * * * (The italics are ours.)

This phrase means, of course, that the direction and supervision of the laboratory would be under military control and that the program of the laboratory would be subject to all the changes in policy, attitude, and point of view which would result from the frequent changes in the personnel directing the laboratory, changes which appear to be inevitable in a military organization. Here again the objects and purposes of a national hydraulic laboratory are lost sight of, the work of the Corps of Engineers alone being considered.

Reason No. 9: "In the Bureau of Standards the laboratory will be centrally located, accessible to the other departments, and will be a service laboratory for them."

To which General Jadwin replies:

"A Mississippi River laboratory would be centrally located with respect to the entire Nation and the rivers of the Nation and would be directly on the particular river which presents the greatest problem." * * *

Washington is the headquarters of all the great Government agencies interested in hydraulics. It is the point from which the field work of these agencies is directed. Field men interested in Government hydraulic projects frequently report here. It is far more accessible, far more centrally located from this standpoint than any point on the lower Mississippi. In his statement General Jadwin is again overlooking the fact that the proposed hydraulic laboratory has a much wider scope and broader functions than those he is contemplating.

Reason No. 10: "The Bureau of Standards has had a long and successful experience in cooperating with other Government establishments and the public."

To which General Jadwin replies:

"The Bureau of Standards might well conduct investigations which deal with filtered water and with the class of problems which enter into such matters as municipal water supply, etc. The problems, apparatus, and technique facing a laboratory to deal with the flow of alluvial rivers are entirely different." * * *

It is absurd and unscientific to classify hydraulic problems on the basis of whether the water is clear or turbid. On this basis a possible investigation of the flow in a conduit leading from a filtration plant might be investigated by the Bureau of Standards, but an investigation of the flow in a conduit of the same shape and size leading to the filtration plant would have to be made by the Corps of Engineers. There is, in fact, no marked difference in the density and viscosity of clear water and of water carrying material in permanent suspension when both are at the same temperature.

I believe General Jadwin's position may be represented as follows: He does not wish any investigation having any bearing whatsoever on projects under the jurisdiction of the Corps of Engineers to be done outside of the immediate and complete control of that organization. He is indifferent to the other hydraulic interests of the country.

The Chief of Engineers in his testimony expressed the opinion that in a laboratory of the kind proposed, serving all field services having hydraulic problems, his work would be unduly delayed because he would have to await his turn. I believe that contingency is amply provided for by the fact that the Secretary of War or his representative forms one member of the committee of three which determines the order in which the projects are to be taken up if any question arises. It seems unnecessary to state that such problems as might be presented to the national hydraulic laboratory by the Corps of Engineers would unquestionably receive prompt attention. I am gratified to learn, however, that the Chief of Engineers believes that a large amouut of work would come to the laboratory from other field services. With this I heartily agree. But the proposed national hydraulic laboratory would be on a scale both as regards equipment and personnel to take care of a large volume of work. This proposed laboratory is not a toy, it is a seriously considered attempt to provide a laboratory commensurate as regards scale, equipment, and personnel with the needs of the country for hydraulic experimentation. The item for permanent equipment alone ($50,000) is as much as he proposes to spend for his whole laboratory. The item for equipment is more than justified by the importance of the problems already presented for consideration.

General Jadwin speaks contemptously of the proposed national hydraulic laboratory staff, which he characterizes as consisting of "one man and some college boys." The time of the man, according to General Jadwin, will be divided between looking after the laboratory and testing cement and steel and brick. These plans are General Jadwin's, not ours. As a matter of fact, the Budget estimate provided for a hydraulic laboratory staff with aggregate salaries amounting to $50,000 a year. Members of this staff are to devote themselves exclusively to the work of the hydraulic laboratory. They have no other duties. The members of the staff will include the best-trained men which we can secure for this purpose, men who have had a thorough fundamental training in engineering with subsequent experience in hydraulic laboratories in this country and abroad.

General Jadwin also characterizes the laboratory procedure as one carried out "with three barrels of sand that are to be brought in there and with this jug of water." This again may be General Jadwin's conception of experimentation in a hydraulic laboratory, but it is not our conception. The experiments must be carried out on an adequate scale. The plans provide, for example, for a flow of

600 cubic feet of water per second in the weir flume. It is generally recognized that most of our college hydraulic laboratories are entirely too small to conduct hydraulic research on an adequate scale. Irrespective of problems in river hydraulics, the Nation is in urgent need of a modern hydraulic laboratory to provide information upon specific problems in hydraulic engineering as they arise in connection with industrial development.

It is freely conceded that if the laboratory were located at some place on the Mississippi the sand and silt at that place would be more readily accessible, but this applies only to that particular position. Material from points 100 or 200 miles up or down the river from the laboratory would necessarily have to be transported to the laboratory, wherever it might be, if such material is required for experimental work in the laboratory. Material from other rivers must be transported if required. The location of the laboratory at any particular place does not get rid of the necessity of transportation of material. Furthermore, there is nothing constant or uniform about the amount of material in suspension in the Mississippi River. A content of sediment representing certain stages of the river, such as flood conditions, low-water conditions, and some intermediate stage, are all that is required for laboratory research. The idea of a floating laboratory is wholly out of the question on account of the undue restrictions in size that would result and particularly on account of the uncertainty in the gradient on the experimental channel when the latter was mounted on a floating base. These gradients must be adjusted with extreme care to conform with full-scale conditions. So far as the transportation of water carrying sediment is concerned, such transportation is wholly unnecessary. We can guarantee to give General Jadwin water carrying material in suspension corresponding to any specified condition in the river and to maintain this material in suspension as it circulates through the hydraulic model.

Such advantages as may result from locating the laboratory with reference to availability of material are far more than offset, in my opinion, by locating it at the Bureau of Standards, where laboratory research is the fundamental spirit of the organization. This does not mean, as General Jadwin is inclined to interpret it, that the work is in any sense divorced from the practical side of the problem. It is work on the practical side of the problem, but the plan insures that the laboratory work will be carried on in such a way as to make the results of the highest possible practical value. Laboratory results may be meaningless and misleading if they are not carried on by men who have a full appreciation of the technical and experimental conditions which must be maintained. Such experiments carried out by a field man might give misleading results not because he is a field man but because he has not had the theoretical training and technical experience in this particular kind of experimentation. The laboratory man in trying to carry out the duties of the field engineer would be equally liable to make mistakes for precisely the same reasons. The proposal then to locate the laboratory in the Bureau of Standards is based upon the belief, which has been amply justified in other instances, that hydraulic laboratory research can be most effectively and expeditiously carried on in surroundings where the staff has contacts with men working in related lines of research, where well-equipped instrument shops are available, where skilled council and advice in connection with the numerous theoretical, and technical matters which may arise may be obtained.

Let us consider the development of a large hydraulic project and the relationship to it of an adequately equipped hydraulic laboratory, manned by personnel skilled and experienced in hydraulic work. The field engineers have their field data before them and several tentative plans have been developed, only one of which will be used. The cost of the final structure will run into millions of dollars. The plans involve certain new engineering features which have not been used before. Which is the best plan? Will the new engineering features work out as predicted? Here is where the hydraulic laboratory comes in. A working model representing each of these plans can be built and actually tried out in the hydraulic laboratory. The principle of hydraulic similitude must, of course, be complied with as strictly as possible in the construction and operation of the models. The field engineers can, of course, observe the operation of the models if they desire. From a study of the operation of the models, changes will be indicated. These changes will be made and the effect of them determined. With the gain in knowledge resulting from these laboratory experiments the field staff is in a position to proceed with greater confidence in laying out the final design of the structure.

A national hydraulic laboratory is needed not for the Corps of Engineers alone, but to advance the hydraulic interests of the whole Nation. It is needed by the United States Geological Survey, by the United States Coast Survey, by the United States Bureau of Reclamation, by the Federal Power Commission, and by the United States Department of Agriculture. These Government services and hydraulic engineers throughout the country have emphasized the importance of the national hydraulic laboratory and of having it located at the Bureau of Standards. The hydraulic problems of these various services of the Government demand consideration along with those of the Corps of Engineers. The needs of all the governmental field services and of the hydraulic engineers of the country as well can be satisfactorily met by the establishment of a national hydraulic laboratory at the Bureau of Standards.

Respectfully,

GEORGE K. BURGESS, *Director.*

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