JOURNAL *of the*

BOSTON SOCIETY

OF

CIVIL ENGINEERS

114 YEARS

1848-1962

JULY - 1962

VOLUME 49 NUMBER 3

FLETCHER granite

for

Bridges and Buildings
Street and Highway Curbing

ASHLAR VENEER

for

Bridge Facing - **Housing**

Landscaping

* * *

INNOVATION

Fletcher Vertical Granite Curb
Sawn Top & Bottom

* * *

GRANITE SURFACE PLATES

* * *

Brochure and price schedule
will be mailed on request

* * *

H. E. FLETCHER CO.

Quarry and Office

WEST CHELMSFORD, MASSACHUSETTS

Phone ALpine 1-4031

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume 49 | JULY, 1962 | Number 3

CONTENTS

PAPERS AND DISCUSSIONS

OF GENERAL INTEREST

Journal of Boston Society of Civil Engineers is indexed regularly by Engineering Index, Inc.

Copyright, 1962, by the Boston Society of Civil Engineers

Second-Class postage paid at Boston, Mass.

Published four times a year, January, April, July and October, by the Society
20 Pemberton Square, Boston, Massachusetts

Subscription Price $6.00 a Year (4 Copies)
$1.50 a Copy
All orders must be accompanied by check

BOSTON SOCIETY OF CIVIL ENGINEERS
OFFICERS, 1962-1963

PRESIDENT

GEORGE G. BOGREN

VICE PRESIDENTS

JOHN F. FLAHERTY
(Term expires March, 1963)

WILLIAM A. HENDERSON
(Term expires March, 1964)

SECRETARY

CHARLES O. BAIRD, JR.

TREASURER

PAUL A. DUNKERLEY

DIRECTORS

HARRY L. KINSEL
ALEXANDER J. BONE
(Term expires March, 1963)

CLAIR N. SAWYER
PAUL S. CRANDALL
(Term expires March, 1964)

PAST PRESIDENTS

EDWARD C. KEANE
ARTHUR T. IPPEN
JAMES F. BRITTAIN

SANITARY SECTION

GEORGE W. HANKINSON, Chairman
WILLIAM C. TRAQUAIR, Clerk

STRUCTURAL SECTION

PERCIVAL S. RICE, Chairman
MAX D. SOROTA, Clerk

TRANSPORTATION SECTION

JAMES W. HALEY, Chairman

HYDRAULICS SECTION

LAWRENCE C. NEALE, Chairman
KEISTUTIS P. DEVENIS, Clerk

SURVEYING & MAPPING SECTION

RICHARD D. RASKIND, Chairman
JOSEPH E. BODIO, Clerk

CONSTRUCTION SECTION

JAMES P. ARCHIBALD, Chairman
DONALD T. GOLDBERG, Clerk

Editor—CHARLES E. KNOX

20 Pemberton Square, Room 601, Boston 8, Mass.

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume 49 | JULY, 1962 | Number 3

TRENDS IN ENGINEERING EDUCATION

BY EARLE F. LITTLETON,* MEMBER

(Presented at a meeting of the Boston Society of Civil Engineers, held on November 15, 1961).

YOUR presence here this evening indicates that you are interested in engineering education. Many of you, however, are not directly associated with engineering education and have not had the opportunity to read the many reports that have been written or the articles that have been published over the past number of years. It may be of help to us this evening as we explore this topic to review the evaluation studies that have been conducted over past years and I shall attempt to do this with a minimum of statistics.

The organization founded in 1893 as the Society for the Promotion of Engineering Education, but now known as the American Society for Engineering Education, has since its founding conducted many studies of engineering curricula. These studies dealt mainly with the content of various programs and the distribution of time among the major divisions of the work. For your information, and for the historical value, it is necessary to go back to the early studies made in 1923 known as the Mann Report. From this early study came the report known as the Wickenden Report which study was made from 1923 to 1929. The Wickenden Report is such a basic report and has been fundamental to many of the reports made since that time that I should like to quote a few parts of this report:

> "The multiplication of trunk and branch curricula based on technical specialization has gone fully as far as can be justified. Further differentiation in courses for undergraduates is much more likely to proceed on functional lines."

* Head, Department of Civil Engineering, Tufts University.

"The most serious deficiency in engineering education is not so much in matter taught or matter omitted in college as in allowing the orderly process of education to stop, where it so often does, at graduation."

The Wickenden Report was then followed in 1940 by Ames and Scope of Engineering Curricula and in 1944 by Engineering Education After the War, both reports being known as the Hammond Reports. Both of these studies renewed the interest that had been generated by the Wickenden Report in the "general academic subjects." The two reports placed strong emphasis on the division of each curriculum into two parts; one, to be the scientific-technological stem, and the second to be the humanistic-social stem. The Hammond reports recommended that about 20% of the total program should be in the humanities and social studies. Both reports recognized also that engineering graduates enter into many kinds of varied activities upon graduation, therefore there should be a differentiation in the type of program taken in the undergraduate years. The reports recognized these varied activities as follows: "In order to provide for the satisfaction of the needs incident to these trends, the 1944 committee suggests, for consideration, a plan of curricula differentiation in the fourth year, through which three options would be offered within each major professional curriculum: (1) continuation of the present type of the four-year program essentially as a terminal program but with modification advocated by the committee, for a majority of the students. (2) an alternative fourth year emphasizing subjects dealing with the management of construction and production enterprises. (3) a fourth year intended to prepare for additional years of advance study by strengthening the student's command and extending his knowledge of basic sciences and mathematics, and by introducing him to the methods of advanced study."

In 1939, D. C. Jackson's Present Status and Trends of Engineering Education in the United States was published, and is considered a supplement to the Wickenden Report. A committee for evaluation of engineering education of the American Society for Engineering Education was appointed in 1952. A preliminary report on evaluation of engineering education was issued by this committee in October 1953; an interim report was published in June, 1954; and the final report on evaluation of engineering education was published in June, 1955. This report shall be referred to as the Evaluation Report or the Grinter Report.

This committee on evaluation included in its studies such topics as: (1) objectives of engineering education and their implementation; (2) the selection and development of an engineering faculty; (3) special factors that influence undergraduate educational achievement; (4) graduate study in engineering. The main part of the report was devoted to curriculum content as related to the objectives of engineering education. The objectives established for engineering education seemed to be in two factors: (1) that the engineering education program of the future should be based upon the obligations of the engineering profession to society and (2) the program should be based upon the importance of developing the student as an individual. The first part of this objective indicates that an engineering curriculum should never remain static. The increasing amount of knowledge of basic science and the vast quantities of material that are included in the engineering sciences, compel us to revaluate our curricula at frequent intervals.

The second objective encourages the development of a social goal in a program of engineering education. This objective leads to the development of leadership, may possibly help in developing some professional ethics, but it should, above all, tend to make the engineering graduate a better citizen and a person better qualified to take his place in society.

To accomplish these objectives the Grinter Report has designated that a curriculum should contain four basic areas: (1) the basic sciences including mathematics, physics, and chemistry; (2) engineering sciences including six sectors, (*a*) mechanics of solids (statics, dynamics, and strength of materials), (*b*) fluid mechanics, (*c*) thermodynamics, (*d*) transfer and rate mechanism (heat, mass, and momentum transfer), (*e*) electrical theory (fields, circuits, and electronics) and (*f*) nature and properties of materials (relating particle and aggregate structure to properties); (3) the humanity and social study area; and (4) engineering analysis and design.

The report of the Task Committee to the American Society of Civil Engineers, which appeared in Civil Engineering February, 1958, disclosed some interesting facts about civil engineering education. I shall not attempt to list them all, but the following are pertinent to the subject of the evening: (1) the quality and quantity of students in civil engineering are not keeping pace with other branches of engineering; (2) there is a definite lack of importance and prestige given civil engineering by the general public; (3) the feeling held by many civil engineers and civil engineering administrators that civil engineering is not a wise choice; and (4) there is an increasing difficulty to attract students to civil engineering. It is very evident that engineering enrollments are decreasing and that civil engineering is losing ground both in numbers and quality of students. These trends may be reversed in the next few years because of the responsibility and task before the civil engineer. It is also evident that civil engineering as a profession has lost ground, as compared to other branches of engineering, in terms of relative importance. This can be reversed if we in civil engineering can achieve a more realistic program of professional education and of public relations. Engineering education must assume the responsibility for the preparation of the young engineer, and must provide an adequate training for the young graduate so that he may find his place in a rapidly changing technology. It is the responsibility of the practicing or professional engineer to advance the prestige of the profession, to keep the house clean and in order, and foster those principles that not only lead to a learned profession but to an ethical profession.

One of our obligations as professional engineers should be to sell engineering education to young secondary school students and especially, as members of a civil engineering society, to sell civil engineering education. To convince them that it is not just a means to a living, but that civil engineering is the branch of engineering most directly concerned with man's environment and the fulfillment of human needs. Not only does the civil engineer plan, conceive, design and construct large projects that alter the face of the earth, but that when these projects are completed he has provided a means for better living, better working, and better recreation. The basic needs of our civilization are transportation, construction, water supply, sanitation and city planning; these are the responsibility of the civil engineer.

The many reports that have been published, including the report of the Task Committee, have for obvious reasons created a great deal of concern for civil engineering and civil engineering education. Many questions and topics have been raised by both engineering educators and professional engineers and in turn these questions have not only been a source of much debate, but of open "warfare."

It is impossible for me to list all of the leading questions of topics that have been raised, but I would like to mention those that I have considered to be some of the important ones so that you may under-stand the basic thinking that is taking place. (1) What is civil engineering? (2) What should civil engineering education achieve? (3) Should we call a specialist a civil engineer? (4) What sequence of subject matter should be included in a curriculum and how many years should it take? (5) Should we do away with the undergraduate civil engineering program and leave all professional education for a fifth and/or possibly a sixth year? This question could also be raised not only for civil engineering but for all branches of engineering. (6) Should the undergraduate program be extended to five or more years?

It was these questions and others that led the Cooper Union to take the initiative to organize a conference on civil engineering education. With the cooperation and the backing of the American Society of Civil Engineers and the American Society for Engineering Education and a grant of money from the National Science Foundation, planning sessions were conducted preliminary to a general conference on July 6, 7 and 8, 1960 at the University of Michigan. I shall refer hereafter to the report from this conference as the Michigan Report. The planning sessions presented the following resolution to the conference: "Therefore, be it resolved that this conference favors the growth in universities and colleges of a pre-engineering, undergraduate, degree eligible program for all engineers, emphasizing humanistic social studies, mathematics, basic and engineering sciences with at least three quarters of the program interchangeable among the various engineering curricula; to be followed by a professional or graduate civil engineering curriculum based on the pre-engineering program and leading to the first engineering degree, with a civil engineering degree awarded only at the completion of the professional or graduate curriculum."

So much then for a quick look at the important studies and reports that have influenced engineering education for approximately fifty years. These have, of necessity, been presented briefly, but I believe you now have some knowledge of the history of engineering education and what has been the background to our present situation.

Probably the greatest influence on engineering education is the major role played by ASEE. Of all the reports that have been published and the studies that have been made, the Grinter Report has made the greatest impact. This report has served as a guide to the Engineers Council for Professional Development, (ECPD), in establishing criteria for the accreditation of curricula. I commend the reading of this report to all who are interested in engineering education.

As to the trends in engineering education, I can only give you my personal impressions. These impressions are based upon progress reports that have been released in the past few years, conversation with engineering educators of other institutions, personal observations of what is taking place at educational institutions throughout the country, and the very definite changes in curricula that are appearing in current engineering bulletins.

What are some of these observations which have been made in regard to the changes in engineering curriculum which have resulted from the Grinter Report? I believe one important trend has been the breaking down of departmental barriers. Not only have science and engineering grown together, but the distinctions that have existed between the old branches of engineering are disappearing, and modern engineering education is finding it necessary to alter its viewpoint rather drastically if it is to maintain its position. Any discussion of engineering education will result in many viewpoints. Some educators will advocate a curriculum that leads to a learned profession, some will favor a broad general form of engineering education, and still others will desire a program of specialization. The types of curricula that would be recommended to accomplish these various aims would also be numerous. Many would suggest, for excellent reasons, the conventional departmental program in existence now with the common freshman year. Others would suggest the five-year program, three in liberal arts and two in engineering. Still others would argue for a common three-year engineering program for all engineers.

Many institutions have already made the move and have introduced drastically new programs of study in the undergraduate years. I believe we will see in the next few years, more and more colleges of engineering introducing an undergraduate program built around basic science, engineering science and the humanities and social studies. The professional or applied engineering science courses will be moved into a fifth year of study and shall be the basis of the first degree in a major area.

Another important trend is the change or shift from the teaching of the more fundamental and general concepts. We are beginning to recognize that engineering education for all branches of engineering encompasses broad classes of basic concepts, theories and engineering systems. If the engineer of the future is to be trained and qualified to handle the engineering problems of the future, he must have his background based on the fundamental and general rather than on the specific. With this type of training he would then be able to handle many types of engineering systems not only as to the techniques of the engineering art, but as to the methodology of approach to the problem.

The young engineering student that we have graduated from our institutions has always been able to make things work. The educational system in which he was trained was primarily concerned with producing an engineer who would be able to take his place in an established economy. From his endeavors and his genius would come some new products and new processes and as a result engineering education had to be steadily, but not rapidly, improved and changed to accommodate these changes. The Evaluation Report, however, was quite emphatic and made it very clear that engineering education could no longer be guided by that which is in existence, but should educate the engineer for that which is not foreseen. The rapid change in our technology could mean that the illustration we use today may be obsolete by the time the young engineer would choose to use this specific knowledge.

We see, therefore, that an education that teaches the specific and develops those skills necessary to take a place in present society, must give way to a form of education in which one acquires an understanding of the general method and approach of engineering problems that at this time are wholly unanticipated. Many educators and professional engineers feel that it is far more important today to be familiar with the most fundamental and far-reaching technological and scientific resources than to be able to do the many specific detailing operations. To provide an educational background to take care of this change in emphasis the engineering curricula have introduced those courses now referred to as engineering sciences. The Evaluation Report defines engineering science as, and I quote, "An engineering science is defined as a subject that involves largely the study of basic scientific principles as related to, and as related through, engineering problems and situations." The report on the engineering sciences based on a study made from 1956 to 1958 says, and I quote: "Engineering science has its root in basic science, but carries knowledge further toward applicability. It delves into the more practical situations, illuminates these with logical reasoning based upon the fundamental laws and generic principles of basic science, and leads into the statement in method of solutions of problems fundamental in engineering analysis, design and synthesis. Engineering science, therefore, stems from two basic areas: mechanical phenomena of solids, liquids, and gases; and electrical phenomena."

Simultaneously with the introduction of the engineering science courses, there has been a considerable decrease in the emphasis placed on techniques and skills. It is no longer necessary for the civil engineer to be an accomplished surveyor. In the same way the engineer who may be concerned with production need not be a skilled machinist. The use of graphical representation has always been an essential means of communication, especially in our field between the architect, the engineer and the contractor. However important it may be, there seems to be no longer a need for an engineer to be trained as a skilled draftsman.

The role of the laboratory has changed a great deal. Recall with me the type of laboratory work we performed 20 or 25 years ago. Much of the time spent was on repetition work, or cookbook type of experiment. It was easy on the instructor, and one found out only if the student could read, and secondly if he could follow directions.

The laboratory should be as effective in teaching as the classroom. It is the place where the student has the opportunity to test theories, to note any contradictions, and expand his knowledge by experimenting. Laboratory time should be spent wisely and should be used when essential data is necessary or some result needs to be interpreted. The use of routine or stereotyped experiments is questionable. A student would profit a great deal more if he were able, under effective guidance, to develop his own tests and draw his own conclusions.

One of the strong recommendations of the Evaluation Report involved an increase in the emphasis on teaching humanities and social studies. The professional engineer can no longer be satisfied in having only technical knowledge and skill, but since he meets with and works with people from all walks of life and in all professions, it has become necessary for him to have some acquaintance with the subject matter of these other fields. It is the aim of this area in the engineering program to provide a foundation upon which the young engineer may build a career. The fields of humanities and social studies from which he might select his courses would include history, economics, and government, which might make him a more competent citizen: or in the fields of literature, sociology, philosophy, psychology, and fine arts that provide a means for broadening his outlook. Through a limited number of courses in his program it is hoped that he would learn a respect for education in all its forms, that he might become aware of what others think and feel.

Another area in which the Evaluation Report gave new emphasis was in the area of engineering analysis and design. There has been an increased tendency on the part of engineering schools to eliminate those courses which were based on standard procedures or could be described as being merely descriptive courses. It is in this area that institutions are doing a great deal of study, or experimenting with various types of design and analysis courses, and although much has been done there still remains a great deal of confusion. To many engineering educators it is evident that this area of our former engineering curricula has been weakened, even though the attempt was being made to strengthen the program. In certain fields courses in design have been eliminated and finally only those courses involving engineering analysis may be found. Constant effort is being made to develop new ways, new approaches, new techniques, to teach analysis and design effectively.

It becomes quite evident when one considers that an engineering curriculum must include basic science, including sufficient mathematics, physics, and chemistry; a reasonable amount of humanities and social studies to permit a student to build upon the foundation gained in his undergraduate days; sufficient courses in the engineering sciences to provide the necessary fundamental background for an engineer to work effectively for a period of about 40 years, and to provide a sufficient number of courses in analysis and design, that it becomes impossible to educate a student with sufficient depth as well as breadth in a period of four years. I do not believe we are still able to train a professional engineer in four years. We should, therefore, decide what we do plan to do in the undergraduate program.

Technical information changes rapidly. It does not last a professional lifetime, its useful life is very short. This would seem to indicate that the knowledge and information an individual will use in a profession will be learned after he has completed his formal education. It, therefore, is the task of engineering education to equip the student with the necessary tools for learning, and we should no longer attempt to provide him the tools to make a living.

A foundation in mathematics and science provides the foundation to make the necessary adjustments in engineering and provides a better background to keep pace with a rapidly changing technology. It is easier, I believe, for the student trained in mathematics and science to step over into the field of engineering, than it is for one trained in engineering to move into the area of science. This may account for the fact that engineering enrollments are decreasing, while those in science are increasing.

Engineering is undergoing a transition, and to what extent this may develop is difficult to say. I believe we should recognize that it is impossible to produce a true professional in four years. It is impossible in four years to provide the necessary foundation for future learning, if we are also responsible to produce engineers for professional practice. I believe that the undergraduate four year program shall become a program of study oriented to the preparation of graduate study, self-education, or in training education. Thus the number of graduate degrees should increase.

We should be careful at the same time how far we move in the direction of an engineering science curriculum. There is a difference between a scientist and an engineer and as long as the end product of the engineer is a useful device or process, we should include in our curriculum some course work that applies mathematics and science to the solution of engineering problems. We are still faced with the age-old problem of how much of our vital human resources remain untapped when we continue to graduate highly trained specialists who have no interest in areas beyond their specialty. On the other hand, we graduate less highly trained students who seem capable of making a living, but are not qualified or are incapable of using their spare time in community service. Both of these educational situations are related; the education has been incomplete.

References

Report on Evaluation of Engineering Education—American Society for Engineering Education, 1955.

Accreditation of Professional—General and Professional—Scientific Engineering Curricula—Committee on Evaluation of Engineering Education, 1953.

Civil Engineering Education, 1959-60—American Society of Civil Engineers and American Society of Engineering Education.

Report of the Task Committee on Professional Education—American Society of Civil Engineers, 1958.

Report on the Engineering Sciences—American Society for Engineering Education, 1958.

"Where Are We Headed in Civil Engineering?" by subcommittee of Committee 1: Educational Policy, Civil Engineering Division, ASEE: Presented June 7, 1957, at the Annual Meeting of the Society at Cornell.

"A Survey of Current Changes That Are Modernizing Engineering Education" by L. E. Grinter, 1959.

"The Applied Civil Engineering Courses in the Light of the Evaluation Report" by Dean F. Peterson, Jr.

CIVIL ENGINEERING EDUCATION

By Ernest L. Spencer,* Member

(Presented at a meeting of the Boston Society of Civil Engineers, held on November 15, 1961.)

The best definition of "Engineering" I believe is that found in the Model Law of 1946. This reads, incidentally, similar to the definition of "Professional Engineers" as defined by our Massachusetts Registration Law.

The Model Law reads as follows:

> "The term 'Practice of Engineering' within the meaning and intent of this Act shall mean any professional service or creative work requiring engineering education, training, and experience and the application of special knowledge of the mathematical, physical, and engineering sciences to such professional services or creative work as consultation, investigation, evaluation, planning, design, and supervision of construction for the purpose of assuring compliance with specifications and design, in connection with any public or private utilities, structures, buildings, machines, equipment, processes, works or projects."

Perhaps it is needless to point out that the words professional, creative, education, training, experience, and application are the important areas for us to consider at this time.

The Technical Sections of the Boston Society of Civil Engineers and the fifteen Technical Sections in the American Society of Civil Engineers indicate the breadth of the Civil Engineering Profession. To quote from Dr. John B. Wilbur's paper given before the Michigan Conference to which Professor Littleton has referred—"We know that a Civil Engineer is an extraordinarily able fellow, if not a near genius, who uses science "plus," and I emphasize the "plus" as well as the science, to fling gleaming spans across yawning chasms, to carve the countryside with interchanges and with super-highways, to change the very geography of the earth with mammoth dams and the waters they restrain, to rear mighty structures skyward where they stand undaunted through earthquake and through storm."

Professor Wilbur goes on to point out that in addition to our

* Professor of Civil Engineering, Chairman, Dept. of Civil Engineering, Northeastern University, Boston, Mass.

awareness of today's rapid tempo of scientific and technological advance we, as Civil Engineers, are aware of further trends of the future, if not actually existing this very moment. These are the population explosion, the rate at which our civilization is plundering its natural resources, and the rate at which our civilization is poisoning and strangling much of the environment in which we live.

Water pollution from industrial and municipal wastes has long been one of our problems on inland waterways, as well as coastal areas, and now we have to contend with the disposal of radioactive waste. The ocean cannot continue to be a disposal area for this radioactive material indefinitely as we are rapidly reaching a danger point in this respect.

The water supply problem is one that is continually growing more acute, especially in the heavily populated areas along the seacoasts and certain inland waterways. This problem involves the quest for new sources of supply, new methods of treatment—possibly a use and reuse type of supply. The U. S. Department of Public Health has embarked upon a campaign to make the public aware of this critical problem.

Air pollution from industrial operations and our ever-growing mass of automobiles have presented smog problems in many areas that require immediate solutions. These air-borne wastes, thought by some to be cancer producing, give every indication to be increasing as our industrial development and Gross National Product inches upward.

Our buildings of today, being "built for eternity," so to speak, could be thought of as restraining the development of our environment. We need but to look around us to observe vast areas of Boston, and other areas, composed of buildings that have become outmoded and inefficient before they have reached an end to their "structural life." New building materials, new structural forms, new construction techniques are a necessity so that our present and future buildings can be more readily and economically altered or replaced as man's needs change.

Although mobility has been classified as one of the basic needs of man it is readily apparent that we are approaching, or perhaps we have arrived at, a transportation crisis. Do we continue to build more expressways into and through our cities; do we continue to expand our tax relief to the railroads and, in the case of Boston, underwrite a deficit ridden public transportation system—or should we look for new forms of transportation, better co-ordination between various forms of transportation and better control over the space allocated for mobility to increase its efficiency.

The problem outlined by Professor Wilbur points out the following:

(a) They all deal with the fulfillment of human needs on a large scale.
(b) They all deal with the land-water-air environment.
(c) They all deal with the adaption and control of that environment.

It is apparent to many that we consider the scientist as one who creates, the technician as one who applies, but the engineer is one who really is concerned with creative application—they are the innovators, directors and applicators all rolled into one. Engineers are concerned with utility and application; it is their job to decide the merits of a project, whether it is economically justifiable or not, whether it will serve the public in its intended function satisfactorily or not—in short, his is a professional responsibility. Little scientific knowledge would find its way into public usage if it were not for the practical applications given to the knowledge by the engineer.

The problems of the scientist usually lend themselves to a mathematical analysis and are much simpler than the problems of Civil Engineers. The Civil Engineering problems deal, not only with the scientific principles, but also are directly associated with our environment, our emotions, our politics, our rights as citizens, and our dignity.

The condemnation of property in connection with the construction of thoroughfares, the location or relocation of the thoroughfares themselves and the attendant political and environmental consequences, public reactions to the locations of sewage treatment plants, with possible resultant property deterioration such as the famous case of the proposed disposal plant opposite Mount Vernon on the Potomac River, are all examples of the opposition confronting Civil Engineers as they strive to serve man and his needs. Building codes, which may be outmoded as soon as they are printed, cannot be written strictly on a scientific basis due to the human elements involved and the ever-changing technological advances. Civil engineers daily copy with similar problems and the decisions made certainly have a direct influence on life, health, property, and public welfare.

Dean Williamson, of Penn State University, writes in the November, 1961 Journal of A.S.E.E. "It would be so nice to have a Maxwell's equation, Bernouli's theorem, or a Prandtl's theory to apply, but where human beings are involved, a solution arrived at in an aggregate or mechanics sense fails miserably when applied, since individual, highly vocal units are involved. The rights of citizens and the dignity of human beings have to be considered."

The profession of engineering must be concerned with the human aspect of its solution whereas a scientist, seeking research in his laboratory and a technician working for an engineer are spared this obligation. They will not be barred from practice if they do choose to forget it.

I have no wish to deny that there exists the need for deeper study and understanding of mathematics and physics, and its related engineering sciences of fluid mechanics, mechanics of solids, thermodynamics, etc. Our problem is not only to give broader knowledge and greater depth but to produce a person that is non-superficial. Depth in education can be provided by using specific applications as examples. Our curriculum should not be devoid of professional awareness nor should economics be neglected.

In brief then, shouldn't we teach the engineering approach—getting on top of new situations through self-study of new areas, the instilling of practical curiosity so that no matter how sophisticated and socially acceptable research may appear, there will always be engineers who can bring the research results down to mankind.

Engineering problems are thrust up from the real world, whereas many scientific problems are theoretical and lend themselves to neat solutions due to the methods of analysis available. Could our swing to the science-oriented curriculum be the result of similar thinking? I have found it very difficult to obtain staff members who have their theoretical background blended with good, sound, practical experience. These men may be available, but they are not interested in the education field. Since it is a problem to find engineering instructors, why not solve this problem by doing away with the engineering aspect and give the students more science and math? It is easy enough to defend this solution if administrators and department heads hold educational conferences, press conferences, professional society meetings and the like, and loudly proclaim this "new look in engineering education." Publicity can often sway man's mind into thinking along most any path. The intent of the publicity can pick the pathway—right or wrong.

Such an outlook, that of avoiding real problems, is bound to be popular in the campus environment since this is the locale that glorifies intellectual advance and scholarly profoundness. Schools do not look upon outstanding achievement as a practicing engineer as any qualification for faculty status unless there are publications. These publications, a must in the education field, have little appeal to the practicing engineer, who is more concerned with getting something accomplished than he is in bragging about it. Prospective faculty members, during interviews, are constantly being quizzed as to their research capabilities and how soon can a paper be published—their ability to teach, their willingness to teach, their plans for developing good courses are ignored—evidently these are not considered as necessary to the teaching profession.

I am firmly convinced that our function as enginering educators, especially in the field of Civil Engineering, is to teach ENGINEERING, the art, the economics, the social-humanistics aspects, the design know-how, the technology, and the professional awareness. To be effective, the instructions must be deep and its breadth sufficient only to the extent that it is not considered narrow, bearing in mind always that engineers must produce—not talk about producing.

PRUDENTIAL CENTER FOUNDATIONS

By Donald G. Ball,* Member

(Presented at a joint meeting of the Boston Society of Civil Engineers and American Society of Engineers, held on November 18, 1959).

In Boston's Back Bay, the Prudential Insurance Company is building a complex of high-rise office, hotel, and apartment buildings surrounded by low level shops and a landscaped plaza, Fig. 1. The development will cover 31 acres in the area previously occupied by the Boston & Albany railroad yards and Mechanics Building.

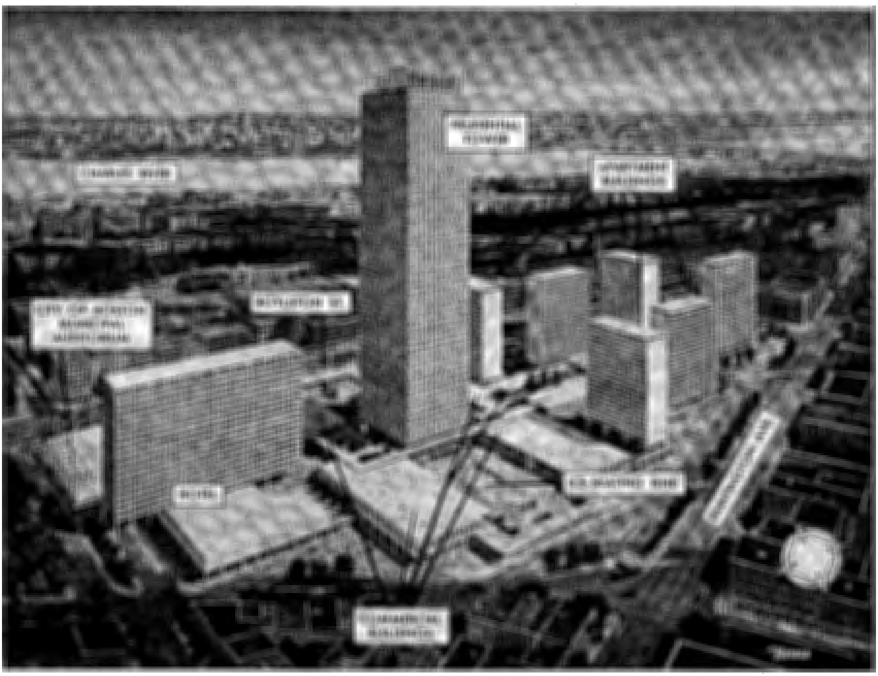


Figure 1.—Prudential Center—Boston.

* Chief Soil Engineer, Metcalf & Eddy, Boston, Mass.

History of the Area

The land at the site came into use less than 100 years ago when the offensive mud flats of Back Bay were filled to eliminate the nuisance and to create usable land for the expanding city. Originally Boston was built on a peninsula of much smaller dimensions than it now occupies. It was nearly surrounded by water being connected to the mainland by a narrow neck. The road along the neck is now in the general location of Washington Street running from downtown Boston southwest to Roxbury. Gradually the Boston area was enlarged by filling with borrow taken first from the tops of hills on the peninsula and later from areas to the west.

The first change in topography of the Back Bay came in the early 1800's when two railroads were built across the mud flats on piling and fill; the Providence & Boston railroad from the southwest, and the Boston & Worcester from due west along the line now occupied by the Boston & Albany. About this same period, the Back Bay was used to develop water power, a dam having been built along the present location of Beacon Street. This connected the Boston peninsula with Gravelly Point in the vicinity of Massachusetts Avenue and continued westward across another bay now identified as the Fens. The power developed was from tidal flow, water entering the filling basin from the Charles River west of Massachusetts Avenue when the tide was high and running through mill races into the receiving basin where the Prudential site and Copley Square are now situated. In 1852, earth filling of the basins was started and continued steadily until the 1870's when building construction in Copley Square began.

Description of Project

At the Prudential Center, a plaza will be constructed over the entire site. This plaza will create a new surface level at a height sufficient to give clearance to railroad and toll road easements running below and a large underground garage.

Buildings will occupy about 25 percent of the area. The remaining surface will be devoted to parking and landscaping that will include reflecting pools, terraces, and covered walkways. The Prudential tower, a 52-story structure, will rise more than 750 feet above the ground and become the tallest building in the world outside of Manhattan. At the foot of the tower will be constructed several low buildings to be occupied by banking facilities, restaurants, shops, and retail stores. Two spacious plazas will extend north and south from the base of the tower building to Boylston Street and Huntington Avenue. Plans call for an ice-skating rink on the south plaza.

On the western section will be erected a 26-story hotel. Adjoining the hotel will be the combined exhibition hall and 5,000-seat auditorium of the City of Boston. Prudential has planned a group of six apartment houses each 26 stories high for the eastern section of the site. These will provide approximately 1,750 apartment units. Main tracks of the Boston & Albany railroad will continue to run across the site diagonally northwest to southeast on an easement under the plaza. Adjoining this is a second easement for a six-lane highway, an extension of the Massachusetts turnpike from Weston to Boston's South Station. Combined width of the two easements will be 132 feet. Parking facilities on the surface and on three levels under the plaza will accommodate about 4,000 automobiles. Escalators and elevators will provide access to the various buildings from the parking areas.

Geology

A generalized soil profile, starting from the surface of the railroad yards at an elevation of 11 feet above Boston City Base, shows eight feet of sand and gravel fill over 3 feet of organic silt and peat that formed the old bay bottom. Under this is 20 feet of sand and gravel over 100 feet of Boston Blue clay. The clay rests on three feet of glacial till over bedrock. Average depth from the railroad yard surface to rock is 145 feet.

The bedrock is an argillite, locally known as Cambridge slate. It is a hard, well indurated rock with a fine grain texture and well defined bedding. It has a dip of 40 degrees to the north or northeast. The rock is gray-blue in color, ranging from quite light to dark, and contains many small veins of calcite. The thickness of the slate in the Back Bay is not known, but at places in the Boston basin may exceed 3,500 feet. At the site, the top of rock lies at about elevation minus 135.

Over the rock lies the glacial till or "hardpan." The till extends over most of Boston, varying in thickness from a few feet to probably well over 100 feet. It forms the distinctive hills on the Boston peninsula and islands in the harbor. Boston Blue clay was deposited over the till closely following the retreat of the glacial ice. The clay is of glacial origin and was deposited in marine or brackish water when sea level stood more than 30 feet higher than at present. Subsequently, the clay was exposed to weathering and erosion when the sea level dropped to between 90 and 100 feet below that of the present. Weathering and desiccation formed the stiff yellow clay layer that is generally found at the top of the soft Blue clay.

Groundwater

One of the early problems in developing the design and construction procedure at Prudential was control of groundwater. Lowering groundwater can have two effects on existing structures. One is to increase the load on the underlying soft clay by taking away the buoyant lift of water on the upper soils, thereby causing settlement. The second is to expose untreated wooden piles to the ravages of decay normally held in check by complete and continual submergence.

In 1910 the Charles River dam was completed and has maintained in the Charles River basin a fairly constant water level close to elevation plus eight in contrast to the previous tidal fluctuations from 0 to plus 10. Because the Back Bay is filled land, most of the existing structures rest on wood piles. The City, recognizing the importance of keeping the wood piles immersed, set elevation plus five as the maximum cutoff elevation.

Occasionally the possibility of groundwater falling below plus five was considered but since no serious foundation failure had ever occurred, very little was done to study the problem until 1929. In that year, the Boston Public Library suffered damage due to pile deterioration costing over $500,000 to repair. Needless to say, this caused grave concern to the owners of other structures in the area, and subsequently several groups began regular groundwater observation programs in the vicinity of their own structures, while the City of Boston began a widespread program covering the entire city. Since the damage to the Library, there is no record of any other major foundation failure due to pile deterioration in Boston. Some property owners still observe groundwater near their own structures, but the City program was abandoned in 1939 except for limited specific areas including a few observation wells in Copley Square.

A study was made of groundwater conditions in the Back Bay, past and present. Several sources of data on previous groundwater observations were available. The most comprehensive set of records were those kept by the City during the period 1929 to 1939. These contained readings at least monthly on wells installed throughout the City. Additional data were obtained from the records kept by Trinity Church in Copley Square and the Public Library in Copley Square. To observe the present groundwater trends, regular observations were also begun on thirty-seven existing wells in the vicinity of the site and nine observation wells installed on the site. One set of readings was taken on existing wells within the sector of the City between the Charles River basin and South Bay, from Massachusetts Avenue to Dartmouth and Union Park Streets. From these data, time elevation graphs of groundwater contour plans were prepared.

The elevation at which groundwater will stand in any given location is the result of several variable factors: the relative elevation of ground surface, the runoff coefficient, permeability of the soil and proximity of local influences such as water mains or sewers, and adjacent bodies of surface or subsurface waters. Many of these factors could not be exactly known. In spite of these limitations, certain facts were developed.

It was evident that low groundwater conditions existed near many of the low level sewers due to infiltration. At some points the sewers were more effective in lowering the groundwater level than at others. Although differential fluctuations occurred due to seasonal and other changes, the depressing effect of sewers remains fairly constant. As for the long term trend, a study of the groundwater graphs to date led us to conclude that groundwater in this area is not significantly lower than it was under similar climatic conditions 25 years ago.

A study of the groundwater graphs and contour plans reveals areas where groundwater continually stands higher than either the Charles River basin at elevation plus 8 or mean sea level in South Bay at elevation plus 5.65. These areas are large enough to preclude the likelihood of being caused by water or steam main leaks. Infiltration of groundwater from adjacent higher ground in Brookline or Beacon Hill is possible, but both of these areas are one mile or more away across the flat man-made land of Back Bay. It is also possible that precipitation combined with somewhat impervious soils maintain these areas of higher groundwater. This possibility is further indicated by the high surface of the clay between Tremont and Washington Streets east of Massachusetts Avenue. Whatever their cause, these areas of high groundwater level appear in all the years studied and always in the same general location.

To analyze the possible effects on groundwater of the construction operations, the effects of similar operations in the past were investigated. Two major construction projects in the area were carried out during the time for which records are available. They were the Huntington Avenue subway and the Christian Science Publishing House. The data show that some sections of the Back Bay are less susceptible to drawdown than others presumably as a result of less permeable soil, a perched water table, or a thinner layer of pervious soil on the clay. Large scale dewatering operations lower the groundwater level by a significant amount over extensive areas of Back Bay.

Records indicate that since the filling of Back Bay, groundwater has been fluctuating generally in the range from elevation plus five to elevation plus eight. This range has been normal during the past 20 to 30 years since the Back Bay has been highly developed and its storm runoff coefficient high.

Infiltration from rainfall and the surrounding bodies of water have combined to produce an equilibrium for this heavily developed sector, consisting of approximately 1,000 acres, which the more complete development of 31 acres of the Prudential site is not likely to alter materially.

Subsurface Investigation

The 26-story and 52-story buildings are of such height that it is necessary to carry their foundations down through the soft Blue clay to rock, but the garage and plaza with the low level structures, one and two stories in height, are light enough so that they can be carried by foundations above the soft Blue clay. Because both types of foundations are involved and because of the large area, the extent of the soil investigations on this project exceed in magnitude any that have been carried out thus far in the Boston area. A total of 67 borings were put down, of which 45 were only carried into the top of the Blue clay. Twenty-two borings went down to the rock and continued as core borings 20 feet to 30 feet into the bedrock. In the shallow borings split spoon samples were taken with a standard 2-inch sampler. In the 22 deep borings, 3-inch diameter undisturbed samples were taken with a stationary type piston sampler except in two of the deep holes which were 6 inches in diameter, making it possible to take 5-inch diameter undisturbed samples. From the smaller borings, 2-inch diameter rock cores were taken and from the two larger borings 3½-inch rock cores.

Professors Arthur and Leo Casagrande were engaged as soil and foundation consultants on the project and all samples were tested at the Harvard University laboratories. Of special interest is the following taken from their report of the subsurface investigation. (In the following quotation reference is made to the water-plasticity ratio of the clay. This is the relation of the natural water content of the soil to the water content of the same soil at its plastic and liquid limits. If the natural water content is at the plastic limit the water-plasticity ratio is zero percent; if at the liquid limit, it is 100 percent; half way in between, 50 percent.)

"Although a large amount of work has been carried out in Boston during the past 25 years on development of sampling tools and technique of sampling for taking undisturbed samples of the Boston Blue clay, an excessive percentage of such samples were found to be disturbed on all boring projects. Similar difficulties developed on this project. Even the strictest adherence to what was considered the best procedures, by experienced and reliable boring foremen, did not prevent satisfactory samples and samples showing excessive disturbance from following each other erratically and for no apparent reason. In an effort to analyze the possible cause of disturbance to samples, we requested the contractor to equip himself with dynamometers and to measure the force during sampling. Such measurements were made in connection with the taking of 5-inch diameter samples.

"From a systematic comparison of the penetration resistance as measured with the dynamometer, of the quality of the samples and of the sensitivity of the clay to remolding as reflected by the water-plasticity ratio, we were able to conclude that in general satisfactory samples were obtained only for clay having a relatively high sensitivity, i.e., for water-plasticity ratios of the order of 80 percent or greater; and that for relatively low sensitivities, i.e., for water-plasticity ratios of less than 50 percent, the samples were disturbed excessively. Satisfactory as well as excessively disturbed samples were obtained for clay having water-plasticity ratios between 50 percent and 80 percent.

"The relationship between the maximum load observed on the dynamometer and the water-plasticity ratio has been plotted. It can be seen that for high water-plasticity ratios, i.e., for relatively high sensitivity, the applied force ranged between one and two tons. For low water-plasticity ratios, i.e., low sensitivity, a force of three to four tons was required. Even greater forces were necessary for samples containing stones. From the plotted data, one can also extrapolate that for clays having water-plasticity ratios much greater than 100 percent, i.e., for extra-sensitive clays, much smaller forces than one ton would be required, in fact, in such clays (e.g., the soft Laurentian clay in Quebec and marine clays of Scandinavia) often the weight of the sampling equipment is sufficient to effect penetration because the remolded clay that forms in immediate contact with the surface of the sampling tube acts as a lubricant.

"The probable explanation for the manner in which sensitivity influences sample disturbance is illustrated in Fig. 2. For a clay of low sensitivity, the total friction force that builds up along the outside surface of the sampling

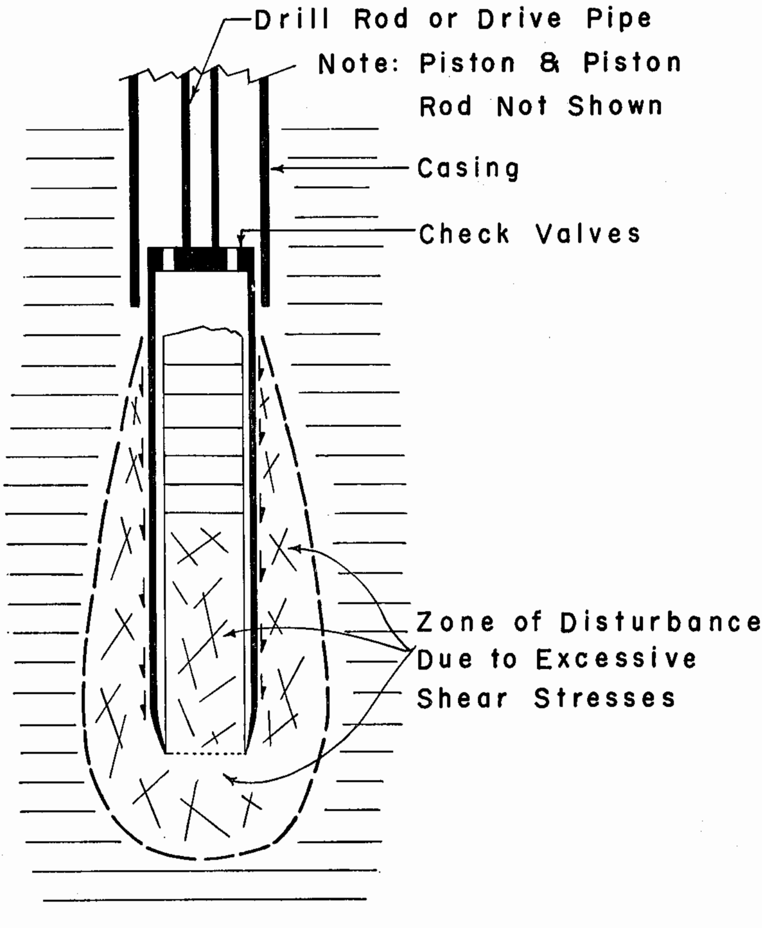


FIGURE 2.—SKETCH ILLUSTRATING SAMPLE DISTURBANCE DUE TO EXCESSIVE FRICTION FORCES TRANSMITTED BY SAMPLER INTO SURROUNDING SOIL. (From Casagrande report.)

tube, while the tube is being pushed into the clay, can reach values which exceed the compressive strength of the clay below the cutting edge. This can readily be checked by computation.

"When the water-plasticity ratios were determined, it was not anticipated that they would be useful in connection with this study. These values were determined for a section of clay a few inches thick, and it may not be representative for the entire length of a sample. On the other hand, the friction that builds up on the outside of the sampling tube is due to the character of the clay over a height of several feet, as well as the presence of sand layers and of stones. Therefore, it is likely that a deliberate effort to obtain all information needed to evaluate the outside friction would develop a clearer relationship than that indicated by the coarse relationship in the plot of dynamometer load and water-plasticity ratio.

"In retrospect, we can now conclude that all development work during the past twenty years has hinged on the assumption that it is chiefly the friction between the sample and the inside of the sampling tube which causes disturbance, and that if this friction were to be eliminated, satisfactory samples would be assured. Hence, almost all important improvements in the design of the sampler and in sampling technique, such as the angle of the cutting edge, the inside clearance, etc., were designed to eliminate this inside friction, and successfully so. But now we realize that in clay of low sensitivity sample disturbance will result in spite of all these precautions because of the excessive friction which is built up along the outside of the sampling tube and which is transmitted in the form of excessive stresses into the clay below the cutting edge. In other words, the clay is already disturbed before it enters the sampling tube."

The report continues with the recommendation that a rotary coring type sampler may be the proper sampling device to use. One of the best methods of determining sample disturbance is described thus:

"A thin longitudinal slice was cut from the center of each clay sample and allowed to dry slowly to the optimum condition for visual inspection. In this state the most plastic clay is still very dark in color, while clays of different degrees of plasticity range in color tone to light-gray, whereas nonplastic silts and sands are then already completely dry and of very light color. In that state representative sections were photographed with process film in order to exaggerate slight differences in color tone."

It can be seen in Fig. 3 that by using processed film and taking the picture at the optimum state of partial drying one can clearly bring out every small detail of stratification and disturbance. In its original state, the samples had fairly uniform gray color and only the sand layers could be identified as such. After complete drying the same samples were also of uniformly light gray color.

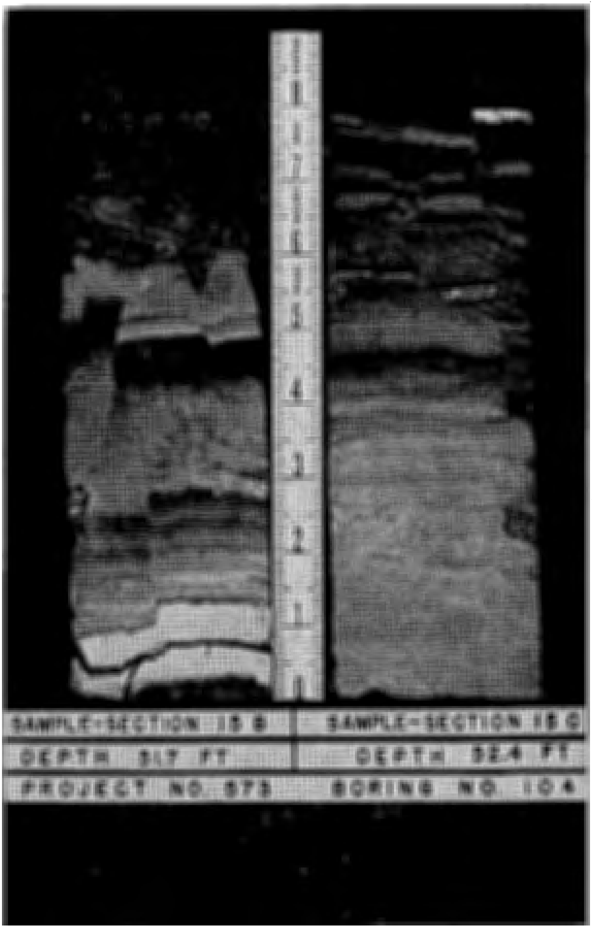


FIGURE 3.—SAMPLE SECTIONS 15B AND 15C: INTENSELY STRATIFIED CLAY, SILT AND FINE SAND; LOWER PART OF 15C IS SILTY FINE SAND; NUMEROUS SHEAR PLANES, PARTICULARLY IN 15B, ARE PROBABLY DUE TO SAMPLING DISTURBANCE. (From Casagrande report.)

FOUNDATION DESIGN

The present contract is only for constructing the foundations for the center section. This is a strip including the tower building running through the middle of the site from Boylston Street to Huntington Avenue. Since the tall buildings are twenty-six stories or over and the low building four stories or less, it is obvious that the foundations for the heavy structures must go down through the clay to bedrock while the light ones can be supported on the sand and gravel over the clay.

Several factors influenced the choice of foundation going to rock: economy, durability (corrosion, if steel were used), and effect of the disturbance of the blue clay on consolidation and settlement of structures immediately adjacent.

In the Casagrande report, it was pointed out that disturbances of the clay due to volume displacement by driving piles to rock would result in additional settlement in a narrow area surrounding the new high buildings. To keep such settlements to a minimum, the types of piles considered were those effecting the least displacement. A cost study narrowed the choice down to two foundation types: steel H-piles and drilled-in caissons.

Bids for the tower building foundation were taken for each as alternates and drilled-in caissons were cheaper by about 20 percent. The latter was chosen for construction. Some steel H-piling is being used to carry loads of intermediate value from the reflecting pool and heavy planter beds immediately around the tower building, but all the tower buildings column loads are to be on drilled-in caissons.

The rest of the structure in the center section (that is, the area around the garage, plaza and low level commercial buildings) is to be founded on a heavy concrete slab covering the entire area resting on the sand and gravel layer that overlies the blue clay. The additional unit load on the blue clay on this area over and above the weight of the material that was removed in making the excavation for the garage ranges from 100 to 300 pounds per square foot. According to consolidation data from tests, the settlement due to this additional load is predicted to be from 2 to 3-½ inches. The load is not uniform, being somewhat greater in the areas of the low level buildings. Some of these buildings are immediately adjacent to the tower building which will be founded on rock so a differential settlement between the plaza area and the tower building is expected. The joints between structures are designed to take this differential settlement without distress.

A complication in the arrangement of the garage is the location of the railroad and highway easement that cuts diagonally across the area. This easement is 132 feet wide and will accommodate two tracks for the railroad and six lanes of the toll road that will come from Route 128 into Boston bringing the traffic from the Massachusetts Turnpike.

To discover if corrosion of steel piling was to be a factor in design, a corrosion survey of the site was conducted. Horizontal and vertical stray current potential gradients were measured and soil and water resistivity and pH measurements were made at several depths. During the soil boring program, zinc reference electrodes were installed in nine test borings. Three electrodes were placed in each of the borings, one 10 feet below the surface, one half-way down to rock and the third five feet above the rock surface. The horizontal and vertical stray current potential gradients were measured at these nine locations. The corrosion consultant, as a result of his study, recommended that all steel H-piles be coated with a coal-tar epoxy resin in the soils above the Blue clay strata. Also that all piles be electrically isolated by avoiding metallic contact with other parts of the structure. The stray currents measured were probably caused by the subways on Huntington Avenue and Boylston Street which bracket the area. It was decided to use cathodic protection in the form of zinc anodes for the steel H-piles in addition to the coating. On the drilled-in caissons only the coal-tar epoxy was used. The zinc reference electrodes are being left in place in the nine boring locations to facilitate corrosion testing of the piles at a later date after construction is completed.

Drilled-in caissons are new to the Boston area. With heavy column loads such as we have at Prudential, the drilled-in caisson seems an ideal type of foundation. The caisson shells for the tower building are 30 inches in diameter, ½ inch thick, steel cylinders driven down to the top of rock. Soil inside the shell is excavated and a 29-inch diameter socket drilled into the rock for a distance of 16 to 23 feet. A heavy steel H-section is lowered into the caisson down to the bottom of the rock socket. This H-section extends from the bottom of the socket to the top of the steel shell. The space between the steel core and the shell is then concreted. Stress is carried by all members. Design unit stress in the steel shell is 8,000 pounds per square inch; in the concrete, 900 pounds per square inch; and in the steel core, 15,000 pounds per square inch. The depth of the rock socket is dependent on the total load carried by the caisson. Caissons for the tower building carry from 1,300 to 1,650 tons each. Four caissons are used for each of the heaviest columns. For design purposes, it is assumed that the load carried by the caisson is distributed to the bedrock by end bearing of the steel H-member in the bottom of the socket and by both end bearing of the concrete filling the caisson and by bond stress of the concrete against the rock socket. In accordance with the requirements of the Boston Building Code, the design load taken by the bedrock in end bearing of the concrete and steel should not exceed 70 tons per square foot. The remainder of the stress is assumed to be transferred to the rock by bond of the concrete at a unit stress of 100 pounds per square inch. It is recognized that these values are very conservative.

Construction

One interesting problem concerned with the construction phase has been the control of groundwater. In order to protect the foundations of the existing structures in the area, which are principally on untreated wooden piles, it was specified that the contractor drive steel sheet piling completely around the working area down to clay to form a tight cofferdam. He was also required to install a backfeed system outside the steel sheet pile cofferdam to return water, pumped from the inside, in order to maintain the level of groundwater in the area.

In general, the sheet piling was driven to the clay without much difficulty except along one section of West Newton Street near the former location of Mechanics Hall. Here the sheet piling ran into subsurface obstructions that made it impossible to get the piling seated into the clay. To tighten areas where piling was not reasonably watertight, neat cement grout was pumped into the soil outside the piling just above the clay layer. It has inhibited the flow to a rate which has made it possible to maintain proper groundwater levels outside the cofferdam. Present rate of pumping is about 500 gpm. At the beginning of construction, backfeed water was placed in horizontal perforated pipes buried just outside the sheet piling at the elevation of the top of the water table. It was found that the original Back Bay bottom made up of mud and organic silt and peat formed a horizontal barrier in some areas keeping the upper water table perched and apparently unaffected by pumping, while groundwater levels in sections some distance away from the site responded immediately to pumping from inside the sheeting. To overcome this, most of the backfeed water is now put down below the silt layer into the sand and gravel above the clay. Daily groundwater readings are taken in observation wells around the site. When lower groundwater is observed, the contractor either stops pumping or adds to or revises the backfeed system.

Through a period of trial and error a backfeed arrangement has been developed which is now effectively maintaining the groundwater levels above elevation plus five while water is drawn down inside the sheeting to elevation minus 12.

An early problem discovered in the combination dewatering and backfeed system was the clogging of backfeed points with an organic slime which formed quite rapidly in the pipes as the water was being transferred from the suction to the backfeed. As the organic slime built up, it broke free in chunks and clogged the points. To overcome this, the contractor installed a chlorination unit treating the water as it leaves the well point pumps. The treated water is passed into a sedimentation tank and there picked up by a pressure pump putting it into the backfeed system. Even with this treatment, periodic cleaning of the backfeed points is necessary. At present, they are being cleaned every two weeks by disconnecting and reversing the flow.

A fluorescent dye was an effective tool in locating places in the steel sheet piling where the principal leakage was taking place. The dye was introduced into the observation well that was most affected by pumping. In some cases this was some distance from the sheeting. Additional observation wells were put inside the excavation just inside the steel sheeting, and samples taken periodically until the dye showed up. Inspection of samples under ultraviolet light made it possible to detect very small quantities of dye.

In the caisson construction, a pervious bedrock combined with a high water table has made inspection of the drilled rock sockets impractical to accomplish in the dry. It is expected that a few caissons can be pumped out for direct inspection by a man lowered into the bottom, but in general most of the caissons have too rapid an inflow of water. To carry out a satisfactory inspection of these sockets, an underwater television apparatus, Fig. 4, was specified capable of operating in about 160 feet of water. The use of underwater TV is not new, but we believe that this is the first time it has been used for inspection of caisson sockets. The apparatus has just been given its first trial run. Fig. 5 is a photograph of the TV monitor screen showing the lower edge of a caisson shell and the upper part of the rock socket.

Coordinating Architect for the project is Charles Luckman Associates; Associate Architect, Hoyle, Doran & Berry; Foundation Engineer, Metcalf & Eddy.

Center section foundation contractor is George A. Fuller Co.,

FIGURE 4.—UNDERWATER TELEVISION CAMERA DESIGNED TO OPERATE 160 FEET BELOW WATER SURFACE.

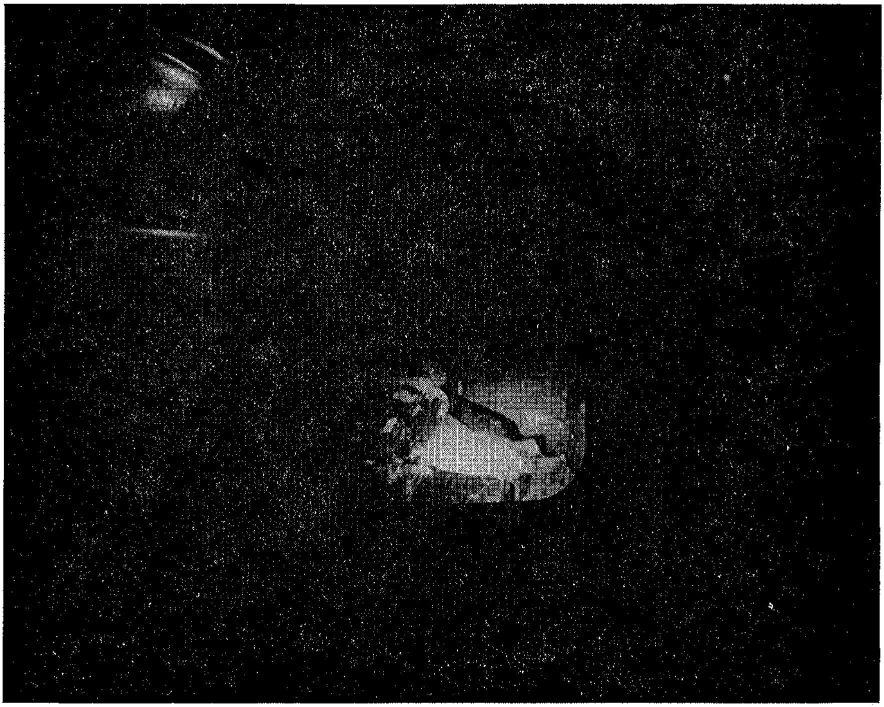


FIGURE 5.—PHOTO OF TV MONITOR SCREEN. UNDERWATER TV CAMERA IS VIEWING UPPER PART OF DRILLED-IN CAISSON ROCK SOCKET.

with subcontractor Western Foundation Co. putting in the drilled-in caissons.

Borings were done by C. L. Guild Construction Co., with H. A. Mohr as consultant. Seismic survey was by Weston Geophysical Engineers. Corrosion survey was by Electro Rust-Proofing Corporation.

Arthur and Leo Casagrande are soil and foundation consultants.

NEW ENGLAND FLOODS AND THE SOCIETY'S FLOOD REPORTS

By Howard M. Turner,* Honorary Member

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Hydraulics and Structural Sections, B.S.C.E., held on February 21, 1962).

The New England flood history is interesting because in the last 35 years since 1927 (except in Maine) there were floods in excess of any preceding records which extend over many years. The latest flood in 1955 was in some ways the greatest of all. This period experienced four large floods—The Vermont flood of 1927, the great flood of 1936, the hurricane flood of 1938, and the recent 1955 flood.

This period is also interesting in that it was accompanied by great progress in the engineering of flood analysis which had started after the 1913 flood in Ohio. Since 1936 the period is also noted for the great flood control programs which have been undertaken by the federal government and various state and local communities.

We are fortunate here in having data from flood records, some of these going very far back, such as the gage heights of the Connecticut River at Hartford, which gives records of large floods for over 250 years. Other flood histories in Connecticut go back to 1634.

Floods Prior to 1927

Prior to the great 1936 flood, the largest one of record on the Connecticut River was in 1854 with a flow at Hartford estimated at 184,000 cubic feet per second (c.f.s.). The 1927 flood was probably a record peak at Sunderland, Mass., but at Hartford it was not quite as great as the 1854 flood. As will be seen later, these floods in the large rivers were all very much less than the great flood of 1936. "Great" floods occurred in 1639 and 1642. A flood in central Connecticut around Waterbury occurred in 1691. It was probably higher than the recent 1938 flood in western Connecticut.

On the Merrimack River there was a large flood in 1785 which is referred to in some places as being the largest on record up to 1936.

* Consulting Engineer, Boston, Mass.

However, it cannot have been very different from the flood of 1852, which had a peak of 108,000 c.f.s. at Lawrence. This was very much less than the great flood of 1936 on the Merrimack. The 1927 flood was not a large one.

On the large rivers in Maine, the flood on the Penobscot in April 1923 is the largest flood of record. This was a major with a peak of 153,000 c.f.s. at Bangor (drainage area 6600 sq. mi.), which has not since been exceeded. Prior to 1936 this was the outstanding of any of the large New England floods. On the Kennebec River the 1901 flood was slightly larger than the 1936 flood. The recent large floods have not been excessive northeast of New Hampshire.

Here in the eastern part of New England there was a large flood in Waltham in a limited area in 1860. A flood that has been used a great deal as an example was the 1886 flood in Boston, the so-called "Stony Brook" flood, which caused a great deal of damage.

There are some incidents which are of interest in connection with these earlier floods which may be worth repeating. In 1850 James B. Francis, the engineer at Lowell, built at one of the critical spots at the head of the original navigation canal, a large drop gate 27 by 25 feet of 18 inch timber to provide a barrier to be used in a great floods. Figure 1. This was called by the inhabitants in Lowell "Francis's Folly" because no one could believe that water would be high enough to require lowering this gate. Francis really was pretty lucky because two years after the gate was installed it had to be lowered during the flood of 1852. It was not lowered again until 1936.

In March 1913, considering the duration, the rainfall intensity, and area covered, occurred what probably was one of the greatest storms ever experienced in the East. This caused the great flood on the Ohio with the disaster on the Miami River at Dayton. New England was outside the center of that flood, but it was a fairly large flood on the Connecticut River, the highest since 1869. The dam of the Connecticut River Power Company at Vernon had just been built. Construction of the redevelopment at Turners Falls, twenty miles below was under way. The eastern abutment of the Vernon dam was on a projection of land, not on ledge, against which the river washed as it curved around below the dam. This spit of land was considerably higher than the abutment of the dam. At Turners Falls it was rumored that the river was washing this land and that there was danger of a channel cutting through so that the river could bypass the dam on the

FIGURE 1.—PAWTUCKET CANAL HEADGATES AT LOWELL, MASS., 1956, SHOWING THE "FRANCES GATE" CLOSED AND ADDITIONAL FLASHBOARD PROTECTION.

east side. This was considered important enough so that men were sent up, who stayed continuously on the job for enough days to be sure that the place was stable. There was some washing. Later the area was protected with riprap. It was during this flood that a Springfield paper came out with the reassuring statement that the dam at Vernon was "bulging but still holding."

THE 1927 VERMONT FLOOD

Then came the 1927 Vermont flood. This was the first of our recent large New England floods. It was caused by a tropical storm from the South. The center of the storm moved up through Vermont in a northerly direction. It lasted from Nov. 2 to Nov. 5, but most of the rainfall came in the two days—the 3rd and 4th. The greatest recorded precipitation for this storm occurred in Vermont, with a maximum of 9.65 inches at Somerset. It is probable, however, that as much as 11 or 12 inches fell in the higher portions of the Green Mountains. A secondary storm area adjacent to Rhode Island also showed nearly as great a maximum—9.37 inches at Westerly, R.I. Over the whole State of Vermont (about 9600 square miles in area), the average rainfall was about 6.0 inches. The rainfall during October had been twice the normal so that the ground was saturated and the streams and ponds full.

The intensity of the storm and the steep slopes of the Vermont topography caused very rapid run-off. Entire river valleys were flooded. The rivers rose rapidly. The average rate of rise on the Winooski at Montpelier Junction was 2.07 feet per hour, on the Westfield the rate of maximum hourly rise was 2.60 feet. It was said that at Waterbury and Bolton, Vermont, a rise occurred of 3 to 4 feet per hour or about a foot every fifteen minutes. Some very high discharge records were noted on the smaller rivers; for example, the White River in Vermont reached a peak flow of 120,000 c.f.s., or 174 c.f.s. per square mile on a drainage area of 690 square miles, which compares with some of the high peak flows of the 1955 flood. There was a great deal of damage. A total of 84 lives were lost. There was no failure of any dam of importance on any of the main rivers, though six smaller dams failed and 68 were damaged. The total damages amounted to about $40,000,000, two thirds of which was in Vermont.

The bulk of this flood was on Vermont rivers. The floods in Massachusetts and Connecticut were not so great, but the flow down the Connecticut River from Vermont was of sufficient magnitude so that the flood at Sunderland probably exceeded the peak of the maximum record flood of 1854.

The Great Flood of 1936

The 1936 flood was different from the 1927 flood and the subsequent recent large floods of New England in that it was due to several storms that lasted several days, and included a good deal of melting snow. This affected the larger rivers generally, more than the smaller streams, though in a great many places these also established record flows. During the period March 9 to 22, 1936, four distinct storm centers passed over the northeastern part of the United States. The first disturbance, that of March 9 and 10, was accompanied by snow in northern New England. On March 10, a gulf disturbance from the Georgia coast moved northeastward with increasing intensity.

Another storm caused more precipitation of snow on March 11 and 12. On the 17th and 18th another storm pressure moved from the Gulf states, causing heavy precipitation over the whole area. Although this centered in the White Mountain area, it reached very considerable magnitude over most of central New England. On the 20th, 21st and 22nd, another small disturbance crossed the area, accompanied by minor rainfalls. Added to the heavy precipitation recorded for these storms, the first heavy rain fell on a snow cover that had a water content of 4 to 10 inches or more in most of Massachusetts, Vermont, New Hampshire and Maine. The total area covered was 66,000 square miles, with more than 6 inches of rain to which, of course, was added the melting snow.

Except in Maine this flood caused maximum flows on the bigger rivers. On the Merrimack it was necessary to protect with sand bags the abutments of the dams at Manchester and down stream. The Francis gate at Lowell was lowered and the judgment of the engineers who had raised the walls at this point by 2½ feet after the 1927 flood was justified as they were of sufficient height. It was necessary to block up the railroad entering Lowell. The direct and indirect damages amounted to $101,000,000 and 11 lives were lost.

Since the 1927 flood there had been constructed three flood reservoirs on the Winooski in Vermont. The large Federal flood control program started with the flood control act of June 1936 and much other flood work was done after this flood. A repetition of the large flood of 1936 on our main rivers will not cause the disaster which occurred then on account of the large flood controlwork now done and proposed.

The Hurricane Flood September, 1938

This was caused by extremely heavy hurricane rainfall. A tropical hurricane moving northward from the Atlantic Coast veered inland from the ocean on the afternoon of September 21, crossed the coast into Connecticut and Massachusetts, and gradually diminishing, went over Green Mountains in central Vermont and passed into Canada. New England had been experiencing heavy rainfall on September 18, to 20th, when the rain just preceding the hurricane brought the total rainfall during the four-day period to an average of more than 11.5 inches over an area of 10,000 square miles. The major storm period essentially embraces the rain that fell on September 17 to 21st. In a very considerable part of Connecticut and central Massachusetts the total storm precipitation in this period exceeded 16 inches, and maxima of more than 17 inches were recorded in central Massachusetts and Connecticut. At Barre, Mass., 11.83 inches was recorded during one 24-hour period, at that time a maximum for record in New England.

This storm produced record floods on small rivers in Massachusetts and Connecticut, exceeding by 50% to 100% the highest flows previously recorded. On drainage areas of less than 50 sq. mi. flows of 500 c.f.s. per square mile were observed. On the Hockanum River in Connecticut the flood run-off was 9.9 inches. On the eastern tributaries of the Connecticut entire river valleys were devastated. Though the flows in the upper Connecticut were minor, the great inflow from the southern area caused the second highest flood at Hartford, 251,000 c.f.s., compared to 313,000 c.f.s. in 1936. This storm did a great deal of damage. Twelve lives were lost and the total direct and indirect flood losses were $69,400,000.

The 1955 Floods

This storm was caused by the Hurricane Diane of August 17-20. This had been preceded by Hurricane Connie from August 11-16 and was followed by another one on October 13 to 17. The first hurricane had saturated the ground so that when the big storm came the great floods were produced. Figure 2 shows the course of Hurricane Diane. It is interesting to note that it moved parallel to the southern shore of Long Island, and thus went from west to east, whereas most of our other storms have moved from south to north. The characteristic of the 1955 storm was the extreme intensity of the storm rainfall. Many of the stations in Massachusetts, Connecticut, registered 12″ or more in a two-day period, with a maximum of 19.75″ in Westfield, 18.15″ of which fell in 24 hours. Rainfall of 3.2″ in an hour was recorded in Mendon, Mass., and 5.2″ in two hours. Figure 3 shows some typical Connecticut rainfall charts. They show that most of the rainfall came in a period of a little over 24 hours.

Record floods on the smaller rivers in Massachusetts and Connecticut were thus caused. Of the two large rivers, the Merrimack had practically no flood at all. On the Connecticut, the peak flow at Hartford was the third highest on record, although the flood was all produced in the lower third of the drainage area. Figure 4 shows

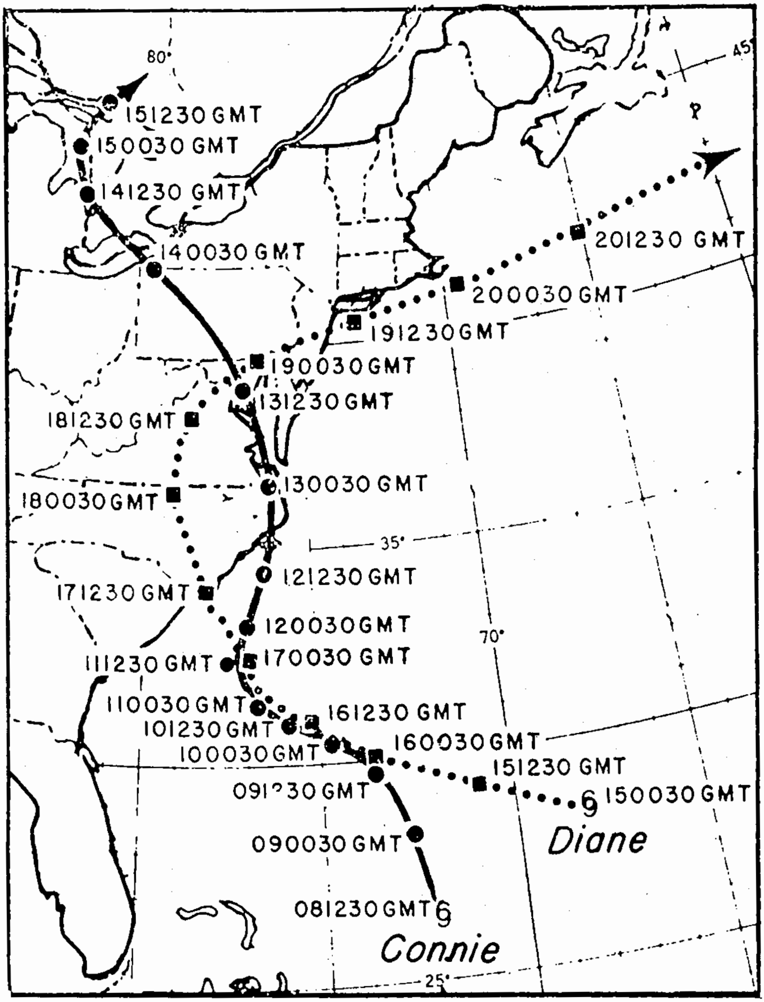


FIGURE 2.—TRACKS OF HURRICANES CONNIE (SOLID LINE) DIANE (DOTTED LINE) WITH 12-HOUR POSITIONS INDICATED, AUGUST 1955. (From W. T. Chapman and Y. T. Sloan, "The Paths of Hurricanes Connie and Diane." Monthly Weather Review, Vol. 83, No. 8, Aug. 1955, p. 171.)

hydrographs of the recent floods at Thompsonville, Conn. which shows clearly the effect of the small drainage area contributing in 1955. Very high flood peaks were reached on rivers with drainage areas less than 350 square miles. Maximum examples are as follows: On

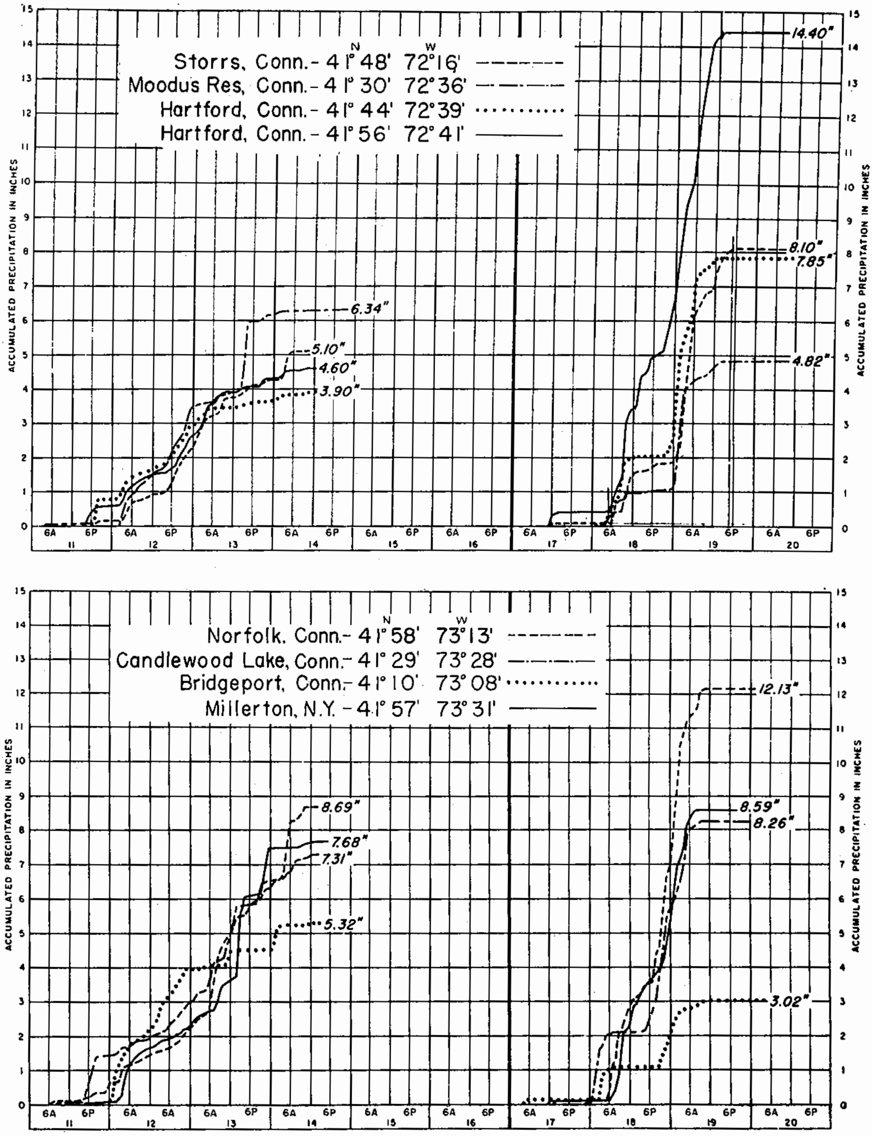


FIGURE 3.—MASS. RAINFALL CURVES AUGUST 11-16 AND 17-20, 1961. (From Weather Bureau Technical Paper No. 26, Hurricane Rains and Floods of August 1955, Carolinas to New England.)

the Naugatuck River in Connecticut, 71.9 square miles, 579 c.f.s. per sq. mi., and 246 sq. mi., 431 c.f.s. per sq. mi. Still River, Connecticut, 84.4 sq. mi., 521 c.f.s. per sq. mi. It is interesting to note what some of the higher peak flows mean in terms of the flood formulas now in use. In Massachusetts, where it is customary to rate floods by the Kinnison-Colby formula, some peak flows reached 84-88% of the "rare" flood, rated as having a frequency of 1,000 years. In Connecticut, the Bigwood-Thomas average curve shows seven times the mean annual flood as having a recurrence interval of about 323 years. Some of the largest records gave peak flows of over 12-15 times the mean annual flood.

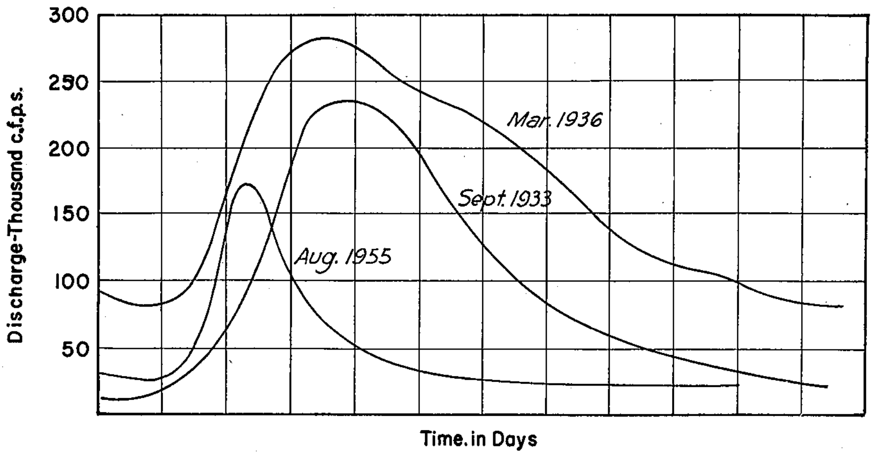


FIGURE 4.—HYDROGRAPHS OF FLOODS AT THOMPSONVILLE, CONN.

Some of the flood run-off figures were also very large: the Quinebaug River at Westville, Mass. 10 in., the Naugatuck River near Naugatuck 11.1 in., and the West Branch of the Farmington River 11.5 in.

No major dams were injured but there were a great many smaller dams which were damaged by various washouts and failures, mostly due to inadequate spillway capacity. The Corps of Engineers' figures are listed showing six dams damaged in Rhode Island, 35 in Connecticut and 165 in Massachusetts. The total damage in the August flood is listed as $531,000,000.

The August 1955 flood was followed by another flood in Connecticut in October which covered part of the previous flooded area and did $50,000,000 worth of damage. The August flood caused the loss of 90 lives and the October flood 17 lives.

The Corps of Engineers' initial reports, published in 1957, the preliminary reports of the Weather Bureau and the U. S. Geological Survey, and the Geological Survey's final report cover the history and data of this flood in great detail.

Since the 1955 floods there has been, of course, much work done so that another 1955 flood will not cause nearly the amount of damage.

Flood Summary

The recent flood history of New England is summarized in Figure 5 which shows the large flood heights of the Connecticut River at

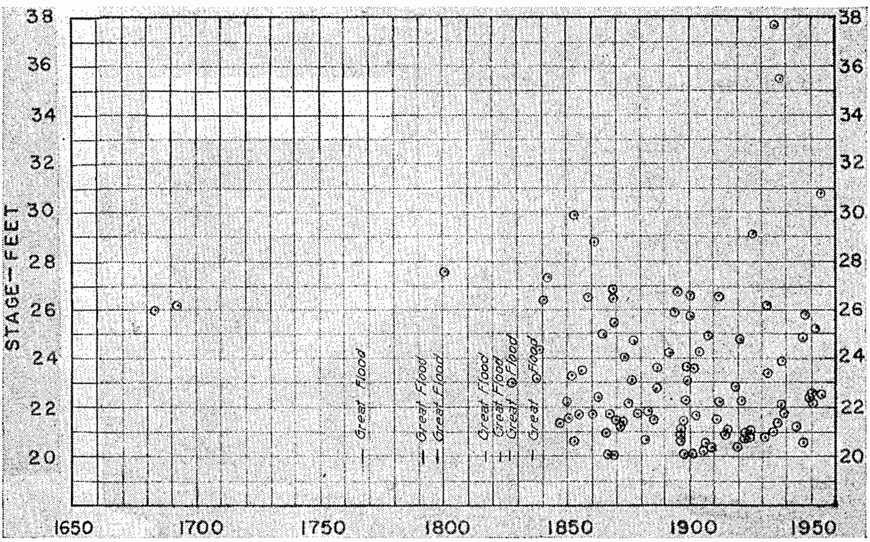


Figure 5.—Flood Crest Stages—Connecticut River at Hartford, Conn.

Hartford back to 1680. The comparative size of the floods since 1927 is clear. Figure 6 shows the areas covered by the 1927, 1938 and 1955 storms in New England. 1936 is not included because of its long duration. It shows that Maine has not been subject to the great floods experienced in the rest of the area. Figure 7 shows the comparative rainfall area depth data of large New England storms. This is taken from the Society's 1942 report with the August 1955 storm added.

FIGURE 6.—MAP SHOWING AREAS HAVING MORE THAN 7 INCHES OF RAIN FOR STORMS OF 1927, 1938, AND 1955.

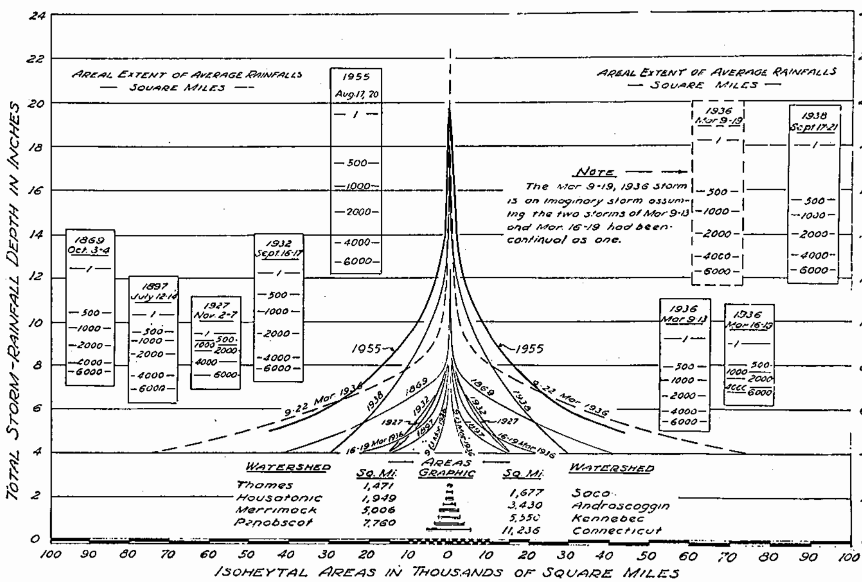


FIGURE 7.—DISTRIBUTION OF STORM RAINFALLS.

It is interesting to show the 1932 storm rainfall which produced no large floods at all as the ground was dry. Figure 8 shows various peak discharges during these floods.

FLOOD ENGINEERING

Before taking up the Society's flood reports, it is interesting to go back briefly over the history of flood analysis. Prior to the 1913 flood, there was little of flood analysis as it is now known. There were formulas used for storm sewers and culverts and some for rivers but not much real river analysis. On the larger rivers, like the Connecticut and the Merrimack, records showing past floods were used. The 1854 flood on the Connecticut, and the 1852 flood on the Merrimack, were taken as the measure of the flood capacity required for dam spillways with, of course, large freeboards which gave factors of safety.

The great 1913 flood gave a great impetus to flood study, particularly the Miami River Conservance work. It is interesting to review the state of the art when these reports were made. Some of the conclusions are now interesting in view of our modern analyses. Considering flood frequency which modern analysis has covered in

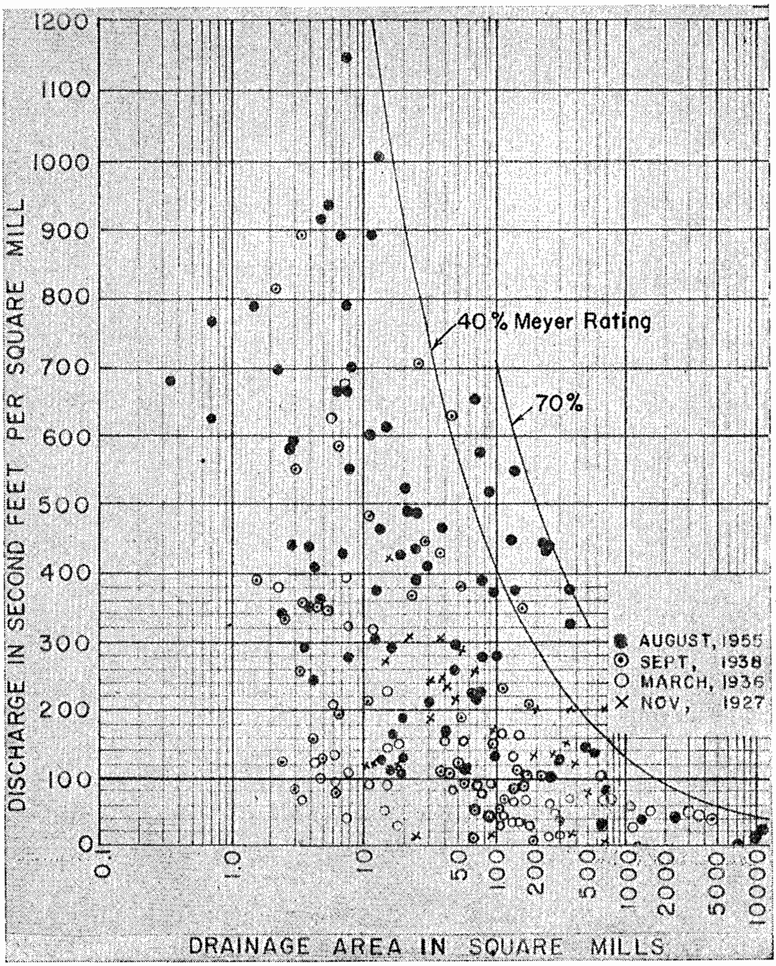


FIGURE 8.—PEAK FLOWS OF NEW ENGLAND STREAMS.

such detail, the Miami study used two plotting analyses, one method giving a frequency of 318 years to the 1913 storm and the other 3000 years. These they discarded. They made studies of various long-time records in Europe, and found that "there is no evidence that would lead to the conclusion that the greatest possible flood discharge could be appreciably more than 20% in excess of the 1913 flood." For their maximum flood they used nearly 40% larger for the design of their flood works. Present conclusions regarding flood frequency and even more so of our present ideas regarding maximum possible floods are much larger.

Two important papers followed,—Weston E. Fuller's "Flood Flows," in the A.S.C.E. transactions of 1914. His formula took into account elements now used,—the drainage area, A, the stream characteristic expressed as a coefficient, C, determined by past floods for each station, and the recurrence interval, T, i.e., the frequency. It is interesting to note that he considered frequencies up to 1000 years. In the discussion of this paper, Maj. C. E. Pillsbury applied the normal law of error, i.e., the probability, to flood flows, and Fuller pointed that the curve would not be the normal probability but a skew curve. Allen Hazen in his discussion refers to his studies and his development of probability paper described in his later paper of the same year on "Storage to be Provided in Impounding Reservoirs." After this date there is a great deal more flood engineering as shown by the steadily increasing flood literature.

The 1930 Flood Report

The Geological Survey published Water Supply Paper No. 636c describing the floods of November 1927, giving rainfall figures, both daily and hourly where available, descriptions and pictures of the flood and data as to the peak flows on the various rivers.

The Society's 1930 Flood Committee Report gave certain data not included in the U. S. Geological Survey report. These included, among other things, the total runoff of certain streams and tables of flood profiles of the various rivers. Flood damage figures were given of various river basins and sub-divided among various items.

The chief contribution which this report made was in its study of the floods for the development of a flood formula for New England. This formula was based on the study of the flood hydrograph and in this chapter the Committee showed: "that a flood hydrograph once determined for a given river even for an ordinary flood will serve as a basis of the estimates of greater flood runoff due to the fact that the base of the flood hydrograph (or time of flood period) appears to be approximately constant for different floods." Figure 9. This use of the flood hydrograph served as the basis for the whole modern analysis of flood flows through the unit hydrograph.

Based on this, the report gave flood characteristic curves developed for stations on various rivers. These curves put the flood hydrographs on a unit basis for one inch of run-off and one square mile of drainage area. This, in a way, anticipated the unit hydrograph now extensively used, except that it used a unit drainage area basis. The

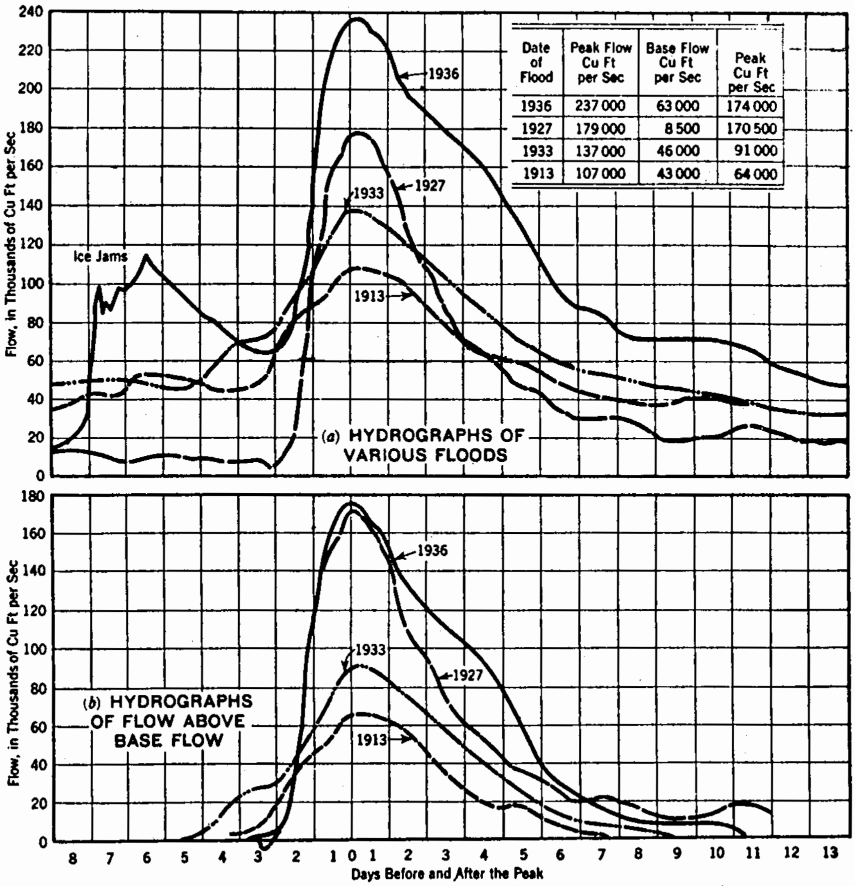


FIGURE 9.—FLOOD HYDROGRAPHS, CONNECTICUT AT SUNDERLAND, MASS. (1936, Montague City).

Committee recommended that floods should be classified in inches of total run-off. The peak discharge for any flood run-off would be then determined by means of the flood characteristic curve.

The report reached some conclusions regarding flood frequency though not by any plotting or computation of the probabily from existing flood records. The conclusion for New England rivers with drainage areas of 10 to 1000 sq. mi. was summarized as follows:

1. "An occasional flood run-off, R, of three inches within the concentration period is to be expected. . . . Information is too limited to definitely state the frequency but in general it appears that such a flood should be looked for with a frequency of between 25 and 75 years, or, say, once in 50 years.

2. "A rare flood run-off, R, of six inches within the concentration period is to be expected. . . . The frequency of such floods is probably somewhere between 50 and 200 years.

3. "The maximum flood run-off, R, is probably not over 8 inches.

4. "From the flood history of New England it appears that storms producing heavy run-off are likely to occur with greater frequency in those regions having a high annual rainfall than in those territories with a low annual rainfall. However, the information available is not sufficient to determine whether there is any direct relation which can be formulated."

It is interesting to compare these with some recent studies. The Kinnison-Colby formula, for example, gives the following averages: a "minor" flood, once in 15 years, 3.6 inches, instead of the 1930 report's, 3″ in 50 years; a "major" flood, once in 100 years, 6.1 inches which compares to the 1930 report run-off of 6 in. with a frequency of between 50 and 200 years; a "rare" flood, 1000 years, 8.9 inches compared to the 1930 report of a maximum "probably not over 8 in." The Kinnison-Colby formulas did not give any maximum run-off figures but their maximum possible peak flows are given as over three times the rare flood.

These figures, as were most all of the figures prior to the latest floods, were thus lower than modern results, particularly if it is assumed that the maximum possible flood should be used in any flood computations.

The 1930 report gave a description of the flood characteristics of various New England streams. This included a very vivid, brief description of the geology of New England written by the late Professor J. W. Goldthwaite of Dartmouth College.

1942 Flood Report

The United States Geological Survey Water-Supply papers covered in detail the data of the 1936 and 1938 floods. The Society's

1942 Report covered these two floods: the Great Flood of March, 1936 and the later Hurricane Flood of September, 1938. The former, which included melting snow, affected generally the large rivers more than the smaller areas. The intensity of the latter, however, affected the smaller rivers. The report covered general descriptions of the floods, storm, rainfall data and maps and flood run-off data, flood run-off analysis, a chapter on flood losses and economics, and a description of the flood control program.

In the study of storm rainfall there was considerable space given to the maximum possible precipitation which had been treated in a Weather Bureau publication, the first of its kind, published in 1940, in the "Maximum Possible Precipitation Over the Ompompanoosuc Basin" in Vermont. The conclusion is given that total precipitation rates could have been from "15% to 30% larger than in the large floods which have been recently experienced." This chapter also covered a considerable discussion of snow melt which added to the 1936 flood. In the section of flood run-off, there was a study such as has been recently made of the effect of storage reservoirs on the flood run-off.

There had been a great deal of work done on flood run-off analysis since the Society's 1930 Flood Report which developed the B.S.C.E. flood formula. In 1932, the unit graph method had been described by L. K. Sherman and the unit hydrograph derived for a given point on a stream became the standard hydrograph used in flood control analyses.

The section on spillway design floods is interesting as it gave a discussion of the use of maximum possible storms as a measure for spillway designs. "With the use of maximum possible storm rainfall, assuming a high percentage of run-off and also melting snow, it is possible to estimate very high peak discharges for spillway design floods. If there are added freeboard for wave action and frost on earth abutments, there is perhaps a tendency to reach a size of spillway that may be prohibitive in cost for any but the very largest structures paid for by public funds. While it is certainly advisable to know the absolute limit which nature may reach, there may be a question in many structures whether such safety is necessary or advisable. Some of the maximum peak floods, reached by this type of analysis, are of such a quantity that there would be a few structures left in the whole river valley were they ever attained, and the failure of a river dam would add but little to the total destruction which would be caused. Like many other engineering problems, the exact figure to use for the design of a given struction will depend on its importance and cost and on the effect of its failure. Important structures for storage reservoirs, impounding very large bodies of water, require a high degree of safety, whereas other structures perhaps on the same river, impounding smaller amounts of water, may not justify anywhere near such extreme values."

The report devoted considerable space to flood frequency study which had been developed since the 1930 Report. It also gave various plottings to determine the frequency of the 1936 flood but was unable to reach any satisfactory result in plotting the extended frequency curves, as for example one case, the Connecticut River before and after the 1936 flood, this conclusion was reached: "Any method of figuring, where a 98-year record shows that a given flood would have had a frequency of very many thousands of years or even would never have occurred, and a record of three years later, 101 years, shows a frequency of once in two hundred and sixty-five years, hardly seems worth the effort involved in the computation." Since the 1930 flood report there had been much work done on the frequency analysis of hydrological data. The frequency of the Connecticut River and the Merrimack River floods were also studied by this method with very varying results. The final conclusion was: "It seems to this Committee that the ordinary river has a normal flood regime, reaching normal maximum of a flood which may be expected perhaps once or twice a century, and that then due to very exceptional conditions there may come a very large flood that has a frequency of several hundred to a thousand or more years. While the frequency figures of the flood regime of a river with a 100-year record may be assembled and plotted for the ordinary floods, up to say that flood expected to be equalled or exceeded once or twice in a century, the attempt to put a frequency beyond that on these very rare floods gives such varying results that it is hardly worth the attempt.

"The use of flood frequency figures also appears to be limited in scope. There seems to be no reason whatever why the frequency should be used in determining the size of flood for which the spillway of a dam should be designed. The capacity of a dam spillway is much better determined by many other factors."

"The use of frequency figures comes down chiefly to the single question of economics on flood control projects as, for example, how much money it is advisable to spend compared to the corresponding benefits." The report stated that actually the 1936 flood on the Connecticut was believed to be the largest in 300 years and that it was satisfied to say that it was a major flood with a frequency of several hundred up to perhaps a thousand years. All this does not greatly differ from the conclusion of the 1961 report.

A chapter on flood control programs summarized the work done on the flood control reservoirs on the Merrimack and Connecticut River basins both by the federal and state governments. Perhaps one of the most interesting of these was the local work done on the Nashua River in Fitchburg as described below: The flood control project on the North Branch of the Nashua River in Fitchburg, Massachusetts, was built after the 1936 flood and finished before the 1938 flood. The former flood had a magnitude of about 11,500 c.f.s. through the city. It caused damages estimated at $2,700,000. Extensive channel improvements were undertaken with Emergency Relief funds, and completed in January, 1938. The September, 1938 flood had a maximum peak of 8,500 c.f.s. at Fitchburg. No flood damages occurred in the city. It is estimated that the channel improvements prevented over $1,500,000 flood damages in the 1938 flood.

As to the desirability of the flood control program as a whole the Committee reached this conclusion:

"As to whether the actual savings which may be experienced are sufficient to justify the large cost of the program, there is a divided opinion among the Committee. There is no division of opinion about the improvement attained whether the cost can be justified or not. The work was begun at a time when large expenditures on public works programs were undertaken for employment purposes. The benefit from this work is certainly as great as or greater than that from many other projects of the public works programs."

The report closed with a description of various flood forecasting systems in use. It reached the conclusion that there was no need of a new organization for gathering flood data and disseminating warnings in New England, and did not favor the elaborate and expensive set-ups sponsored by state and federal bureaus such as were then operating in Pennsylvania. This was summed up as follows:

"The facilities now existing, though varying considerably in different states, are adequate if properly handled and extended to take care of some of the outlying areas on the smaller streams. Every effort should be made to keep the existing organizations on the alert and ready to function at all times."

THE 1961 FLOOD REPORT

The recent report covering the 1955 flood gives very little factual data. This was given in various publications by the U.S. Corps of Engineers, the Weather Bureau and the Geological Survey. The Society's report is rather a summary and review of the floods and discussion of the latest flood engineering and its application to the 1955 floods and to local conditions. Various chapters have been selected for comment.

Chapter III of the report is devoted to the effect of reservoirs and flood protection works. When it is considered that there was a great deal of flood control works, reservoirs and channel improvements in existence during the time of this flood, it is interesting to speculate on how much worse it would have been if these works had not existed. On six Federal flood control reservoirs in the flooded area the total of the in-flow peak in the August flood was 38,800 c.f.s. and the total of the maximum out-flow peaks was 10,250 c.f.s.—a reduction of 18,550 c.f.s. The effective reduction was much greater than this as the out-flow peaks were several days later than other flood peaks, and thus came at a time when the main flood peaks on other streams had passed. Figure 10 shows a graph of the operation of the Knightsville Reservoir on the Westfield River. This shows the great reduction and also the delay in the out-flow, which was entirely shut off until over two and a half days after the flood in-flow peak.

In addition to the government flood control works the effect of the many private reservoirs also served to reduce the flood peaks. For example, Shepaug Reservoir on the Housatonic reduced the estimated out-flow peak of 95,000 c.f.s. to 65,000 c.f.s. In addition to this, the many local protection works saved a great deal of damage. The report lists a total benefit in the saving of damages on the Connecticut River basin of $6,480,000 by reservoirs and $21,780,000 by protection works, or a total of over $28,000,000 in the August flood and a total of $5,040,000 in the October flood; on the Thames River a total of $4,300,000 in the August flood and $250,000 in the October flood. Practically none of these works were effective in the floods covered by the previous reports.

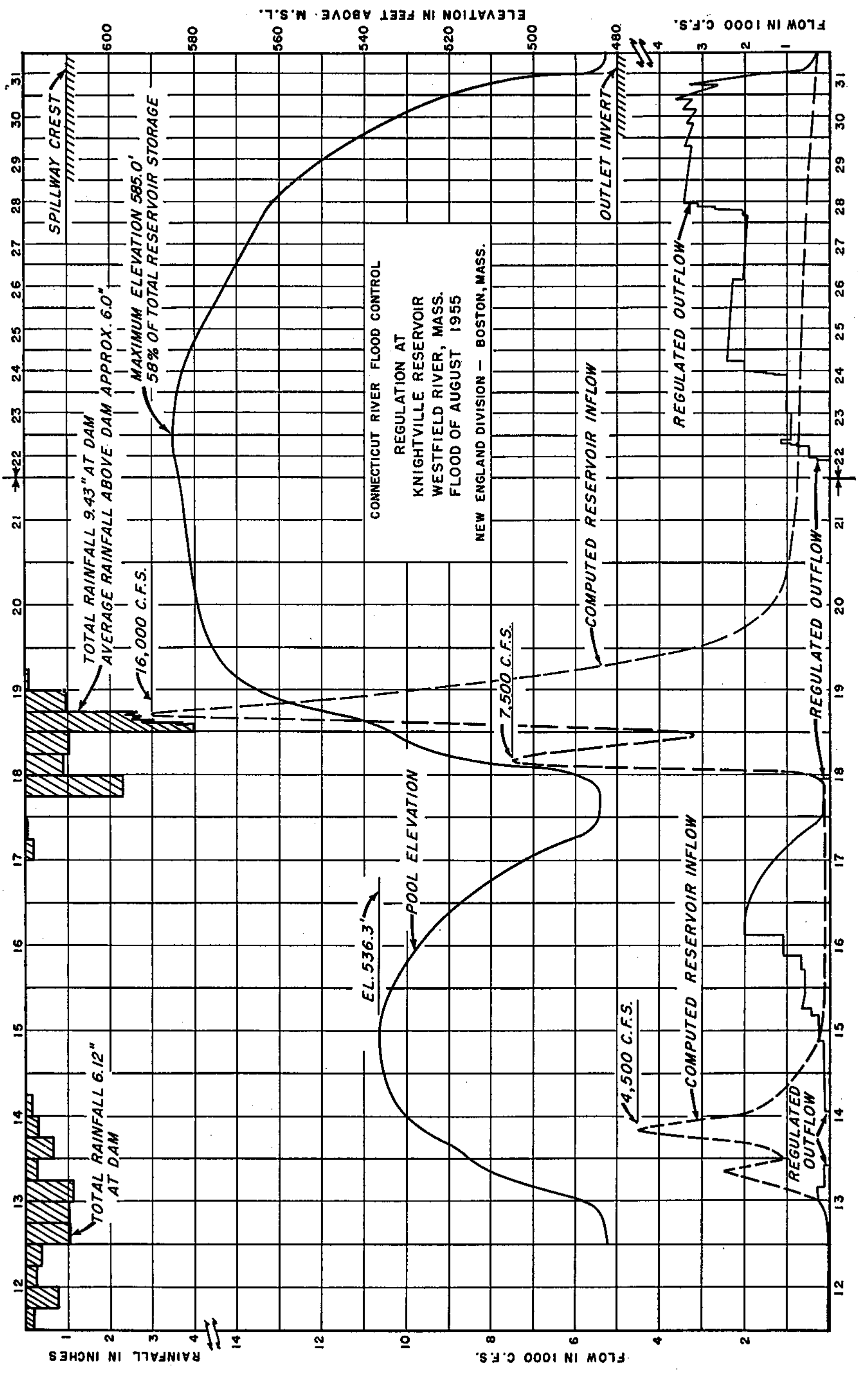


FIGURE 10.—REGULATION AT KNIGHTVILLE RESERVOIR DURING FLOOD OF AUGUST 1955. (From New England Floods of 1955, Part 5, Corps of Engineers, U.S. Army, New England Division, Waltham, Mass.)

Chapter V deals with flood protection measures, including flood control, flood forecasting and warning, and flood insurance. It discusses the topography and points out that the vegetation probably has small effect on large floods.

The report contains a discussion of flood control, pointing out that New England is somewhat behind other sections of the country in the flood control works done. A list is given of the present and proposed U.S. Government flood control reservoirs showing ten that were not in existence at time of the 1955 flood, and four more that are now under construction. In the same way, it lists seven local protection works which were not available in 1955, and five more are under construction. The report also lists flood control projects by the U. S. Department of Agriculture, and the various States which have been completed since 1955.

There follows a discussion of flood forecasting which is now pretty well established. It sums up this question as follows: "The preparation of a flood forecast and the related public warning statement is done by an agency of the Federal government and this is proper and necessary since rainfall patterns and river drainage areas are for the most part interstate." The Chapter closes with a discussion of flood insurance concluding that a self-sustaining program of flood insurance is impossible due to the type of peril involved.

Chapter VI is a review of the various work that has been done on flood analyses in the twenty years since the 1942 report. The first subject considered is flood frequency. The conclusion of the 1942 report is repeated as follows: "that the graphical method of making use of some form of probability plotting may be used for drawing a curve through the actual points plotted from such a record, but there is grave doubt as to whether any extension beyond the length of the record by any method gives a result at all reliable." It is noted that the Joint Division Committee on Floods of the American Society of Civil Engineers, 1951, was equally emphatic in pointing out the errors that can result from the extrapolation of computed frequency curves. The report continues "The difficulty becomes obvious when the flood peak discharge of certain streams in New England are plotted on some form of probability paper. Most of the points follow a general trend, but the discharges from the large floods of 1927, 1936, 1938 and 1955 may depart radically from any orderly pattern."

The report further states "The above general conclusions regarding the inadvisability of extending frequency curves need not be a reason for disregarding the many contributions to the subject of flood frequency, particularly as they enter into the development of the flood formulas now in use." The report then considers the question raised as to whether there may be, as has been suggested, two or more frequency curves for a given station with the greatest floods forming a steeper part than the frequent floods. The Committee reaches the following conclusion: "Benson points out that 'There is in general no particular flood magnitude below which all floods are caused by one factor and above which they are caused by another.' This is particularly true in New England. On this basis, these extremely large floods should be carefully analyzed to determine any unusual conditions contributing to their magnitude." The report further states that "It is believed that in New England, for the purpose of an economic analysis, the accuracy of predicting the frequency-magnitude relationship by the statistical methods now available will be at least of the same order as the accuracy of the cost and value estimates for a period of about 300 years in the future. Where public safety is involved methods which utilize all meteorological and hydrological factors known should be employed in the design of hydraulic structures."

The next subject discussed is Flood Formulae for New England, starting with the B.S.C.E. flood formula first given in the 1930 Flood Report. It is pointed out that this formula, in a general way, proposed to follow the methods proposed earlier by Weston E. Fuller in that the flood flows are based on basin characteristics reflected in the actual floods at each point.

This is followed by a discussion of the Kinnison-Colby formula first proposed in 1945 and widely used in Massachusetts. This was the first flood formula which was based on stream characteristics determined from the topography of the watershed itself and not purely from the hydrograph of the stream. In other words, the formula enabled one to predict floods on rivers where there were no past records but where the flood characteristics could be determined from a topographical map. This formula took care of the frequency by classifying floods as "minor," 15 years; "major," 100 years; "rare," 1,000 years and maximum. This is the first formula that actually put an estimated figure on the maximum possible flood.

The Bigwood-Thomas formula for Connecticut, based on an analysis of various floods in Connecticut, was expressed in a frequency magnitude curve extending to a frequency of 300 years. The coefficient used was based upon general factors of watershed characteristics. The area and the slope were important factors. The report gives comparisons of this formula of the Kinnison-Colby formulas expressed in terms of ratios to the mean annual flood.

One of the latest studies of New England flood streams was developed by Manuel A. Benson, of the U. S. Geologic Survey, from an analysis of vast amounts of flood data using graphical multiple correlation and digital computers. A great number of various steam characteristics were studied and it was found that the drainage area and slope of the stream were the two most significant characteristics of an area for producing floods.

The report analyzed the recent U. S. Bureau of Public Roads charts of "Peak Rates of Runoff, New England, New York and New Jersey" for providing a uniform basis for design in connection with the interstate highway construction program. These were analyzed in terms of ratios to the mean annual floods for various streams in all the New England states and with a comparison of the maximum floods of record. The B.P.R. curves were stated to cover 50-year flood peak.

Chapter VI next discussed drainage basin characteristics and reached the following: "A recent U. S. Geological Survey Water Supply Paper (986C) gives the characteristics of 340 drainage basins in the Northeast. Of the basin characteristics, all studies for New England flood formulas have found the drainage area to be of first importance in correlating flood peaks. Second in importance is some measure of slope. These two factors alone were the bases of the Kinnison-Colby (except for minor floods) and the Bigwood-Thomas formulas; other characteristics were found less significant and were omitted. Benson's conclusions were the same as to importance of these characteristics, but additional factors were included to obtain even better correlation. The report states:

"Although the magnitude of the flood peaks of the 1955 flood may have raised questions as to the validity of the frequency-magnitude relations expressed by the various formulas, no studies have as yet indicated that any specific changes should be made in the selection or use of the basin characteristics."

The report gives a comparison of the 1955 floods with the U. S. Corps of Engineers' project floods, and of the storm with the U. S.

Weather Bureau maximum probable precipitation noting that for six and twelve-hour depth of rainfall the maximum precipitation estimates greatly exceed the actual storm by nearly two times. For 24-48 hours' duration, however, the 1955 maximum storm rainfall ran from 70 to 83 per cent of the maximum possible.

The chapter closes with an analysis of the unit hydrographs, a subject that was much discussed in the two previous flood reports. This discussion refers to the 1930 report where it was noted that the length of the base of the hydrograph at a given point for floods of all sizes due to storms with the concentration period of the storm was practically constant, and finds that:

"The basic assumption that the length of the base of the flood hydrograph is approximately constant for all floods (excluding, of course, those due to storms of longer duration than the normal concentration period of the stream at the measuring station) still holds generally true within the range of accuracy required and obtained in studies based on hydrologic data though there may be more variation in the smaller streams. This is the basis of the unit hydrograph, Figure 11.

When the unit hydrograph was first used it was assumed that it would be approximately similar for all sizes of floods. Hathaway and Kinnison and Colby's paper showed that this was not true, particularly on smaller drainage areas, that the peaks of the unit hydrographs derived from large floods are generally higher than those derived from small floods. Figure 12. The reasons for this variation in the peak of the unit hydrograph for large floods over that for small floods have not been found. The report points out that this variation is greater in the case of hydrographs for short periods: that is, for a 6-hour unit graph rather than for a 24-hour unit graph. It concludes:

"A great part of the value and usefulness of the unit graph is to enable a large flood at a given point on a river to be predicted from a small flood at that point. This advantage is lost if the unit graph of a small flood cannot be used without great error for this purpose.

"When due consideration is given to the smaller variation of unit graph peaks for longer storms and a certain general usable uniformity in the increase in unit graph peaks with a given increase in flood peaks, it should be possible to use the small flood unit graph to predict the flood peak of a large flood of normal duration without

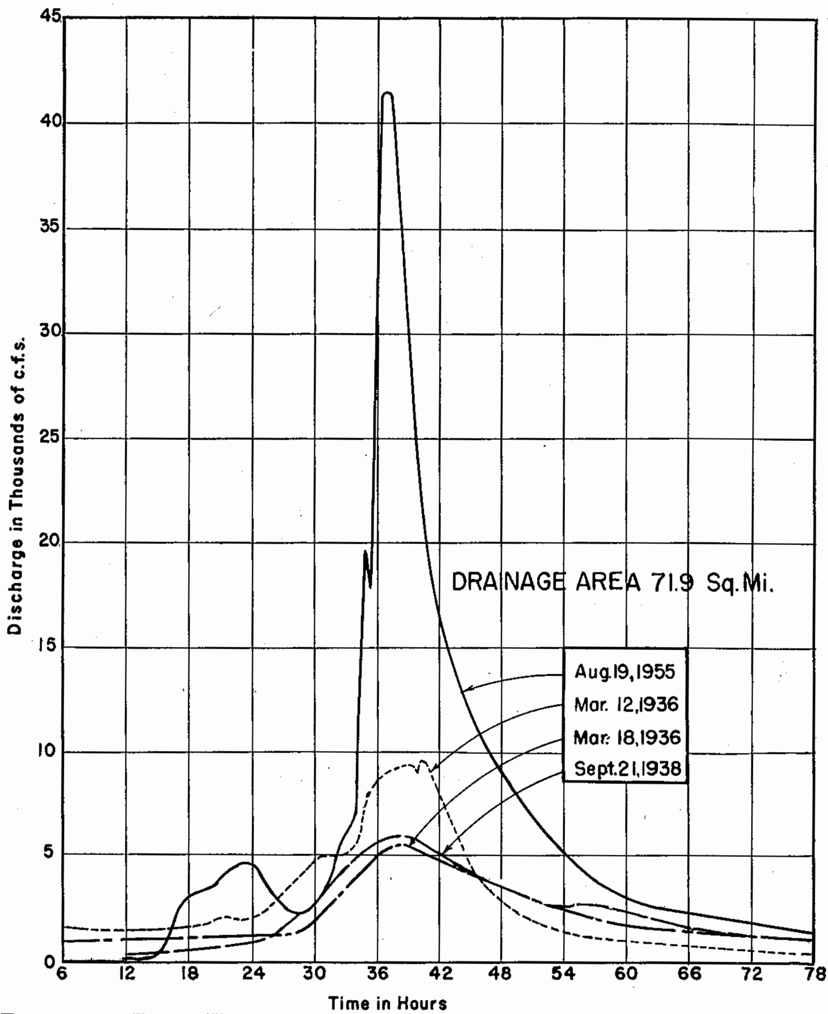


FIGURE 11.—FLOOD HYDROGRAPHS OF NAUGATUCK RIVER NEAR THOMASTON, CONNECTICUT.

more error than may be expected in such computations based on hydrologic data and valid assumptions."

Chapter VII deals with the design criteria for dams and channels. Referring to the former, it notes that the Corps of Engineers base their spillway design floods for critical structures on the maximum possible storm which may give results several times the August 1955 flood. As contrasted to this is the smaller spillway design of the dams for small watersheds used by the Soil Conservation Service of the U. S. Department of Agriculture. There follows a discussion of the economics of spillway designs, where it is pointed out that 1955

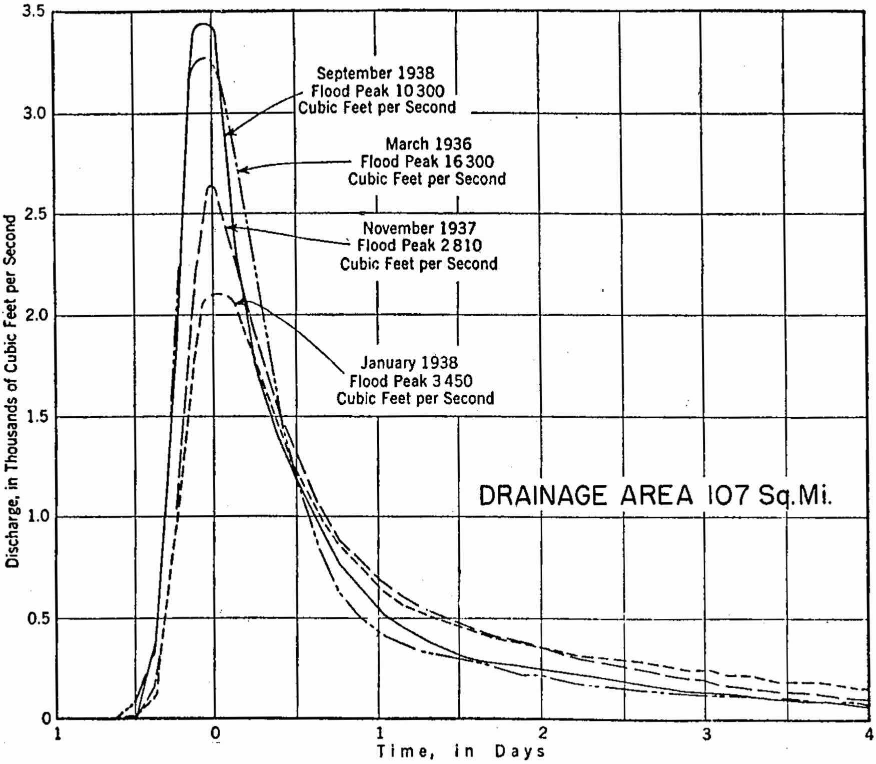


FIGURE 12.—SIX-HOUR HYDROGRAPHS COMPUTED FROM INDICATED FLOODS, NORTH NASHUA RIVER, NEAR LEOMINSTER, MASS.

is now a certain important measure of spillway capacity. The report concludes:

"The 1955 floods, in the areas of their greatest severity, exceeded all records. The rainfall intensity exceeded all records for the area, and it is believed was the greatest during the more than 300 years that the area has been settled. But we can establish no figure for their probability of recurrence upon which we have any confidence.

The interval might be 100 years or it might be 1,000 years. This would mean that for most major works the probability should be considered that a storm of equal or greater intensity than those of 1955 will visit the general area some time within the life of the project." It is pointed out: "No one formula nor method can be recommended as best suited for all cases, nor, for that matter, for any particular case."

There is a further discussion of the criteria for flood channels, covering municipal storm drainage systems and small brooks and channels. The section on culverts and bridges lists the requirements of the various New England states for culverts. Various examples of recent flood channel construction are given, including the present practice of the U. S. Corps of Engineers in determining their standard project flood which it is noted is larger than the maximum flood of record, with an exceedance of 10 to 60 per cent. The channel improvements on the larger rivers of New England are also described. The 1955 flood has become a measure of required capacity of many flood channel works.

The last chapter discusses the regulations by public authorities and is valuable in giving a history of the Flood Control Acts of New England, and of the Federal Power Commission and the Department of Health, Education and Welfare of the Federal Government. It then discusses the various laws in the different New England States regarding the regulations of all river construction particularly, generally, dams, water supply and sewerage. It is interesting to note that in Massachusetts there is a flood zoning law which is an ordinance or by-law which provides that lands deemed subject to seasonal or periodic flooding shall not be used for resident or other purposes in such a manner as to endanger the health or safety of the occupants thereof. The chapter then describes the flood control compacts on interstate rivers, on the Merrimack, Connecticut and Thames Rivers.

In conclusion, one is tempted to conclude that from an engineering standpoint Nature has recently co-operated with the Engineer in giving flood data which has added to our confidence in our flood engineering.

STRUCTURAL FEATURES OF THE UNISPHERE

By Charles I. Orr*

(Presented at a meeting of the Structural Section, B.S.C.E., held on May 9, 1962).

Some months ago American Bridge Division of United States Steel was handed one of its most intriguing and challenging assignments: the fabrication and construction of the UNISPHERE, theme symbol of the New York World's Fair. Upon completion, the UNISPHERE will be presented to the New York World's Fair Corporation by United States Steel.

Essentially, the UNISPHERE combines problems in esthetics and engineering, common ingredients in most structures. However, their complexity in the case of the UNISPHERE, we believe, makes it unique. Peter Muller-Munk and his team of industrial designers, who are the consultants, described the esthetic problems this way:

> The Unisphere cannot be treated as a building or other traditional monumental structure, for in reality it is a piece of open sculpture. This is perhaps the most demanding form of art. It must exist from all sides with no one texture, surface, or line out of harmony with another.

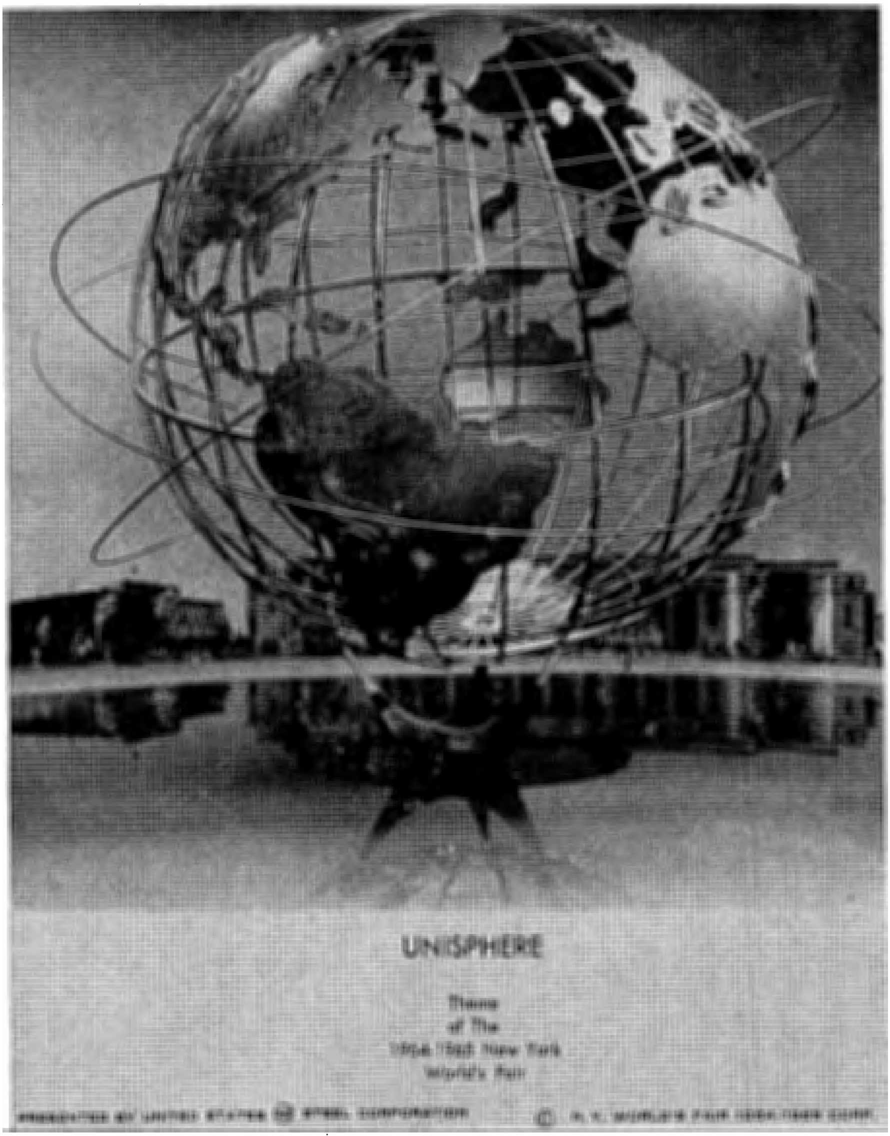
The basic framework of the UNISPHERE is an armillary sphere, 120 feet in diameter, made of stainless steel meridians and parallels. This framework supports the land masses portraying the continents and principal islands of the world with their mountain ranges and recognizable shore lines. These, too, are stainless steel. Capital cities of the various countries will be indicated with lights. Surrounding the sphere are three stainless steel orbits, symbolizing man's achievement in space.

The axis of this structure is tilted 23½ degrees from the vertical, corresponding to the earth's inclination to its orbital plane. The entire light, yet massive, symbolic spherical structure is supported on a sculptured tripodic steel base and is surrounded by a reflecting pool and fountains.

Let's examine each element of this unusual structure, or monument, in greater detail, with special emphasis on the structural parts in which you gentlemen have the greatest interest.

* District Engineer, American Bridge Division, United States Steel Corporation, New York.

The framework is exposed for all to see. Exposed structural steel and its incorporation into the esthetic treatment of a structure is not new—we see examples of it more and more frequently. In this case,



however, we have the ultimate in emphasis on the all stainless steel framework.

The first consideration was the spacing of members. The usual spacing on maps and globes is ten degrees for the latitudes or parallels, and fifteen degrees for the longitudes or meridians. Since it is desired that the UNISPHERE have educational value for the thousands of school children who will see it, this familar arrangement was desirable if it could be used. It was fortunate that the spacing satisfied other requirements. The distance between parallels is about 10 feet and the distance between meridians varies from 15 feet at the Equator to 2½ feet at eighty degrees of latitude. Esthetically, the arrangement gave the openess wanted and, structurally, the spans of the members between joints were not excessive. A much greater spacing would have complicated the problem of supporting the land masses, especially the islands and peninsulas.

To aid in the determination of the shape of the members, four 2-foot diameter models were constructed—one with all round members, one with all square members, one with rectangular meridians and square parallels and one with rectangular meridians and round parallels. Rectangular meridians and round parallels were chosen since this presented the best appearance and gave an interesting contrast in the form of the members. Also, the joint details were less troublesome than if all round members had been used.

There are many types and grades of stainless steel. Several have been developed for highly specialized service to resist extremes in temperature or highly corrosive agents. In this case a steel was required that has good resistance to atmospheric corrosion and desirable weldability. USS 18-8 S stainless steel conforming to AISI Specification 304 was selected. This material has proven itself in many previous applications to be suitable for this purpose.

After deciding on the shape of the members and on the material, the approximate dead load was readily determined with a few assumptions and simple calculations. Approximately 600,000 pounds of stainless steel are required.

It was then necessary to determine the magnitude of the wind forces on the structure. It was easy to make qualitative predictions. For instance, it was almost a certainty that the maximum drag would occur when the majority of the land masses were on the leeward side. A turbulent flow would certainly be set up when the wind passed through the grid formed by the members on the windward side, and there would no doubt be some shielding of the leeward side by the land masses and members but the effect of turbulence and the degree of shielding could not be predicted with any degree of accuracy. It was decided that the only reliable method of determining the wind forces would be to conduct wind tunnel tests on a scale model. One of our architectural models was used for this purpose. The tests were made at the University of Maryland wind tunnel.

The model was tested at three wind velocities: 50, 75 and 100 miles per hour. At each wind velocity the model was turned in direction to the wind in 15-degree increments for a complete 360 degrees. Resisting forces and moments were measured at a reference point near the base for each test. All tests showed consistent results and there was no "velocity effect," since the ratio of velocity pressure to drag was constant. The results confirmed our prediction that the maximum drag would occur with the majority of the land areas on the leeward side, but the magnitude of the drag was greater than had been expected. It was of interest to note that despite the unsymmetrical arrangement of the land masses, there was practically no yawing or twisting movement.

Using the drag coefficients determined from the wind tunnel tests, the UNISPHERE was designed for a wind velocity of 110 miles per hour at the allowable unit stresses permitted by the New York City Building Code. This will provide adequate factors of safety for gusts up to 130 miles per hour. The total drag at 110 miles per hour is 396,000 pounds, or 35 pounds per square foot of the projected area of a solid sphere.

Making a stress analysis was the toughest problem. There are well over 2,000 redundants considering that there are three unknown force components and three unknown moment components at each joint. Obviously, some method of simplifying the problem had to be found. The possibility of using one of the usual methods of dome analysis was considered—at least for the upper portion. However, all of these methods required some simplifying assumption, such as neglecting the out-of-plane bending moments in the rings or parallels. This may be a reasonable assumption when the spring line of the ribs is at a large angle to the vertical and when a separate system of bracing is used to resist lateral forces. In this case the ribs, or meridians, are nearly vertical in the area of the Equator, and, since there can be no bracing, the large transverse wind shears and the transverse components of the dead load can only be resisted by the bending moments in the parallels.

Simplified manual calculations were used to determine the approximate relative stiffness of the members. It was then necessary to locate an electric computer facility with the greatest available capacity. The facility selected was that of General Dynamics Electric Boat Division which is used in the design of the hulls of atomic submarines as well as other complex structures. Even this computer could not handle the problem without considerable simplification. An elastic analysis was used, considering each member as a straight line between joints.

The sphere was first divided into two half-sections by passing a vertical plane through the inclined axis midway between two points of support. This cut the number of joints in half. To further reduce the number of unknowns, the section from 40 degrees north to the North Pole, and the section from 70 degrees south to the South Pole, were considered as rigid shells with the meridians fixed around the perimeter of the shells. A conservative manual analysis was made of the members in these sections and stresses were later compared for consistency with the stresses in adjacent members. For the most part, minimum thickness material could be used.

The remaining section was then divided transversely to form two overlapping parts. The top part extended to 20 degrees south, where the ends of the meridians were assumed to be fixed. This analysis was used to design the members from 40 degrees north to the Equator.

The internal stresses in the meridians at the Equator, as determined from this analysis, were then applied as external forces along with the other loads in analyzing the lower part. The rigid shell was assumed to be hinged at the South Pole. Hinges were also assumed at the other two support points. Even with the divisioning into sections, the solution of the lower part alone involved the solving of 670 simultaneous equations.

This analysis did not permit the application of wind loading in all directions but it was found that the maximum wind load stress in any member for the one condition analyzed could be used to design all of the members at any particular latitude, except in the region of the supports. A separate elastic analysis of the support area was made for three different wind loading conditions, and by comparing results with the other solutions a stress distribution pattern in this area was established.

It is interesting to note that the largest moments always occurred at the joints. The effect of axial stress was almost negligible compared to the bending moments caused by the transverse loads. In the center portion of the sphere, points of counterflexure were approximately at the centers of the members, except where the meridians join the Equator. Due to the stiffness of this section, the joints of counterflexure were closer to the 10-degree parallels, causing larger moments at the Equator ends of the meridians.

Except in the area of the supports, the meridians are 8 inches wide and 12 inches deep, and are fabricated from four welded plates. The parallels are tubular sections 8 inches o.d. above the Equator, 9 inches o.d. immediately below the Equator, and 10 inches o.d. in the lower portion of the Southern Hemisphere. The Equator is a rectangular box section 18 inches wide and 14 inches deep. Wall thicknesses vary from 3/16 inch to 1 inch, except at the supports. At the two supports on the 50-degree parallel, both meridians and parallels are 10 inches wide and 3 feet deep with flanges as thick as 3 inches. At the South Pole support, the meridians are 8 inches wide and 2 feet deep with ½ inch thick walls.

It was apparent from the beginning that only welding would be suitable for the field connections. No other method could give the continuity of action and appearance that was required.

Many joint details were studied and it was finally decided to fabricate the meridians in long sections, butt welding the parallels to the sides of the meridians in the field. Tubing diaphragms of the same size as the adjoining parallels are shop-welded inside of the meridians at each joint. Each meridian is fabricated in four shipping sections.

The field welding process that will be used is a type of metallic inert gas welding, known as short-circuited arc. This process utilizes a coiled wire which serves as a consumable bare electrode providing the filler metal for the weld. The weld zone is protected from atmospheric contamination by a continuous blanket of inert gas fed through the tip of the welding torch. A motorized wire feed unit pushes through the welding torch at a speed selected by the operator. The operation requires a constant potential welding power source. It usually operates on lower arc voltages (14 to 19 volts) than the spray arc technique. This pin points the arc heat and produces a small relatively cold weld puddle which minimizes metal distortion.

Overhead welds can be made fairly easily and short gaps, which invariably occur in field fit-up, can be spanned with no difficulty, making the process ideal for our purpose.

Of course the structural design of the UNISPERE frame could not be completed without concurrent consideration of the design of the land masses. The first thought was to use a wire mesh that would be open enough to reduce the wind drag on the structure. If the land areas were made of solid material we would, in effect, have a "big sail" that would catch the wind in the same manner as the spinnaker on a sail boat. Many types of mesh were investigated; some appeared quite promising at first but all became virtually invisible when held up against the sky. Even a mesh with as little as 20 percent voids faded when held against the bright backdrop. Even a full-scale mock-up was made and mounted 50 feet in the air above Flushing Meadows at the exact site of the UNISPHERE. After extensive studies, it was necessary to face the fact that we were "stuck" with our "big sail." A mesh dense enough to produce the desired visual effect would not appreciably reduce the wind load and could even ice over so that in fact it would become a solid sheet.

Attention was then turned to solid materials, and after much investigation a non-directional patterned rigidized stainless steel sheet was selected, especially designed for the UNISPHERE.

Steel is shown to its best advantage when it is used in crisp, angular fashion, so it was decided that the mountains, instead of being formed of sheets pounded into irregular shapes like wrinkled tin foil, would be built up layer cake style in a series of steps, creating the effect of a huge contour map. This treatment also will have educational value since the edges of the steps represent 1,000 meter contour lines. The mountains are made to an exaggerated vertical scale forty-four times the true scale since, in their actual proportions, they would appear insignificant.

The rigidized stainless steel sheets are mounted on a subframework of channels and angles. Of course these are stainless steel, too. This framework is joined to the UNISPHERE members by welding and bolting. The large areas will be fabricated in sections, preassembled and fitted in the shop. The sculptured sheets will be attached to the subframe with pop rivets—naturally of stainless steel.

This symbolic world will be encircled by three stainless steel orbits which, according to an early press release, "float in space with no visible means of support." Actually, the orbits will be anchored to the earth with small stainless steel strands, as the rim of a bicycle is anchored to its hub. Although faintly visible, these ties will not detract from the sculptured contour of the Theme Center.

By this time, quite a support problem had accumulated dead weight of the material, the wind blowing on our sails, and the orbits waving in the breeze. There was a temptation to design a substantial base with a rigid ring girder and a series of rugged steel columns, or even a foundation of massive masonry. However, the consultants, Peter Muller-Munk and Associates, thought it would be nice if the earth were supported on three needle points—again, practically no visible means of support, as in nature.

Thus, they developed an open sculptured base supporting the world at three points and holding it 15 feet above the reflecting pool at its inclination of 23½ degrees. Of course the feasibility of this three-point support was investigated before making the final stress analysis. Naturally, the base is covered with stainless steel. However, for the structural core the only departure was made from the selected material, stainless steel. This structural core is USS Cor-Ten steel. This base consists of three tapered, welded girders, each with one very narrow flange and one wide flange. The intersection at the center is secured with A325 high strength bolts. The superstructure is attached to the base at each point of support with a ring of high strength stainless steel bolts. Each corner of the base is anchored to the foundation with ten 2½-inch diameter bolts of USS-Tl steel. The foundation will be designed by consultants of the Fair Corporation to transfer the load to the same pile cluster that supported the Perisphere of the 1939-1940 World's Fair.

With the completion of the design, the problems are of course far from over. There are still hurdles in fabrication and erection but we are convinced of one thing, that is, the right material is being used—steel. Like the man says on television: "Only steel can do so many things so well." Its inherent properties have enabled us to achieve the fine line appeal that was desired without resorting to bracing or by otherwise compromising esthetics.

While, perhaps the birth of the UNISPHERE is not as exotic as problems connected with space explorations, it, nevertheless, represents a delicate, intricate exercise in design and engineering skills.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

APRIL 30, 1962:—A Joint Meeting of the Mass. Section of American Society of Civil Engineers with the Boston Society of Civil Engineers was held this date at the Hotel Lenox, Boston, Mass., President William H. Mitchell of the ASCE presiding.

After dinner, President Mitchell called the meeting to order at 7:30 P.M. and after introducing head table guests, turned the meeting over to George G. Bogren, President of Boston Society of Civil Engineers to conduct any necessary business. President Bogren called upon the Secretary for routine announcements after which the meeting was turned back to President Mitchell of ASCE who introduced the guest speaker, Mr. Edward Roemer, Chairman of Government Center Commission.

Mr. Roemer presented an interesting paper on #1 General Plans for Government Center from State Viewpoint. #2 Procedures Used for Hiring Professional Engineer's Services.

A brief discussion period followed, with adjournment called at 9:10 P.M.

Eighty members and guests attended the dinner, and 85 attended the meeting following the dinner.

CHARLES O. BAIRD, JR., *Secretary*

MAY 16, 1962:—A Joint Meeting of the Boston Society of Civil Engineers with the Surveying & Mapping Section was held this evening at the United Community Services Building, 14 Somerset Street, Boston, Mass., and was called to order by President George G. Bogren, at 7:00 P.M.

President Bogren stated that the Minutes of the previous meeting held April 30, 1962 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

President Bogren announced the death of the following member:—

Ralph B. Brasseur, who was elected a member June 15, 1927 and who died June 10, 1961.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership May 14, 1962.

Grade of Member—William A. Wahler.

President Bogren announced that this was a Joint Meeting with the Surveying and Mapping Section and called upon Richard D. Raskind, Chairman of that Section to conduct any necessary business at this time.

President Bogren introduced speaker of the evening, Richard L. Cameron, Cambridge Air Force Research Center who gave a most interesting illustrated talk on "New England During the Ice Age."

A discussion period followed the talk.

Fifty three members and guests attended the dinner and eighty three members and guests attended the meeting The meeting adjourned at 8:45 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MAY 23, 1962:—A Joint Meeting of the Boston Socitety of Civil Engineers with the Sanitary and Construction Sections was held this evening at the United Community Services Building, 14 Somerset Street, Boston, Mass., and was called to order by President George G. Bogren, at 7:00 P.M.

President Bogren stated that the Minutes of the previous meeting held May 16, 1962 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unles there was objection.

President Bogren announced the death of the following member:—

LeRoy G. Brackett, who was elected a member April 21, 1915, and who died May 12, 1962.

President Bogren annuonced that this was a Joint Meeting with the Sanitary and Construction Sections and called upon George W. Hankinson, Chairman of the Sanitary Section to conduct any necessary business at this time, and James P. Archibald, Chairman of Construction Section to conduct any necessary business at this time.

President Bogren introduced speaker of the evening M. Hugh P. Ripman, Head, Industry Division, International Bank for Reconstruction and Development, who gave a most interesting talk on "The Challenge of Civil and Sanitary Engineering Work in Underdeveloped Countries."

A discussion period followed the talk.

Fifty three members and guests attended the dinner and eighty five members and guests attended the meeting. The meeting adjourned at 9:00 P.M.

CHARLES O. BAIRD, JR., *Secretary*

HYDRAULICS SECTION

MAY 2, 1962.—The meeting was called to order by Lawrence C. Neale, Chairman of the Section, at 7:10 P.M. at the Society Rooms, 20 Pemberton Square.

The minutes of the previous meeting (February 21, 1962) were passed over since they were read and approved at the previous meeting of the main society. Mr. Neale announced the dates of the section meetings scheduled for November 7, 1962, Febrauary 6, 1963 and May 15, 1963.

The Chairman the introduced the speaker, Mr. Frank E. Perkins, Research Engineer, Hydrodynamics Laboratory, Massachusetts Institute of Technology, whose subject was "A New Approach to the Study of Transients in Hydro-Power System."

Mr. Perkins discussed the limitations and approximations in the previous analytical and experimental methods of investigation of hydraulic transients, which for the most part represented isolated portions of the system independently. He then described the Hydroelectric Power Systems at Garrison Dam, consisting of the characteristics of conduits, valves, surge tanks, turbines, governors and other pertinent components, which were connected together in a digital computer study, representing the entire system. The experimental portion of the program consisted of automatic recordings of pressures at many locations accompanied by changes in the previously described components, which were also recorded. The preliminary results of data processing show good correlation between analytical and experimental programs. An accurate analysis made possible by the comprehensive analytical and experimental program seems to indicate that surge tanks at Garrison Dam are larger than necessary. This new approach should result in increased safety and economy of design for future works.

The meeting was adjourned at 8:45 P.M. after a question and answer period. Attendance was 35.

KEISTUTIS P. DEVENIS, *Clerk*

STRUCTURAL SECTION

APRIL 11, 1962.—A regular meeting of the Structural Section was held this evening in the Society Rooms and was called to order by Chairman Percival S. Rice at 7:05 P.M.

The Chairman announced that Mr. Roland S. Burlingame would present the announced paper instead of Mr. R. Ernest Leffel, who was unable to attend because he was seriously ill.

The Chairman introduced the speaker of the evening, Mr. Roland S. Burlingame, Partner, Camp, Dresser & McKee, who spoke on "Construction of a Novel Pre-Stressed Water Tank for Cali, Columbia."

The speaker informed the meeting that he had not been associated with the subject project and that his talk would be based on his interpretation of Mr. Leffel's notes which were recorded in French.

The tank which has a 4,000,000-gallon water storage capacity was designed and built by French engineers for Cali, Columbia, a city with a population of approximately 250,000 people. It is 158 feet in diameter and is made up of 108 identical, 27-foot high, precast, prestressed concrete units. After the precast units were erected and the prestress wires from the individual units were connected, the joints between the units were temporarily sealed on the inside with rubber sheets and the tank was filled with water, thus putting the exposed prestress wires in tension. At the completion of this operation, the joints between units were filled with concrete, thereby forming a continuous concrete compression ring when the water table is lowered.

Slides were shown to illustrate the major design and construction features of the tank.

The Chairman on behalf of the group thanked the speaker for taking Mr. Leffel's place and congratulated him on his presentation of the subject matter.

After a brief question and answer period, the meeting was adjourned at 8:00 P. M.

The meeting was attended by 26 members and guests.

MAX D. SOROTA, *Clerk*

ADDITIONS

Members

Howard B. Bacon, 41 Barrett St., Needham 92, Mass.

Clifford S. Copithorne, 18 Bogle St., Weston 93, Mass.

Benjamin E. Eaton, Jr., Auburn, N.H.

Sepp Firnkas, 120 Boylston St., Boston 16, Mass.

Arthur R. Giangrande, 27 Pleasant St., N. Reading, Mass.

J. Preston LeBlanc, 47 Preston St., Lynn, Mass.

Robert L. McGillicuddy, 16 Summer St., Everett 49, Mass.

Joseph M. Pecora, 12 Farmcrest Ave., Lexington 73, Mass.

Lino Patti, 12 Vermont Ave., Somerville, Mass.

Seymore A. Potter, Jr., N.E. Corps of Engrs., 424 Trapelo Rd., Waltham 54, Mass.

William Simonson, 44 Revere Beach Pky., Revere 51, Mass.

Juniors

Warren D. McLea, 13 Forest Ave., Natick, Mass.

Deaths

Ralph B. Brasseur, June 10, 1961

LeRoy G. Brackett, May 12, 1962

PROFESSIONAL SERVICES
AND
ADVERTISEMENTS

The advertising pages of the JOURNAL aim to acquaint readers with Professional and Contracting Services and Sources of Various Supplies and Materials. You would find it of advantage to be represented here.

Volume 49 JULY, 1962 Number 3

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROFESSIONAL SERVICES

INDEX TO ADVERTISERS

BARNES ENGINEERING COMPANY, Inc.

Civil Engineers

411 Lexington Street

AUBURNDALE 66, MASS.

Brask Engineering Company

ENGINEERS

177 STATE STREET, BOSTON

CA 7-3170

CLARKESON ENGINEERING COMPANY, Inc.

Design, Construction Inspection

Airports, Bridges, Tunnels, Highways, Traffic and Transportation Analyses and Reports, Valuations.

285 Columbus Ave., Boston 16, Mass.

Commonwealth 6-7720

CAMP, DRESSER & McKEE

Consulting Engineers

Water Resources - Water and Air Pollution
Water Works - Water Treatment
Sewerage - Wastes Treatment
Refuse Disposal - Flood Control
Reports, Design, Supervision

18 TREMONT STREET BOSTON 8, MASS.

Coffin & Richardson, Inc.

Consulting Engineers

68 DEVONSHIRE STREET

BOSTON 9, MASSACHUSETTS

Congdon, Gurney & Towle, Inc.

Engineers

53 State Street Boston, Mass.

CRANDALL DRY DOCK ENGINEERS, Inc.

Dry Docks — Piers — Waterfront Structures
Skilled Divers for underwater examination and repair.

238 Main Street Cambridge, Mass.

William S. Crocker, Inc.

(Formerly Aspinwall & Lincoln)

Registered Professional Engineers
Registered Land Surveyors

255 Atlantic Avenue Boston, Mass.

Richard J. Donovan, Inc.

CIVIL CONSTRUCTORS & ENGINEERS

Designs
Reports—Surveys
Estimates—Locations
Supervision—Appraisals
Construction—Consultation

540 Main Street, Winchester, Mass.

Duffill Associates, Inc.

Consulting Engineers

TWO PARK SQUARE

BOSTON 16, MASSACHUSETTS

Tel. 423-4700

EDWARDS and KELCEY

Engineers and Consultants

HIGHWAYS — STRUCTURES
TRAFFIC — PARKING
TERMINAL FACILITIES

470 Atlantic Avenue, Boston 10, Mass.

Fay, Spofford & Thorndike, Inc.

Engineers

Airports, Bridges, Express Highways, Water Supply, Sewerage, Drainage, Port and Terminal Works, Industrial Plants, Incinerators.

11 Beacon Street, Boston, Mass.

HARRY R. FELDMAN, INC.

Civil Engineers and Land Surveyors

Engineering and Survey Service for Consulting Engineers - Architects Contractors - Appraisers Municipalities

27 School Street Boston 8 Mass.

William A. Fisher Co., Inc.

Consulting Engineers

Design — Supervision — Reports
Traffic — Transportation — Planning

185 Devonshire St., Boston 10, Mass.

Ganteaume & McMullen

Engineers

99 Chauncy Street

BOSTON

HALEY & ALDRICH

Consulting Soil Engineers

Site Investigations; Soil Mechanics Studies for Foundations, Retaining Walls, Dams, Highways, Airfields and Marine Structures

Office and Laboratory

238 MAIN ST. CAMBRIDGE 42, MASS.

HALEY & WARD

Engineers

Successors to Frank A. Barbour

Water Works and Sewerage Valuations
Supervision of Construction and Operation

73 TREMONT ST. BOSTON, MASS.

J. F. HENNESSY

Civil Engineer

4 Cypress Street, Brookline, Mass.

Telephone LO. 6-3860

HOWARD, NEEDLES, TAMMEN & BERGENDOFF

Consulting Engineers

Bridges, Structures, Foundations
Express Highways, Airports

80 Boylston Street
Boston 16, Mass.

99 Church Street
New York 7, N. Y.

JACKSON & MORELAND, INC.
JACKSON & MORELAND INTERNATIONAL, INC.

Engineers and Consultants

Electrical—Mechanical—Structural
Design and Supervision of Construction for Utility, Industrial and Atomic Projects
Surveys—Appraisals—Reports
Technical Publications

BOSTON — WASHINGTON — NEW YORK

Charles A. Maguire & Associates

Engineers

14 Court Square Boston, Mass.

CHAS. T. MAIN, INC.

Consulting Engineers

Industrial Plants
Steam & Hydroelectric Plants
Electrical Engineering
Investigations — Reports — Appraisals

Boston, Mass. Charlotte, N. C.

METCALF & EDDY

Engineers

Soils, Foundations, Waterworks, Sewage Works, Drainage, Irrigation, Flood Control, Refuse, Industrial Wastes, Airports, Highways, Military Projects, Industrial and Commercial Facilities

Statler Bldg. Boston 16, Mass.

MORAN, PROCTOR, MUESER & RUTLEDGE

Consulting Engineers

Foundations for Buildings, Bridges and Dams; Tunnels, Bulkheads, Marine Structures; Soil Studies and Tests; Reports, Design and Supervision.

415 Madison Ave., New York 17, N. Y.

Eldorado 5-4800

New England Survey Services Inc.

Civil Engineers - Surveyors

FIRST ORDER SURVEYS

Bridges - General Construction - Highways - Housing - Land Court - Land Takings - Topographical Surveys. Fairchild Aerial Survey Inc. & Donald J. Belcher & Associates Inc. Representatives. Aerial Surveys - Oblique Views - Contour Maps.

255 ATLANTIC AVE. BOSTON 10, MASS.

Parsons, Brinckerhoff, Quade & Douglas

ENGINEERS

Bridges, Highways, Tunnels, Airports, Harbor Works, Dams, Traffic and Transportation Reports, Industrial Buildings, Sewerage and Water Supply.

126 State St., Boston 8, Mass.
165 Broadway, New York 6, N. Y.

The Pitometer Associates

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement and Special Hydraulic Investigations

New York 50 Church Street

Alonzo B. Reed, Incorporated

141 Milk Street Boston 9, Mass.

Planning
Civil, Mechanical, Electrical,
Transportation
Construction Management

MAURICE A. REIDY

Consulting Engineer

Structural Designs Foundations

101 Tremont Street

BOSTON, MASSACHUSETTS

Gilbert Small & Co.

INCORPORATED

Engineers

Structural Designs

Foundations - Buildings - Bridges

10 STATE STREET BOSTON 9, MASS.

Steinman, Boynton, Gronquist & London

CONSULTING ENGINEERS

HIGHWAYS — BRIDGES — STRUCTURES

117 Liberty Street, New York 6, N. Y.

THE THOMPSON & LICHTNER CO., INC.

Engineers

Designs and Engineering Supervision
Investigations, Testing and
Inspection of Structural Materials
Concrete, Asphalt, Soils Control

Offices and Laboratory, 8 Alton Place, Brookline 46, Mass

HOWARD M. TURNER

Consulting Engineer

Investigations, Valuations, Plans, Supervision of Construction, Water Power, Water Supply, Flood Control, Public Utility and Industrial Properties.

6 Beacon Street : : : : Boston

WESTON & SAMPSON

Consulting Engineers

Water Supply, Water Purification, Sewerage, Sewage and Industrial Waste Treatment. Supervision of Operation of Treatment Plants Laboratory

14 BEACON STREET, BOSTON

FRANK H. WHELAN, INC.

Consulting Engineers

Bridges Buildings
Appraisals Investigations
11 BEACON STREET
BOSTON 8, MASSACHUSETTS
CApitol 7-8960

WHITMAN & HOWARD

Engineers

(Est. 1869. Inc. 1924)

Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works, Sewerage, Drainage, Waterfront Improvements and all Municipal or Industrial Development Problems.

89 Broad Street Boston, Mass.

S. J. TOMASELLO CORPORATION

General Contractors
Asphalt Pavements

598 Columbia Road Dorchester 25, Massachusetts

Tel. AVenue 2-6393

New England Concrete Pipe Corp.

NEWTON UPPER FALLS, MASSACHUSETTS

LAsell 7-4560

MANUFACTURERS OF

Plain and Reinforced Concrete Sewer and Culvert Pipe

Pre-cast, Pre-stressed Concrete Structural Units

PLANTS

Newton, Westfield, Dedham, Massachusetts : : : Providence, Rhode Island

Northern Steel Inc.

1 STATE STREET, BOSTON, MASSACHUSETTS

Concrete Reinforcing Bars

Works at

Glenwood Station, Medford, Massachusetts

BOSTON BLUE PRINT COMPANY, INC.

777 Boylston Street

Boston 16, Massachusetts

ALL TYPES OF REPRODUCTION PROCESSES

EXCLUSIVE DISTRIBUTORS

GURLEY ENGINEERING INSTRUMENTS

POST DRAFTING & ENGINEERING MATERIALS

PIPE FOUNDERS SALES CORP.

CAST IRON PIPE AND FITTINGS

and

High-Silicon Acid Resisting Cast-iron Materials

10 HOLDEN STREET : MALDEN 48, MASSACHUSETTS

DAvenport 4-3920

GIL MOORE & COMPANY

Representatives for

Henry Pratt Co. — Rubber Seat Butterfly Valves
Golden-Anderson — Altitude & Pressure Reducing Valves
American Meter Co. — Chemical Proportioning Pumps
General Rubber Corp. — Rubber Expansion Joints & Soundzorbers

Statler Office Bldg. — Boston, Mass., Liberty 2-3082

BERKE MOORE COMPANY, INC.

General Contractors

8 NEWBURY STREET BOSTON, MASS.

COM 6-0245

From PCA's $10,000,000 laboratories come great advances in concrete research

When you need the facts on concrete just call on PCA

Your local PCA field office is one of thirty-five across the nation—staffed by professionally qualified engineers, architects and farm specialists. Backed by more experts at PCA national headquarters in Chicago, they are here to help you with up-to-the-minute advice and information on every phase of concrete construction.

It's a service made possible by the more than 70 member cement companies who voluntarily support the Portland Cement Association in its research, educational and technical service activities.

Informative literature of every type on modern uses of concrete is yours for the asking. For an authoritative, friendly source of information—call on PCA.

PORTLAND CEMENT ASSOCIATION

20 Providence Street, Boston 16, Massachusetts

A national organization to improve and extend the uses of concrete

Telephone COlumbia 5-2600

BEACON PIPING COMPANY

Power Plant Piping - High Pressure Piping

Fabricators of Piping

200 FREEPORT STREET

DORCHESTER 22, MASSACHUSETTS

John Fairfield, Pres. H. G. Fairfield, Treas. M. M. Stewart, Gen. Mgr.

Old Colony Crushed Stone Company

Crushed Stone and Bituminous Concrete

Truck and Rail Shipments

OFFICE AND WORKS

VERNON and INTERVALE STS., QUINCY, MASSACHUSETTS

Telephone: Office: PR 3-0604

CONCRETE PILES
BORINGS
CAISSONS

RAYMOND CONCRETE PILE DIVISION

RAYMOND INTERNATIONAL INC.

147 Medford St. • Charlestown 29, Mass.

Telephone CHarlestown 2-4300

SAN-VEL CONCRETE CORP.

Prestressed - Precast Concrete Products

AND

Transit Mixed Concrete

Littleton HUnter 6-3501 Boston CApitol 7-9898

Cast Iron Pipe and Fittings

for

Water, Gas, Sewerage and Industrial Service

UNITED STATES PIPE AND FOUNDRY CO.
250 Stuart Street **Boston 16, Mass.**

WEST END IRON WORKS

CAMBRIDGE, MASSACHUSETTS

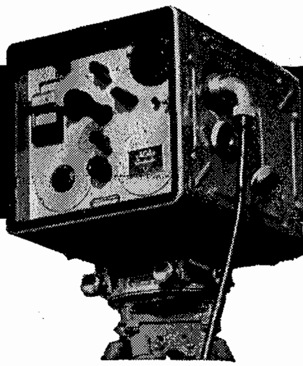
STRUCTURAL STEEL

FOR

BRIDGES AND BUILDINGS

The most recent advance in distance measuring . . .
utilizes modulated light beams

THE GEODIMETER® MODEL 4a



DISTANCE IN FEET	ERROR RATIO
500	1/ 12,000
1,000	1/ 23,000
1,500	1/ 37,000
5,280	1/105,000
20,000	1/144,000

Using a modulated light beam which is projected to a passive type reflector, the Geodimeter Model 4a has accuracy and time-saving characteristics unequalled within ranges of 50 feet to 3-5 miles and fully qualifies as a first order instrument.

Truly portable, the Geodimeter Model 4a is only 12 inches square and weighs 35 pounds. In most instances one man can now complete routine or difficult surveys in a fraction of the time required by other means.

SEE OUR COMPLETE STOCK OF
SURVEYORS' • BUILDERS' • ENGINEERS'
INSTRUMENTS and ACCESSORIES

CARL HEINRICH COMPANY • 711 CONCORD AVE., CAMBRIDGE 38, MASS.
TELEPHONE UNIVERSITY 4-4840

The Heffernan Press Inc.

35B NEW STREET · WORCESTER 5, MASS., U.S.A.

PRINTERS TO
BOSTON SOCIETY OF CIVIL ENGINEERS AND OTHER GOOD PUBLICATIONS.

S. Morgan Smith Company

Manufacturers of

HYDRAULIC TURBINES

and Accessories

Rotovalves

Axial Flow Pumps

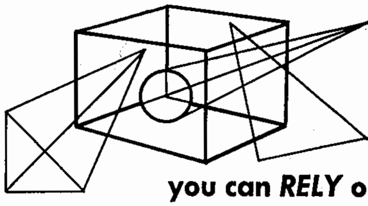
Butterfly Valves

Liquid Heaters

176 Federal Street

BOSTON, MASSACHUSETTS

From every *ANGLE* . . .



you can *RELY* on

MAKEPEACE

and K+E for

TOP-QUALITY

- Precision Instruments
- Micro-Master® 105mm
- BLUEPRINTS • PHOTOSTATS
- PLAN REPRODUCTIONS
- OFFSET PRINTING

Complete Repair and Rebuilding Service

Call COpley 7-2700

B. L. MAKEPEACE INC.

1266 Boylston St., Boston

Asphalt Paving

WARREN BROTHERS ROADS COMPANY

Leaders in design and construction of asphalt pavements since 1902. Engineering staff and testing laboratory available to furnish specifications and advice on unusual paving problems.

Cambridge, Massachusetts TRowbridge 6-4320

Please mention the Journal when writing to Advertisers

COMMITTEES

1962-1963

NOMINATING COMMITTEE

Past Presidents (Members of the committee)

Arthur Casagrande
John S. Bethel, Jr.
Elliott F. Childs
George M. Reece
(Term expires March, 1963)

William L. Hyland
James W. Daily
Richard W. Albrecht
Roy L. Wooldridge
(Term expires March, 1964)

PROGRAM

George G. Bogren, *Chairman ex-officio*

John F. Flaherty
William A. Henderson
Charles O. Baird, Jr.
George W. Hankinson
Percival S. Rice
James W. Haley
Lawrence C. Neale
Richard D. Raskind
James P. Archibald

PUBLICATION

William A. Henderson, *Chairman*

Charles E. Knox
George W. Hankinson
Percival S. Rice
James W. Haley
Lawrence C. Neale
Richard D. Raskind
James P. Archibald

LIBRARY

Earle F. Littleton, *Chairman*

Robert L. Fuller
Eugene Mirabelli
John C. Adams, Jr.
Joseph Capone, Jr.

HOSPITALITY

Clement D. Zwodniak, *Chairman*

Arthur L. Quaglieri
Robert C. Marini

DESMOND FITZGERALD AND HERSCHEL AWARD

Ralph M. Soule, *Chairman*

Thomas R. Camp
Saul Namyet

SANITARY SECTION AWARD

Joseph C. Lawler, *Chairman*

George M. Reece
Ralph M. Soule

STRUCTURAL SECTION AWARD

Myle J. Holley, Jr., *Chairman*

Saul Namyet
Richard Olney

HYDRAULICS SECTION AWARD

Elliot F. Childs, *Chairman*

Clyde W. Hubbard
Lee M. G. Wolman

SURVEYING AND MAPPING SECTION AWARD

Charles M. Anderson, *Chairman*

Lewellyn T. Schofield
Nelson W. Gay

TRANSPORTATION SECTION AWARD

Alexander J. Bone, *Chairman*

Thomas C. Coleman
James W. Haley

CONSTRUCTION SECTION AWARD

Ernest L. Spencer, *Chairman*

Robert J. Hansen
Frank J. Heger

SUBSOILS OF BOSTON

Donald G. Ball, *Chairman*

Harl P. Aldrich, Jr.
Ronals C. Hirschfeld
Lawrence G. Ropes

MEMBERSHIP CENTRAL COMMITTEE

Benedict J. Quirk, *Chairman*

Fozi M. Cahaly
George W. Hankinson
Percival S. Rice
James W. Haley
Lawrence C. Neale
Richard D. Raskind
James P. Archibald

AUDITING COMMITTEE

Harry L. Kinsel
Clair N. Sawyer

INVESTMENT COMMITTEE

Paul A. Dunkerley, *Chairman*

George G. Bogren
John F. Flaherty

ADVERTISING COMMITTEE

Robert C. Marini, *Chairman*

Charles E. Knox
Lee M. G. Wolman
Anthony S. J. Tomasello

JOINT LEGISLATIVE COMMITTEE

Edward Wright, *Chairman*

Frank L. Heaney
Ralph M. Soule

EDUCATION COMMITTEE

George W. Hankinson, *Chairman*

Arthur Casagrande
Earle F. Littleton
Arthur T. Ippen
William F. M. Longwell

COMMITTEE ON PROFESSIONAL CONDUCT

Howard M. Turner, *Chairman*

John B. Wilbur
William L. Hyland
Thomas R. Camp
Gordon M. Fair

PUBLIC RELATIONS COMMITTEE

John F. Flaherty, *Chairman*

Richard F. Battles
Ernest L. Spencer