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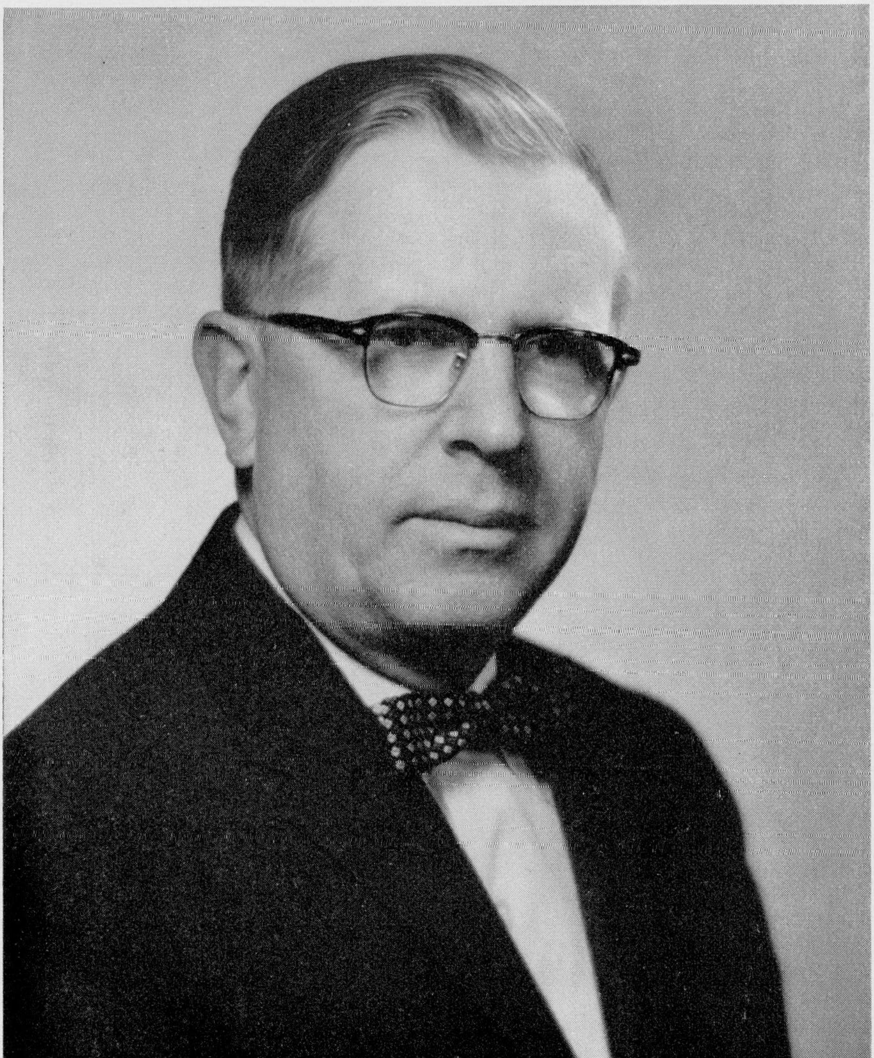

WILLIAM A. HENDERSON

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Boston Society of Civil Engineers 1964-65

JOURNAL OF THE
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THE CIVIL ENGINEER IN MUNICIPAL SERVICE

PRESIDENTIAL ADDRESS BY JOHN F. FLAHERTY
(Boston Society of Civil Engineers, March 16, 1964.)

CIVIL engineers in municipal service represent a considerable proportion of the entire profession. It is the purpose of this paper to consider the present status of these employee-engineers and their problems, viewed against a background of their past and with an appraising look at their fúture. In so doing, we must also evaluate the effect of consulting engineering firms whose practice includes an appreciable amount of municipal work, as the quantity of work assigned to consultants has a considerable effect on the municipal engineering employee.

The opinions expressed here are undoubtedly influenced by my experience over the past thirty-three years as an employee of the City of Boston in various civil engineering positions. I realize that conditions vary from city to city throughout the country in regard to the organization of departments employing civil engineers, and in regard to their status, salaries, benefits, and other conditions of employment. However, I believe that the statements made here will be broad enough in scope to be applicable to many cities.

The City Engineering Department was established in 1850 with Ellis S. Chesborough as Boston's first City Engineer. Incidentally, he was a founder member of the Boston Society of Civil Engineers (1848) and many of his successors were also members of that Society.

Prior to this time civil engineers were engaged primarily on transportation projects, the construction of canals being abandoned for the building of railroads. About this time began the construction of public water supply, the development of water power for the textile industry, the construction of City pavements, bridges, and gas works, and extensive land and waterfront developments.

The construction in Boston, during the latter part of the 1800's, of extensive sewerage and drainage works, the extension of the water supply system, the laying out and construction of streets and bridges, and the development of a rapid transit system, provided employment for practically all of the available civil engineers.

The scope of these major projects attracted top ranking engineers to the Citys' service, as there was here an opportunity to acquire experience and status not available elsewhere. There were, of course, consulting engineers engaged on many of these projects, but principally as individual consultants, some of whom had small office staffs. The day of the consulting engineering firms with large staffs had not yet arrived and practically all the engineering work was performed by the City's own engineering personnel.

Since the 1880's, the necessity for providing the major facilities needed to serve several adjacent communities and of a scope beyond the resources of individual communities to provide, such as water supply and sewage disposal systems, bridges, turnpikes, expressways, solid waste disposal facilities, and airports, had led to the formation of state or county agencies or commissions and privately financed authorities to take over the construction and operation of such facilities. While many of these agencies have large and complete engineering staffs, some have few engineers on their staffs and rely on private engineering firms for the design, supervision of construction and, in some cases, management of their operations.

This trend to the construction of major engineering structures by such agencies has attracted some of the best engineering talent to those agencies and to their consultants. The relatively minor construction (with some exceptions) left to the city engineering staffs has resulted, in many cases, in a reduction in the status of the city's engineering departments and their having difficulty in recruiting and retaining capable civil engineers.

Consequently, city engineering departments have been consolidated with, or incorporated into, Public Works Departments or Highway Departments, with a loss of status for the engineers. Conversely, the staffs of many state agencies and consulting engineering firms have grown in numbers and status.

In most cities the Public Works Department is assigned the task of providing the required civil engineering services. In general, these consist of the laying-out and construction or reconstruction of streets, the extension or repair of sewerage and drainage, the maintenance and extension of the water distribution system, and the construction of bridges, pumping stations and refuse incinerators. The civil engineers in the Public Works Departments are also, in most cities, placed in the top management and operations positions, being responsible for the maintenance and operation of the highways, bridges, drainage, water distribution and waste collection and disposal facilities.

Several factors, some mentioned previously, have led to the difficulties now confronting many of the civil engineers in municipal service. Absorption into a large operations department where the engineers are a small minority; the reduction in scope of major projects to be worked on; and the tendency of some municipalities to grant pay increases based on a fixed sum rather than on a percentage basis, thereby reducing the pay differential between the engineer and the clerk or laborer; have resulted in a reduction in status of the engineer. This reduction in status and the relatively low salary schedule are the reasons for many cities being unable to attract engineering graduates over the past 25 years or retain some of their better qualified young engineers.

The Civil Service laws of some states require that education may not be made the sole qualification for employment. Therefore, in some states, qualifications for engineering positions are based on experience in the work, with a stated period of education allowed to be substituted for each year of required experience. Consequently, appointing authorites cannot insist on requiring that a prospective employee must be a graduate or a registered professional engineer. Because of these laws, a Civil Service Commission cannot impose such conditions on a candidate applying for an engineering position of a professional grade; and further, in view of the difficulty of the municipalities acquiring graduate engineers, it appears that a policy of promotion from within the departments has developed. This contributes still further to the inability of cities to attract qualified engineers into municipal service.

Normally, a consulting engineering firm would be engaged by a city to design a structure or facility beyond the capability of the city's engineering staff, as it is not feasible to retain the required number of specialists on the city's staff on a full-time basis. However, with the emasculation of the city engineering staffs, there appears to be a tendency to engage consultants to perform work of a routine nature that ordinarily would be performed by the municipal staff. Such assignment creates further dissatisfaction amongst the city's engineering staff. The advantage of steady employment and fringe benefits, such as pensions, paid vacation and sick leave (which induced some to enter Civil Service years ago) no longer lies heavily with municipal employees. Continuous employment is a certainty for capable employees in most large engineering firms today and many of the fringe benefits are also available in private employment. Furthermore, problems that the engineer in private employment does not have to contend with are: frequently working under substandard conditions; being the target of complaints from some unreasonable citizens who treat him as a servant (in the full sense of the word) rather than as a professional; and, if in operations, being subject to call at any time outside of regular working hours in the event of equipment failure or plant breakdown, to work on snow removal, or to render assistance in times of natural disasters, such as hurricanes, floods, etc.

It would indeed be unfortunate if I were to convey the idea, because of the statements made herein, that the civil engineer in municipal service is an unqualified, disgruntled and uncooperative individual. On the contrary, the municipal engineers I have worked with and talked with at various meetings throughout the country are, on the whole, a fine group of dedicated, conscientious, capable and hard-working public employees, proud of their accomplishments, performing their duties in many cases under severe handicaps, and compare very favorably with civil engineers in the employment of other governmental agencies, both Federal and State, and with those in private practice.

There is a hard core of engineering personnel required by a municipality below which it is impractical to operate. An intimate knowledge of the city's various public works systems and facilities is vital, particularly when emergencies arise. A large amount of detail may be recorded and filed, but, unless someone knows how to make this information readily available when required to effect emergency repairs or when making extensions, changes, or replacements in the system, considerable time and money will be spent making investigations and inspections to acquire information that could be easily obtained from an engineer familiar with the system.

The employment of the same consulting office by a municipality in order to benefit by that firm's knowledge of the system gained during prior assignments does not always prove advantageous to the city. In many cases the engineers employed by the consultant who acquired some knowledge of the system on a prior project are no longer with that firm when another problem in that same system arises. At the fees a consulting engineering firm must charge on relatively minor assignments, this engineering can be performed as well, and at a lower cost, by a municipal engineering staff. It is therefore in the best interests of the municipality and the engineering profession that an adequate staff of civil engineers be retained by the municipality on a full-time basis, and that consulting engineers be engaged only when required to render services of a major and specialized nature beyond the scope of the municipal engineering staff.

Where a municipal engineering staff has been allowed to atrophy by failure to obtain replacements, and by lack of incentives, steps should be taken to improve status by upgrading men in the service and acquiring qualified personnel by establishing an adequate salary schedule. Action from three separate sources now being taken in the fields of legislation, education and municipal service, and similar actions that will undoubtedly follow, will eventually improve the status of the civil engineer in municipal service.

The passage of legislation requiring mandatory registration as Professional Engineer of all engineers in charge of engineering work for all governmental agencies will result in upgrading the qualifications established by civil service commissions and municipal personnel officers. Where too low, salary schedules will have to be revised upward in order to obtain engineers who qualify by registration for filling the positions of a professional grade. Others who do not qualify will be limited to engineering work of a sub-professional nature.

The report on "Governmental Manpower for Tomorrows Cities" by the Municipal Manpower Commission calls attention to the importance of and the need for well-trained, competent, imaginative and strongly motivated public service personnel. Cognizance of the problem has been taken by the American Public Works Association, a national organization of over 6700 public works officials including a large number of municipal engineers.

The A.P.W.A. Education Foundation is in the process of developing educational programs to prepare persons for service in the field of public works and is endeavoring to obtain assistance by means of grants in aid and from educational institutions. According to this foundation "the overall management, planning, design, construction, operation and maintenance of such facilities (public works) requires a high degree of expert knowledge. The increasing cost and complexity of government and the growing demand for public works make it absolutely essential for persons to be adequately prepared by training and experience for positions of leadership and responsibility in the field of public works. There is a need for in-service training programs designed to transfer pertinent knowledge to persons in position of responsibility and authority. Civil Engineering is regarded as a prerequisite for top level public works executives. However, little or no attempt is made by civil engineering schools to expose students to city planning, municipal law, political science, public finance, sociology, economics, personnel management and similar courses which are equally important for administration of public works programs".

The A.P.W.A. Education Foundation proposes the development of educational and training programs that would include research into the future manpower requirements; development of a graduate program at several well-recognized universities leading to the award of a professional degree of Master of Public Works; an executive development seminar program for public works personnel not expected to participate in the masters degree program; the development of in-service training programs for supervisory personnel; and the possibility of developing a public works institute of technology.

Locally, the City of Boston has contracted with Northeastern University for professional services in conducting a survey of the educational and training needs of the Public Works Department. This survey will include an examination and evaluation of the structure and functioning of the department and a determination of the duties assigned to the key engineering, technical, supervisory and managerial positions and the essential qualifications needed; a study and evaluation of the need for a continuing program of on the job and/or off the job education and training; the preparation and submission of recommendations concerning changes in the departmental structure and in position duties, the responsibilities and qualifications; and an outline of the nature, scope, content, plan of operation and annual cost of conducting a program of on the job and/or off the job education and training; all for the purpose of developing and maintaining a progressive, effective, well managed Public Works Department organization, competent to meet the growing needs of the City of Boston.

Recognition of the problems of the municipalities in acquiring and retaining adequate civil engineering staffs, and the effect of the problems on the personnel of those staffs, by the aforementioned and other agencies, will eventually result in an improvement in the status of the civil engineers in municipal service.

To hasten and implement the formation of programs designed to facilitate the improvement of municipal engineering staffs, the civil engineering profession must take greater recognition of this problem as it affects so large a number of its members. Fellow engineers in other governmental agencies, both Federal and State, consulting engineers, engineering instructors, and the engineering societies, both national and local, should extend all the assistance possible in supporting the efforts of the more progressive municipalities and their engineering employees in their efforts to improve the status of these engineers.

The municipalities must recognize that they could not exist without the services of the civil engineers engaged in public works. A city could not live without its water supply, and without the distribution of food and other vital supplies over its highways and bridges; it would be wiped out by disease without adequate sewerage; and would soon be buried under tons of rubbish without a solid wastes disposal system. The municipal civil engineer does require special training and knowledge (much of which can only be acquired through experience in municipal service) and to acquire and retain capable men, the municipalities must provide an improved system of incentives and salary schedules.

Civil Service Commissions must establish more stringent qualifications for engineering positions of professional grades and in those states that do not now require it, registration as a professional engineer.

The municipal engineer on his part must willingly enter into and assist in furthering programs developed for upgrading the group and the individual. He must be willing to take part in civic affairs, meet with public officials and attend meetings of civic organizations so as to carry to them a message as to what his department's services provide for their health, comfort, and convenience and the important role of the civil engineer in providing these services. Only by so doing can he generate a civic awareness of his importance to the community and generate a willingness on their part to assist him in his quest for improvement of his professional status. Only by so doing can he overcome the attitude that has developed to treat the municipal engineer as a public servant rather than as a professional man. Only when public officials and the general public views the municipal engineer as a professional will they lend assistance to his efforts for improving his lot.

The role of the civil engineer in the development of our cities is one that the profession can be proud of, and in general, the outlook for his future appears promising. The indications are that the various steps mentioned herein will tend to upgrade and improve the status of the civil engineer in municipal service to the extent that he will once more be looked upon, as he was in the nineteenth century, as a most distinguished citizen of his community.

GEOLOGY OF THE CITY TUNNEL EXTENSION GREATER BOSTON, MASSACHUSETTS

By Marland P. Billings* and F. Lyle Tierney**

The City Tunnel Extension, for water distribution in Greater Boston, extends for 7.10 miles in a northeasterly direction from Chestnut Hill Reservoir in the western part of Boston to the western part of Malden. The tunnel, ranging in depth from 235 to 400 feet beneath the surface, is entirely in bedrock. The diameter of the concrete lining is 10 feet.

The tunnel cuts diagonally across a major fold, the Charles River syncline, the axis of which trends east-west. The axis of the syncline is 2.8 miles northeast of the southwest end of the tunnel and 4.3 miles southwest of the northeast end of the tunnel. Numerous lesser folds, ranging in wave length from a few thousand feet to a few feet, are superimposed on the major syncline.

The Roxbury Formation, which was exposed in the southwesterly 2.5 miles of the tunnel, consists chiefly of conglomerate, sandstone, and argillite. The sandstones and argillite are generally pink, purplish-gray, or red. The thickness of the Roxbury Formation here is 2335 feet, but this is only the upper part of the formation. The Cambridge Formation, which was exposed in the northeasterly 4.6 miles of the tunnel. consists chiefly of gray argillite (siltsone), which in many places is laminated to very thin-bedded. Less common rocks are sandstone, quartzite, shale, and tuff. The Cambridge Formation is 6759 feet thick here, but this is only the upper part of the formation.

The evidence from this tunnel demonstrates for the first time that the Roxbury and Cambridge Formations are actually facies of one another. While gravels were being deposited on deltas and fans in the southern part of the area, silts were accumulating in a shallow body of water to the north.

Slaty cleavage, present only locally, dips on the average 70°N. One hundred six faults were mapped. The apparent displacement (vertical separation) is generally only a few feet, but in 17 faults is greater than the height of the tunnel. One hundred fourteen shears were mapped. A total of 298 dikes, sills, and unclassified bodies were mapped. Most are mafic rocks, that is, diabases in various stages of alteration, but 32 are melaphyres.

In general the quality of the rock was excellent for tunneling. No rock bolts were used and only 2103 feet, or 5.6 per cent was supported by structural steel. Thirty-three per cent of the support was due to weak shales and related rocks, 33 per cent was related to dikes, 16 per cent was due to shear zones, and 18 per cent was in sedimentary rocks, probably due to closely spaced joints and fractures.

* Professor of Geology, Harvard University, Cambridge, Mass.
** Formerly Geologist, Metropolitan District Commission, Boston, Mass.

INTRODUCTION

Location, Size and Construction of the Tunnel

The City Tunnel Extension, a water supply tunnel built under the supervision of the Construction Division of the Metropolitan District Commission, Commonwealth of Massachusetts, extends in a northeasterly direction for 7.10 miles from the Chestnut Hill Reservoir in the western part of Boston to the southwestern part of Malden (Fig. 1). The tunnel is entirely in bedrock, at depths ranging from 235 feet to 400 feet. The ground surface in this area ranges from sea level to 200 feet above sea level.

There are four shafts, 7, 8, 9, and 9a (Fig. 1). The invert of the tunnel at Shaft 7 (station 252 + 61.50) is at elevation minus 100 feet (Boston City Base, which is mean low sea level and is 5.65 feet below the U. S. Geological Survey base). From the base of this shaft the tunnel trends N 44°-53′-05″ E for 300 feet. This shaft and this section of the tunnel had been constructed under a previous contract and a concrete plug had been placed at station 255 + 00. The invert of the tunnel at Shaft 8 (station 413 + 63.01) is —375.00 feet. This is the shaft where the headframe was erected and from which most of the construction was carried on. Between the concrete plugs at station 255 + 00 and Shaft 8 the tunnel trends N 51°-10′-38″ E and the slope down toward the northeast is 0.01734 ft/ft. The invert of the tunnel at Shaft 9 (station 556 + 03.11) is —390.00 feet. Between Shafts 8 and 9 the tunnel trends N 26°-49′-54″ E and the slope, downward toward the northeast, is 0.00105. The invert at Shaft 9A (station 627 + 72.20) is —358.00 feet. Between Shafts 9 and 9A the tunnel trends N 26°-59′-16″ E and the slope, upward toward the northeast, is 0.00574. The interior diameter, after the concrete lining was implaced, is 10 feet, but before lining the diameter was about 13½ feet.

The contractor was a combine of Morrison, Knudson, Kewitt and Maney. Shafts 8, 9 and 9A were constructed in 1951–53. Driving of the tunnel began in both directions from Shaft 8 on June 5, 1954. The south heading was completed on September 3, 1955. The north heading was completed on March 1, 1956. The tunnel is now in operation.

Geological Mapping

Although some inspections were made during the driving of the tunnel, the geological mapping was done later, after the walls had

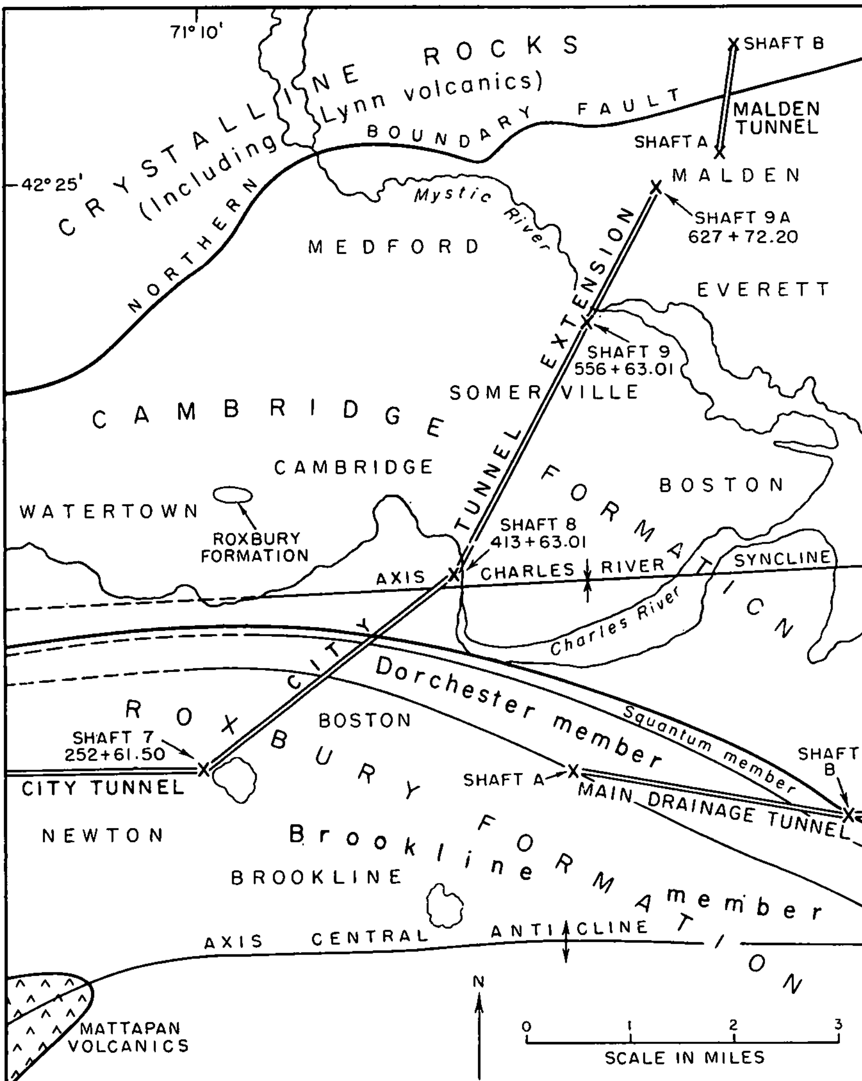

FIG. 1.—LOCATION MAP

been washed down prior to concreting. Mapping by Billings and Tierney began on November 18, 1955 and ended on April 16, 1957. Tierney at that time was geologist for the Metropolitan District Commission, but Billings at that time had no official connection with the Commission.

Thirty-five days were spent underground by the authors in the detailed mapping. The data were plotted on a scale of one inch to 20 feet. The time available permitted mapping of only one wall, which, throughout most of the investigation, was the southeast wall. Although the northwest wall and roof were not formally mapped, they were carefully studied and pertinent data were recorded. A folio of the maps and sections on a scale of one inch to 20 feet has been deposited with the Construction Division, Metropolitan District Commission and with the Department of Geological Sciences, Harvard University.

Regional Setting

The most extensive general account of the geology of the Boston area is by LaForge (1932). The rocks here belong to two groups, the relatively young unconsolidated surficial deposits and the much older consolidated bedrock (LaForge, 1932, Pl. I and II).

The surficial deposits range in thickness from zero—where bedrock crops out—to hundreds of feet. They consist largely of glacial deposits, such as till, gravel, sand, and clay, and of river deposits, chiefly sand and clay. Over the tunnel line the surficial deposits obtain a maximum known thickness of 150 feet. The present paper is not concerned with these surficial deposits.

The bedrock in the area covered by Fig. 1 belongs to two major groups, an older crystalline group and the younger Boston Bay group.

The crystalline rocks in the northern part of Fig. 1 consist of quartzite, amphibolite, diorite, quartz diorite, granodiorite, and the Lynn Volcanics. These rocks range in age from Precambrian to Middle Paleozoic. None of these units appear in the tunnel and hence need not concern us further. The Mattapan Volcanics, in the extreme southwest corner of Fig. 1, are correlated with the Lynn Volcanics.

The Boston Bay group, which occupies most of the area covered by Fig. 1, has been traditionally divided into two formations, a lower unit called the Roxbury Conglomerate and an upper unit called the Cambridge Argillite. Some poorly-preserved cylindrical casts and molds of roots or trunks of trees (Burr and Burke, 1899) are either *Cal-*

lixylon or *Cordaites,* genera that together span a period from the Upper Devonian to the Permian (Elso Barghoorn, personal communication).

The Roxbury Conglomerate, occupying the southern third of Fig. 1, contains, in addition to the typical conglomerate, such rocks as sandstone, argillite (siltstone), and melaphyre flows, tuffs, and breccias. LaForge (1932, p. 5) thought that the Roxbury Conglomerate was 1500 to 3000 feet thick, but Billings (1929, p. 106) believed that it was at least 4000 feet thick in places. Emerson (1917, p. 56) and LaForge (1932, p. 39-42) recognized that locally the Roxbury Conglomerate may be divided into three units: the Brookline Conglomerate member at the base, the Dorchester Slate member in the middle, and the Squantum Tillite member at the top. The upper two members were well exposed in the Main Drainage Tunnel (Rahm, 1962, p. 329). LaForge realized, however, that this three-fold subdivision could not be applied everywhere to the Roxbury Formation.

The Cambridge Argillite, occupying the central third of Fig. 1, has been traditionally considered to overlie the Roxbury Formation. Most of the rocks in the Cambridge Formation are gray laminated to very thin-bedded argillite. The minerals of which it is composed are chiefly clay to silt sizes, less commonly the size of very fine sand. Since slaty cleavage is not common, the term slate, so commonly applied to the formation, is inappropriate. Moreover, although the term shale has been used sometimes, it is inappropriate since the rock does not break into thin sheets parallel to the bedding. Depending upon whether the particles are of clay or silt size, the rocks might be respectively called mudstone or siltstone, but mudstone has a connotation of weakness that is not justified in this case. LaForge (1932, p. 5) gives the thickness of the Cambridge Formation as 2000 to 3500 feet. In the Main Drainage Tunnel Rahm (1962, p. 329) measured the thickness of the lower part of the Cambridge as 3922 feet.

One of the important results of the present study has been to demonstrate that the Roxbury and Cambridge Formations are actually facies of each other.

Igneous rocks are associated with the Boston Bay group. One variety has been separately mapped by LaForge (1932) as the Brighton Melaphyre, which is partly extrusive and partly intrusive. Since the extrusive phases are contemporaneous with the Roxbury Conglomerate, all the melaphyres have been considered to be of Roxbury age. Dikes of diabase, altered diabase, diorite, and related types are common; in this report they are collectively referred to as mafic rocks.

Method of Presentation of Data

The basic data on the geology of the City Tunnel Extension are presented here in geological maps, structure sections, and tables.

Fig 2 shows the symbols used on the following geological maps and structure sections.

Figs. 3 to 6 are geological maps of the tunnel on a scale of one inch to 250 feet. Since these maps have been reduced in scale 12½ times from the original folios, some generalization has been necessary, and only representative structural data are shown. Joints have been omitted. Each strip is 1000 feet long. The stations are given in the upper left-hand and upper right-hand corners (320, for example, means station 320 + 00). The elevation of the invert of the tunnel, referred to the Boston City Base, is shown in the lower left-hand corner of each strip. The lower side of each strip shows the geology exposed at breast level on the southeast wall of the tunnel. On the scale employed (0.1″ = 25 feet) the northwest wall would be only 0.05″ above the base of the strip. The patterns representing the various kinds of rocks would not be legible. Consequently, in order to make a readable map, the top of each strip is 50 feet northwest of the southeast wall, that is, about 38 feet northwest of the northwest wall of the tunnel. See Fig. 2 for the symbols. The arabic numerals under each strip refer to the stratigraphic units to which the rocks have been assigned. The numbers are the same as those used in Tables 1 and 2 and in Figs. 7 and 8.

Figs. 7 and 8 show the geological structure section along the line of the tunnel. They represent the structure one would see on the northwest wall of a trench 500 to 700 feet deep. The base of the sections is 500 feet below mean low sea level; the top is the surface of the earth. Between stations 355 + 00 and Shaft 9A (station 627 + 72.20), a distance of 5.1 miles, the sections are based entirely on the data obtained in the tunnel. Some surface data around Shaft 9 are consistent with the interpretation shown. Southwest of station 355 + 00 outcrops are available, but even here they are sporadic and much of the interpretation is based on the tunnel. The thickness of the various units is

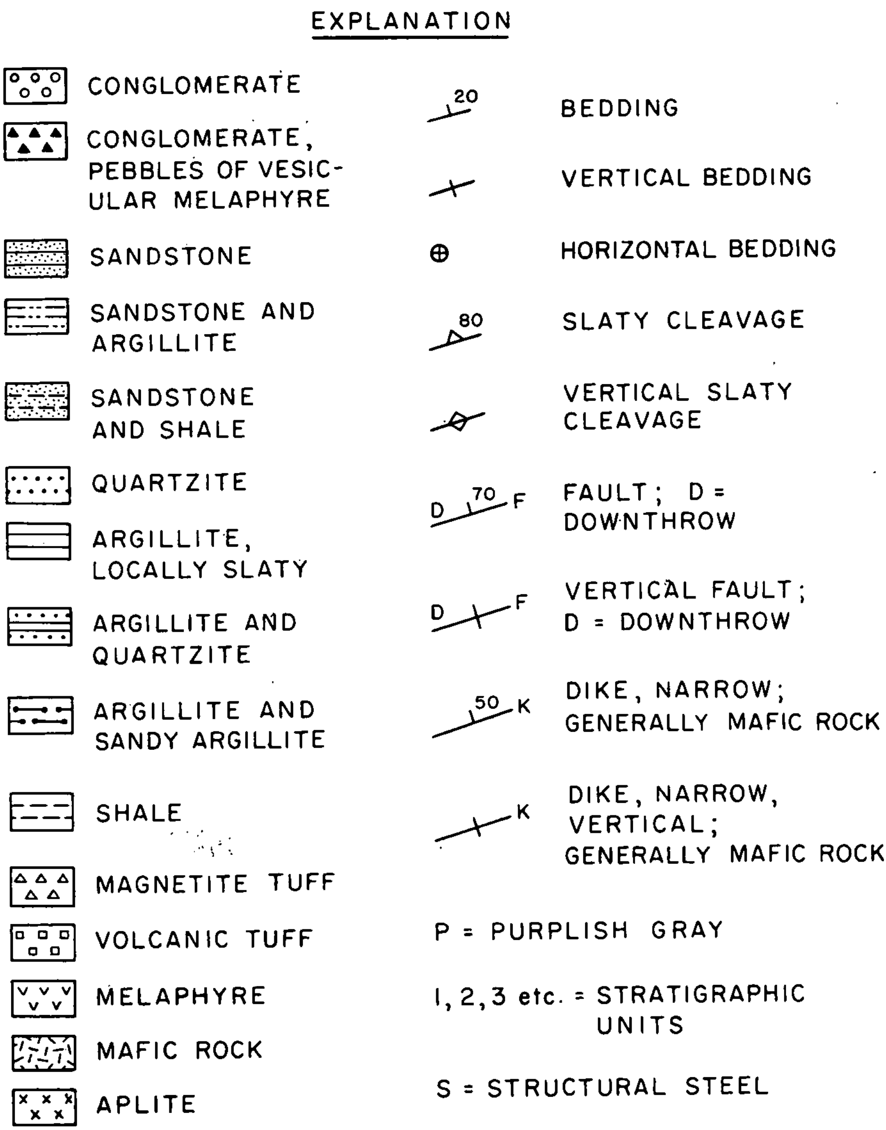

FIG. 2.—EXPLANATION OF SYMBOLS FOR FIGURES 3–9

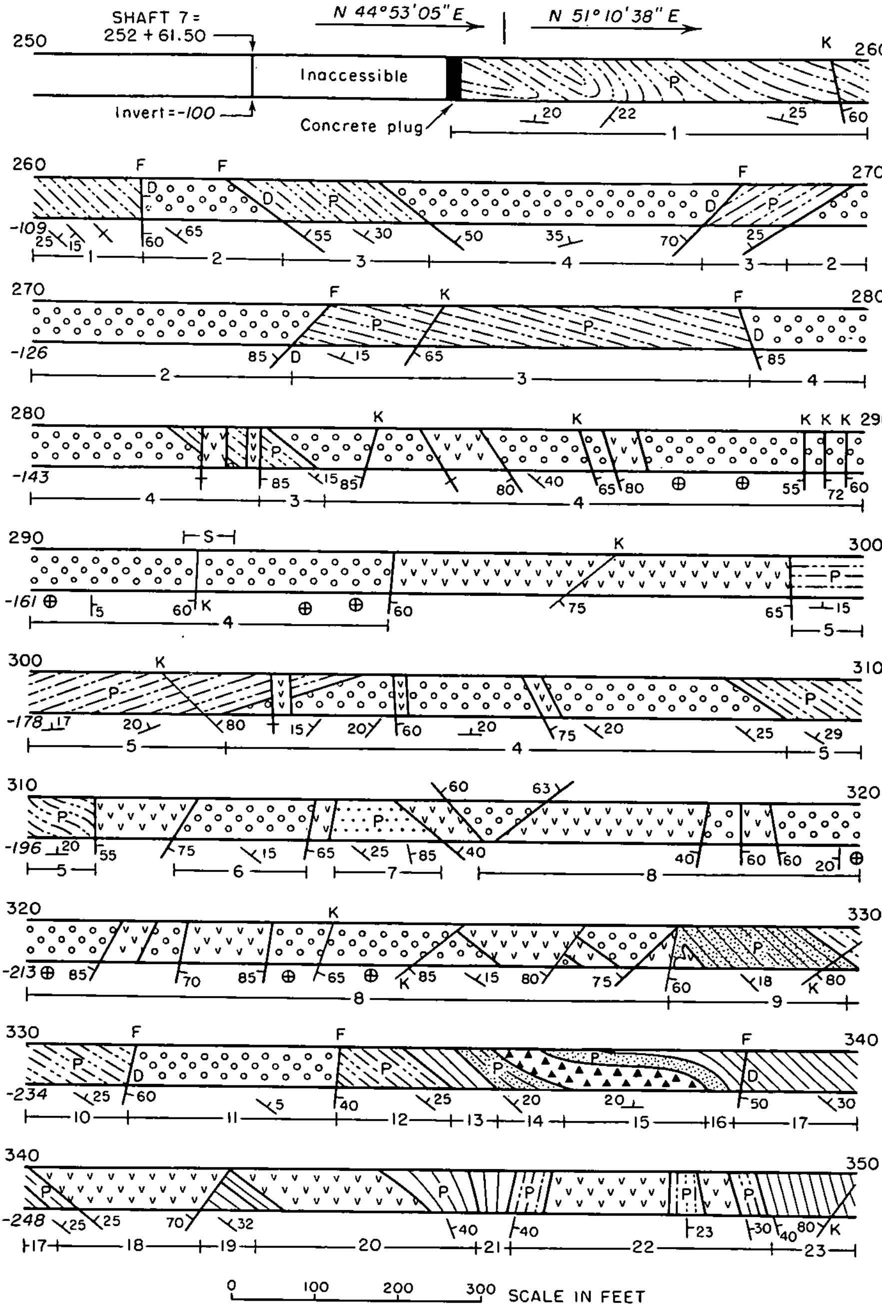

FIG. 3.—GEOLOGICAL MAP, SHAFT 7, (STATION 252 + 61.50) TO STATION 350 + 00.
Bottom side of each strip is southeast wall of tunnel. Top of each strip is 50 feet northwest of southeast wall of tunnel, that is, 38 feet northwest of northwest wall of tunnel. Figures above each strip are stations. Negative figure in italics at lower left-hand corner of each strip is elevation of invert (bottom of tunnel), Boston City base. See Fig. 2 for meaning of symbols.

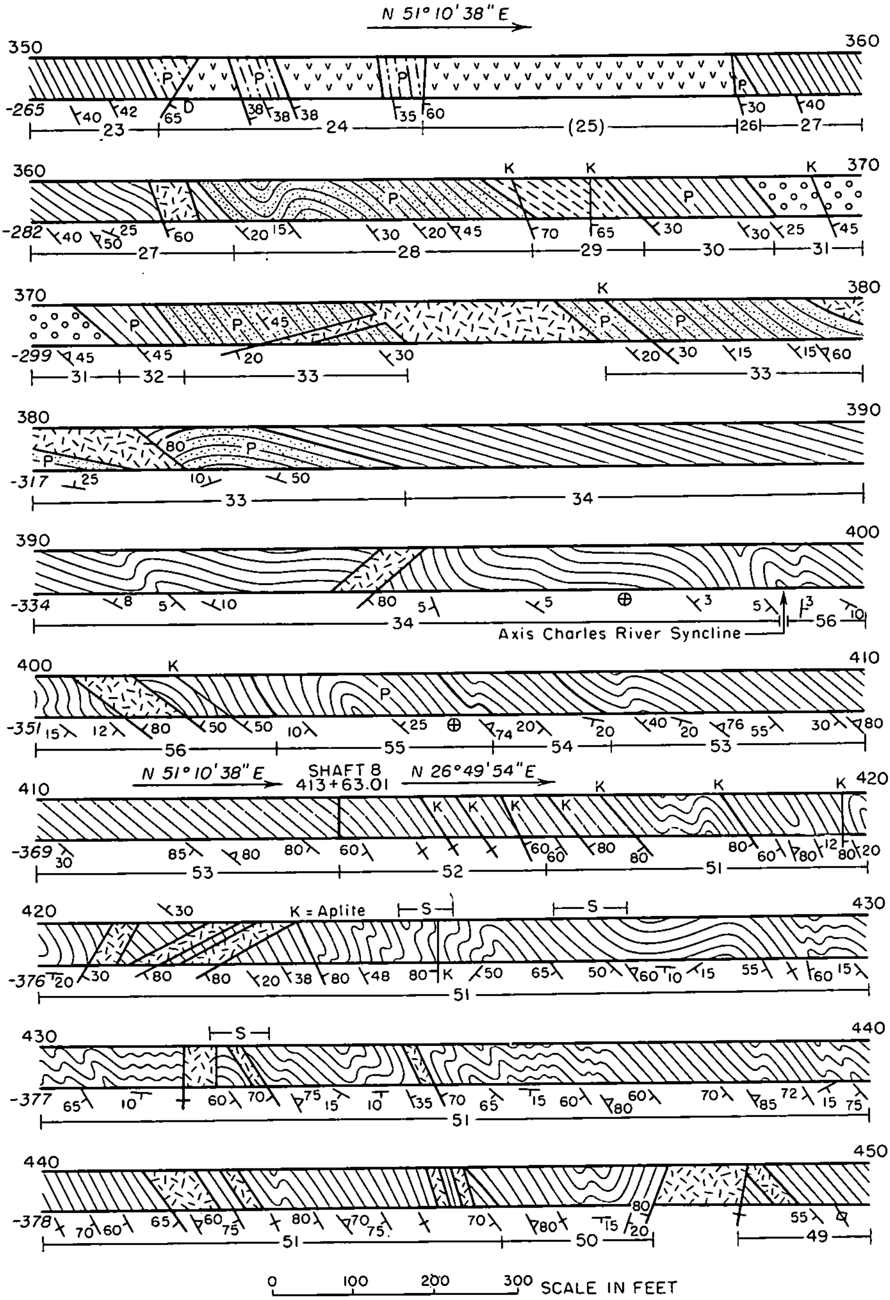

FIG. 4.—GEOLOGICAL MAP, STATIONS 350 + 00 TO 450 + 00

Note that on either side of the Charles River syncline two different sets of numbers are used for stratigraphic units.

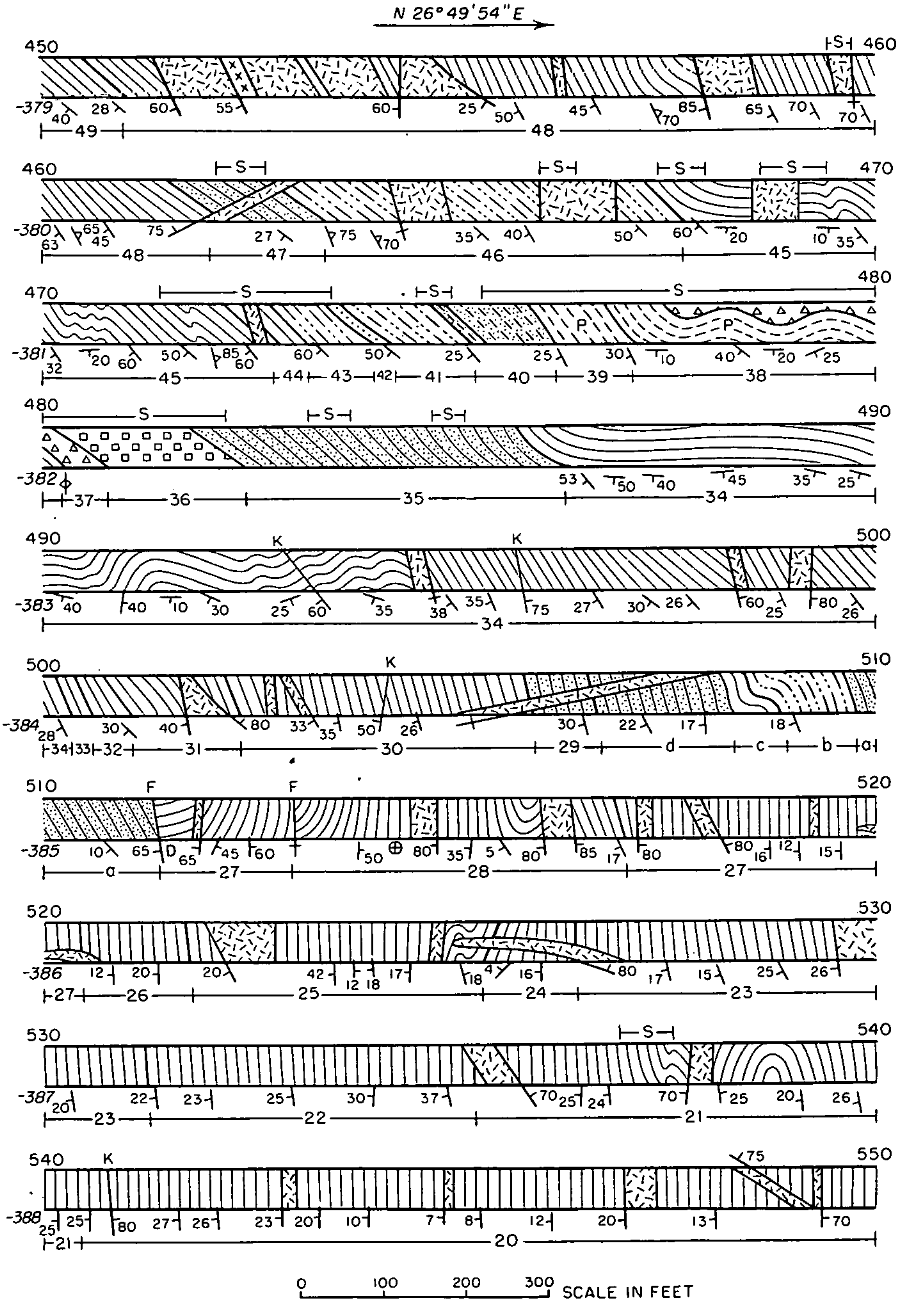

FIG. 5.—GEOLOGICAL MAP, STATION 450 + 00 TO 550 + 00

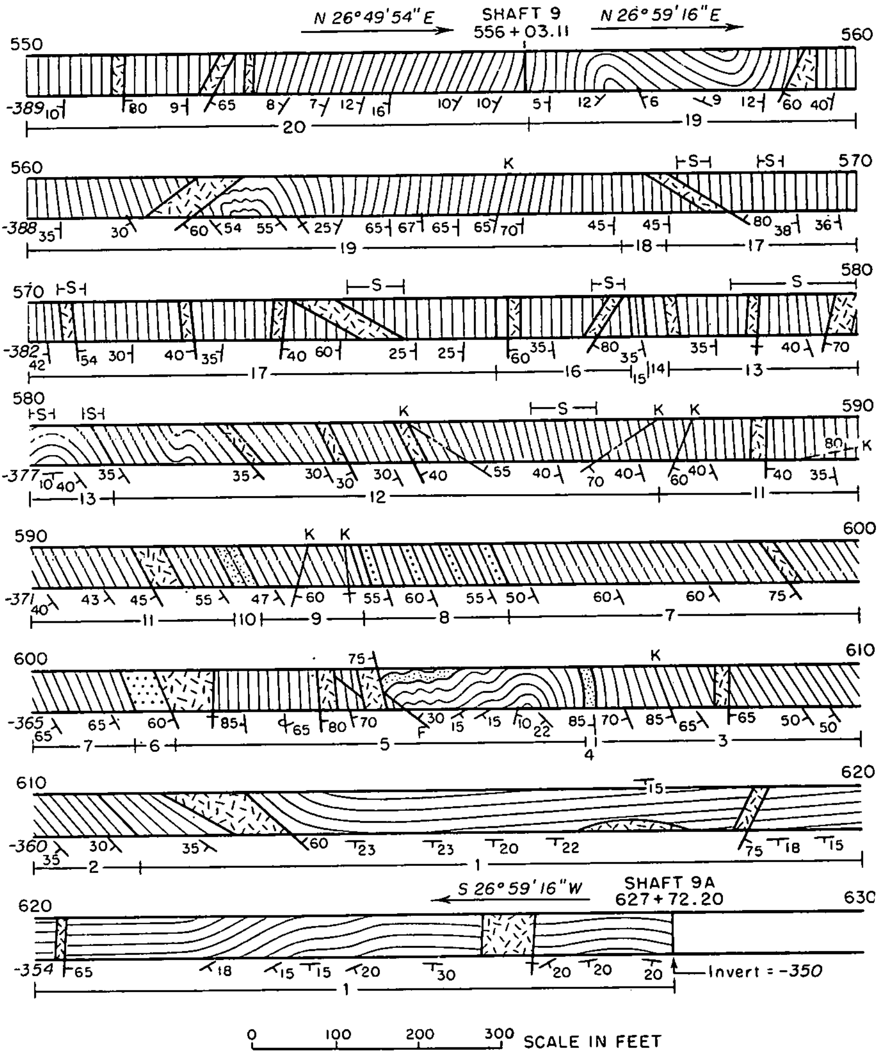

FIG. 6.—GEOLOGICAL MAP, STATION 550 + 00 TO SHAFT 9A (STATION 627 + 72.20).

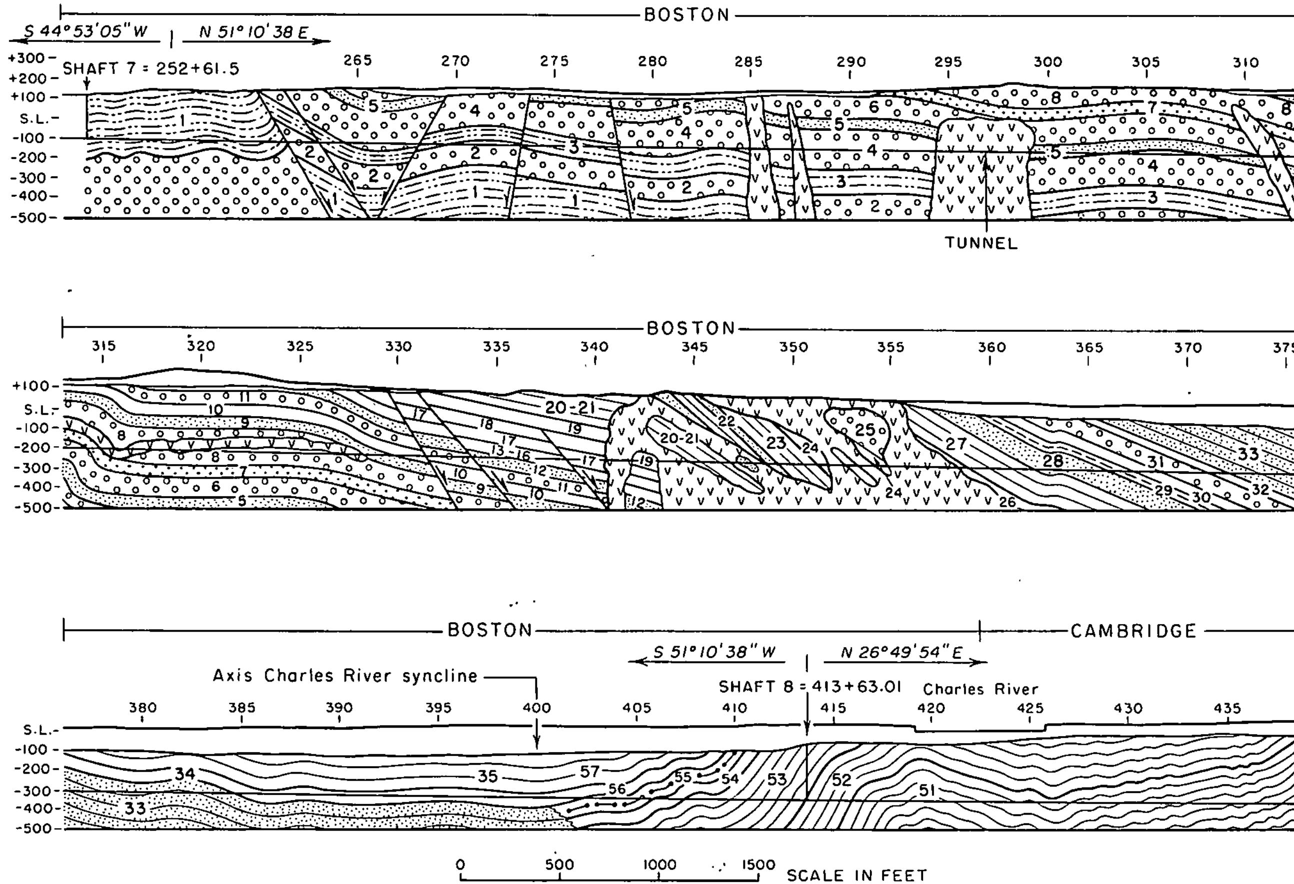

FIG. 7.—GEOLOGICAL STRUCTURE SECTION, SHAFT 7 (STATION 252 + 61.50) TO STATION 438 + 75. SEE FIG. 2 FOR SYMBOLS. NUMBERS ABOVE SECTIONS ARE STATIONS.

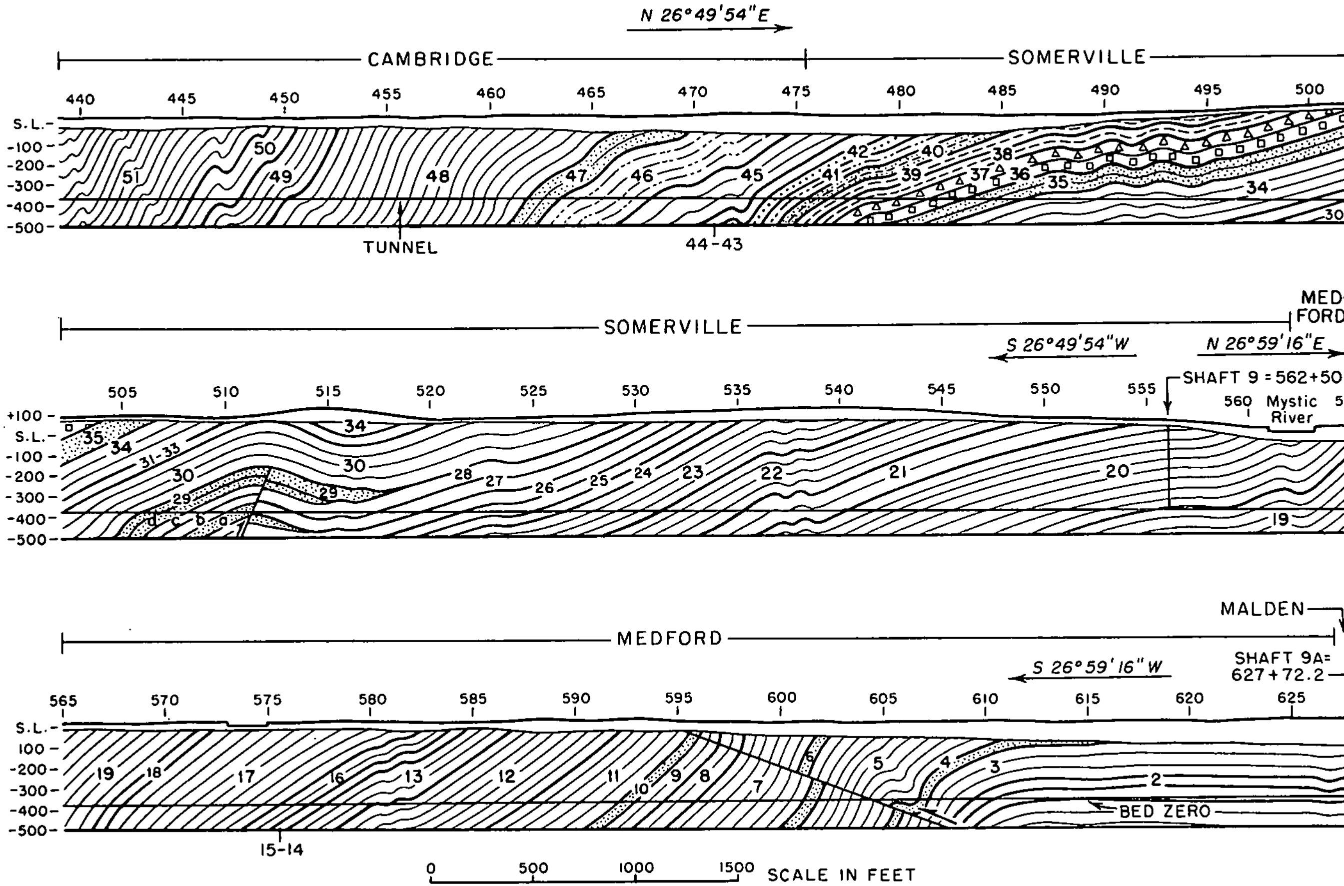

Fig. 8.—Geological Structure Section, Station 438 + 75 to Shaft 9A (Station 627 + 72.20)

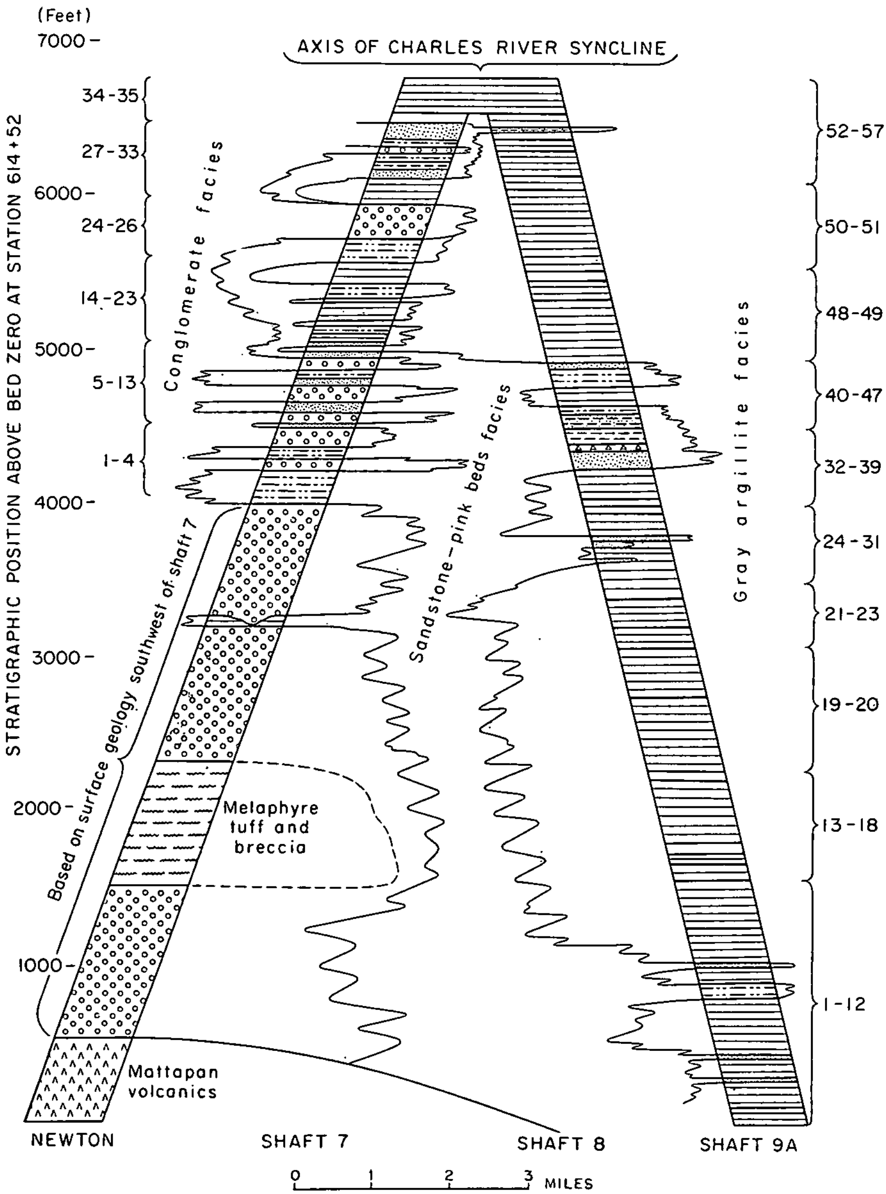

Fig. 9.—Facies Changes in Boston Bay Group. For Symbols See Fig. 2. Numerals on Right and Left Indicate Stratigraphic Units as Used in Figures 3–8 and in Tables 1 and 2. (See p. 148.)

undoubtedly less regular than implied by Figs. 7 and 8. That is, the beds are more lens-like.

Tables I and II describe the lithology of the various stratigraphic units shown in Figs. 3-8. The axis of the Charles River syncline is at station 398 + 98. Table I is the stratigraphy for the south limb of the syncline, that is, the area southwest of station 398 + 98. The units are numbered from 1 to 35, 1 being the lowest stratigraphically, and 35 being the highest. This column, although based largely on data obtained in the tunnel, does make some use of surface data. Moreover, unit 35, lying above the tunnel level in the center of the syncline, is largely conjectural, but three drill holes penetrated it for short distances. Table II is the stratigraphy of the north limb of the Charles River syncline, that is, the area northwest of station 398 + 98. This column is based entirely on data obtained in the tunnel, except for unit 57, which is equivalent to unit 35 and is based on the same data. The various units are numbered 1 to 57, 1 being the oldest. This numbering system is completely independent of that used in Table I.

These tables give the following data. The kind of rock in each unit is described. The stations between which the unit was exposed in the tunnel are also given. The thickness (*th*) is listed. The cumulative thickness (*c*) is the stratigraphic thickness between the top of the unit and the base of the lowest unit. In the south limb of the syncline the lowest beds are pink argillite in unit 1 near Shaft 7. In the north limb of the syncline the lowest unit is at station 614 + 52. The letter *n*, used only in Table I, refers to the stratigraphic distances between the top of the unit and the lowest unit at station 614 + 52; in this way the stratigraphic position of the various units in the two limbs may be compared.

Lithology

General Statement

The rocks listed in Tables I and II and shown in Figs. 2 to 8 are sedimentary and igneous. The sedimentary rocks are conglomerate, sandstone, quartzite, argillite, and shale. The extrusive igneous rocks are tuff. The intrusive igneous rocks are melaphyre and mafic rocks, a term used here for diabase, altered diabase, and diorite. Aplite is very rare.

Conglomerate

Conglomerate, a well-known rock in the Boston area, is confined in the tunnel area to the south heading, more specifically to the region

TABLE I

STRATIGRAPHIC COLUMN OF SOUTH LIMB OF THE CHARLES RIVER SYNCLINE*

35. Argillite. Gray. Between tunnel and top of ledge. Only partially penetrated by drill holes; th = 212, c = 2759.

34. Argillite. Gray, slabby. Sta. 384 + 45 to 398 + 98; th = 60; c = 2547; n = 6547.

33. Sandstone. Red, fine-grained. Sta. 371 + 73 to 384 + 45; th = 126; c = 2487; n = 6487.

32. Argillite and sandy argillite. Gray, buff, red and reddish-purple; one 3 foot bed of gray grit at top. Sta. 371 + 08 to 371 + 73; th = 26; c = 2361; n = 6361.

31. Conglomerate. Pebbles are well-rounded, average 1" to 3" in dameter, some are 6" to 8" in diameter. A few beds of quartzite and sandstone, each a few inches thick. Sta. 368 + 97 to 371 + 08; th = 61; c = 2335; n = 6335.

30. Argillite, with some quartzite and conglomerate. Mostly argillite that is red, pink, gray, and greenish-gray flaggy. Contains gray quartzite beds 1" to 3' thick. Also one conglomerate bed, with quartzite pebbles ½" to 3" in diameter, 5 feet thick. Sta. 367 + 37 to 368 + 97; th = 52; c = 2274; n = 6274.

29. White shale, with buff and dark green quartzite beds ¼" to 8" thick. Sta. 365 + 87 to 367 + 37; th = 40; c = 2222; n = 6222.

28. Sandstone. Pink, fine-grained, well-bedded. Bed of quartzite, 3 feet thick at top. Sta. 362 + 34 to 365 + 87; th = 79; c = 2182; n = 6182.

27. Argillite. Gray and greenish-gray, flaggy. Some black argillite beds ¼" thick. One bed of gray fine-grained sandstone 3 feet thick. Sta. 358 + 72 to 362 + 34; th = 128; c = 2103; n = 6103.

26. Argillite. Pink and red, flaggy. Sta. 358 + 47 to 358 + 72; th = 12; c = 1975; n = 5975.

25. Conglomerate, some interbedded sandstone. In conglomerate pebbles are rounded, average 1 to 2 inches in diameter, maximum 5 inches; mostly quarzite, some granite. Sandstone is gray, in beds 1 to 4 inches thick. Exposed only at surface, on Allston Street and Quint Avenue. In tunnel is absent because of melaphyre intrusion between sta. 354 + 69 to 358 + 47; th = 222; c = 1963; n = 5963.

24. Pink sandy argillite, red sandstone, and pink flaggy argillite. Sta. 351 + 55 to 354 + 69, much of this unit is absent because of melaphyre intrusions between 351 + 74 to 352 +63 and 353 + 10 to 354 + 22; th = 164; c = 1741; n = 5741.

23. Argillite. Gray and greenish-gray, flaggy. Sta. 348 + 90 to 351 + 55; th = 140; c = 1557; n = 5577.

22. Medium coarse pink feldspathic sandstone; pink fine-grained sandstone, and purplish-gray argillite. Sandstones best exposed at surface on High Rock Way. Sta. 345 + 85 to 348 + 90; absent between stations 346 + 30 to 347 + 75 and 348 + 21 to 348 + 58 because of melaphyre intrusions; th = 103; c = 1437; n = 5437.

21. Argillite. Gray, laminated. Sta. 345 + 44 to 345 + 85; th = 20; c = 1334; n = 5334.

20. Argillite. Purplish-gray, locally red; very thin-bedded, flaggy. Sta.

TABLE I (continued)

342 + 81 to 345 + 44, and on surface in Ringer Playground; is absent between stations 343 + 16 and 344 + 94 because of melaphyre intrusion; th = 132; c = 1314; n = 5314.

19. Argillite. Gray to greenish-gray. Sta. 342 + 09 to 342 + 81; th = 22; c = 1182; n = 5182.

18. Argillite. Purplish gray, very thin-bedded, flaggy. Sta. 340 + 38 to 342 + 09; also based on poor surface data south of Warren Street. At tunnel level absent between sta. 340 + 48 to 342 + 09 because of melaphyre intrusion; th = 43; c = 1160; n = 5160.

17. Argillite. Gray to greenish gray, laminated, flaggy. Sta. 338 + 54 to 340 + 38; th = 60; c = 1117; n = 5117.

16. Interbedded red ripple-marked flaggy argillite and pink to red feldspathic sandstone. Sta. 338 + 22 to 338 + 54; th = 22; c = 1057; n = 5057.

15. Interbedded pink sandstone and conglomerate. The conglomerate is a unique type, containing pebbles of vesicular melaphyre from ¼" to ½" in diameter, occasionally 2". Conglomerate beds are 3" to 6" thick. Sta. 336 + 48 to 338 + 22; th = 8; c = 1035; n = 5035.

14. Pink sandstone. Bedding very obscure in upper part. Sta. 335 + 64 to 336 + 48; th = 22; c = 1027; n = 5027.

13. Argillite. Greenish gray, laminated, flaggy. Sta. 335 + 14 to 335 + 64; th = 16; c = 1005; n = 5005.

12. Interbedded laminated flaggy red argillite, sandy argillite, and gray sandstone. Ripple marks on argillite. Sta. 333 + 74 to 335 + 14; th = 43; c = 989; n = 4989.

11. Conglomerate. Coarse gray conglomerate. Pebbles average 1" to 2" in diameter, some as much as 6" in diameter; pebbles are quartzite and granodiorite. Sta. 331 + 29 to 333 + 74; th = 80; c = 946; n = 4946.

10. Interbedded argillite and gray fine-grained unbedded sandstone. Chiefly red argillite, locally with slaty cleavage; gray sandstone beds are 2 to 5 feet thick. Bed of gray conglomerate at base contains pebbles ¼" to ½" in diameter. Sta. 329 + 89 to 331 + 29; th = 46; c = 866; n = 4866.

9. Pink poorly bedded sandstone. Sta. 327 + 68 to 329 + 89; th = 49; c = 820; n = 4820.

8. Conglomerate. Pebbles average 2" in diameter, some as much as 4" in diameter. Sta. 315 +52 to 327 + 38; but locally absent because of melaphyre intrusions; th = 105; c = 771; n = 4771.

7. Quartzite. Laminated, appearing pink underground. Sta. 313 + 64 to 315 + 00; th = 69; c = 666; n = 4666.

6. Conglomerate. Coarse conglomerate, some boulders as much as 6" in diameter; boulders are quartzite and granite. Sta. 311 + 79 to 313 + 64; th = 80; c = 597; n = 1597.

5. Interbedded red sandstone, pink flaggy argillite, and pebble conglomerate. Sta. 299 + 17 to 302 + 48 and 309 + 10 to 310 + 85; th = 20; c = 517; n = 4517.

4. Conglomerate. Coarse conglomerate, boulders as much as 12" in diameter; boulders are quartzite and granodiorite. Sta. 264 + 56 to 268 + 02; 278 + 71 to

282 + 78; 283 + 55 to 294 + 32, and 302 + 48 to 309 + 10; th = 119; c = 497; n = 4497.

3. Interbedded sandstone and argillite. Gray, white, and pink sandstone, purplish-gray fine-grained sandstone, pebbly sandstone and purplish-red flaggy argillite. Sta. 262 + 11 to 264 + 56, 268 + 02 to 269 + 21, 273 + 29 to 278 + 71; and 282 + 78 to 283 + 55; th = 74; c = 378; n = 4378.

2. Conglomerate. Pebbles of quartzite and vein quartz, average 1" in diameter, but some are 2". Sta. 261 + 30 to 262 + 61 and 269 + 21 to 273 + 29; th = 69; c = 304; n = 4304.

1. Interbedded argillite and sandstone. Red, gray, and purplish-gray flaggy argillite and fine-grained reddish-sandstone. Sta. 255 + 11 to 261 + 30; th = 235; c = 235; n = 4235.

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* Although this column is based largely on data from the tunnel, it incorporates some data from the surface exposures of the geology. The melaphyres and mafic rocks exposed in the tunnel are all intrusive, hence are not part of the stratigraphic column. That part of the tunnel southwest of station 398 + 98 is in the south limb.

Numeral preceding each description is an arbitrary designation to correlate stratigraphic units in this table with those used in geological maps and structure sections. Figures after descriptive text are: Sta. = stations between which unit is exposed; th = thickness of unit in feet; c = cumulative thickness, that is, thickness between top of unit and base of unit 1 of this limb; n = thickness between top of unit and base of unit 1 of north limb, which is at station 614 + 52.

Using traditional stratigraphy, Cambridge Formation consists of units 32 to 35; Squantum Tillite is represented by a waterlaid conglomerate, unit 31; the Dorchester Shale consists of units 12 to 30; and the Brookline member consists of units 1 to 11.

TABLE II

STRATIGRAPHIC COLUMN OF NORTH LIMB OF THE CHARLES RIVER SYNCLINE*

Axis of Charles River Syncline at 398 + 98

57. Argillite. Gray. Between tunnel and top of ledge in center of syncline; th = 212; c = 6759.

56. Argillite. Gray. Sta. 402 + 89 to 398 + 98; th = 88; c = 6547.

55. Argillite and sandy argillite. Purplish-gray argillite and sandy argillite; one light-greenish-gray argillite bed 1' thick; a bed of chocolate-brown sandstone 6" thick at top; sta. 405 + 46 to 402 + 89; th = 33; c = 6459.

54. Argillite. Light gray and greenish-gray, laminae 1/16" to 1"; light-gray quartzite 3' thick at base; Sta. 406 + 90 to 405 + 46; th = 41; c = 6426.

53. Argillite. Gray, slaty in places. Sta. 413 + 63 to 406 + 90; th = 197; c = 6385.

Shaft 8 = Sta. 413 + 63.01

52. Argillite. Gray, locally slaty. Sta. 416 + 12 to 413 + 63; th = 138; c = 6188.

51. Argillite. Gray, greenish-gray, black, bedding obscure in many places, locally good; several beds of chocolate-brown sandstone 1" to 3" thick; slaty cleavage at top of section; Sta. 445 + 42 to 416 + 12; th = 525; c = 6050.

50. Slate. Greenish-gray and purplish-gray. Sta. 447 + 84 to 445 + 42; th = 67; c = 5525.

49. Argillite. Gray, greenish-gray, dark gray, local slaty cleavage, 3 chocolate-brown sandstone beds 1/4" thick; Sta. 450 + 98 to 447 + 84; th = 121; c = 5458.

48. Argillite. Gray to greenish-gray, bedding good to obscure; local slaty cleavage, sta. 461 + 99 to 450 + 98; th = 415; c = 5337.

47. Sandstone. Green, fine-grained sandstone beds 1′ to 3′ thick, well cleaved; one bed of banded argillite 1′ thick; Sta. 463 + 41 to 461 + 99; th = 30; c = 4922.

46. Argillite and sandstone. Interbedded light-gray slaty argillite (locally banded), dark green fine-grained sandstone, and green fine-grained unbedded argillaceous sandstone; Sta. 467 + 70 to 463 + 41; th = 115; c = 4892.

45. Argillite. Some in alternating lighter and darker gray laminae, ¼″ to 3″ thick; some is gray, bedding obscure; a little slaty cleavage; sandy argillite near base; Sta. 472 + 80 to 467 + 70; th = 96; c = 4777.

44. Slate. Gray, bedding obscure. Sta. 473 + 20 to 472 + 80; th = 35; c = 4681.

43. Argillite and sandstone. Interbedded gray and light-green gray argillite and green fine-grained sandstone; laminae ¼″ to 2″. Sta. 474 + 00 to 473 + 20; th = 43; c = 4646.

42. Quartzite. Greenish-gray. Sta. 474 + 20 to 474 + 00; th = 8; c = 4603.

41. Argillite and sandstone. Interbedded light-gray argillite and greenish sandstone in beds 3″ to 8″ thick; Sta. 475 + 20 to 474 + 20; th = 34; c = 4595.

40. Shale and sandstone. Interbedded light-gray shale, purplish-gray fine-grained sandstone, greenish sandstone, and feldspathic quartzite; Sta. 476 + 16 to 475 + 20; th = 45; c = 4561.

39. Shale. Purplish gray. Three beds of feldspathic quarzite, each one foot thick; Sta. 477 + 10 to 476 + 16; th = 67; c = 4516.

38. Shale and buff sideritic tuff. Purplish-gray shale and white sideritic tuff (Spec. 201, Table 3). Sta. 480 + 25 to 477 + 10; th = 38; c = 4449.

37. Magnetite tuff. Porphyroblasts of magnetite in a gray slaty matrix; Sta. 481 + 00 to 480 + 25; th = 25; c = 4411.

36. Volcanic tuff, gray to white, in places bedded, chemical analysis (Spec. 204, Table 3); Sta. 482 + 40 to 481 + 00; th = 30; c = 4386.

35. Sandstone. Greenish gray, bedding very obscure; Sta. 486 + 30 to 482 + 40; th = 123; c = 4356.

34. Argillite. Lighter and darker gray laminae 1/16″ to 2″ thick, but laminae 1/16″ thick also occur within beds 2″ thick. Beds pinch and swell; Sta. 500 + 35 to 486 + 30; th = 190; c = 4233.

33. Argillite. Lighter and darker gray laminae 1″ thick; but some are 2″ thick; Sta. 500 + 60 to 500 + 35; th = 8; c = 4043.

32. Argillite. Lighter and darker gray laminae generally 1/32″ to 3″ thick, but one of lighter beds is 6″ thick. Beds pinch and swell, minute cross-bedding, weakly graded; Sta. 501 + 10 to 500 + 60; th = 22; c = 4035.

31. Argillite. Lighter and darker gray laminae 1/16″ to 2″ thick. Minute cross-bedding and channeling. Pyrite cubes ⅛″ to ¼″ across; Sta. 502 + 40 to 501 + 10; th = 51; c = 4013.

30. Argillite. Lighter and dark gray laminae 1/32″ to 2″ thick, in parts of section laminae pinch and swell; Sta. 505 + 98 to 502 + 40; th = 143; c = 3952.

29. Sandstone. Greenish-gray, fine-grained, bedding obscure; Sta. 506 + 75 to 505 + 98; th = 32; c = 3809.

TABLE II (continued)

Correlative with Units 27 & 28

d. Sandstone. Greenish-gray, fine-grained, bedding obscure, a few laminae 1/16" to 1" thick; Sta. 508 + 30 to 506 + 75; th = 60; c = 3717.

c. Argillite. Lighter and darker gray laminae 1/16" to 3"; Sta. 508 + 95 to 508 + 30; th = 11; c = 3706.

b. Argillite. Light gray; sandstone in places; Sta. 509 + 80 to 508 + 95; th = 39; c = 3667.

a. Sandstone. Gray and yellow, fine-grained; Sta. 511 + 38 to 509 + 80; th = 26; c = 3641.

Anticlinical axis at sta. 511 + 38. Synclinal axis at sta. 514 + 50; units 27 and 28 repeated between stations 514 + 05 to 511 + 38.

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28. Argillite. Light gray, dark gray and black laminae ¼" to 2" thick; one pyrite-rich laminae is ⅛" thick; one limestone laminae is ½" thick; Sta. 517 + 05 to 513 + 00; th = 55; c = 3777.

27. Argillite. Lighter and darker gray laminae, ⅛" to 2" thick; a few of lighter beds are thicker, one is 6" thick; Sta. 520 + 45 to 517 + 05 and 513 + 00 to 511 + 38; th = 81; c = 3722.

26. Argillite. Lighter and darker gray beds. Some beds are as much as 6" thick, but within them show laminae 1/16" to ¼" thick; lighter (coarser) beds grade up into darker (finer); Sta. 521 + 80 to 520 + 45; th = 39; c = 3641.

25. Argillite. Lighter and darker gray laminae ¼" to 4" thick; lighter (coarser) beds grade upward into darker (finer) beds; Sta. 525 + 30 to 521 + 80; th = 58; c = 3602.

24. Argillite. Light gray, laminae 1/16" to ⅛" thick; pyrite present; beds ⅛" thick entirely pyrite; Sta. 526 + 40 to 525 + 30; th = 19; c = 3544.

23. Argillite. Similar to unit 1; Sta. 531 + 30 to 526 + 40; th = 137; c = 3525.

22. Argillite. Uniformly light gray; Sta. 535 + 20 to 531 + 30; th = 169; c = 3388.

21. Argillite. Lighter and darker gray laminae ⅛" to 5" thick; Sta. 540 + 40 to 535 + 20; th = 122; c = 3219.

20. Argillite. Similar to unit 16; Sta. 556 + 03 to 540 + 40; th = 335; c = 3087.

Shaft 9 = Sta. 556 + 03

19. Argillite. Similar to unit 16; Sta. 567 + 15 to 556 + 03; th = 485; c = 2762.

18. Argillite. Lighter and darker gray laminae, 1/16" to 2" thick, that pinch and swell. Two beds of light-gray quartzite, each 3' thick; Sta. 567 + 67 to 567 + 15; th = 31; c = 2277.

17. Argillite. Lighter and darker gray laminae ⅛" to 2" thick, some of which pinch and swell; Sta. 575 + 64 to 567 + 67; th = 421; c = 2246.

16. Argillite. Lighter and darker gray laminae, 1/16" to 2" thick; Sta. 577 + 30 to 575 + 64; th = 87; c = 1825.

TABLE II (continued)

15. Argillite. Gray. Contains 4 beds of light-gray quartzite from 1" to 8" thick, that pinch and swell; grain size ⅛"; Sta. 577 + 40 to 577 + 30; th = 8; c = 1738.

14. Argillite. Lighter and darker gray beds ⅛" to 2" thick; minute cross-bedding and channeling; Sta. 577 + 70 to 577 + 40; th = 9; c = 1730.

13. Argillite. Lighter and darker gray laminae ¼" to 2" thick; Sta. 581 + 00 to 577 + 70; th = 131; c = 1721.

12. Argillite. Lighter and darker gray beds, 1/16" to 3" thick, many of which pinch and swell; Sta. 587 + 60 to 581 + 00; th = 312; c = 1590.

11. Argillite. Similar to unit 1; Sta. 592 + 39 to 587 + 60; th = 247; c = 1278.

10. Sandstone. Gray, bedding generally obscure, locally faint laminae ⅛" thick; Sta. 592 + 70 to 592 + 39; th = 21; c = 1031.

9. Argillite. Similar to unit 1; a coarse quartzite 2" thick at Sta. 592 + 88; Sta. 594 + 00 to 592 + 70; th = 77; c = 1010.

8. Argillite and quartzite. Light-gray argillite beds, much of it in beds 6" to 5' thick; about 15% of this unit consists of light-gray, fine-grained quartzite in beds 3" to 7' thick; Sta. 595 + 75 to 594 + 00; th = 103; c = 933.

7. Argillite. Similar to unit 1; Sta. 601 + 25 to 595 + 75; th = 370; c = 830.

6. Quartzite. Light yellow, fine-grained, laminae 1/16" to ½"; Sta. 601 + 66 to 601 + 25; th = 16; c = 460.

5. Argillite. Similar to unit 1; Sta. 606 + 74 to 601 + 66; th = 150; c = 443.

4. Sandstone. Gray, fine-grained; Sta. 606 + 80 to 606 + 74; th = 5; c = 293.

3. Argillite. Similar to unit 1; Sta. 610 + 00 to 606 + 80; th = 184; c = 288.

2. Argillite. Light gray, minute cross-bedding; Sta. 610 + 30 to 610 + 00; th = 18; c = 104.

1. Argillite. Gray, in many places very thin-bedded, alternating lighter and darker gray beds, ¼" to 1" thick; Sta. 627 + 72 (Shaft 9A) to 610 + 30; th = 86; c = 86.

* This column is based exclusively on data from the tunnel, utilizing the data northeast of station 398 + 98.
Numerals and abbreviations have same significance as in Table 1.
Using the traditional stratigraphic nomenclature all these rocks belong to the Cambridge Argillite.
Cumulative thickness is measured above bed at station 614 + 52, which is 1320.20 feet S 26°-59'-16" W of Shaft 9A.

southwest of station 371 + 00. The clasts, that is, the pebbles, cobbles, boulders, etc. are round to subround and generally range in diameter from 1 to 4 inches, but, as noted in Table I, may be larger; boulders 12" in diameter were noted in unit 4 of the south limb. The clasts are generally guartzite, granite, and granodiorite, less commonly felsite and melaphyre. A very exceptional conglomerate was found in unit 15; the pebbles were vesicular melaphyre, ¼" to ½" in diameter, even as much as 2" in diameter.

The matrix of the conglomerate is gray feldspathic sandstone, in which the individual grains average 0.05 inch in diameter.

In much of the conglomerate recognizable bedding is very difficult or impossible to find. In some instances bedding is shown by an occasional small sand lens, a few inches thick and a few feet long. Less commonly, bedding may be shown by sand beds, a foot or so thick, that may be followed for many feet. There are places where thin conglomerate beds are interbedded with sandstones.

Sandstone

The sandstones are fine-grained to medium-grained rocks composed primarily of rounded quartz grains 0.03 to 0.08 inch in diameter, but containing some feldspar, mica, chlorite, and an occasional rock fragment of similar size. Some of the sandstones are thinly laminated to laminated (beds 0.03 to 0.2 inch thick), others are thick-bedded (beds 2 to 5 feet thick) and in still others the bedding is very obscure or absent. Some sandstones are tens of feet thick without any visible bedding.

On the south limb of the Charles River syncline the sandstones are generally pink, less commonly red or purplish-gray. Light-gray to dark-gray sandstones are distinctly subordinate here.

On the north limb of the Charles River syncline the sandstones are generally greenish-gray to dark-green, less commonly gray or yellow. Only one unit was purplish-gray. This contrast in color on the two limbs is related to the general change in facies to be discussed below.

The thickest sandstone units on the south limb are unit 28, a pink, fine-grained, well-bedded sandstone that is 79 feet thick, and unit 33, a red fine-grained sandstone that is 126 feet thick. On the north limb, unit 35, a greenish-gray sandstone, in which the bedding is very obscure, is 123 feet thick.

Quartzite

Although quartzite, like sandstone, is composed largely of quartz grains, it breaks across the grains rather than around them, and hence is more glassy in appearance than sandstone.

Quartzites are rare on the south limb of the Charles River syncline. Gray, buff and dark green, they form beds from ¼″ to 3″ thick, interbedded with other rocks. But unit 7, a laminated pink quartzite, is 69 feet thick.

The quartzites are generally light-gray to gray on the north limb, and form beds 3″ to 3 feet thick, and in one case, 8 feet thick. Some of these rocks are feldspathic quartzite. Unit 7 is a light-yellow fine-grained quartzite 17 feet thick.

Argillite

Argillite is the most common rock on the north limb of the Charles River syncline and is abundant on the south limb. The typical argillite is gray and is characterized by beds that generally range in thickness from 0.03 inch to 3 inches. The shade of gray varies in intensity; the particles in the light-gray rocks are silt or even fine sand, whereas in the darker layers they are clay or fine silt. Much of the argillite on the north limb shows a rythmic banding resulting from the alternation of lighter and darker gray beds 0.5 inch to 3 inches thick. In some parts of the section beds several feet thick of slightly different grain size may alternate with one another, but each may itself consist of thin beds a fraction of an inch to several inches thick.

In general the bedding is remarkably regular, that is, the beds, even though a fraction of an inch thick, maintain a rather uniform thickness for many feet or tens of feet; conditions of sedimentation must have been relatively quiet. But locally the individual laminae, although only a fraction of an inch thick, may show cross-bedding of particles that are silt or fine sand size. Some of these thin beds show pronounced pinching and swelling, that is, a bed that is 0.5 inch thick may thin to 0.2 inch within a few inches. Cross-bedding and pinch-and-swell are generally associated. Such features indicate subaqueous currents. The splitting properties of the argillites are blocky, slabby, or flaggy, that is, the fractures parallel to the bedding are 6 to 50 inches apart (McKee and Weir, 1953). Locally the rocks split into thinner slabs a few inches thick.

Although the argillites in the north limb of the Charles River syncline are generally gray, a few stratigraphic units are purplish-gray. In contrast, on the south limb, 60 per cent of the argillites are red, purplish-gray or pink. The other 40 per cent are gray and greenish-gray. Also the argillites on the south limb are flaggy to slabby, splitting into sheets 2 to 6 inches thick.

Ripple marks were observed on the south limb in stratigraphic units 12 and 16, both of which are red.

Slaty cleavage is characteristic of the argillite in many places, and such rocks can be appropriately called slates. The description in Tables I and II indicate which units possess such cleavage. Moreover, the geological maps, Figs. 3-6, show the attitude of the cleavage at representative localities. The cleavage in general dips north at angles of 60° to 80°.

Rocks that are intermediate in character between argillites and sandstones are called sandy argillites.

Shale

The term shale is used here for a group of relatively soft rocks. They are laminated rocks that are white, light-gray or purplish-gray. On the north limb of the Charles River syncline thin shales, which extend from stations 476 + 16 to 480 + 25 in units 38 and 39 had to be supported all the way by structural steel. X-ray studies by Martin Cassidy and comparison with similar rocks in the Main Drainage Tunnel (Rahm, 1962, p. 334) indicate that these rocks are composed chiefly of quartz, sericite (white mica), and kaolin with lesser amounts of chlorite and albite. It is the abundance of sericite and kaolin that makes these rocks weak.

Tuff

Some very unusual and structurally weak rocks appear to be volcanic tuffs, some of which may have been greatly altered shortly after deposition.

The white volcanic tuff (unit 36) is an irregularly bedded rock that extends from station 480 + 82 to station 482 + 40. The beds range in thickness from 0.05 to 0.5 inch; the fine-grained beds are composed of clay-size particles, whereas the coarser beds are composed of silt-size particles. A chemical analysis of one of these rocks, Spec. 204, is given in Table III. The rock now consists largely of sericite, quartz, albite and chlorite. A mode, based on the chemical analysis and X-ray data, is given in Table IV.

The buff sideritic tuff is interbedded with the shale that extends from station 477 + 10 to station 480 + 25, unit 38. A chemical analysis of a specimen from station 479 + 97 is given in Table III. This is an unbedded white, porcelaneous rock, speckled by light-orange siderite crystals 0.005 to 0.01 inch in diameter. The rock consists chiefly of quartz, siderite, chlorite, and small amounts of goethite. A mode, based on chemical analysis and X-ray data, is given in Table IV.

The magnetite tuff extends from station 480 + 25 to 481 + 00,

TABLE III
CHEMICAL ANALYSES

	Spec. 201 Station 479 + 97 Sideritic Tuff	Spec. 204 Statino 481 + 47 Volcanic Tuff
SiO_2	45.16%	54.68%
TiO_2	1.07	0.72
ZrO_2	0.10	—
Al_2O_3	7.88	20.74
Cr_2O_3	0.15	—
Fe_2O_3	9.43	1.57
FeO	13.09	6.37
MnO	0.38	0.15
MgO	8.23	0.45
CaO	0.72	0.41
BaO	—	0.19
P_2O_5	0.36	0.26
NiO	0.05	—
CuO	0.12	—
Na_2O	0.24	2.28
K_2O	0.05	4.72
CO_2	7.98	—
H_2O (+)	3.32	7.47
H_2O (−)	1.56	0.25
Total	99.89	100.26
S, SO_3	nil	nil
C	tr	—

Soluble in
H_2SO_4 (1:5) presumably carbonate,
FeO 11.40
MnO 0.35
MgO 0.60

Analyst Jun Ito

unit 37. It is a speckled rock, in which round grains of magnetite, 0.01 to 0.05 inch in diameter are set in a light-yellow granular groundmass. There is a weak fissility parallel to the bedding. X-ray study indicates this rock is composed of about 15 per cent magnetite, 25 per cent quartz, and 60 per cent kaolinite.

Melaphyre

Melaphyre is confined to the south limb of the Charles River syncline. The term melaphyre, although little used in modern geological literature, has been traditionally used in the Boston area for altered basalts or andesites. LaForge (1932, p. 42) called it the Brighton Melaphyre. Although some of the melaphyre in the Boston area is extrusive, forming either lava flows or beds of tuff and breccia, in the tunnel area it is all intrusive, chiefly as dikes or large irregular bodies.

In the tunnel area the typical melaphyre is a dark-green to a yellow-green medium-grained crystalline rock, which, however, is in places strongly mottled in shades of green and red, the differently colored patches being a foot or so in diameter. Vesicles that average

TABLE IV
MODES OF ANALYZED ROCKS

	Spec. 201, Sta. 479 + 97 Sideritic Tuff	Spec. 204, Sta. 481 + 47 Volcanic Tuff
Quartz	28	20
Sericite	—	40
Albite	2	19
Chlorite	18	18
Siderite	20	—
Magnetite	6	2
Kaolin	19	
Goethite	6	
Rutile	1	1
Apatite	tr	tr

0.1 to 0.2 inch in diameter are completely or partially filled by calcite, epidote, and chlorite; they are abundant in places, absent elsewhere. Thin sections show that the melaphyres consist largely of secondary minerals, such as albite, hornblende, chlorite, epidote, and calcite.

Mafic Rocks

The term mafic rock is used in this paper for medium-grained to fine-grained dark-green rocks. Some are relatively fresh diabase, in which the texture is typically ophitic, and the minerals are labradorite and augite. Others are altered diabase, in which the original minerals have been partially altered to hornblende, chlorite, albite, and epidote. In the northwestern portion of the tunnel there were many dikes and sills of a rock that was mapped as light-brown mafic rock; these have not yet been studied in thin sections.

The mafic rocks occur as dikes and sills that range in thickness from less than a foot to hundreds of feet.

Aplite

The term aplite has been used here for pink, fine-grained rock that occurs in a few dikes and sills northeast of Shaft 8.

STRUCTURAL GEOLOGY

General Statement

The structural geology is concerned with the folds, slaty cleavage, joints, faults, shears, dikes, and sills. The type of projection used to show the orientation of planar and linear structural features is described in Billings (1954, p. 108-115, 482-487). All projections are on the lower hemisphere and an equal area projection is used. For linear features, such as fold axes or the intersection of two planes, each point on the diagram represents the projection, to a horizontal plane, of the pole of the linear feature. For a planar feature, such as a joint or a fault, each point represents the projection, to a horizontal plane, of the pole of a perpendicular to the plane.

Folds

The geological structure along the line of the tunnel is best displayed in Figs. 7 and 8. It has been repeatedly emphasized that the major structure is the Charles River syncline, the axis of which is located at station 398 + 98, 1365 feet southwest of Shaft 8 (Figs. 1 and 7). The axis of a major anticline, the central anticline, lies some 3 miles to the south (Fig. 1). On the north the north limb of the Charles River syncline is truncated by the northern boundary fault (Fig. 1). The wave length of the major folds is thus at least 7 miles. Superimposed on these great folds are lesser folds that are well shown in Figs. 7 and 8. The wave lengths of such folds is a few hundred to 2500 feet. Still smaller folds, with a wave length of 100 to 200 feet are also shown in Figs. 7 and 8. Still smaller folds, with a wave length of a foot or so, cannot be shown on the scale of Figs. 7 and 8.

Some of the folds are very broad and open. The center of the Charles River syncline is an example. A broad open anticline lies just southwest of Shaft 9A. Another broad open anticline is near station 485 + 00. Similarly, south of Shaft 8, although the structure is complicated by faults, several broad open anticlines and synclines are discernible.

Some of the folds are sharper, with limbs dipping as much as 45°, such as the anticline at station 420 + 00. Some folds are asymmetrical, as southwest and northwest of Shaft 8, where the north limbs of the synclines dip more steeply than the south limbs. The bedding is locally vertical and in a few places is overturned.

The attitude of fold axes may be determined in two different ways. The axes may be observed, in which case it is possible to record the strike (azimuth) of the horizontal projection of the axis and its plunge (Billings, 1954, p. 46). Secondly, if the attitude of the beds on the two limbs of a fold are known, it is possible to calculate the attitude of the axis (Billings, 1954 p. 459-465).

In Fig. 10C, representing the north limb of the Charles River syncline, two symbols are used. The open circle is for the axes of observed folds that were a foot or, at the most, a few feet across. The greatest concentration represents axes plunging 8° in a direction N 87°E. Each dot represents the intersection of the bedding measured at two adjacent exposures; these dots occupy much the same part of Fig. 10C as the open circles.

On the south limb of the Charles River syncline no minor folds were observed. But each dot in Fig. 10B represents the intersection of the bedding measured at two adjacent exposures. Although the axes of some of these folds plunge very gently east or west, many of them plunge gently northwest. These are "half-folds," where beds striking east-west and dipping north swing into north-south strikes and gentle westerly dips. That is, incipient drag folds on the south limb of the Charles River syncline plunge gently west.

Slaty Cleavage

Slaty cleavage is locally present throughout the tunnel. It is generally confined to the finer grained argillites, which in such cases may be appropriately called slates. Cleavage has also been observed in some of the other rocks, such as the finer grained sandstones and even in some of the mafic dikes. The average strike of the cleavage is N 80°E, the dip is 60° to 90°N (Fig. 10A).

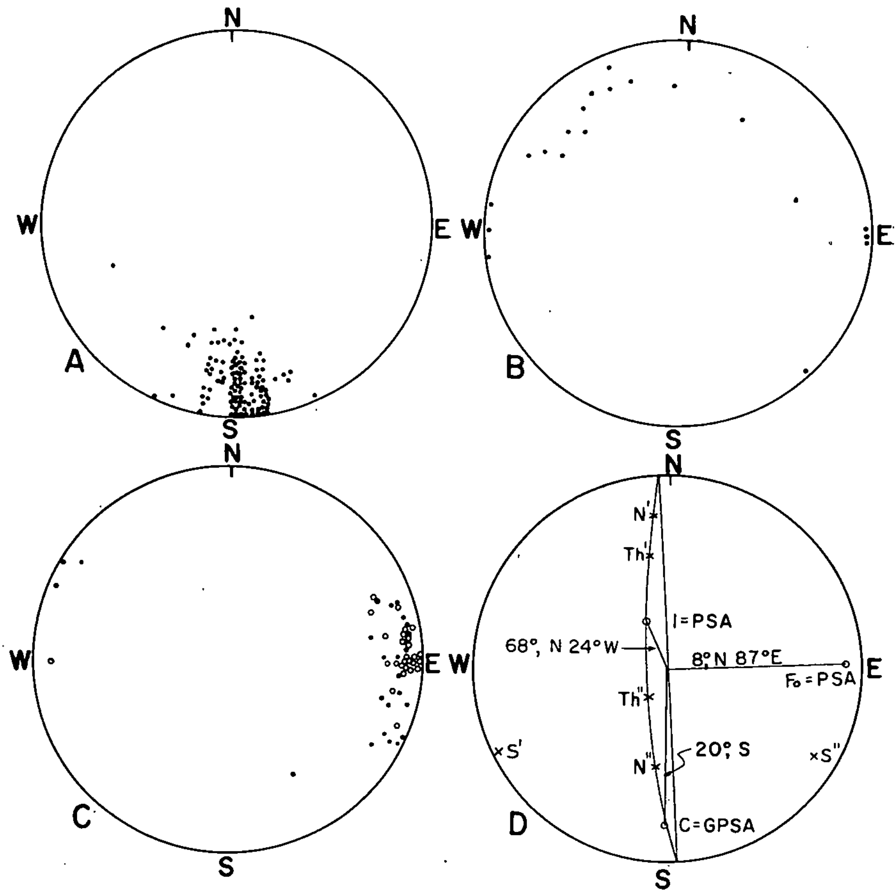

FIG. 10.—POINT DIAGRAMS. PLOTTED ON LOWER HEMISPHERE OF EQUAL AREA NET.

A. Poles to 111 planes of slaty cleavage.

B. South limb of Charles River syncline. Axes of 26 "half-folds"; each dot represents intersection of the bedding measured at two adjacent exposures.

C. North limb of Charles River syncline. Open circles are axes of 28 observed minor folds. Each of the 24 dots represents the intersections of bedding measured at two adjacent exposures.

D. Stress axes during folding. C = average position of poles of perpendiculars to cleavage. Fo = average position of observed minor fold axes. I = intersection of planes perpendicular to axes represented by C and Fo. GPSA = greatest principal stress axis (compression). PSA = other principal stress axes. Th′ and Th″ = poles of perpendiculars to potential shear fractures and thrust faults. N′ and N″ = poles of perpendiculars to potential normal faults. S′ and S″ = poles of perpendiculars to potential shear fractures and strike-slip faults.

Joints

Joints are smooth fractures in rocks. Although characteristically 5 to 20 feet apart, they may be closer or further apart. A joint may be a few feet or many hundreds of feet long. Strictly speaking there is no movement of the opposite sides in directions parallel to the joint plane. If there had been much movement, the fracture would be called a fault. Joint sets consist of a group of several parallel joints. Fig. 10A is a plot of 125 joint sets in the north limb of the Charles River syncline. Actually, of course, there are thousands of individual joints in the tunnel, and time permitted only a spot check. Fig. 10B is a plot of 5 joint sets in the south limb; unfortunately the attitude of most of the joint sets in the south limb were not recorded.

It is apparent that most of the joints strike between N 10°W and N 30°E and dip steeply to both the east and west at angles ranging from 65° to 90°. A less common group strikes N 50°W and dips 60° to 90°SW or NE. A third group strikes N 60°E, dips 60° to 90°NW. Joints striking N 45°E and dipping SE are lacking.

Faults and Shears

A fault is a fracture along which there has been relative movement of the two walls parallel to the fracture. In this report the term fault is generally used for those fractures along which there has been visible offset of some structural feature, such as bedding or a contact. In the City Tunnel Extension the faults are generally sharp, tight fractures. Some, however, are zones a few inches or feet thick that consist of gouge (clay), breccia, or cleaved rock. Few of the faults necessitated structural support. Shear is used here for those planar zones a few inches to a few feet thick that are characterized by strongly cleaved rock. Offset of older structural features, such as bedding or contacts, is not detectable, in most cases because such features are not present in the affected rocks. Shears necessitated structural support only where they were parallel to the tunnel and in the roof.

Where sufficient data are available it is possible to determine the direction and amount of movement along a fault (Billings, 1954, pp. 124-146, 455-481). In the City Tunnel Extension, largely because sufficient data were not generally available, but partly because of the restrictions of time, precise quantitative solutions were not made. But qualitative answers were usually available. Faults were classified as minor if the disrupted structural feature, such as a bed or contact, was present on both sides of the fault. Since the observations were usually on the walls of the tunnel, it meant that the vertical separation along the fault was less than the height of the tunnel, that is, less than 12 feet. If the displacement along the fault was of such magnitude that the same structural features were not present on opposite sides of the fault, it was classified as major. This meant that the vertical separation was greater than 12 feet.

A normal fault is one in which, in a vertical section at right angles to the strike of the fault, the hanging wall appears to have gone down. A reverse fault is one in which, in a similar section, the hanging wall appears to have gone up.

Data for 106 faults are given in Table V. It should be pointed out that during the field work some of the minor faults were not recorded,

TABLE V
FAULTS AND SHEARS

			South Limb	North Limb	Entire Tunnel
	Total		67	39	106
		Normal	54	16	70
	Separation	Reverse	4	10	14
Faults		Unclassified	9	13	22
	Size	Major	14	3	17
		Minor	53	36	89
Shears			53	61	114

largely because of the restrictions in available time. It will be noted that 84 per cent of the faults are classified as minor; the vertical separation along them averaged only a few feet. But 16 per cent of the faults were major; most of them are shown in the structural section, Figs. 7 and 8. The vertical separation is more than 12 feet. This also means that the net slip is unknown. In the structure section and calculations of thickness of beds it has been assumed that the net slip along these faults is 20 feet. The geological data on the surface is not inconsistent with this assumption.

Concerning vertical separation, the table shows that 83 per cent of the faults that could be classified are normal, 17 per cent are reverse.

As shown in Table V, data on 114 shears were recorded, but undoubtedly some small ones were not noted during the field work. Some of the shears are undoubtedly faults, but because of the nature of the exposures it was impossible to demonstrate visible offset of a structural feature.

The orientation of the faults and shears is shown in Figs. 11C and D.

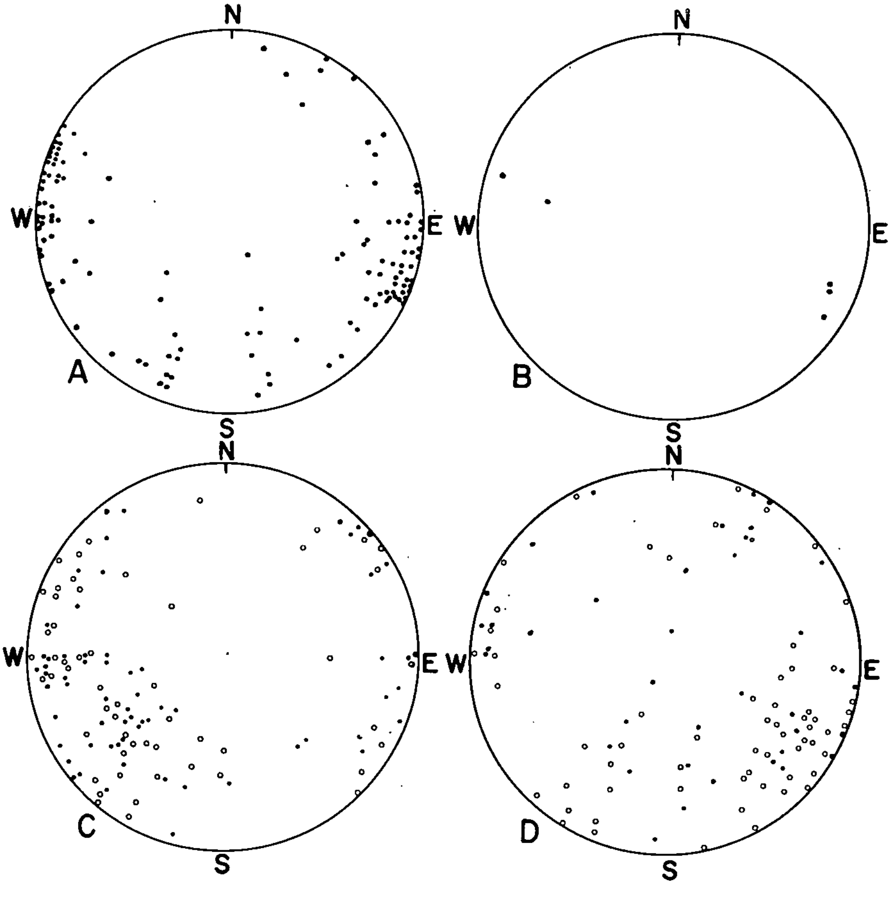

Fig. 11.—Point Diagrams, Poles to Joints, Faults, and Shears. Plotted on Lower Hemisphere of Equal Area Net.

A. North limb of Charles River syncline, 125 joint sets.

B. South limb of Charles River syncline, 5 joint sets (only a few of joint sets on this limb were mapped).

C. South limb of Charles River syncline. Dots = 67 faults. Open circles = 53 shears.

D. North limb of Charles River syncline. Dots = 39 faults. Open circles = 61 shears.

The faults and shears on the south limb of the Charles River syncline, Fig. 11C, show the same broad range in distribution. The most common faults and shears here have an average strike of N 45°W and an average dip of 60°NE, but there is considerable spread. A few points in the northeast part of the diagram represent faults and shears with the same general strike but dipping steeply SW. A second group of faults and shears that has an average strike of N 25°E dips steeply SE or NW; but there is considerable spread.

The faults and shears on the north limb of the Charles River syncline (Fig. 11D) show considerable spread. The greatest concentration of points represents faults and shears with an average strike of N 40°E, and dips ranging from 50°NW to 90°. A second set strikes N 60°W and dips from 30°NE and SW to 90°. The average strike of a third group is N 10°E and the dips are steep toward the southeast.

Slickensides, which are parallel to the direction of last movement, were recorded along 50 of the faults and shears. The average rake is about 45°, indicating that the strike-slip component along the faults and shears is about equal to the dip-slip component.

Dikes and Sills

The data for the dikes and sills are summarized in Table VI. Two hundred and ninety-eight dikes, sills, and unclassified bodies were mapped, 221 of which were dikes, 58 were sills, and 19 were unclassified. All the igneous bodies were recorded and mapped.

The thickness of a dike or sill is the distance across it measured perpendicular to its contact. The average thickness of the mafic dikes is 10.1 feet, whereas the average thickness of the melaphyre dikes is 45.9 feet. The larger melaphyres are probably rather irregular bodies and the term dike may not be always appropriate. In some cases one contact is crosscutting, the other is concordant, that is, sill-like; such bodies were classified as dikes.

The average thickness of the mafic sills, of which there are 53, was 8.5 feet, whereas the average thickness of the melaphyre sills, of which there are 3, was 55.0 feet.

The orientation of the dikes are shown in Fig. 12. One point is shown for each dike for which data could be obtained. On the north limb the strike of most of the dikes ranges from N 60°E, through East to N 45°W. The dips are both N and S at angles ranging from

TABLE VI
DIKES AND SILLS

		South Limb			North Limb			Entire Tunnel		
		No.	Thickness (ft)		No.	Thickness (ft)		No.	Thickness (ft)	
			Ave.	Range		Ave.	Range		Ave.	Range
Dikes	Mafic	43	5.0	0.2–40.0	146	11.6	0.5–94.0	189	10.1	0.2–94.0
	Melaphyre	29	45.9	0.5–410.0	—	—	—	29	45.9	0.5–410.0
	Aplite	—	—	—	3	7.3	2.0–15.0	3	7.3	2.0–15.0
Sills	Mafic	5	14.9	1.0–68.0	48	7.8	0.5–64.0	53	8.5	0.5–68.0
	Melaphyre	3	55.0	17.0–93.0	—	—	—	3	55.0	17.0–93.0
	Aplite	—	—	—	2	9.5	9.0–10.0	2	9.5	9.0–10.0
Unclassified	Mafic	—	—	—	19	—	—	19	—	—
Total								298		

50° to 90°. A few dikes strike N 15°E, most of them dipping steeply NW and SE.

On the south limb the most abundant mafic and melaphyre dikes have an average strike of N 45°W and an average dip of 60°NE, but with a range from 30°NE through the vertical. A second group strikes, on the average, N, and dips steeply east and west.

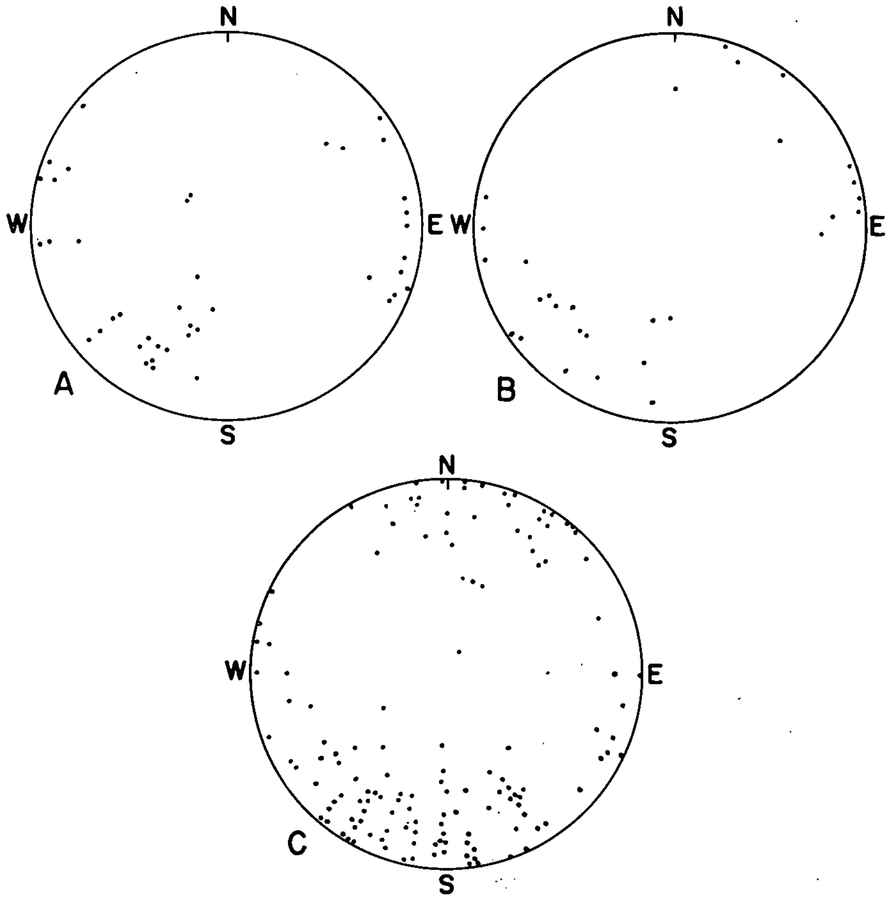

FIG. 12.—POINT DIAGRAMS, POLES TO CONTACTS OF DIKES. PLOTTED ON LOWER HEMISPHERE OF EQUAL AREA NET.

A. South limb of Charles River syncline, 43 mafic dikes.
B. South limb of Charles River syncline, 29 melaphyre dikes.
C. North limb of Charles River syncline, 146 mafic and 3 aplite dikes.

Regional Stresses

Some and perhaps all of the structural features are related to a regional stress pattern that was present during the folding of the rocks (Figure 10D) and perhaps earlier.

The attitude of the slaty cleavage is relatively uniform and has an average dip of 70°N (Fig. 10A). Such cleavage forms at right angles to the greatest principal stress axis, compression being taken as positive (Billings, 1954, pp. 340-343). On Fig. 10D C = GPSA is the projection of the pole of the greatest principal stress axis.

The fold axes have an average plunge of 8° in a direction N 87°E. This represents a second principal stress axis, Fo = PSA in Fig. 10D.

The intersection of the two planes perpendicular to the other two axes represents the third principal stress axis, I = PSA on Fig. 10D.

If Fo were the intermediate principal stress axis and C = GPSA were the greatest principal stress axis, the two sets of shear fractures (represented by thrust faults, shears, and certain joints), in accordance with theory (Billings, 1954, pp. 164-177), would dip approximately 50°S and 10°N (Th′ and Th″ of Fig. 10D), but considerable spread might be expected because of the inhomogeneity of the rocks. Fractures with such an orientation are rare on the south limb of the Charles River syncline (Figs. 11B and 11C), but some on the north limb (Figs. 11A and 11D) may fall into this category. The thrust faults at stations 510 + 30 and 604 + 45 apparently belong to this group.

If C = GPSA were to be temporarily the least principal stress axis due to the release of compression after folding, two sets of normal faults might develop. The average positions of the projections of the poles of the perpendiculars to such faults are at N′ and N″ in Fig. 10D. Such faults appear to be rare on the south limb (Fig. 11C), but some may be present on the north limb (Fig. 11D).

If I (Fig. 10D) were at times the intermediate principal stress axis during deformation, the average positions of the projections of the poles of the perpendiculars to the two sets of shear fractures would be at S′ and S″. If we take the spread into account, the concentrations would be in the SW, NW, NE, and SE parts of the diagrams. Such a pattern is rather well shown in Fig. 11C but is less obvious in Fig. 11D.

The projection of poles perpendicular to extension fractures would concentrate at Fo (Billings, 1954, p. 96). Some of the points in the western and eastern parts of Fig. 11C and D may represent such extension fractures. The most abundant joints of Fig. 11A and B are apparently shear fractures when the intermediate axis corresponded to I, and extension fractures.

In summary, most of the joints, shears, and faults appear to be shear fractures and extension fractures that formed when Fo was the least principal stress axis and I was the intermediate principal stress axis. This stress distribution resulted from a gigantic couple, with the upper part of the crust of the earth shearing southward relative to deeper parts of the crust.

Stratigraphy

General Statement

The most important geological result of the present investigation has been the recognition that the Roxbury and Cambridge Formations are facies of one another.. But before discussing this further, a brief discussion of errors in the stratigraphic measurements is desirable.

Errors in Stratigraphic Measurements

The stratigraphic columns for the two limbs of the Charles River syncline are given in Tables I and II. The meaning of the letter symbols in these tables has been described on a previous page. The thickness is given to the nearest unit, although the actual calculations were carried out to the first decimal. It is only proper, however, to discuss the errors that enter into these calculations.

The basic equation (Billings, 1954, p. 43)

$$t = s\ (\sin\delta \cos\sigma \sin\alpha \pm \sin\sigma \cos\delta) \qquad (1)$$

where t = thickness, s = slope distance (in this case the distance along the tunnel over which the unit is exposed), δ = angle of dip of strata, σ = angle of slope of ground (in this case the slope of the tunnel), and α = the horizontal angle between the strike of the stratum and the trend of the tunnel. The slope of the tunnel was neglected, hence the equation reduces to:

$$t = s\ (\sin\delta \sin\alpha) \qquad (2)$$

Measurements of the attitude of the bedding were made at intervals, perhaps averaging 25 feet. In making the calculations it was assumed that a measured attitude was constant halfway to the next measurement in either direction. This, of course, introduced an error into the results. Moreover, the error in measuring the angles δ and α could be several degrees. Because of this procedure, the error for any single calculation of thickness, generally involving a few feet or tens of feet, could be 10 per cent. But over longer distances these errors should be compensating, and it is believed they introduce no important error in the results. The time necessary to do the work more precisely would have been prohibitive.

Another problem concerns the dikes. A detailed discussion is impossible here. A vertical dike that strikes at right angles to the tunnel presents no problem, assuming the walls of the dike pulled apart at right angles to the contacts of the dike to permit intrusion. But in all other cases, a correction is necessary. Some corrections are negative, some are positive. The calculation of these corrections took several weeks; it turned out that the total effect of all the dikes was essentially compensating.

Another problem concerns the 17 major faults, along which the displacement is unknown. It has been assumed that in each case the net slip was of the order of 20 feet. Comparison of the data in the tunnel with the surface data indicates this is not unreasonable.

Facies Changes

Very early in the trips into the City Tunnel Extension the axis of the Charles River syncline was located approximately. Moreover, it became apparent that the lithology on the opposite limbs of the syncline was very different. Whereas the south limb consisted chiefly of conglomerate and pink sandstones and argillites, with gray argillites distinctly subordinate, the north limb was largely gray argillite. Although the contrast in lithology can be deduced from a study of the geological maps (Figs. 3-6) and from the structure sections (Figs. 7-8), it is most readily observed in a special facies diagram (Fig. 9, p. 124). The data are represented on an inverted V in order to show that the data for successively lower stratigraphic units come from localities progressively further apart horizontally. The inverted V shows the position of the tunnel if the beds were returned to their original horizontal position. A diagram was prepared originally that took into account every minor fold in the tunnel, but this diagram was not readily readable on the scales available.

In order to complete the diagram, and show all of the Roxbury Formation, the southern leg of the inverted V has been extended downward to the Mattapan Volcanics in the core of the Central anticline in Newton. This part of the diagram is based on surface data and obviously is not as detailed as that based on the tunnel.

Three facies are shown in the diagram: a conglomerate facies, a pink sandstone-argillite facies, and a gray argillite facies. The first two facies constitute what has been traditionally called the Roxbury Conglomerate, whereas the third facies constitutes what has been called the Cambridge Argillite. But the diagram shows the Cambridge type of lithology inter-fingers with the Roxbury type of lithology.

The origin of the facies relationship may be interpreted as follows. The Boston Bay group was deposited in a basin; the sediments were derived from the south. A body of water occupied the northern part of the basin, but a deltaic plain occupied the southern part. The shore line of the body of water was near the axis of the present Charles River syncline, but shifted back and forth several miles. Gravels were deposited by streams on the deltaic plains. The pink sands and silts were deposited in shallow near-shore lagoons, where surface waves occasionally disturbed the water sufficiently to produce ripples. Still further north, in the main body of water, gray silts were slowly deposited in relatively quiet water, as evidenced by the thin bedding. At times rather strong currents swept the floor of the water body, producing minute cross-bedding and pinching and swelling of the beds. Occasionally there were sudden catastrophic changes in water level, as evidenced by the large disconformity on the north side of Beacon Street one mile WSW of Shaft 7 (Billings, 1929, p. 105).

In Fig. 1 (p. 113) a correlation has been made with the rocks in the Main Drainage Tunnel, where Rahm (1962) mapped the Dorchester Shale, Squantum Tillite, and Cambridge Argillite. No tillite has been recognized in the City Tunnel Extension. But by projection of the strikes of the strata in the two tunnels it appears that the conglomerate constituting unit 31 (Table I) is to be correlated with the Squantum. It would be interpreted as a waterlaid gravel laid down at the same time as the tillite. Units 30 to 12 inclusive are considered to belong to the Dorchester Shale, whereas unit 11 and everything below it belongs to the Brookline member.

Engineering Aspects of the Geology

Structural steel was used for roof support in 2103 feet, that is, 5.6 per cent of the tunnel. Only 56 feet or 0.35 per cent of the south

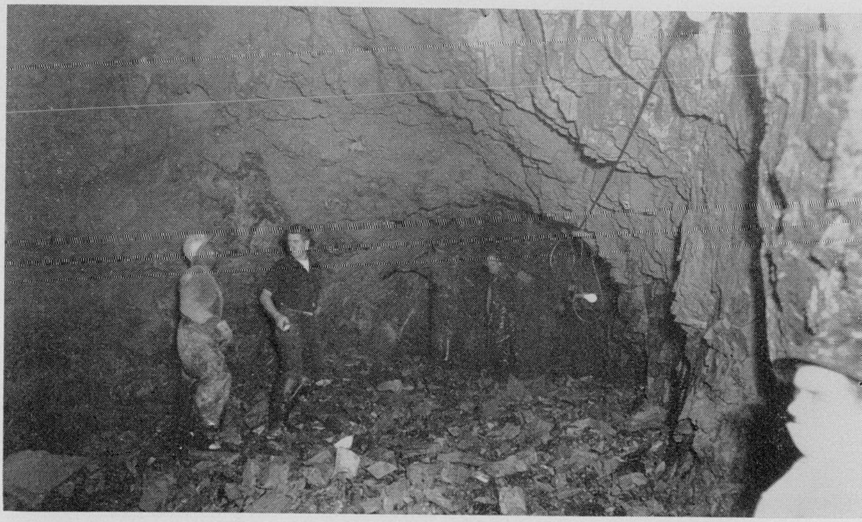

FIG. 13.—LOOKING AT NORTH HEADING SCALING OPERATIONS, STA. 424 + 14, SHAFT #8, CONTRACT 193, CITY TUNNEL EXTENSION, JULY 20, 1954.

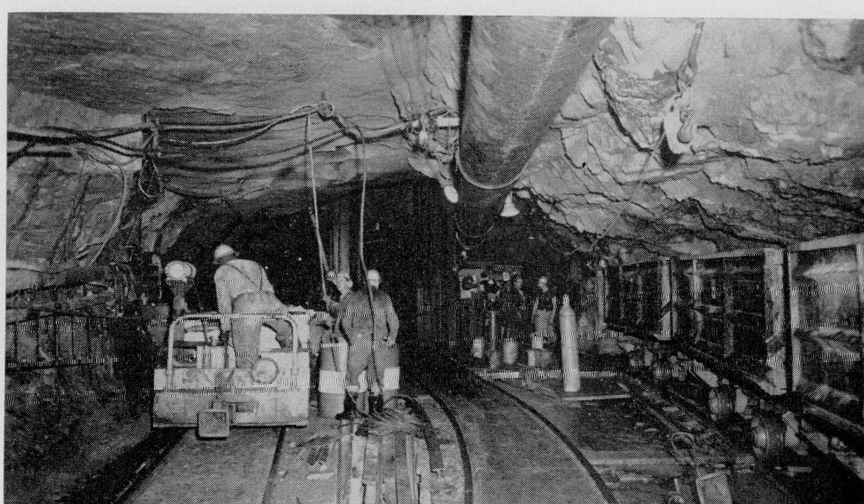

FIG. 14.—LOOKING NORTHERLY, VIEW AT BOTTOM OF SHAFT #8, CITY TUNNEL EXTENSION, CONTRACT 193, AUGUST 20, 1954.

heading required support. This indicates that the Roxbury Formation, through which the south heading is mostly driven, is composed of very strong rocks. However, 2047 feet or 9.5 per cent, of the north heading required support; this heading lies in the Cambridge Formation. Eleven per cent of C heading of the Main Drainage Tunnel, also in the Cambridge Formation, required support (Rahm, 1962, p. 359). However, as will be shown below, it is the dikes cutting the formation that necessitated some of the support.

In analyzing the reasons why support was necessary in parts of the City Tunnel Extension, we may consider four categories: shales, dikes, shears, and joints.

The longest section needing continuous support was between

FIG. 15.—LOOKING NORTHERLY TOWARD SHAFT #8 FROM STA. 254 + 90, SHOWING TUNNEL LINING PLACED UNDER CONTRACT 115, CITY TUNNEL EXTENSION, SEPTEMBER 12, 1955.

stations 475 + 29 and 482 + 23. This area was in gently dipping weak sedimentary rocks, units 36 to 40 of Table II; these rocks are mostly shale and tuff. Two chemical analyses are given in Table III. It is these rocks that necessitated 33 per cent of the total support used in the tunnel. Similar rocks in the Dorchester Shale in A heading of the Main Drainage Tunnel (Rahm, 1962, p. 359) were continuously supported.

Another 33 per cent of the total support required was related to dikes. The margins of some dikes are shear zones and the dike rock itself may be extensively fractured. During folding the contacts of the dikes controlled the location of excessive movements. But of the 33 per cent, only 21 per cent is related exclusively to dikes, 9 per

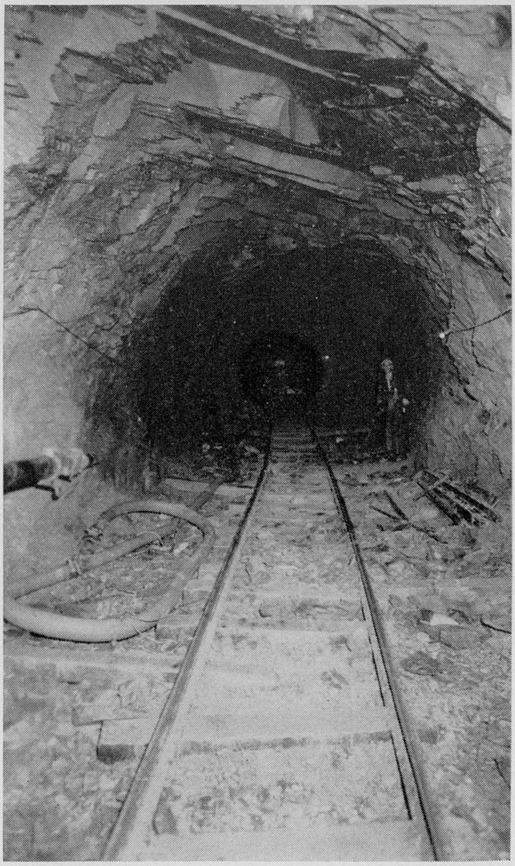

FIG. 16.—LOOKING SOUTHERLY, SHOWING GUNITED SECTION OF UNLINED TUNNEL AT BULKHEADED END OF CONCRETE TUNNEL LINING PLACED UNDER CONTRACT 115, CITY TUNNEL EXTENSION, CONTRACT 193, SEPTEMBER 12, 1955.

cent is related to dikes and sills, and 3 per cent to dikes and faults. About 63 per cent of the dike footage in the tunnel did not require support. In C heading of the Main Drainage Tunnel, whereas 26 per cent of the dikes necessitated support, only 10 per cent of the argillites of the Cambridge Formation needed support (Rahm, 1962, pp. 359-360.)

Sixteen per cent of the total support used was necessitated by steep shears parallel to the tunnel, especially where near the roof.

Eighteen per cent of the total support was used in argillites and sandstones. This was due either to excessive splitting parallel to the bedding or to closely spaced joints.

It is important to note that most of the faults and only a few

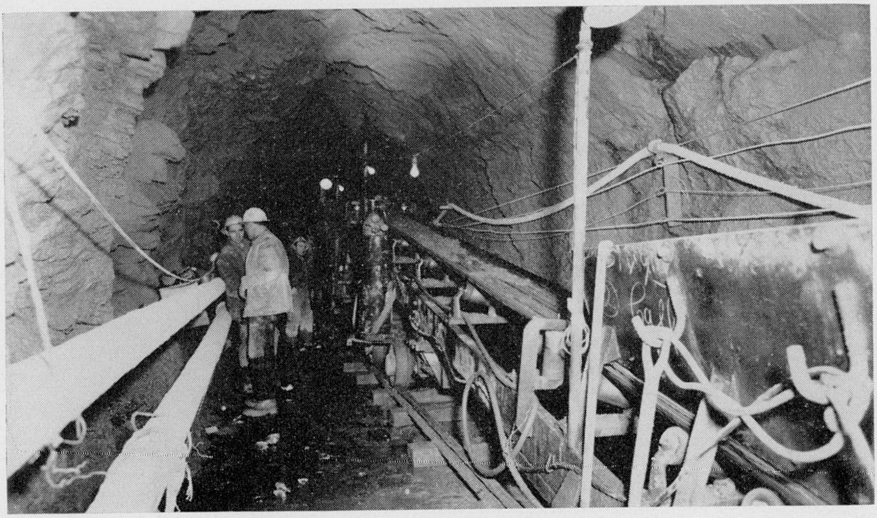

FIG. 17.—LOOKING SOUTHERLY, STA. 402 + 50, SHOWING CONCRETE CONVEYOR, CITY TUNNEL EXTENSION, SHAFT #8, CONTRACT 193, MARCH 28, 1956.

of the shears necessitated support. Moreover, the joints, although present throughout the tunnel, seldom were close enough to necessitate support.

ACKNOWLEDGMENTS

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some of the specimens collected by Cassidy have been used. In the spring of 1959 Lincoln S. Holliston, a student of Billings, mapped the bedrock geology of the Brighton area over the tunnel line.

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PROTOTYPE SIMULATION

By R. T. McLaughlin*

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Introduction

Definitions

It is quite likely that at present the words prototype simulation will convey several different meanings to various civil and hydraulic engineers. To some, they may convey the idea of scale models of structures and facilities, to others they may mean the study of flow situations by means of analog and digital computers, while to still others they may signify a well defined procedure in the field of applied probability and operations research. All three groups might be correct because according to various established practices these words could be used for any of the three concepts.

Since the use of physical or scale models is already a well developed art in civil engineering it has been decided that the writer will emphasize the second and third concepts. The concepts will be further confined to problems encountered in the hydraulic and water-resource aspects of civil engineering. Thus, prototype simulation will have two definitions here:

(1) The study of flow situations by means of mathematical models and computers.

(2) The study of design and operation of hydraulic systems when some of the important parameters can only be described statistically.

Mathematical Models and Computation

When a hydraulic engineering problem cannot be fruitfully studied by a scale model, there are two alternative devices: models with different physical elements and mathematical models. Since the use of different physical elements is based on mathematical similarity, mathe-

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matical modelling is the basis for both alternatives to scale modelling. For example, the electrical circuit with capacitance, inductance and resistance is a model of a mechanical system with spring, mass and damping because both systems can be described by the same equation or mathematical model.

A mathematical model is simply a set of numbers, graphical representations and/or symbols that represent the various physical elements of a hydraulic engineering problem. In addition, these items may represent socio-economic and behavioristic elements of the problem. The approach is simply to have a number, curve or symbol represent every quantity and interrelationship that occurs in the real problem and every change in the quantities and interrelationships. Tables of physcial data, graphs and equations are all examples of mathematical models. What will be emphasized in this discussion of simulation are mathematical models that help determine how a hydraulic structure or facility will function when put to the task for which it was designed.

The use of a mathematical model implies results in terms of numbers, and numbers mean computation. The recent development that has paved the way for greater use of mathematical models has been the tremendous increase in capacity to compute resulting from the development of modern digital and analog computers. The capacity to compute is so essential in modern approaches to hydraulic engineering that the art of developing good mathematical models is often subordinated to the art of using the computer. Such an approach misplaces the emphasis. Nevertheless, it must be admitted frankly that the use of meaningful mathematical models is not, in general, possible without the powerful computational capability afforded by modern computers.

Major Categories of Problems

The hydraulic problems that are handled by mathematical models can be divided into an ordered set of three major categories each of which actually includes its predecessors. These categories are simulation of physical systems, simulation of operation and optimum design. In that order they proceed progressively from emphasis on mathematics and physics of flow to emphasis of socio-economic matters and management decision. They also increase in scope, for simulation of operation cannot be performed without knowledge of the physical performance, and optimum design must be based on knowledge of operation and performance. Each of the categories will be discussed in following parts of the lecture.

Scope

It is not intended that this paper shoud be a complete survey of all work related to the topic. All that is attempted is to give a few concepts and examples that together will indicate the nature and range of such work and the impact that it is bound to have on future approaches to hydraulic engineering. The majority of possible examples cannot be included and this is not to imply that those selected are more suitable than those omitted.

Simulation of Physical Aspects of Hydraulic Problems

Automation of Solutions of Flow Equations

(a) *Automation of present manual techniques.* To date a large part of study of hydraulic problems by means of simulation on computers has consisted of the solution of flow equations that cannot be readily solved directly. Some examples of these are:

(1) Flood routing problems (1).*
(2) Study of surges in sewers (2).
(3) Analysis of surge tanks (3).
(4) Water hammer analysis (4).
(5) Prediction of waves generated by winds (5).
(6) Analysis of pipe networks (6)(7)(8)(9).

All of the problems just listed had been solved graphically or numerically before the advent of high speed automatic computation. Therefore, the use of computers at first represented primarily a labor saving method. Often the methods used with the computer were precisely those used for manual calculations. Thus developed the emphasis on merely computerizing the calculations.

However, even this elementary approach has brought about a change in engineering practice. Once a calculation has been programmed for the computer, the effect of a whole series of conditions and assumptions can be determined by changing a few parameters. For example, once a flood routing computation is set up on a computer it is possible to study the effect of a complete series of flood flows,

* Numbers in parentheses refer to references at end.

some observed historically and others only anticipations of future possibilities. As a result, engineers are now using the computerized calculation to study the effects of variables just as they use hydraulic models. This is the first stage of prototype simulation.

(b) *Extension of equations and solutions.* The next stage of simulation is the extension of flow equations to include terms previously omitted and to be less restrictive in the assumptions. As an example, the effects of friction can be more readily included in water hammer analysis (4). As another example, the effect of changes of channel cross section and other complications can be handled in flood routing (1). The essential aspect of such extensions is that the equations or mathematical models become more realistic representations of the prototype.

An important extension of the solution of equations has been the use of simulation for handling complicated boundary value problems. In these cases, the equations themselves have not been extended beyond classical form, but boundary conditions too difficult for classical methods have been handled successfully. It will be recalled that in the boundary value problem an equation describes the flow in a region, but the solution depends upon pressures and velocities along the boundaries of the region. The combination of boundary shapes and conditions that can be readily handled by classical methods is rather limited from the engineering point of view.

An interesting example is the solution of boundary value problems occurring in ground water phenomena. For steady incompressible flow in porous media the piezometric head h(x,y,z) satisfies the Laplace equation

$$\nabla^2 h(x, y, z) = \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = 0. \qquad (1)$$

The variables x,y, and z are the space coordinates. It will be recalled that in such an equation h is a potential function. The partial derivatives of h give u, v and w, the components of velocity in the directions of x,y and z respectively. The velocities are given by

$$u = -K\frac{\partial h}{\partial x}, \quad v = -K\frac{\partial h}{\partial y}, \quad z = -K\frac{\partial h}{\partial z} \qquad (2)$$

where K is the transmission coefficient frequently called the coefficient of permeability. Many of the listeners have probably solved equation (1) graphically by means of flow net construction.

Because many phenomena can be described by equation (1), simulation has been frequently used to obtain solutions. Two-dimensional flow in porous media has been simulated by viscous flow between closely spaced plates and by electric current in thin sheets of conducting material. One of the more recent developments has been the use of passive element electric networks to simulate three-dimensional flow in large scale or complicated flow problems.

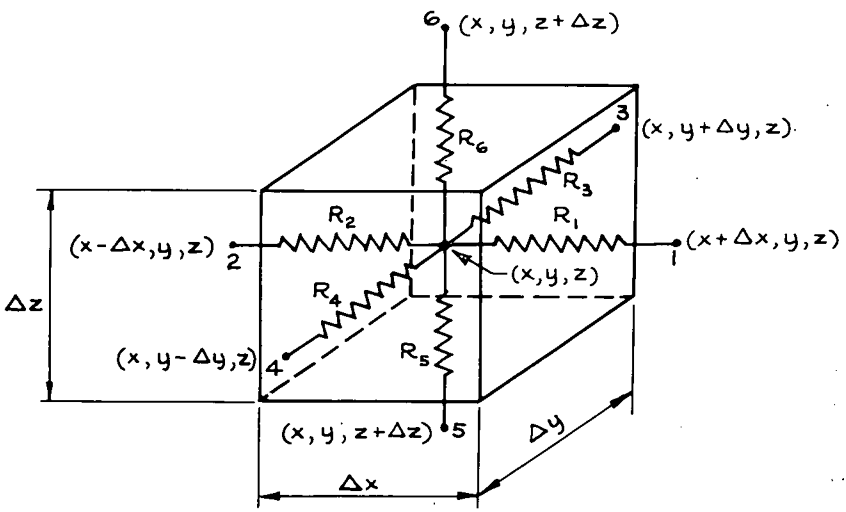

FIG. 1. RESISTANCE CIRCUIT ELEMENT REPRESENTING ELEMENT OF VOLUME IN CARTESIAN COORDINATES

The electric network used actually discretizes the Laplace equation (12). The porous media through which the fluid flows is actually a continuous element of resistance. If the fluid motion is represented by currents flowing in the direction of velocity components, a small volume of material can be represented by resistance in the x, y and z directions as shown in Fig. 1. Here the points 0,1,2,3,4,5,6 shown represent the centers of the volume element shown and the six adjacent elements. These points are nodes or nodal points. The resistances, R, connect the seven nodes and carry currents between them.

If E_1, E_2, etc., represent voltages at the nodes, Kirchoff's Law for conservation of current leads to the equation

$$\frac{E_1 - E_0}{R_1} + \frac{E_2 - E_0}{R_2} + \frac{E_3 - E_0}{R_3} + \frac{E_4 - E_0}{R_4} + \frac{E_5 - E_0}{R_5} + \frac{E_6 - E_0}{R_6} = 0 \quad (3)$$

It can be shown that equation (3) is equivalent to the difference form of Laplace's equation. If, h_1, h_2, etc. are potentials at the nodes, the partial derivative between 0 and 1 is given by

$$\left(\frac{\partial h}{\partial x}\right)_{0-1} \cong \frac{h_1 - h_0}{\Delta x}$$

while that between 2 and 0 is given by

$$\left(\frac{\partial h}{\partial x}\right)_{2-0} \cong \frac{h_0 - h_2}{\Delta x}$$

It follows that the second partial derivative at 0 is given by

$$\left(\frac{\partial^2 h}{\partial x^2}\right)_0 = \frac{1}{\Delta x}\left(\frac{h_1 - h_0}{\Delta x} - \frac{h_0 - h_2}{\Delta x}\right) = \frac{1}{\Delta x^2}(h_1 + h_2 - 2h_0) \quad (4)$$

If Δx, Δy and Δz are made equal, in an isotropic medium, the resistances R_1, R_2, etc. will be made equal. Thus, equation (3) becomes

$$E_1 + E_2 + E_3 + E_4 + E_5 + E_6 - 6E_0 = 0 \quad (5)$$

while (1) becomes

$$h_1 + h_2 + h_3 + h_4 + h_5 + h_6 - 6h_0 = 0 \quad (6)$$

and measurement of voltage will determine the value of h.

An aquifer can be represented by a network made up of a number of the elements shown in Fig. 1. Compressibility of the aquifer can be handled by attaching a capacitor to node 0 in each element to form a resistance-capacitance circuit element (12). Networks using both types of elements have actually been set up on a series of parallel panel boards. At the boundaries of the network, currents and voltages can be controlled to represent velocities and head at the boundaries of the aquifer. Inside the aquifer, conductors can be made to represent wells. Such a network with proper controls, amplifiers, and other devices constitutes an analog computer.

Analog computers have been used to study groundwater basins both in steady and transient state. Most of the complications in soil formations and flow conditions can be represented by appropriate circuits.

Study of Hydraulic Systems

(a) *Difficulties in system analysis.* Another stage of prototype simulation is the analysis of hydraulic systems. A hydraulic system can be defined as a collection of hydraulic structures or devices that function together as a unit to accomplish some specific objective. An example of such a system is the total complex of inlets, conduits, surge tanks, hydraulic machinery, outlets and control mechanisms found in a pumping station or hydro-electric generating station. Each of the individual elements mentioned are components of the system and each functions according to its own flow equation. Since the output of one component is the input of one or more others, the solution of the equation of one component is affected by the solution of one or more others. Consequently, the equations of all components must be solved simultaneously. It follows that the study of a system of hydraulic components leads to the solution of a set of simultaneous flow equations.

Before the advent of modern computers, the study of hydraulic systems was severely limited. The limitations arose, of course, from difficulty in solving a set of simultaneous equations for unsteady or non-linear flows. It was almost invariably necessary to assume steady flow or to neglect some of the interaction between components. This difficulty in computation actually affected the whole approach to hydraulic design. To be sure it was acknowledged that certain collections of components acted as a system, as in sewer systems, distribution systems, irrigation systems, etc. In fact, however, the performance of the components as part of a system has been seldom investigated. In general design procedures, each component is designed individually to handle the sum of all the inputs that come to it. For example, each given section of a storm system sewer is designed to handle the combined flow of all upstream branches leading to it. Seldom is the behavior of the whole system studied for various unsteady or off-design conditions.* The design and operation implications of this are discussed below. For the present, attention is fixed on the problem of understanding the physical behavior of a whole system.

One might ask why engineers did not use hydraulic scale models for system study as they had for design of individual structures. The answer is that hydraulic models are not, in general, well suited to system studies. The fundamental nature of similarity works against a scale model of a whole system. A system that includes closed conduits and free surface flow must be scaled in one part according to Reynolds number and in another according to Froude number. A proper study of component interaction requires kinematic and dynamic similitude where the components are connected, which would not be possible in a mixed Reynolds-Froude system. Even if the whole system is closed conduit or free surface the scale needed for some components might be impractical for the whole system. Thus, hydraulic modelling leads one away from system study.

(b) *Mathematical model and computation.* It is evident from the difficulties outlined that the study of total systems will usually involve mathematical models and solutions by automatic computation. As already mentioned, the problem usually centers around the solution of a simultaneous set of equations. Some of the problems involved can best be shown by a simple but interesting example.

Fig. 2 shows the vertical section through a system of open channel, conduit, surge tank and penstock that conveys water to a hydro-electric generating station. The rectangular channel is 6 feet wide and carries 60 cfs at a depth of 4 feet. The conduit has a constant diameter of 3 feet, a length of 400 feet and a friction factor, f, of 0.015. The surge tank has a constant circular cross section 12 feet in diameter. The problem is to study the interaction of the channel, conduit and surge tank when a valve in the penstock is suddenly closed. This example is an extension of one given by McNown, reference (11), page 465.

In order to discuss the problem analytically the following symbols will be used:

U = mean velocity in open channel, positive toward entrance to conduit

* Conditions of flow other than those for which the design calculations were made.

D = diameter of conduit
A = cross-section area of conduit = constant
L = length of conduit
V = mean velocity in conduit, positive toward penstock
Q = flow rate in conduit = VA
V′ = mean velocity in penstock, positive toward power house
t = time after valve closure
A_0 = cross-section area of surge tank = constant
f = friction factor assumed constant
y = depth of water in channel at inlet to conduit
g = acceleration due to gravity
z = vertical distance from bottom of channel at inlet to water surface elevation in surge tank
a = friction coefficient = fL/2Dg

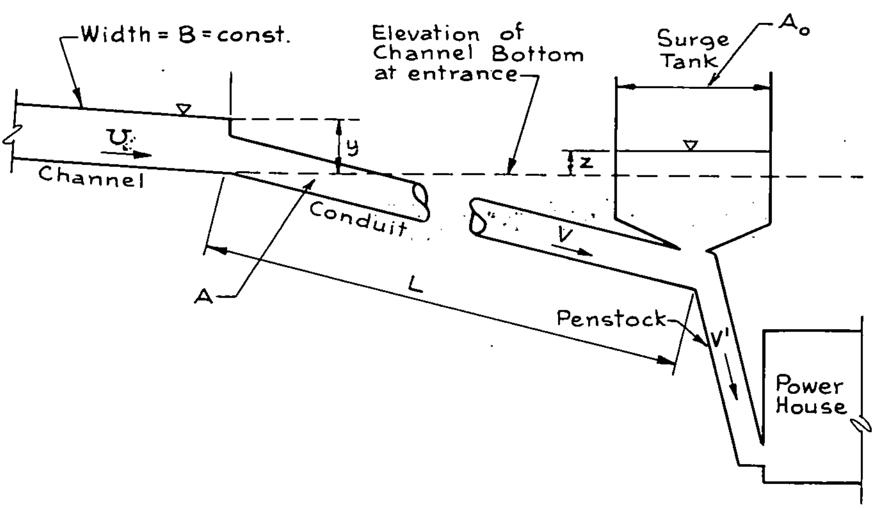

FIG. 2. EXAMPLE SYSTEM

First it should be noted that the problem has mixed similarity criteria. The channel would be scaled by Froude number, while the conduit would be scaled by Reynolds number. Other effects, such as water hammer, non-linearity in the surge tank, etc. would cause other difficulties. Therefore, the first major phase of the study should be done with a mathematical model. Experience has shown that it is best to begin with the simplest models and include more complications in sucessive stages. Then the knowledge gained in preceding stages can help in the next stage. Furthermore, the systems point of view indicates that it is best to begin with all of the important factors in the simplest form rather than to go into any single factor in great detail.

One might anticipate that in this problem one of the larger overall hydraulic effects will be the interaction between surges in the tank and in the channel. Therefore, one would begin with a simple cylindrical surge tank, a rigid conduit and a frictionless channel. Friction in the conduit might even be neglected at first, but it is a simple matter to include friction by assuming that the friction factor is constant. However, friction experienced by water entering the surge tank can be omitted. Finally, in the first stage of calculations, the channel can be assumed long enough to prevent surges from reaching the upstream end and returning to the conduit inlet.

The momentum equation for the conduit and tank can be written in the finite difference form for step calculations. With the simplifying assumptions made for this stage of the calculations, the momentum equation becomes

$$\frac{\Delta V}{\Delta t} = \frac{g}{L}\left[(y - z) - \frac{fL}{D}\frac{V^2}{2g}\right]$$

$$\Delta V = \frac{g}{L}\,[y - z - aV^2]\,\Delta t \qquad (7)$$

where

$$a = fL/2gD.$$

When the valve in the penstock is closed, the continuity equation becomes

$$\Delta z = \frac{A}{A_0}\,V\Delta t \qquad (8)$$

The change ΔV in the conduit represents a change of flow ΔQ where

$$\Delta Q = A\,\Delta V \qquad (9)$$

The resulting change in flow rate in the open channel at the inlet is

$\Delta Q/B$ per unit width of channel. In response, a surge of height Δy will form at the inlet of the channel and move upstream.

If the equation for surge in a rectangular channel (10) is written in terms of ΔQ and Δy it becomes

$$\left(v - \frac{\Delta Q}{B\Delta y}\right) = \left[\left(2 + \frac{\Delta y}{y}\right)\left(1 + \frac{\Delta y}{y}\right) y\right]^{1/2} \sqrt{g/2} \tag{10}$$

Equations (7), (8), (9) and (10) are then solved simultaneously.

The details of the numerical method and its adaption to computation are given in the Appendix. At this point the results can be presented graphically as shown in Fig. 3. The solid curves show y and z as functions of time. It will be noticed that y continues to increase until the slope of the z-curve reaches the inflection point around $t = 50$

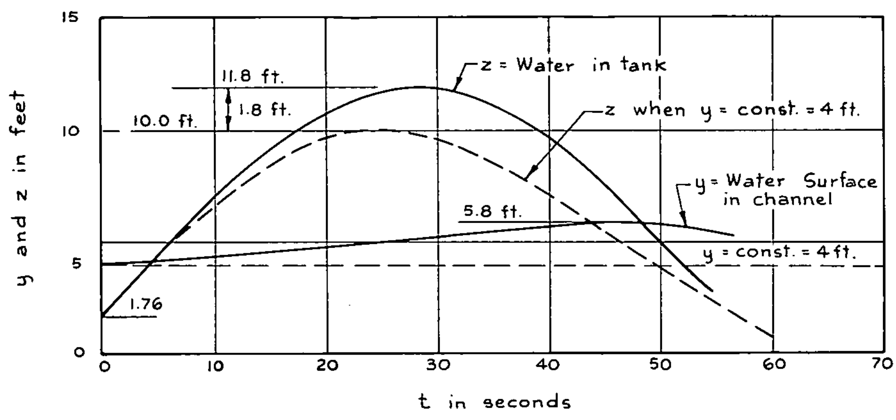

FIG. 3. SURGES IN TANK AND CHANNEL

seconds. At that time the flow in the conduit toward the inlet begins to decrease causing negative values of Δy. The maximum value of y represents an increase of 45% of the original depth.

The effect of interaction is quite marked in Fig. 3. The broken line shows the values of z obtained by McNown (11) for the same surge tank when y is constant. It can be seen that the interaction increased the maximum value of z by 1.8 feet. Interestingly, this is almost exactly the change in y. The percent increase in surge is equal to 1.8 (100)/(10 — 1.76) = 22.

At this point the problem could be pursued further by considering friction in the channel, water hammer and a more complicated surge tank.

(c) *Combination of mathematical and scale models.* In the development of large scale systems for aircraft, spaceflight, communications and warfare, there will be found the technique of studying in detail the performance of a single component as part of the whole system. The technique is to control inputs and outputs of the real component by a computer that has the mathematical model of the rest of the system.

The promise that this method holds for hydraulic engineering problems can be demonstrated in the same example presented in section (b) above. Suppose that the channel is unlined and of finite length. It is desired to study the effect of surges and reflections on stability of the channel. Suppose also that the study has progressed to the stage where a complicated surge tank and water hammer are being considered. These two can be handled by a mathematical model far more readily than the channel stability. Thus it would be desirable to use a scale model for the channel with the effect of conduit and surge tank represented by the computer.

It should be emphasized that this approach is not merely controlling inputs to model by a computer. The surges in the channel are measured and fed back to the computer. Thus, the physical model controls the calculations for surge tank and water hammer just as much as these calculations control the model.

Operation and Design Studies

Purpose and Techniques

(a) *Overall simulation.* The simulation of physical system discussed above determine, essentially, what the system will do when subjected to a given set of physical conditions. It does not consider specifically the conditions to be expected or the decisions that will be made by the individuals who control the system. Nor does it consider the objectives of the systems and the value of the outputs. These matters constitute the difference between analysis and design. If prototype simulation is to be used for design, the probability of inputs, the control decisions and the value of outputs must be included. This combination of physical and operational simulation might be called overall simulation.

Civil engineers designing hydraulic systems have traditionally been concerned with these overall matters. They are not new. What is new is the way that they can now be handled. It has already been mentioned that in the traditional analysis of physical systems the flow was often considered steady and fixed and interaction between components was not really investigated. Similarly either the design or operation procedure was fixed first; the other was then determined and the outputs were evaluated. The interaction between design, operation and output was not really investigated. Thus, just as one of the objectives of simulation of physical systems is a thorough study of interaction of components, an objective of overall simulation is a thorough study of interaction of design, operation and output.

(b) *Objective and optimization.* There is no reason to make design or operation decision without objectives. For overall simulation these objectives must be known well enough to be assigned some quantitative or comparative value, usually in economic units. In the past the objective has often been fixed both in nature and magnitude. For example, a flood control objective might be set as protection from flood flows up to 5000 cfs. In simulation the nature of the objective is set but not the magnitude. Thus, the objective might be flood protection expressed in dollar value of benefit minus cost. The magnitude will vary with the magnitude of design flood. The objective is a function of the system selected and it is common to speak of the objective function.

Normally the purpose of the design is to maximize the objective function. This function will depend on three sets of variables: input probabilities, component sizes and operation procedures. Consequently, finding the maximum is a difficult task. The two primary approaches at present are mathematical programming and simulation.

Mathematical programming is a set of steps and calculations to find the maximum value of the objective function. The word programming refers not to computers but to programming the system itself. Thus, mathematical programming is a mathematical method for selecting component sizes, and operation procedures.

"Simulation" in the operations sense refers to a specific use of what has been called the overall simulation above. If all the variables in the overall simulation were changed one at a time, the time required to find the maximum benefit would be prohibitive, even using a computer. The alternative is to select complete sets of the magnitudes of the variables. For a river basin, for example, a single complete set might include the capacities of each dam on the river, operating procedures and allocations of water for irrigation. With these magnitudes the overall simulation is run using probabilistic inputs such as runoff. The benefit over the years of simulated operation is one value of the objecttive function. Then another complete set of magnitudes of variables is selected. The overall simulation is again run using probabilistic inputs to obtain another value of the function. The process is repeated enough to determine the nature of the objective function and to locate the maximums. This whole process is called simulation in operation research and system engineering.

Example

The use of overall simulation and operations research in water resource engineering is so new that concrete examples are rare. Examples that can be found are quite complicated and beyond the scope of a single lecture, but anyone wishing to pursue the matter will find examples in references (13), (14), and (15).

It is not too difficult, however, to construct a simple example that demonstrates the interaction of variables mentioned above. Consider a city with two sources of water. One is a nearby surface reservoir large enough for over-year storage, and water from it costs a reasonable amount. The second is a more distant reservoir. Water from the second must be pumped, and the cost of such water is relatively high. The situation is such that for a decade or so the city can use the first reservoir as a primary source and the secondary on a standby basis. Thus, the second reservoir is used for recreation until water is needed. For this example, it is assumed that the second reservoir has sufficient water for this need. The problem is to find the optimal size of the first reservoir and the capacity of conduit and pumping equipment to get water from the second.

This problem can be reduced to determining the net benefit as a function of operation and size of the first reservoir. Assume, for this simple example, that the operating rule is to supply the same amount, F, of water every year. Let the size of the first reservoir be S and the net benefit N. Then N is to be determined as a function of S and F. In Fig. 4 the function N(S,F) is represented by a surface with S and F as independent variables. These are often called decision variables.

For a given statistical distribution of inflows and size of the first reservoir any design flow up to the average annual inflow can be selected. Whenever the yearly inflow is greater than the design flow plus the storage volume available at the beginning of the year, the excess must be released and wasted. The lower the design flow, the more the waste and the lower the actual yield of useable water over a period of years. However, the higher the design flow, the more water shortage in years of low inflow. This shortage determines the size of the pumping equipment and conduit from the second reservoir. Therefore, for a given distribution of inflows and a given reservoir size, the unit cost of water supply will vary with the design flow or operation.

To study this problem one can select a set of values S_1 and F_1. The inflow, waste and water shortage can be calculated year by year using the actual record of yearly inflows. The maximum shortage over the period of record will then determine the capacity of pumping equipment and conduit from the second reservoir. With the capacities determined, the operation and maintenance cost can be calculated year by year. If the value of capital, operation and maintenance over the period of study is subtracted from the value of water over the period, the result is the net benefit over the period. This benefit, called N_{11}, is plotted vertically above S_1, F_1 in Fig. 4.

Actually N_{11} can be studied more thoroughly than the preceding paragraph indicates. First one considers the existing record of inflows as merely a sample of a large population of possible inflows. The sample is analyzed to estimate the statistical properties of the population. From the statistical properties of the population, it is possible to generate artificial records of inflows that are equally as probable as the real record. The analysis of the preceding paragraph can be repeated for many such artificial records. The result is many values of N_{11} which themselves form a statistical distribution. From this distribution of N_{11} it is possible to determine the expected value, confidence limits, effect of the length of original record, etc. In Fig. 4, N_{11} could also represent the expected value.

The process is repeated for various values of S and F, and for each pair a value for the original record. When all N's are plotted as shown in Fig. 4 they define the surface N(S,F) shown. The highest point in the surface is the maximum N and its location determines the optimum values S_{op} and F_{op} shown in Fig. 4.

The study just outlined is a simulation because it is based on simulating the actual passage of events over the design period of years and summing the actual cost over the simulated passage of events. It differs in this respect from other approaches such as solution of equations or mathematical programming.

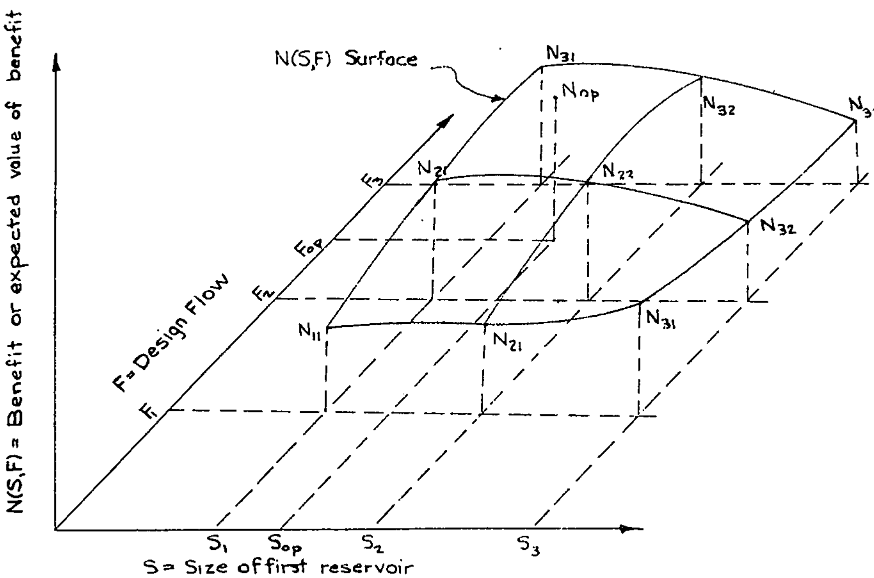

Figure 4. Surface of benefit as a function of decision variables

CLOSURE

Prototype simulation aids in the study of the performance of hydraulic structures and water-resource systems over a range of conditions. Except for the traditional hydraulic scale models, most simulations are based on mathematical models. Therefore, simulation usually means computation and numerical results. The recent advances in simulation would not be possible without computers. Despite this, the essence of good simulation is the formulation of meaningful mathematical models. The mere computerizing of a calculation to save time does not take full advantage of the use of prototype simulation. Since most things to be designed function as part of a system, realizing the full potential of simulation will usually involve the total system approach to optimum design.

TABLE I
STEP CALCULATIONS

t sec	V fps	Δz ft	z ft	y ft	y-z ft	aV^2 ft	$y\text{-}z\text{-}aV^2$ ft	ΔV fps	Δ Q/B ft^2/sec	Q/B ft^2/sec	Δy ft	U fps
0	8.50		1.76	4.0	2.24	2.24	0			10.0		2.5
		2.63						—0.40	—0.46		0.05	
5	8.10		4.39	4.05	—0.34	2.03	—2.37			9.54		2.37
		2.52						—0.96	—1.13		0.12	
10	7.14		6.91	4.18	—2.78	1.59	—4.37			8.41		2.01
		2.23						—1.76	—2.17		0.23	
15	5.38		9.14	4.40	—4.74	0.89	—5.63			6.24		1.42
		1.68						—2.27	—2.67		0.27	
20	3.11		10.82	4.67	—6.15	0.30	—6.45			3.57		0.77
		0.97						—2.57	—3.02		0.26	
25	0.54		11.79	4.83	—6.96	0	—6.96			0.55		0.11
		0.03						—2.79	—3.29		0.25	
30	—2.25		11.82	5.08	—6.74	—0.16	—6.58			—2.74		—0.54
		—0.7						—2.67	—3.10		—0.24	
35	—4.92		11.15	5.32	—5.82	—0.75	—5.07			—5.84		—1.10
		—1.52						—2.03	—2.49		0.18	
40	—6.95		9.63	5.50	—4.13	—1.49	—2.64			—8.33		—1.52
		—2.18						—1.06	—1.25		0.09	
45	—8.01		7.45	5.58	—1.87	—2.04	0.17			—9.58		—1.72
		—2.52						0.07	0.08		0	
50	—7.94		4.93	5.58	1.66	—1.95	3.61			—9.50		—1.64
		—2.50						1.48	1.72		—0.11	
55	—6.46		2.43	5.47	3.04	—1.26	4.30					
		—2.03						1.73				
60	—4.73		0.40									

APPENDIX

Numerical Calculations for Example

Equations (7), (8), (9), and (10) lead naturally to the step calculation setup in Table I. The terms to be calculated are shown at the top of the columns, and the values of these terms at various times are shown in the rows. In each row the top line shows values at the beginning of a 5-second increment, while the second line shows changes during the increment.

Beginning at $t = 0$, the velocity in the conduit is 8.50 fps and the head loss for this velocity, aV^2, is 2.24 ft. Hence, $z = 4 - 2.24 = 1.76$. The calculations proceed in a straight-forward manner across the row except for the Δy column. The value of Δy is determined last by solving equation (10) by trial and error.

The computer logic for these calculations would follow the steps shown plus a small subroutine to solve equation (10) by iteration.

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INTERCITY TRAVEL PROGNOSTICATION

By E. G. Plowman*

(Presented at a meeting of the Transportation Section, B.S.C.E., held on February 26, 1964.)

In choosing the title for this talk, the word prognostication seemed particularly appropriate. Of course it means forecasting, but with more than a tinge of emphasis or shading of meaning in the direction of worry or foreboding. Surely we all look forward with some concern to the effect of urban sprawl and rapid urban population growth on passenger travel in potential megalopolitan areas such as from Washington to Boston, Jacksonville to Miami, Milwaukee to South Bend and Los Angeles to San Diego.

The boundary line between intracity and intercity travel has been changed by the automobile and the truck. Just a few years ago all of Boston's internal travel used streetcar, bus or train radial routes that converged and then touched or entered the Central Business District area between North and South Stations and Park Square. Today Boston's intracity travel pattern is becoming of highway type. There are two sets of radial highways. Adjustment between the inner and outer radials is a function of Route 128. This busy, high-speed beltway from Salem to Braintree also has developed an amazing economy of its own, consisting of industries, office or laboratory buildings and shopping centers.

Intracity travel in the past used the same tracks and often the same vehicle as intercity journeys. The commuter from Winchester to North Station got on a Lowell or Concord train. The Boston and Worcester interurban electric cars came from Newton to Park Square over MTA streetcar tracks. This common use of facilities and equipment for intracity and intercity travel may be a thing of the past.

In these two important ways, the relation of intracity to intercity travel has changed. Use of highways rather than train service between fixed stations has made the intracity travel boundary more flexible and more subject to change. The new problems inherent in separate arrangements for intercity travel may, for example, include higher con-

* U.S. Deputy Undersecretary of Commerce for Transportation (Policy)

struction cost, more desirable land use alternatives, and necessary relocation of downtown terminals.

At present intercity travel may be thought of as journeys of at least 40 miles between well-defined urban areas and not of intracity type. This means they are not regularly repeated home-to-work or school or shopping center trips. Between Boston and Lawrence or Lowell, or between Boston and Providence, some of the travel is of this latter intracity type, illustrating again the flexible boundary between intra- and intercity travel.

In order to get well beyond the intracity area, consideration may be given to travel between Boston and the Holyoke-Springfield-Hartford complex of Connecticut Valley cities. Travel is by rail, air and highway. Dominance of the highway mode is reflected in the decline of train patronage. There is fairly frequent air service from Logan Airport to the Hartford-Springfield Regional Airport. Limited access, high-speed throughway roads run from Boston to both Springfield and Hartford.

Mechanical power was successfully used for transportation in 1807 on the Hudson River, and in 1830 on a 30-mile railroad in England. Ever since then inventors have been thinking up new ways to make personal travel faster, more comfortable and more convenient. For intercity travel it would seem that the maximum had already been attained. But this is not true, if one is to judge by recent progress and by the numerous untested innovations.

Progress has been real. The limited access, divided highway, the high-speed railroad train and the jet airplane are all receiving the acid test of actual use. Of course the most costly of the high-speed railroads, the Tokaido Line in Japan, is still under construction, but its technology and economics have been thoroughly tested in France and elsewhere.

Other intercity travel innovations may be just around the corner. Most important, perhaps, is the helicopter or some combination of vertical take-off and landing with faster means of forward travel. One inherent advantage of the helicopter is the ability to use small heliports located at standard airports in the suburbs and downtown. Giant helicopters should be able to operate at relatively low seat-mile cost. In the United States, Europe and Pakistan commercial intercity flights by helicopter already are operating on an experimental basis.

Another innovation is the monorail. So far as I know, this type of railroad has never been tried out on an intercity basis. Numerous short monorails have been built, some for economic and some for purely research reasons.

Two general types of monorails have been in this quasi-prototype stage. The cars may ride on top of the single rail, or they may be suspended from it. In either case means must be provided to prevent excessive leaning to one side or the other under any predictable condition, such as stopping at other than a station or being subjected to high cross-wind velocity. When the car rides the top of the monorail there is no need for an elevated structure provided there are no grade crossings. On the other hand, the suspended type can have its track and its electricity transmission cable completely shielded from the weather.

This brief review of intercity travel devices, actual and potential, has covered five types, namely, the limited access highway, the high-speed train, the jet airplane, the helicopter and the monorail. These five have one characteristic in common—high capital investment cost, especially in megalopolitan areas where land cost becomes a major factor.

The experimental steam-powered vessels that preceded Robert Fulton's *Clermont* were all failures. An important reason was lack of patronage. Today this is a major issue again, since private operation of one's own automobile is the dominant travel mode. There is not much point in spending millions of dollars to construct helicopters and heliports, for example, if they are not going to be patronized by the traveling public.

One hears many different views as to the future place of common carriers as intercity travel devices. The nonstop intercity bus using a fast throughway road; the jet or prop-jet airplane and perhaps the helicopter; and the high-speed railroad in either present-day or monorail form, all seem to have an important role. How important depends on the degree of continued preference for one's own automobile even when the intercity journey is hundreds of miles long.

There is a school of thought on this subject that would use negative or positive measures to reduce intercity travel by automobile. An example of a negative measure might be failure to eliminate peak-hour congestion due to use of the same throughway facilities for commuting to and from work. A positive measure might be enforcement of more nearly uniform speed in each lane by prohibiting passing of other vehicles to an even greater extent than presently permitted. These are not presented as suggestions, only as examples.

My own view is that motorists do not like any regimentation that is not obviously to their interest as individuals. They are not likely to accept situations contrived for the purpose of reducing their intercity journeys in their own cars.

The nub of the question, then, is whether motorists desiring to travel between cities will find it to their self-interest to patronize the common carriers of the future. I believe they will, both because of the additional choices of route, time in transit, etc., thus made possible and because the more frequent and more comfortable busses, planes and high-speed trains will each offer some advantage in cost or time as compared to motoring. After all, assuming that urbanization continues its rapid growth trend, there will be room for the common carriers as well as the millions of private automobiles.

The Under Secretary for Transportation in the Department of Commerce has been studying these matters for about a year. His research projects have given special attention to the intercity travel problems of the almost continuous chain of cities extending from Washington to Boston. This megalopolitan area has about one-fifth of the Nation's population. By 1980, it will have about 50,000,000 inhabitants. This densely populated area, less than 2 percent of the land area of the United States, will continue to need the finest possible intercity travel facilities for motorists, busses, airplanes and high-speed trains.

Belief in the reality of this need does not get us from here to there. In this talk I have suggested some of the problems rather than hazarding any forecast as to solutions. The proper relation between intracity and intercity travel, the future role of intercity travel by automobile, the technical and economic development of helicopter travel and the construction and operation of high-speed railroads are problems deserving your earnest consideration.

JAMES F. BRITTAIN

JAMES F. BRITTAIN
1898-1964

It was with sorrow and shocked disbelief that the many friends of James F. Brittain learned of his passing away on April 11, 1964, less than four months after retiring as Hydraulic Engineer at Stone & Webster Engineering Corporation.

Fred, as he was known to his many associates and friends, was President of the Boston Society of Civil Engineers in 1961-1962, following many years of faithful service to the Society. Born in Somerville in December, 1898, he was a product of the Boston area school system and received his B.S. degree in Civil Engineering from Massachusetts Institute of Technology in 1922. After serving a year as an instructor at the Institute, he joined the consulting-engineering firm of Weston & Sampson. He then worked for a period with the Providence Water Supply Board. From 1927 to 1941, he was Assistant and Senior Civil Engineer with the Metropolitan District Water Supply Commission in Boston. In this position, he was responsible for much of the design work of the 25 miles of tunnel and 15 miles of aqueduct for the Quabbin Dam Project. With the coming of the war, Fred joined Fay, Spofford & Thorndike where he supervised design of the structural and architectural phases for army bases and then in 1942 became structural engineer with the U.S. Navy in Clearfield, Utah. Here he directed preparation of construction plans for a Naval Supply Depot. From 1942 to 1944, Fred was in charge of engineering in the construction of sectional steel battleship floating dry docks for Pacific Bridge Company in San Francisco. He also directed repairs to dry docks constructed by other builders. The construction of these dry docks was a valuable addition to the war effort, enabling repair of damaged combat ships in the South Pacific. From 1944 to 1945, Mr. Brittain worked with the U.S. Army Engineers, New England Division, at Boston. Before coming to Stone & Webster Engineering Corporation, he worked for Chas. T. Main, Inc., Boston, as a Division Engineer responsible for the preparation of reports and estimates on hydroelectric projects.

Fred joined the Hydraulic Division of Stone & Webster in 1946 and worked on many hydraulic projects, particularly those connected with circulating water for large steam plants. In 1955, his work took him to Brazil on difficult drainage problems. Because his experience was more varied than most and he always seemed to find time to be helpful, he was frequently consulted by members of the Hydraulic, as well as other divisions, on their special problems.

Fred had many interests other than engineering, among them being his fine old home built about the year 1700 in South Weymouth, his collections of finely bound books, particularly on architecture, his beautiful flower garden and his love of repairing antique furniture.

Fred leaves his wife, Barbara (Allen) Brittain, and three daughters, Miss Gail Brittain of Weymouth, Mrs. Patricia Ellis of Corpus Christi, Texas, and Mrs. Barbara Gustafson of Chelmsford, Massachusetts. He had grandchildren in Texas and Chelmsford.

To those who knew him, Fred Brittain will be most remembered for his unfailing willingness to be helpful to others no matter how inconvenient it might be to him at the time. He was modest of his own achievements and it was a privilege to have known him.

Of General Interest

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

JANUARY 22, 1964:—A Joint Meeting of the Boston Society of Civil Engineers with the Construction Section was held this evening at the Society Rooms, 47 Winter Street, Boston, Mass., and was called to order by President John F. Flaherty, at 7:00 P.M.

President Flaherty stated that the Minutes of the previous meeting, December 18, 1963 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 Flaherty announced the death of the following member:

William F. Uhl, elected a member November 15, 1911, Honorary Member, February 7, 1955, who died December 23, 1963.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership January 22, 1964:—

Grade of Member.—Attila M. Bene, Richard C. Jasper, Robert J. Kiley, Frank Tetzlaff

Grade of Junior.—Kenneth A. Goff

President Flaherty requested the Secretary to present recommendation of the Board of Government to the Society for action. President stated that this matter was before the Society in accordance with provisions of the By-Laws and notice of such action published in the ESNE Journal January 13, 1964.

Secretary presented the following recommendations of the Board of Government to the Society for action at this meeting.

MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $5000 from the Principal of the Permanent Fund to the Current Fund for current expenditures. Also that a fund be established by a loan of a sum not to exceed $6800 from the Principal of the Permanent Fund for re-publishing Vols. I and II and a new Vol. III of 'Contributions to Soil Mechanics.' Proceeds from sale of publication to be used to repay the loan."

On motion duly made and seconded it was VOTED "that the Board of Government be authorized to transfer an amount not to exceed $5000 from the Principal of the Permanent Fund to the Current Fund for current expenditures. Also that "a fund be established by a loan of a sum not to exceed $6800 from the Principal of the Permanent Fund for re-publishing Vols. I and II and a new Vol. III of 'Contributions to Soil Mechanics.' Proceeds from sale of publications to be used to repay the loan."

President Flaherty stated that this was the final action on this matter.

President Flaherty stated that this was a Joint Meeting with the Construction Section and turned the meeting over to James P. Archibald, Chairman of that Section to conduct any necessary business at this time.

Chairman Archibald introduced the speaker of the evening, Mr. Samuel E. Mintz, Asst. Dir. of Planning and Design of Waterfront Redevelopment Corp. of Boston, who gave a most interesting illustrated talk on "Downtown Waterfront Development in Boston."

A discussion period followed the talk.

Fifty members and guests attended the meeting.

The meeting adjourned at 8:45 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MARCH 16, 1964:—The 116th Annual Meeting of the Boston Society of Civil Engineers was held today at the M.I.T. Faculty Club, 50 Memorial Drive, Cambridge, Mass., and was called to order at 4:00 P.M., by President John F. Flaherty.

President Flaherty announced that the reading of the Minutes of Society meetings had been omitted during the year. The Minutes of the January, and February meetings will be published in a forthcoming issue of the Journal. The Minutes of the April, May, Sept., Oct., Nov. and December 1963 meetings to be declared approved as published.

It was VOTED "to approve the Minutes as published."

The Secretary announced the names of applicants for membership in the Society.

The Annual Reports of the Board of Government, Treasurer, Secretary and Auditors were presented. Reports were also made by the following committees: —Hospitality, Library, John R. Freeman, Public Relations, Advertising, Subsoils of Boston, Joint Legislative Committee, Committee on Professional Conduct and Educational Committee.

It was VOTED "that these reports be placed on file."

The Annual Report of the various Sections were read and it was VOTED "that the Annual Reports of the various Sections be placed on file."

President Flaherty stated that all foregoing reports would be published in the April, 1964 issue of the Journal.

The Report of the Tellers of Election, Robert E. Cameron and Charles A. Parthum was presented and in accordance therewith the President declared the following had been elected Officers for the ensuing year:—

President	William A. Henderson
V-President	John M. Biggs
Secretary	Charles O. Baird, Jr.
Treasurer	Paul A. Dunkerley
Nominating Committee	Robert A. Bierweiler Donald R. F. Harleman Charles Y. Hitchcock, Jr.

The retiring President John F. Flaherty then gave his address entitled "The Civil Engineer in Municipal Service."

Thirty five members and guests attended the business meeting.

The Meeting adjourned at 5:40 P.M., to re-assemble at 7:00 P.M., the Annual Dinner being held during the interim.

The President called the meeting to order at 7:10 P.M.

Following general remarks and the introduction of the newly elected President, William A. Henderson, and other guests at the head table, President Flaherty announced that Honorary Membership in the Society has been conferred on three of the Society's distinguished members, in accordance with the vote of the Board of Government on February 3, 1964.

Thomas R. Camp, who has been a member since Oct. 15, 1930
E. Sherman Chase, who has been a member since Nov. 23, 1922
Gordon M. Fair, who has been a member since Dec. 15, 1915

President Flaherty presented the newly elected Honorary Members with certificates of Honorary Membership which read as follows:

"In recognition of his outstanding achievements in the field of Sanitary Engineering as a Teacher, Investigator, Author, Consultant, and his devoted services to the Society with special emphasis on Professional Ethics

THOMAS RINGGOLD CAMP
has been duly elected an
Honorary Member
By direction of the Board
of Government
February 3, 1964

JOHN F. FLAHERTY, *President*
CHARLES O. BAIRD, JR., *Secretary*

"An International Sanitary Engineer who has caused focal attention to bear upon Boston's professional personnel as being the center of Sanitary Engineering brings recognition to

EDWARD SHERMAN CHASE
who has been duly elected an
Honorary Member
By direction of the Board
of Government
February 3, 1964

JOHN F. FLAHERTY, *President*
CHARLES O. BAIRD, JR., *Secretary*

"Professor, International Consultant, Lecturer, Author, Adviser, and a long and distinguished career in the art of Sanitary Engineering Education together with his untiring service to the Society brings recognition to

GORDON MASKEW FAIR
who has been duly elected an
Honorary Member
By direction of the Board
of Government
February 3, 1964

JOHN F. FLAHERTY, *President*
CHARLES O. BAIRD, JR., *Secretary*

President Flaherty stated that a number of prizes were awarded annually for worthy papers presented at the Society and Section meetings and also Scholarship Awards. The Secretary read the names of recipients and asked them to come forward and President Flaherty presented the awards and scholarships. President Flaherty then introduced the guest speaker of the evening, Brig. General William Whipple, Jr., who gave a most interesting illustrated talk on "New York World's Fair Engineering and Construction."

At the conclusion of the talk President Flaherty turned the meeting over to President Elect, William A. Henderson.

President Henderson presented retiring President John F. Flaherty with a certificate of appreciation for services rendered.

One hundred ninety members and guests attended the dinner and meeting.

CHARLES O. BAIRD, JR., *Secretary*

Award	*Recipient*	*Paper*
Clemens Herschel Award	Frank L. Lincoln Capt. J. E. Rehler	"Reconstruction of Dry Dock No. 3 at the Portsmouth Naval Shipyard"
Structural Section Award	Robert V. Whitman	"Tests Upon Thin Domes"
Transportation Section Award	Edward C. Keane Simon Kirshen	"Specifications—Their Use and Abuse"
Surveying & Mapping Section Award	Louis H. Smith	"Subdivision Control"
Board of Government Award	Charles M. Anderson	"Legal Aspects of Surveying"
Letter of Commendation	Jean de Valpine	"Engineering Negligence, the Engineer, and the Legal Duty of Professional Performance"
Desmond FitzGerald Scholarship	Nils-Frederick Braathen, of Northeastern University	
William P. Morse Scholarship	Linfield C. Brown, of Tufts University	

HYDRAULICS SECTION

MARCH 4, 1964:—The Annual Meeting of the Hydraulics Section of the Boston Society of Civil Engineers was held jointly with that of the Sanitary Section in the Society Rooms, 47 Winter Street, Boston, Massachusetts and was called to order by the Chairman of the Sanitary Section, Mr. George W. Hankinson, at 7:05 P.M.

Chairman Hankinson dispensed with the reading of the minutes and proceeded with the report of the nominating committee for the Sanitary Section and the subsequent election of the proposed slate of officers. The meeting was then turned over to Mr. Richard Dutting, Chairman of the Hydraulics Section.

Chairman Dutting dispensed with the reading of the minutes and presented the report of the nominating committee. The following officers were elected for 1964:

Keistutis P. Devenis, Chairman
Peter S. Eagleson, Vice-Chairman
Nicholas Lally, Clerk
Allen Grieve, Executive Committee
Frank L. Heaney, Executive Committee
Athanasios A. Vulgaropulos, Executive Committee

The speakers were Mr. Worthen Taylor, Massachusetts Dept. of Public Health and Mr. Paul Prendeville, Camp, Dresser and McKee, who discussed plans for pollution abatement in the Merrimac River. Mr. Taylor reviewed the history of the growth and decay of "wet industries" in the Merrimac Valley and the accompanying change in the nature of the primary pollution from industrial wastes to domestic sewage. He then reviewed the development of state and federal anti-pollution legislation and enforcement up to the present interest of the Federal Government in the Merrimac problem. Mr. Prendeville described the nature of the Merrimac pollution and the treatment system proposed by Camp, Dresser and McKee for its relief. A spirited discussion period followed.

The meeting adjourned at 8:45 P.M. with 54 persons in attendance.

PETER S. EAGLESON, *Clerk*

STRUCTURAL SECTION

JANUARY 15, 1964:—A regular meeting of the Structural Section was held at the United Community Services Building on Wednesday evening, January 15, 1964. Professor T. W. Lambe of M.I.T. delivered a paper entitled "Building Foundations on the M.I.T. Campus."

The scope of Dr. Lambe's talk covered: (1) Description of subsurface conditions at M.I.T.; (2) Review of foundation types and long term settlement records of existing buildings; (3) Description of a new method of estimating settlements, and finally (4) Presentation of data on current measurements of pore water pressure and settlement within the blue clay stratum at locations of new buildings.

In contrast to Terzaghi's theory of consolidation (based on one-dimensional compression) the new method recognizes cases where the stress system is not strictly one-dimensional. Where the new method is used, laboratory consolidation is performed under similar stress conditions as are anticipated in the field.

Other business conducted at the meeting was as follows:

1. Election of committee to nominate next year's executive committee.
   These were: Myle J. Holley, Percival S. Rice, Paul S. Crandall, Chairman.
2. Max Sorota made an announcement concerning the forthcoming lecture series on prestressed concrete.

Attendance was 80.

DONALD T. GOLDBERG, *Clerk*

A regular meeting of the Structural Section was held in the Society Rooms at 7:00 P.M., on Wednesday evening, February 12, 1964.

Dr. Frank J. Heger of Simpson, Gumpertz and Heger delivered a paper entitled "Approximate Methods for Buckling of Shells."

Dr. Heger briefly reviewed the mathematical and physical concepts involved in thin shell behavior and described the particular characteristics of cylindrical, spherical, and hyperbolic paraboloid shell shapes. He emphasized that buckling generally controls design.

Several unusual and interesting applications as applied to reinforced plastic shells, were described. Sandwich construction, employing lightweight filler material placed between plastic sheets (from about 0.1″ to 0.25″ thick) are frequently used. The speaker described some design and construction details and used slides to show various applications.

Other business conducted at the meeting was the election of next year's executive committee. These were: Chairman, Max D. Sorota, Vice-Chairman, Donald T. Goldberg, Clerk, Robert L. Fuller, Executive Committee, Mark M. Kiley, Maurice A. Reidy, Jr., Charles C. Ladd.

The meeting adjourned at 8:15 P.M. Attendance 25.

DONALD T. GOLDBERG, *Clerk*

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT FOR YEAR 1963-1964

Boston, Mass., March 16, 1964

To the Boston Society of Civil Engineers:

Pursuant to the requirements of the By-Laws the Board of Government presents its report for the year ending March 16, 1964.

The following is a statement of the status of membership in the Society:

Honorary	7
Members	1042
Associates	5
Juniors	36
Students	3
Total	1093
Student Chapters	2

Summary of Additions

New Members	55
New Juniors	11

Reinstatements

Members	8

Summary of Transfers

Junior to Member	8

Summary of Loss of Members

Deaths	10
Resignations	6
Dropped for non-payment of dues	20
Dropped for failure to transfer	1

Life Members	104
Members becoming eligible today for Life Membership	10
Applications pending on March 16, 1964	7

Honorary Membership is as follows:

Thomas R. Camp, elected, February 3, 1964
E. Sherman Chase, elected, February 3, 1964
Gordon M. Fair, elected, February 3, 1964
Frank M. Gunby, elected, February 15, 1950

Karl R. Kennison, elected, February 7, 1951
Frank A. Marston, elected, February 15, 1960
Howard M. Turner, elected, February 18, 1952

The following members have been lost through death:

Steven R. Berke, June 6, 1963
Warren M. Campbell, May 21, 1963
William T. Crossland, Sept. 24, 1963
Henry F. Dolliver, June 5, 1963
Charles M. Spofford, July 2, 1963
Edwin A. Taylor, 1963
Karl Terzaghi, Sept. 25, 1963
William F. Uhl, Dec. 23, 1963
Frank V. Wright, Dec. 4, 1963

Meetings of the Society

March 21, 1963. Address of the retiring President George G. Bogren. "Public Image of the Engineer."

May 8, 1963. Joint Meeting with Structural, Hydraulics and Construction Sections. Capt. J. E. Rehler, U.S. Navy and Frank L. Lincoln, Fay, Spofford and Thorndike, Inc. "Reconstruction of the Portsmouth Dry Dock, No. 3, Portsmouth Naval Ship Yard."

September 25, 1963. Joint Meeting with Transportation Section. Donald E. Graham, Planning Project Director, Boston Regional Planning Project. "Can We Plan for the Future?"

October 17, 1963. Joint Meeting with Massachusetts Section, American Society of Civil Engineers (Student Night). Dr. Melvin W. First, Assoc. Prof. of Applied Industrial Hygiene, Harvard University School of Public Health. "Environmental Problems Around the World."

November 20, 1963. Joint Meeting with the Structural and Hydraulics Sections. Dr. Arthur T. Ippen, Prof. of Hydraulics, M.I.T. "Engineering Problems Around the World."

December 18, 1963. Joint Meeting with Sanitary Section. Mr. Gerald N. McDemott, Sanitary Engineer, Advanced Waste Treatment Program, Robert A. Taft, Engrg. Center. "Advanced Waste Treatment—Its Present Status and Future Outlook."

January 22, 1964. Joint Meeting with Construction Section, Mr. Samuel E. Mintz, Asst. Director of Planning and Design of Waterfront Redevelopment Corp. of Boston. "Downtown Waterfront Development in Boston."

Sections

Eighteen meetings were held by the Sections of the Society during the year. These meetings of the Sections offering opportunity for more detailed discussions continue to demonstrate their value to their members and to the Society. A wide variety of subjects were presented. The Annual Reports of the various Sections will be presented at the Annual Meeting and will be published in the Journal.

Attendance at Meetings

Date	*Place*	*Meeting*	*Dinner*
March 21, 1963	Science Museum	161	161
May 8, 1963	United Community Services Building	90	65
September, 25, 1963	Society Rooms	25	
October 17, 1963	Northeastern University	200	200
November 20, 1963	United Community Services Building	36	25
December 18, 1963	Society Rooms	30	
January 22, 1964	Society Rooms	50	

Average Attendance 85

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of $71,499.40. The Board of Government authorized the use of as much as necessary of the current income of this fund in payment of current expenses. By vote of the Society (as prescribed by the By-Laws) at the December 18, 1963 and January 22, 1964 meetings, the Board of Government was authorized to transfer an amount not to exceed $5000 from the Principal of the Permanent Fund for current expenditures. Also authorized to establish a Fund by a loan of a sum not to exceed $6800 from the Principal of the Permanent Fund for re-publishing Vol. I, Vol. II and a New Vol. III of "Contributions to Soil Mechanics," proceeds from sale of publications to be used to repay the loan. The amount necessary to transfer from the Principal of the Permanent Fund for current expenditures was $3,683.25.

John R. Freeman Fund. In 1925 the late John R. Freeman, a Past President and Honorary Member of the Society, made a gift to the Society of securities which was established as the John R. Freeman Fund. The income from this fund is to be particularly devoted to the encouragement of young engineers. Mr. Freeman suggested several uses, such as the payment of expenses for experiments and compilations to be reported before the Society; for underwriting meritorious books or publications pertaining to hydraulic science or art; or a portion to be devoted to a yearly prize for the most useful paper relating to hydraulics contributed to this Society; or establishing a traveling scholarship every third year open to members of the Society for visiting engineering works, a report of which would be presented to the Society. A Scholarship of $7500 was awarded to Edward R. Holley, Jr., for year 1963-64. Also an appropriation of $2410.17 was made for payment of Hydraulic Lecture Series.

Edmund K. Turner Fund. In 1916 the Society received a bequest of $1,000 from Edmund K. Turner, a former member of the Society, "the income of which

* Details regarding the values and income of these funds are given in the Treasurer's report.

is to be used for library purposes." The Board voted to use $75 of the income of this fund for the purchase of books for the library. The expenditure from this fund during the year was $75.

Alexis H. French Fund. The Alexis H. French Fund, a bequest of $1,000, was received in 1931 from the late Alexis H. French of Brookline, a former Past President of the Society. The income of this fund is "to be devoted to the library of the Society." The Board voted to use $75 of the income of this fund for the purchase of books for the library. The expenditure from this fund during the year was $75.

Tinkham Memorial Fund. The "Samuel E. Tinkham Fund," established in 1921 at Massachusetts Institute of Technology by the Society, "to assist some worthy student of high standing to continue his studies in Civil Engineering, had a value of $2381.16 on June 30, 1963. Terry J. Vander Werff, a student in Civil Engineering, Class of 1966, was awarded this Scholarship of $100 for year 1963-64.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund established in 1910 was a bequest from the late Desmond FitzGerald, a Past President and Honorary Member of the Society, provided that the income from this fund shall "be used for charitable and educational purposes." The Board voted April 18, 1963 to appropriate from the income of this fund the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of Desmond FitzGerald, and be given to a student at Northeastern University. No expenditure was made from this fund for the current year.

Clemens Herschel Fund. This fund was established in 1931, by a bequest of $1,000 from the late Clemens Herschel, a former Past President and Honorary Member of the Society. The income from this fund is "to be used for presentation of prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgment." The Board of Government voted on April 18, 1963 that payment of Prize Awards be appropriated from the income of this fund. The expenditure made during the year from this fund was $103.75.

Edward W. Howe Fund. This fund, a bequest of $1,000, was received from the late Edward W. Howe, a former Past President of the Society. No restrictions were placed upon the use of this money, but the recommendations of the Board of Government were that the fund be kept intact, and that the income be used "for the benefit of the Society or its members." The Board voted on April 18, 1963 "that a sum not to exceed $50 be appropriated from the income of this fund for use of Committee on Professional Conduct, and a sum of $25 be appropriated from this fund for use of Legislative Committee." No expenditures were made from this fund during the year.

William P. Morse Fund. This fund, a bequest of $2,000, was received in 1949 from the late William P. Morse, a former member of the Society. No restrictions were placed on the use of this money, but the recommendations of the Board of Government were "that this fund be kept intact and that the income be used for the benefit of the Society or its members." Upon recommendation of the Committee appointed by the President, the Board voted on April 5, 1954 "to appropriate from the income of this fund the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of William P. Morse, and be given to a student at Tufts University." No expenditure was made from this fund during the year.

Frank B. Walker Fund. This fund, a bequest of $1,000, was received in 1961 from Mary H. Walker, wife of Frank B. Walker, a former Past President of the Society. No restrictions were placed on the use of this money, but the recommendations of the Board of Government were "that this fund be kept intact and that the income be used for the benefit of the Society or its members." No expenditure was made from this fund during the year.

Prizes

Award	*Recipient*	*Paper*
Clemens Herschel Award	Frank L. Lincoln Capt. J. E. Rehler	"Reconstruction of Portsmouth Dry Dock No. 3, Portsmouth Naval Shipyard."
Structural Section Award	Robert V. Whitman	"Tests Upon Thin Domes Buried in Sand."
Transportation Section Award	Edward C. Keane Simon Kirshen	"Specifications—Their Use and Abuse."
Surveying & Mapping Section Award	Louis H. Smith	"Subdivision Control"
Special Award of Board of Government	Charles M. Anderson	"Legal Aspects of Surveying"
Letter of Commendation	Jean De Valpine	"Engineering Negligence, the Engineer and the Legal Duty of Professional Performance"

Library

The report of the Library Committee contains a complete account of the Library Committee's activities during the past year.

Committees

The usual special committees dealing with the activities and conduct of the Society were appointed. The membership of these committees is published in the Journal and the reports of the committees will be presented at the Annual Meeting.

Your Board, in conclusion, wishes to express its appreciation of the excellent work done by the Officers of the Sections and by the Committees of the Society.

JOHN F. FLAHERTY, *President*

REPORT OF THE SECRETARY

Boston, Mass., March 16,1964

To the Boston Society of Civil Engineers:

The following is a statement of cash received by the Secretary and of the expenditures approved by the President in accordance with the Budget adopted by the Board of Government.

For the Year Ending March 16, 1964

	Expenditures	Receipts
Office		
Secretary's Salary & Expense	$ 880.61	
Treasurer's Honorarium	499.09	
Stationery, Printing & Postage	743.11	
Incidentals and Petty Cash	136.42	
Insurance & Treasurer's Bond	87.15	
Quarters, Rent, Tel. & Light	5,314.06	
Office Secretary	5,591.92	
Social Security	249.72	
Meetings		
Rent of Halls, etc.	80.00	
Stationery, Printing & Postage	36.00	
Hospitality Committee	879.77	$ 673.25
Reporting & Projection	24.00	
Annual Meeting, March 1963	1,199.62	863.25
Sections		
Sanitary Section	14.00	
Structural Section	107.89	
Transportation Section	4.00	
Hydraulics Section	—	
Surveying & Mapping Section	4.00	
Construction Section	21.96	
Journal		
Editor's Salary & Expense	755.00	
Printing & Postage	6,579.76	
Advertisements	—	1,186.10
Sale of Journals	—	3,133.41
Sale of Reprints	51.23	51.23
Copyright	16.00	
Library		
Periodicals	70.00	
Binding	74.60	
Forward	$23.419.91	$5,907.24

REPORT OF THE SECRETARY (Continued)

	Expenditures	Receipts
Brought Forward	$23,419.91	$5,907.24
Miscellaneous		
Binding Journals for Members	7.70	7.70
Badges	—	10.00
Bank Charges	9.92	—
Miscellaneous	740.56	77.00
Engineering Societies Dues and Charge for Journal Space	1,347.70	
Public Relations Committee	85.47	
Dues from B.S.C.E. Members		11,724.00
Trans. Income Perm. Fund		4,202.07
Trans. Prin.		3,683.25
	$25,611.26	$25,611.26

Entrance Fees to Permanent Fund $670.00

55 New Members; 11 New Junior Members; 8 Juniors transferred to Member; 4 New Student Members.

The above receipts have been paid to the Treasurer whose receipt the Secretary holds. The Secretary holds cash amounting to $30 included as payment under item 25 (Petty Cash) to be used as a fixed fund or cash on hand. $269.15 withholding tax and $97.00 Social Security which is payable to Collector of Internal Revenue and State of Massachusetts in April, 1964 is not included in the above tabulation.

CHARLES O. BAIRD, JR., *Secretary*

REPORT OF THE TREASURER

Boston, Mass., March 16, 1964

To the Boston Society of Civil Engineers:

This report covers the period beginning March 1, 1963 to the close of business on March 2, 1964.

The Boston Safe Deposit and Trust Company holds the Society investment securities and serves as custodian and investment counsel. All security transactions during the year were made by the custodian upon a vote of approval of the Board of Government of the Society. On March 4, 1964 the Boston Safe Deposit and Trust Company furnished the Treasurer of the Boston Society of Civil Engineers with a certified audit of the account.

The financial standing of the Society as of March 2, 1964 is summarized in seven of the tables accompanying this report. These tables are as follows:

Table	I	Distribution of Funds
Table	II	Distribution of Funds—Receipts and Expenditures
Table	III	Record of Investments—Bonds
Table	IV	Record of Investments—Stocks
Table	V	Record of Investments—Savings Bank
Table	VI	Comparison of Book Values and Market Values of Stocks, Bonds, Savings Bank, and Investment Cash
Table	VII	Comparison of Book and Market Values of Funds

Three additional tables have been prepared to show the comparison of the Book Values, Market Values, and earnings from the Society holdings during the past five years. These tables are as follows:

Table	VIII	Comparison of Book Values During Last Five Years
Table	IX	Comparison of Market Values During Last Five Years
Table	X	Comparison of Earnings from Invested Funds During Last Five Years

Mr. Karl R. Kennison reported in a letter to the Treasurer on the status of the irrevocable trust funds of the Massachusetts Hospital Life Insurance Co. established by him for the Society. The following is a summary of his report:

Trust #4315	178.32 shares
Trust #4444	183.74 shares
Total	362.06 shares
Capital Gain this year	3.36 shares

In January 1964 the quoted bid price was $23.51 per share. The total value of the two trusts was $8512.03.

The following is a record of the security changes accomplished by the Boston Safe Deposit and Trust Company with the approval of the Board of Government:

Consolidated Edison Co. of New York
Sold 50 rights

Commercial Credit Co. (9 M's)
Bought 240 shares

Standard Oil Co. of New Jersey
Sold 75 shares

Texaco Inc.
Sold 94 shares

Continental Insurance Co.
Sold 158 shares

Hartford Fire Insurance Co.
Received 2 shares in stock dividend
Received 8/100 shares in stock dividend
Bought 92/100 shares
Received 1 share in consolidation
Total increase 3 shares

Receipts from the Secretary including dues, advertisements in the Journal, sale of Journals and other items not specifically listed in Table II amounted to $17,725.94.

Expenditures are listed in detail in the report of the Secretary, and the membership is referred to this report for further infomation. Several groups of expenditures are not covered there or require further clarification in this report.

Surveying Lectures

In the spring of 1963 the Surveying Section sponsored a series of ten lectures using money from the Surveying Lecture Fund (Table II).

Total Expenditures	$257.16
Total Income	$150.00
Net Expenditure	$127.16

John R. Freeman Fund

In the spring of 1963 the Freeman Fund Committee chose to award a Graduate School Scholarship to Edward R. Holley Jr. of Arlington, Massachusetts in the amount of $7,500.00 for a twelve month period.

Scholarship to E. R. Holley Jr.	$3,750.00
Administrative Expenses, Printing, and Postage	25.00
Total	$3,775.00

Also in the spring of 1963 the Freeman Fund Committee chose to underwrite from the John R. Freeman Fund the expenses of a series of thirteen lectures to be given by the Hydraulics Section in the fall of 1963.

Expenditures for Hydraulic Lectures	$2,860.17
Income from Non-members	450.00
Net Expenditures	$2,410.17

Edmund K. Turner and Alexis H. French Funds

The Library Committee was awarded $75.00 from the income of each of the above funds for the purchase of new books for the Library. The total retail value of the books purchased was about $185.00. In addition the Board of Government awarded the Library Committee the sum of $50.00 taken from the Current Fund to engage two students to separate and shelve a large number of old books which have been in storage for years.

Journal of the Boston Society of Civil Engineers

Expenses necessary to publish the Journal are taken from the Current Fund.

Printing, Postage, and Copyright	$6,595.76
Receipts from Advertisements	1,186.10
Net Expenditures	$5,409.66

TABLE I
Distribution of Funds

	Book Value Mar. 1, 1963	Interest and Dividends		Net Profit or Loss at Sale or Maturity		Transfer of Funds		Book Value Mar. 2, 1964
						Purchased	Sold	
	1	Cash 2	Credit 3	+ 4	— 5	+ 6	— 7	8
Bonds	62,293.77	2,402.50						62,293.77
Savings Bank	4,808.92		206.52					5,015.44
Stocks	53,228.79	5,505.58		15,538.92		10,024.85	4,960.55	58,293.09
Available for Investment	2,919.21					1,719.17		4,638.38
	123,250.69	7,908.08	206.52	15,538.92		11,744.02	4,960.55	130,240.68

Columns 1 + 3 + 6 — 7 = 8

TABLE II

Distribution of Funds—Receipts and Expenditures

March 1, 1963 to March 2, 1964

Funds	Book Value Mar. 1, 1963	Allocation of Income-Profit and Loss		Received	Expended	Book Value Mar. 2, 1964
		Income Col. 2 & 3	Net Profit Col. 4 & 5			
Permanent	69,833.82	4,635.99	+8,842.29	3,006.54	14,819.24	71,499.40
John R. Freeman	40,113.83	2,586.90	5,012.45	450.00	6,879.71	41,283.47
Edmund K. Turner	1,436.58	94.97	180.91		83.90	1,628.56
Desmond FitzGerald	2,698.83	178.12	334.24		63.08	3,148.11
Alexis H. French	1,423.85	94.13	179.31		83.82	1,613.47
Clemens Herschel	1,225.63	79.03	143.95		111.04	1,337.57
Edward W. Howe	1,440.76	95.67	181.44		8.93	1,708.94
William P. Morse	2,764.45	183.57	348.14		17.13	3,279.03
Frank B. Walker	1,191.77	79.14	150.08		7.39	1,413.60
Surveying Lectures	618.56	38.87	74.14	150.00	343.96	537.61
Transportation Lectures	283.61	18.82	35.72		1.75	336.40
Structural Lectures	446.70	29.39	56.25	1,424.00	386.70	1,569.64
Boring Data	145.50	0.00	0.00	65.00	0.00	210.50
Vol. I	1,910.30	0.00	0.00	476.43	2,386.73	0.00
Sanitary Lectures	—2,283.50	0.00	0.00	131.88	0.00	—2,151.62
Soil Mechanics	0.00	0.00	0.00	6,664.00	3,838.00	2,826.00
Subtotal	123,250.69	8,114.60	+15,538.92	12,367.85	29,031.38	130,240.68
Current	1,500.00	4,202.07		21,409.19	25,611.26	1,500.00
Totals	124,750.69	12,316.67	+15,538.92	33,777.04	54,642.64	131,740.68

Secretary's change fund of $30.00 should be added to show total cash

Cash Balance—Investment Fund		4,638.38
	Current Fund	1,500.00
	Total Cash	6,138.38

$7,885.32 Transferred from Permanent Fund to Current Fund

$4,202.07 Transferred from Income to Permanent Fund

$3,683.25 Transferred from Principal of Permanent Fund

$2,336.54 Remaining in Vol. I Fund transferred to Permanent Fund

$6,500.00 Transferred from Principal of Permanent Fund to establish Soil Mechanics Fund

TABLE III

RECORD OF INVESTMENTS—BONDS

March 1, 1963 to March 2, 1964

Bonds	Date of Maturity	Interest Rate	Interest Received	Par Value	Book Value Mar. 2, 1964	Market Value Mar. 2, 1964
Aluminum Company of America	Apr. 1, 1983	$3\frac{7}{8}$	193.75	5,000.00	5,037.50	4,737.50
Associates Investment Co. Deb.	Aug. 1, 1979	$5\frac{1}{8}$	307.50	6,000.00	6,000.00	6,210.00
Columbia Gas System Inc. Deb. Series D	July 1, 1979	$3\frac{1}{2}$	70.00	2,000.00	2,066.17	1,807.50
Consumers Power Co. 1st Mortgage	Sept. 1, 1975	$2\frac{7}{8}$	86.25	3,000.00	3,140.35	2,583.75
Flintkote Co.	Apr. 1, 1981	$4\frac{5}{8}$	462.50	10,000.00	10,450.00	10,100.00
Florida Power Co. 1st Mortgage	July 1, 1984	$3\frac{1}{8}$	31.25	1,000.00	1,017.50	823.75
Florida Power Co. 1st Mortgage	July 1, 1986	$3\frac{7}{8}$	193.75	5,000.00	5,037.39	4,600.00
General Motors Acceptance Corp.	Sept. 1, 1975	$3\frac{5}{8}$	181.25	5,000.00	5,101.80	4,612.50
Georgia Power Co. 1st Mortgage	Dec. 1, 1977	$3\frac{3}{8}$	168.75	5,000.00	5,162.50	4,437.50
Province of Ontario	Sept. 1, 1972	$3\frac{1}{4}$	97.50	3,000.00	2,936.25	2,715.00
Public Service Electric and Gas Co.	June 1, 1979	$2\frac{7}{8}$	115.00	4,000.00	4,097.50	3,320.00
So. Pacific 1st Series A Oregon Lines	Mar. 1, 1977	$4\frac{1}{2}$	180.00	4,000.00	4,191.30	4,000.00
Superior Oil Co., Deb.	July 1, 1981	$3\frac{3}{4}$	150.00	4,000.00	4,000.00	3,735.00
Tidewater Oil Co., Deb.	Apr. 1, 1986	$3\frac{1}{2}$	70.00	2,000.00	2,032.50	1,755.00
U. S. Treasury Notes, Series A	May 15, 1964	$4\frac{3}{4}$	95.00	2,000.00	2,022.81	2,005.00
Totals			2,402.50	61,000.00	62,293.77	57,442.50

TABLE IV

Record of Investments—Stocks

March 1, 1963 to March 2, 1964

Stocks	Classification	Number of Shares	Dividend Received	Book Value Mar. 2, 1964	Market Value Mar. 2, 1964
American Telephone & Telegraph Co.	Common	157	565.20	5,645.92	22,078.13
Commercial Credit Co.	Common	240	108.00	9,963.21	9,600.00
Consolidated Edison of New York, Inc.	Common	50	161.25	2,433.75	4,243.75
Continental Insurance Co.	Common	0	260.70	0.00	0.00
General Electric Co.	Common	150	307.50	2,341.47	12,843.75
Hartford Fire Insurance Co.	Common	107	138.27	1,534.39	7,463.25
General Motors Corp.	Common	126	504.00	5,576.32	10,080.00
Jewel Tea Co.	Common	62	99.20	1,467.10	3,231.75
National Dairy Products Corp.	Common	100	220.00	1,154.74	6,900.00
New England Electric System	Common	198	225.72	3,070.39	5,321.25
Pacific Gas and Electric Co.	Common	315	315.00	3,594.69	9,961.88
Scott Paper Co.	Common	263	216.98	5,944.04	9,928.25
Southern California Edison Co.	Common	177	181.86	1,932.99	5,774.63
Standard Oil of New Jersey	Common	225	765.00	2,264.35	18,478.13
Texaco, Inc.	Common	250	661.30	1,708.61	18,500.00
Union Carbide Corp.	Common	100	360.00	2,958.44	12,000.00
Pacific Gas and Electric Co.	Preferred	100	150.00	2,704.89	3,250.00
Radio Corporation of America	Preferred	20	70.00	1,720.75	1,580.00
Southern California Edison Co., Ltd.	Preferred	120	120.60	1,140.24	3,705.00
Southern Railway Co.	Preferred	75	75.00	1,136.80	1,537.50
Totals			5,505.58	58,293.09	166,477.27

TABLE V
Record of Investments—Savings Bank

Savings Bank	Classification	Interest Received	Book Value Mar, 2, 1964	Market Value Mar. 2, 1964
First Federal Savings and Loan Assoc. of Boston, Acct. No. 1S-631	Savings Account	206.52	5,015.44	5,015.44

TABLE VI

COMPARISON OF BOOK VALUES AND MARKET VALUES OF STOCKS, BONDS, SAVINGS BANK, AND INVESTMENT CASH

	Book Value March 2, 1964	Market Value March 2, 1964
Bonds	62,293.77	57,442.50
Stocks	58,293.09	166,477.27
Savings Bank	5,015.44	5,015.44
Available for Investment	4,638.38	4,638.38
Total March 2, 1964	130,240.68	233,573.59
Total March 1, 1963	123,250.69	222,528.77
Increase	6,989.99	11,044.82

TABLE VII

COMPARISON OF BOOK AND MARKET VALUES OF FUNDS

	Book Value March 2, 1964	Market Value March 2, 1964
Permanent	71,499.40	128,615.06
John R. Freeman	41,283.47	74,261.83
Edmund K. Turner	1,628.56	2,929.50
Desmond FitzGerald	3,148.11	5,662.90
Alexis H. French	1,613.47	2,902.35
Clemens Herschel	1,337.57	2,406.05
Edward W. Howe	1,708.94	3,074.09
William P. Morse	3,279.03	5,898.41
Frank B. Walker	1,413.60	2,542.82
Surveying Lectures	537.61	967.07
Transportation Lectures	336.40	605.12
Structural Lectures	1,569.64	2,823.51
Boring Data*	210.50	210.50
Sanitary Lectures*	—2,151.62	—2,151.62
Soil Mechanics*	2,826.00	2,826.00
Subtotal	130,240.68	233,573.59
Current	1500.00	1,500.00
Total	131,740.68	235,073.59

* These funds are not interest earning invested funds, but are cash, assets or publications representing a cash outlay.

TABLE VIII

Comparison of Book Values During Last Five Years

	1960	1961	1962	1963	1964
Bonds	51,942.25	51,942.25	50,818.46	62,293.77	62,293.77
Stocks	52,108.32	55,193.47	55,960.99	53,228.79	58,293.09
Savings Bank	4,291.23	4,442.74	4,616.55	4,808.92	5,015.44
Available for Investment	725.74	3,091.79	1,998.10	2,919.21	4,638.38
Totals	109,067.54	114,670.25	113,394.10	123,250.69	130,240.68

TABLE IX

Comparison of Market Values During Last Five Years

	1960	1961	1962	1963	1964
Bonds	44,690.65	47,112.52	45,747.51	58,323.13	57,442.50
Stocks	133,957.52	150,583.26	177,346.88	156,477.51	166,477.27
Savings Bank	4,291.23	4,442.74	4,616.55	4,808.92	5,015.44
Available for Investment	725.74	3,091.79	1,998.10	2,919.21	4,638.38
Totals	183,665.14	205,230.31	229,709.04	222,528.77	233,573.59

TABLE X

Comparison of Earnings from Invested Funds During Last Five Years

	1960	1961	1962	1963	1964
Interest from Bonds	2,133.52	1,922.50	1,907.50	1,892.50	2,402.50
Dividends from Stocks	5,000.46	5,028.66	5,259.55	5,515.00	5,505.58
Savings Bank Interest	136.12	151.55	173.81	192.37	206.52
Totals	7,270.10	7,102.67	7,340.86	7,599.87	8,114.60

Volume I Fund and Soil Mechanics Fund

In the fall of 1963 the supply of Volume I and Volume II of the Soil Mechanics Series was nearly exhausted. The Board of Government voted to close the Volume I Fund and to transfer the money in that account to the Permanent Fund. See Table II. The balance in that fund as of February 1, 1964 was $2,336.54. This amount was added to the previous expenditures and the account reduced to $0.000. The same amount was added to the Received Column of the Permanent Fund.

Since the demand for these publications still persists (they are used as textbooks in colleges and universities throughout the world), the Board voted to republish Volumes I and II, and further, to develop and publish a Volume III. The Board voted to request the membership for permission to withdraw $6,500.00 from the principal of the Permanent Fund to establish a new Soil Mechanics Fund. The second and final vote authorizing this transfer was taken at the January, 1964 meeting. The new Fund was established February 3, 1964. Volumes I and II have already been reprinted and some have been sold. Volume III is being prepared for publication.

The net income to the Permanent Fund from interest and dividends less the expenses charged to the Fund was $4,202.07. In order to meet current expenses for the year it became necessary to transfer $7,885.32 from the Permanent Fund. Of this amount $4,202.07 was transferred from income to the Fund, and $3,683.25 was transferred from the principal of the Permanent Fund.

Of the funds on hand as indicated in the following tables, $366.15 is held in escrow for Federal Withholding Tax, Massachusetts Income Tax, and Social Security Payments.

PAUL A. DUNKERLEY, *Treasurer*

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 16, 1964

To the Boston Society of Civil Engineers:

We have reviewed the records and accounts of the Secretary and Treasurer of the Boston Society of Civil Engineers, and we have compared the bank statement of securities held by the Boston Safe Deposit and Trust Company with the enumeration submitted by the Treasurer.

We have found them to be in order and to account accurately for the Society's Funds.

JAMES F. HALEY
JAMES W. DAILEY

REPORT OF THE EDITOR

To the Board of Government
Boston Society of Civil Engineers

The Journal was issued quarterly, for the months of April, July, and October, 1963, and January, 1964, as authorized by the Board of Government on December 20, 1936.

During the year there have been published 14 papers, including 11 which were previously presented at meetings of the Society and Sections.

The four issues of the Journal contained 353 pages of papers and proceedings, 11 pages of index and 40 pages of advertising, a total of 404 pages.* An average of 1650 copies per issue were printed.

The cost of printing the Journal was as follows:

Expenditures	
Composition and printing	$5,156.92
Cuts	933.40
Wrapping, mailing & postage	267.24
Editor	755.00
Copyright	16.00
Reprints	51.23
Envelopes for mailing	222.20
	$7,401.99
Receipts	
Receipts from Sale of Journals	$3,133.41
Receipts from sale of Reprints	51.23
Receipts from Advertising	1,186.10
	$4,370.74
Net cost of Journal to be paid from Current Fund	$3,031.25

ROBERT L. MESERVE, *Editor*

REPORT OF THE HOSPITALITY COMMITTEE

February 27, 1964

To the Boston Society of Civil Engineers:

The hospitality Committee submits the following report for the year 1963-1964:

A total of seven meetings of the Society were held during the past year. Included in this total were the Annual Dinner, a Student Night Meeting, and five regular meetings of the Society.

Catered dinners were served prior to four of the seven meetings.

The average attendance of members and guests for all seven meetings or dinner (using the larger attendance figure) was 85, as compared to last year's average of 86.

Attendance at regular meetings of the Society during the past year was 46 persons per meeting, which was less than last year's average of 61. This represents a 24 per cent decrease in attendance from last year's record.

* These figures are estimated, since the January issue is still in production.

SUMMARY OF MEETINGS

Date	Place	Attendance Meeting	Dinner
March 21, 1963	Science Museum	161	161
May 8, 1963	United Community Services Building	90	65
September 25, 1963	Society Rooms	25	
October 17, 1963	Northeastern University	200	200
November 20, 1963	United Community Services Building	36	
December 18, 1963	Society Rooms	30	
January 22, 1963	Society Rooms	50	

ROBERT C. MARINI, *Chairman*

REPORT OF THE LIBRARY COMMITTEE

To the Boston Society of Civil Engineers:

The Library Committee is pleased to report that a great deal has been accomplished in bringing the Library up to date.

With the approval of the Board of Government the sum of $50 was expended for services to arrange the materials stored in the rear room for final disposal. These old books are available for any member to take and final disposition will be made by June 1, 1964.

The periodicals purchased or received by exchange were listed, a copy is attached to this report, and on approval by the Board of Government the following actions were taken:

1. The periodicals listed under items 10, 11, 12 and 21 will be disposed.
2. The periodicals listed under items 13, 14, 15, 16, 17, 19 and 20 are to be kept for a period of one year.
3. The periodicals listed under items 1-9 inclusive are to be kept complete.
4. The periodical list under item 18 is to be kept for a period of five years.

The books in the main part of the Library are being reviewed by the Executive Committees of the six sections. All of the books have been listed into the five groupings: (1) hydraulics, (2) sanitary, (3) transportation, (4) surveying and mapping, and (5) structures, mechanics, soil mechanics and construction. As the reviews are completed, the lists with recommendations are filed with Mrs. Boudia for action by the Board of Government.

The list of new books added to the Library this year is attached with this report. A total of fifteen (15) books valued at about $185 were purchased for $150. One book was contributed by the Portland Cement Association and four books were contributed by the American Institute for Steel Construction.

Periodicals Received by the Boston Society of Civil Engineers

Name	Date of First Copy	Bound	Remarks
1. πEng. News Record	1878 to date	Yes	are used to some degree
2. πCanadian Eng'r.	1895 to date	Yes	only complete file in Boston. are used by many
3. πInd. Arts Index	1913 to date	Yes	used a great deal
4. Civil Eng'r'g.	1930 to date	Yes	used a great deal
5. J.N.E. Water Works	1880 to date	Yes	used to some degree
6. J. Amer. Water Works	1890 to date	Yes	used to some degree
7. Indust. Wastes	1929	Yes	used a great deal
8. ASCE Proceedings	1874 to date	Yes	used quite often
9. ASCE Trans.	1874 to date	Yes	used quite often
10. Inst. Civil Eng'r.	1863 to date	Some	used some, entire is available at Boston Public Library
11. Jour. Franklin Inst.	1826 to date	Some	not used—is available at Boston Public Library
12. Eng. Inst. Canada	1919 to date	Yes	not used too much
13. πN.E. Const.	1963		at present, kept 1 year
14. πPublic Works	1963		at present, kept 1 year
15. πWater and Sewage Wks.	1963		at present, kept 1 year
16. πRoads and Streets	1963		at present, kept 1 year
17. Consult. Eng'r.	1962		have only for 2 years
18. Jour. Amer. Concrete Inst.	1963		started last year
19. Military Eng'r.	1963		started last year
20. N.E. Road Builders	1963		kept 1 year—is used
21. U.S. Geological Water Supply		up to 1934 not since 1934	available at Boston Public Library

π Periodicals subscribed to B.S.C.E.

Books Added to Library

1963-1964

"Introduction to Structural Stability Theory"—George Gerard, McGraw-Hill, 1962
"Design of Thin Concrete Shells, Vol. I"—A. M. Haas, Wiley, 1962
"Creep in Structures"—N. J. Hoff, Academic Press, 1962
"Microbiology for Sanitary Engineers"—McKinney, McGraw-Hill
"Theories & Practices of Industrial Waste Treatment"—Nemerow, Addison-Wesley
"Desalination Research Conference Proceedings"—National Academy of Sciences
"Air Pollution, Vol. I"—A. Stern, Academic Press
"Air Pollution, Vol. II"—A. Stern, Academic Press
"Water Waves"—J. J. Stoker, John Wiley, 1957
"Water Hammer in Hydraulics and Wave Surges in Electricity" L. Bergeron, John Wiley
"Manual on Industrial Water and Industrial Waste Water" A.S.T.M., 1916 Race Street, Philadelphia 3, Penna. 1963
"E.I.T. Review"—Faires and Richardson, Prentice-Hall, Inc.
"Weather Handbook"—Edited by H. McKinley Conway Jr., Conway Publ. Co., Inc., 2592 Apple Valley Rd., Atlanta 9, Ga. 1963
"Ground Water & Seepage"—M. E. Harr, McGraw-Hill
"Building Failures"—Thomas H. McKaig, McGraw-Hill
"ACI Book of Standards"—American Concrete Institute[1]
"Light Gage Cold-Formed Steel Design Manual"[2]
"Commentary on Plastic Design in Steel"[2]
"Manual of Steel Construction"[2]
"Design Manual for Orthotropic Steel Plate Deck Bridges"[2]

REPORT OF THE JOINT LEGISLATIVE COMMITTEE

February 12, 1964

To the Boston Society of Civil Engineers:

There were five bills of major interest taken up by the General Court in the 1963 session. All failed to pass. They were all opposed by your Legislative Affairs Committee. These bills were as follows:

S368 Requiring the seal of an architect or engineer on plans and specifications for construction or alteration of buildings and structures.

S956 Providing for appointment of an additional member of the Board of Registration of Professional Engineers and of Land Surveyors who would be a safety engineer.

H1103 Defining the phrase "Field Engineer" and to provide for registration of field engineers.

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1 Contributed by Portland Cement Association.

2 Contributed by American Institute of Steel Construction.

H1104 Requiring that the seals of professional engineers bear an identification of the field of practice of said engineers.

H1951 Providing for the formation of professional corporation of licensed or registered members of the engineering profession.

A corporation was formed on January 15, 1963, known as the Committee to Uphold the Principles of Engineering Registration Laws, Incorporated. We have cooperated with this new corporation.

There are many bills of interest in the agenda of the current legislative session. Your committee is continuing to join with representatives of other professional engineering societies to make sure that the voice of the engineer is heard on Beacon Hill.

The interest and cooperation of individual members of our society are welcomed.

EDWARD WRIGHT
RALPH M. SOULE
FRANK L. HEANEY, *Chairman*

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass., March 16, 1964

To the Boston Society of Civil Engineers:

Last Spring the committee offered a year's Scholarship of $6000 for a single man and $7500 for a married man plus expenses for traveling and equipment. Five applications were received, three from New England, one from Wisconsin and one from California. The Scholarship was awarded to Edward R. Holley, Jr., of Arlington, Mass. He is conducting research at Massachusetts Institute of Technology. His subject is the "general problem of hydraulic effects on the oxygen balance in rivers and estuaries."

The committee also has financed the John R. Freeman Lectures on "Fundamental Hydraulic Processes in Water Resources Engineering", organized by the Hydraulics Section. This was a very successful series of 13 lectures held from September 24 to December 17, 1963.

HOWARD M. TURNER, *Chairman*

REPORT OF COMMITTEE ON SUBSOILS OF BOSTON

March 10, 1964

To the Boston Society of Civil Engineers:

Following is the report of the Committee on Subsoils of Boston:

The U.S. Geological Survey is currently preparing a geologic map of greater Boston which will show the top of bedrock and the upper and lower surfaces of the overlying layers of till, clay, sand and gravel, organic silt, fill, etc.

As source material they are using the published and unpublished boring logs collected by the BSCE Committee on Subsoils of Boston as well as many additional logs and other data that they have acquired from other sources. The published USGS maps will show contours only.

Total time for completion is estimated to be four years but it is not known at present whether the maps will be published as completed or all at one time.

Mr. Clifford Kaye, in charge of this project for the USGS, has agreed to make the boring logs and location maps available to the BSCE.

It is recommended that the Committee on Subsoils of Boston continue to pass on subsurface information that it acquires to the USGS. A decision on whether the BSCE should publish the borings can be made when the plotted data becomes available.

DONALD BALL, *Chairman*

REPORT OF THE ADVERTISING COMMITTEE

March 16, 1964

To the Boston Society of Civil Engineers:

The Advertising Committee held no formal meetings during 1963, it being the custom to have the Office Secretary act as the advertising agent for the Journal.

The following number of advertisements were printed in the Journal during the past year.

	April	July	Oct.	Jan. (1964)
Professional cards	30	30	30	31
Full Page	1	1	1	2
½ page	1	1	1	1
¼ page	13	13	13	14
Inside Front Cover	1	1	1	1

The total accounts were $1,186.10

The Chairman regrets that due to personal illness and illness in his family during the past year, he was unable to devote the necessary time to this phase of the Society's operation.

Inasmuch as the number of advertisers has gradually declined over the past few years, the Committee recommends, as did the Committee just prior, that some agency or solicitor be employed to go out and make personal contact with prospective advertisers at their place of business.

ANTHONY S. J. TOMASELLO, *Chairman*

REPORT OF JOINT COMMITTEE ON PROFESSIONAL CONDUCT

Boston, Mass., March 16, 1964

To the Boston Society of Civil Engineers:

The Committee has continued its interest in the whole general question of awarding engineering contracts by public bodies and in opposing any method that in any way consists of competitive bidding. It is still trying to make progress in its question of the methods of awarding contracts by the Metropolitan District Commission. It has brought this matter to the attention of the Massachusetts Commission of Administration and Finance.

The Committee has discussed without formulating any conclusions the contributions by engineers to political candidates and campaigns.

There have been various other questions which have been referred to the committee which need not be detailed in this report.

Howard M. Turner, *Chairman*

REPORT OF THE MEMBERSHIP CENTRAL COMMITTEE

March 16, 1964

To the Boston Society of Civil Engineers:

The Membership Central Committee has been relatively inactive during the year 1963-64. Solicitation of new members has been accomplished principally by individual contacts. The increase in membership during the current year has been as follows:

New Members	55
New Juniors	11
New Students	3
Reinstated	8
Juniors transferred to member	8
Applications pending as of March 1, 1964	7
Life Members	114
Members eligible today for Life Membership	10
Honorary Membership	7
Total Membership as of March 1, 1964	1093
This compares with a total membership a year ago of 1,047	

Summary of Loss of Members

Deaths	10
Resignations	6
Dropped for nonpayment of dues	20
Dropped for failure to transfer	1

The continued growth of the Society is important, and every one of us is strongly urged to seek new candidates for membership through his association with other engineers. The Committee recommends that a strong appeal for new members be made at all meetings of the Society and its various sections.

FOZI M. CAHALY, *Chairman*

REPORT OF THE EDUCATION COMMITTEE

February 24, 1964

To the Boston Society of Civil Engineers:

In May, 1963, the Education Committee was approached by Ernest Leffel, representing the Education and Professional Development Committee, A.S.C.E., requesting that we take part in a discussion concerning the presentation of an Orientation Program to High School Guidance Counselors. Ideas were exchanged between the chairmen of the two committees. However, on June 4, 1964, the A.S.C.E.'s Committee decided not to include the B.S.C.E. Education Committee in its plans.

During the year, a request from the New England School Science Advisory Council (N.E.S.S.A.C.) that the Boston Society of Civil Engineers take a more active part in the Council's activities was transmitted to the Education Committee by the Board of Government for recommendations concerning the request.

The Committee met and made specific recommendations to the Board of Government. It is the hope of the Education Committee that a close cooperation between the Boston Society of Civil Engineers and the New England School Science Advisory Council can be effected during the ensuing year.

GEORGE W. HANKINSON, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HYDRAULICS SECTION

Boston, Mass. March 5, 1964

To the Hydraulics Section
Boston Society of Civil Engineers:

The following meetings were held during the past year:

May 8, 1963—This was a joint meeting with the Main Society, Structural and Construction Sections. Capt. J. E. Rehler, Civil Engineer Corps, U.S. Navy and Mr. Frank L. Lincoln, Fay, Spofford & Thorndike, Inc., spoke on "Reconstruction of Portsmouth Drydock No. 3." Attendance 90.

November 20, 1963—This was a Joint Meeting with the Main Society and Structural Section. The speaker was Dr. Arthur T. Ippen, Prof. of Civil Engineering at M.I.T., and the subject was "Engineering Problems Around the World." Attendance 36.

March 4, 1964—The Annual meeting was held jointly with that of the Sanitary Section. The nominating committee, Lawrence C. Neale, Donald R. F. Harleman, John B. McAleer presenting the following slate of officers for 1964 which were approved by voice vote:

Chairman	Keistutis P. Devenis
V-Chairman	Peter S. Eagleson
Clerk	Nicholas Lally
Executive Committee	Allan Grieve
	Joseph L. Heney
	Athanasios A. Vulgaropulos

The speakers were Mr. W. Taylor, Massachusetts Department of Public Health and Mr. P. Prendeville, Camp, Dresser & McKee who discussed plans for pollution abatement in the Merrimac River. Attendance 54.

Special Lecture Series—At the request of the Hydraulics Section and with the support of the Board of Government a committee consisting of K. P. Devenis, J. B. McAleer, J. W. Daily and R. F. Dutting was appointed to organize a Special Lecture Series on Fundamental Hydraulic Processes in Water Resources Engineering. A series of thirteen lectures were given for which pre-printed notes were available. The notes have been corrected and collated and extra copies are available for sale. An outline of the lecture series follows:

Date	Topic	Speaker	Attendance
Sept. 24, 1963	Introduction	A. T. Ippen	138
Oct. 1	Fundamentals I	P. S. Eagleson	155
Oct. 8	Fundamentals II	P. S. Eagleson	56
Oct. 15	Prototype Simulation	R. T. McLaughlin	112
Oct. 22	Measurement and Data Processing	L. C. Neale	116
Oct. 29	Density Currents	D. R. F. Harleman	121
Nov. 5	Diffusion and Mixing	W. E. Dobbins	102
Nov. 12	Cavitation	J. W. Daily	92
Nov. 19	Sedimentation in Natural Channels	J. F. Kennedy	89
Nov. 26	Suspension in Shear Flows	J. W. Daily	102
Dec. 3	Flow Through Porous Media	R. R. Rumer	92
Dec. 10	Tidal Hydraulics and Waves	A. T. Ippen	90
Dec. 17	Tidal Hydraulics and Beach Erosion	J. M. Caldwell	89

PETER S. EAGELSON, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

March 3, 1964

To the Sanitary Section
Boston Society of Civil Engineers:

A brief account of the four meetings held by the Sanitary Section during the past year is as follows:

March 6, 1963—Annual Meeting. The Officers and members of the Executive Committee elected were:

Chairman	Charles Y. Hitchcock
V-Chairman	Francis T. Bergin
Clerk	William C. Traquair
Executive Committee	Roland S. Burlingame
	Robert L. Meserve
	George F. Parsons

Mr. Frank L. Heaney of Camp, Dresser & McKee spoke on the "Pros and Cons of Regional Incinerators." Twenty-three members and guests attended the meeting.

May 22, 1963. An outing was held at the Northeastern Radiological Health Laboratory at Winchester. Dr. Dade W. Moeller, officer in charge of the laboratory, gave a talk following dinner. Eighteen members and guests toured the laboratory and thirteen attended the dinner.

October 2, 1963. A paper entitled "Mamaroneck (New York) Sewage Treatment Plant" was presented by Mr. Robert W. Muther of Metcalf & Eddy. Fifteen members and guests attended the meeting and twelve attended the dinner prior to the meeting.

December 18, 1963—Joint Meeting with Parent Society. George M. Reece, Robert H. Culver and George W. Hankinson were elected to the Nominating Committee of the Sanitary Section.

Following the short business meeting, Mr. Gerald N. McDermott, Sanitary Engineer in the Advanced Waste Treatment Research Program of the Robert A. Taft Engineering Center, spoke on "Advanced Waste Treatment—Its Present Status and Future Outlook." Fifteen members and guests attended the dinner prior to the meeting and thirty-one attended the meeting.

Three meetings of the Executive Committee were held during the year.

WILLIAM C. TRAQUAIR, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

March 2, 1964

To the Structural Section
Boston Society of Civil Engineers:

The following meetings were held during the past year:

April 10, 1963—Dr. Howard Simpson, Partner, Simpson, Gumpertz, & Heger, spoke on "The 1963 ACl Building Code." Attendance 125.

May 8, 1963—Mr. Frank L. Lincoln, Vice-President, Fay, Spofford & Thorndike, Inc.; Mr. A. F. Watts of A. S. Wickstrom, Inc.; and Capt. J. E. Rehler, USN, spoke on "Reconstruction of Portsmouth Drydock No. 3." Attendance 90. This meeting was held jointly with the parent society.

October 9, 1963—Mr. Robert Wellner, Bethlehem Steel Co., spoke on "Use of V-Steels in Bridge Design" Attendance 24.

November 20, 1963—Dr. Arthur T. Ippen, Professor of Civil Engineering at M.I.T. spoke on "Engineering Problems Around the World". Attendance 36. This meeting was held jointly with the Hydraulics Section and the parent society.

December 11, 1963—Dr. Jacob Feld, consulting engineer, spoke on "Some Difficulties in Prestressed Concrete Work." Attendance 75.

January 15, 1964—Dr. T. W. Lambe, Professor of Civil Engineering at M.I.T., spoke on "Building Foundations on the M.I.T. Campus." Attendance 80.

February 12, 1964—Dr. Frank J. Heger, Partner, Simpson Gumpertz & Heger spoke on "Approximate Methods for Buckling of Shells." At this annual meeting of the Structural Section, the following officers were elected for the forthcoming year: Chairman, Max D. Sorota; Vice-Chairman Donald T. Goldberg; Clerk, Robert L. Fuller; Executive Committee, Mark M. Kiley, Maurice A. Reidy, Jr., Charles C. Ladd. Attendance 25.

In addition to the above meetings, the Structural Section and the Construction Section sponsored a series of nine lectures on the subject of prestressed concrete, to run between February 20 and April 28, 1964.

The total attendance at the seven meetings was 455, averaging 65 per meeting.

DONALD T. GOLDBERG, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE TRANSPORTATION SECTION

March 12, 1964

To The Transportation Section
Boston Society of Civil Engineers:

The four following meetings of the Transportation Section were scheduled during the past year:

April 24, 1963—Donald Cather of DeLeuw Cather presented a paper "Transportation Planning." Thirty-three were in attendance.

Scheduled September 18, 1963 meeting was changed to September 25 Joint Meeting with the main society. Mr. Donald Graham, Director, Boston Regional Planning Project, presented a talk entitled "Can We Plan for the Future?" Thirty members and guests attended.

Scheduled November 27, 1963 meeting was changed to November 25 for ex-Gov. John Volpe's convenience who was to speak on "Construction of Roads in Russia." This meeting was cancelled in order to observe the proper period of mourning at the time of President Kennedy's death.

February 26, 1964—Dr. E. G. Plowman, U.S. Deputy Under Secretary of Commerce for Transportation, presented a very interesting paper entitled "The Washington-Boston Study." Attendance was thirty-nine.

Because of the weakened structure of this Section and because of the unavailability of two key officers the election of new officers was postponed until a future date.

ERNEST A. HERZOG, *Chairman*

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 51 APRIL, 1964 Number 2

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROFESSIONAL SERVICES

INDEX TO ADVERTISERS

COMMITTEES

1964-1965

NOMINATING COMMITTEE

Past Presidents (Members of Committee)

Edward C. Keane
Myle J. Holley, Jr.
Clyde W. Hubbard
Frank L. Heaney
(Term expires March, 1965)

Arthur T. Ippen
Robert A. Bierweiler
Donald R. F. Harleman
Charles Y. Hitchcock, Jr.
(Term expires March, 1966)

PROGRAM

William A. Henderson, *Chairman, ex-officio*

Leslie J. Hooper
John M. Biggs
Charles O. Baird, Jr.
Robert L. Meserve
Francis T. Bergin
Max D. Sorota
Keistutis P. Devenis
Ernest A. Herzog
Leonard Tucker

PUBLICATION

Simon Kirshen, *Chairman*

Robert L. Meserve
Francis T. Bergin
Max D. Sorota
Keistutis P. Devenis
Ernest A. Herzog
Leonard Tucker

LIBRARY

George W. Hankinson, *Chairman*

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

HOSPITALITY

Robert L. Fuller, *Chairman*

Arthur L. Quaglieri
William Parker, 3rd

DESMOND FITZGERALD & HERSCHEL AWARD

Ralph M. Soule, *Chairman*

Edward C. Keane
Saul Namyet

SANITARY SECTION AWARD

William L. Hyland, *Chairman*

George M. Reece
Ralph M. Soule

STRUCTURAL SECTION AWARD

Percival S. Rice, *Chairman*

Saul Namyet
Edward C. Keane

HYDRAULICS SECTION AWARD

Clyde W. Hubbard, *Chairman*

Lawrence C. Neale
Richard F. Dutting

SURVEYING & MAPPING SECTION AWARD

Charles M. Anderson, *Chairman*

Wilbur C. Nylander
Richard D. Raskind

TRANSPORTATION SECTION AWARD

Alexander J. Bone, *Chairman*

Thomas C. Coleman
Ernest A. Herzog

CONSTRUCTION SECTION AWARD

James P. Archibald, *Chairman*

Robert J. Hansen
Frank J. Heger

SUBSOILS OF BOSTON

Donald G. Ball, *Chairman*

Rev. Daniel Linehan
Harl P. Aldrich, Jr.
Ronald C. Hirschfeld

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Fozi M. Cahaly, *Chairman*

Francis T. Bergin
Max D. Sorota
K. P. Devenis
Ernest A. Herzog
Leonard Tucker

AUDITING COMMITTEE

James W. Daily
Richard F. Dutting

INVESTMENT COMMIITTEE

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